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Three studies during three consecutive summers were conducted at the Squaw Butte Experiment Station to estimate relative and quantitative forage intake of spring and fall calving cow-calf pairs on summer range. In a drylot study (experiment 1) individual animal consumption of fescue or meadow hay cut at 2- to 10-day intervals from May 16 to August 22 was determined for 6 spring and 6 fall cow-calf pairs. Spring cows consumed more hay than did fall cows (10.72 vs. 10.00 kg/day; $P = 0.08$) and produced more milk (3.73 vs. 2.13 kg/day between June 4 and July 8; $P < 0.01$). Fall calves consumed more hay than did spring calves (3.48 vs. 1.28 kg/day; $P < 0.01$), had greater total weight gains (68.2 vs. 50.2 kg; $P = 0.05$), and required less total feed invested (cow + calf) per unit of gain (20.16 vs. 24.38 kg feed/kg gain; $P = 0.20$). Fall pair intake exceeded that for spring (13.48 vs. 12.00 kg/day; $P < 0.01$), and total feed required

per unit of total animal (cow + calf) gain favored the fall treatment (11.66 vs. 14.42 kg feed/kg gain for spring; $P = 0.23$). Intake estimates for fall pairs (6) on pasture expressed as a percent above spring pair (6) intake (as determined by clipping plots before and after grazing for four, 5- to 10-day periods between May 10 and August 28) were 6, 19, 22, and 24% in May, June, July, and August, respectively (experiment 2). Fall cows gained more (85.9 vs. 68.4 kg; $P = 0.13$) and produced less milk (1.78 vs. 4.34 kg/day; $P < 0.01$) than did spring cows. Calf gains between treatments were not different. Measuring individual intake by cows and calves (six pairs per treatment) on pasture using total fecal collection (six, 5-day trials between April 29 and August 30; experiment 3) resulted in higher mean forage intakes for spring cows (11.98 vs. 10.90 kg/day; $P = 0.02$), higher fall calf intake (4.25 vs. 0.94 kg/day; $P < 0.01$), and higher fall pair intake (15.19 vs. 12.89 kg/day; $P < 0.01$) relative to opposing treatments. Fall calves gained more than did spring calves (118.5 vs. 89.8 kg; $P < 0.01$), and fall cows gained more than did spring cows (116.4 vs. 75.8 kg; $P < 0.01$) while producing less milk (2.47 vs. 5.24 kg/day; $P < 0.01$). Fall pair intake, as a percent above spring intake, increased linearly ($Y = 1.074X + 5.257$, where X = week number beginning May 1) from May through August. Quantitative differences in intake also increased linearly at approximately 0.077 kg/week on pasture from an early May difference of 1.63 kg.

Adjustments to account for an early fall calf weaning on July 20 or May 1 gave estimates of fall cow or cow-calf range forage intake, relative to spring, of 100% and 72%, respectively. Relative differences in intake of the two cow groups were comparable in all three studies.

Forage Intake and Related Performance Criteria of Spring and Fall Calving Cow-Calf Pairs on Summer Range

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TABLE OF CONTENTS

LIST OF TABLES

Table		Page

LIST OF FIGURES

FORAGE INTAKE AND RELATED PERFORMANCE CRITERIA OF SPRING AND FALL CALVING COW-CALF PAIRS ON SUMMER RANGE

INTRODUCTION

In the attempt to meet the needs for increased levels and efficiency of livestock production, operators have utilized a variety of approaches including improved genetics, better nutrition, expansion and/or improvement of physical facilities, and various management practices. One aspect of management is the time of calving, the regulation of which has historically been strongly influenced by such factors as climate, labor and market conditions, and feed availability and quality. In recent years more emphasis has been placed on tailoring the management system to capitalize on all available resources to maximize returns. Fall calving is one such system that offers several economic and managerial alternatives in many geographical areas, such as the high desert of eastern Oregon, where spring calving has been the predominant system. Little information exists on the nutrient requirements of the fall calving cow-calf pair in relation to the spring calving cow-calf pair (hereafter also known as fall and spring pair, respectively). Because of the complexity of the interrelations among factors affecting intake, the comparative consumption of spring and fall pairs is not readily apparent. Before the optimum managerial potential of these or any system can be realized, more information is needed regarding the nutrient requirements of the animal classes involved in that system. This study was designed to obtain experimental estimates of comparative and quantitative forage intake by spring and fall cow-calf pairs grazing a spring-summer range.

LITERATURE REVIEW

According to one author (Ensminger 1963), there are two major breeding and calving systems, one involving a year-round breeding period and the other employing a limited breeding season, usually timed for spring or fall calving. Several textbooks on beef cattle production (Kays 1958; Stephens 1962; Wagnon, Albaugh, and Hart 1960) indicated that fall calving is suitable for the warmer south and southwestern areas of the United States, but that spring calving is preferable in colder northern areas. However, several recent papers have reported some definite advantages accruing from a fall calving program in many of these colder areas under certain conditions (Davis and Wheeler 1970; Meiske et al. 1973; Mueller and Harris 1967; Raleigh 1970; Raleigh, Turner, and Phillips 1970). Only one of these reports (Meiske et al. 1973) gives data on actual TDN (total digestible nutrient) intake, although as presented, the data do not provide a basis for comparing relative intake of spring and fall pairs while grazing concurrently on range. Other reports (Mueller and Harris 1967; Raleigh 1970) allude to the greater ability of the fall calf (compared to the spring-born calf) to directly utilize the range forage at its peak of quality. However, it is evident that sufficient data are not available in the literature to adequately assess the relative or quantitative forage needs of the spring and fall pair on range.

Forage Intake as Influenced by Animal Requirements

As pointed out in the previous discussion, additional information is needed to define the nutrient requirements, as measured by forage consumption, of the animals involved in the two management systems being considered in this study. The literature does, however, contain numerous references to factors which would influence relative consumption, although it would be difficult to determine the magnitude of any differences based only on published reports.

Forage Intake by the Calf

An examination of the literature suggested that those factors that would have the greatest influence on forage intake by the calf were maintenance and growth requirements and milk consumption.

Maintenance. One of the obvious differences between spring and fall calves at spring turnout time is body size, since fall calves may be six months older and weigh two to three times as much as the spring calf (Raleigh *et al*. 1970). Consequently, it should be expected that the fall calf would have a correspondingly greater maintenance requirement when adjusted for metabolic body size (see discussion by Maynard and Loosli 1969, p. 414). Differences in body size would also affect the size of the activity increment for maintenance (Maynard and Loosli 1960, p. 419), since several studies report that the energy cost of activity is related to body size.

Christopherson and Young (1972) used sheep and cattle to show that horizontal walking required 0.41 cal/kg/m traveled, whereas that for vertical movement was 5.2 cal/kg/m. It was also observed that walking downhill required nearly as much energy as uphill walking. Clapperton (1964), using sheep, found a cost of 0.54 cal/kg/horizontal m and 6.36 cal/kg/vertical m, somewhat higher than that reported in the previously cited study, and this cost increased with the speed of travel. In a calorimetric study with sheep (Corbett and Farrell 1970), a comparison of well-fed and undernourished grazing sheep indicated that energy expenditure for maintenance was positively related to live weight.

There is very little data suggesting how far the spring or fall calf might travel. However, a behavioral study by Dwyer (1961) indicated that at two months of age the calf spent less time grazing and more time lying down and did not always follow its dam in her grazing activities. In contrast, the calf's grazing and traveling activities were similar to the dam's at four to five months of age. This suggests that the fall calf would travel farther and thus have a higher energy requirement for activity, irrespective of the difference in body weight, particularly during the early part of the grazing season. As the spring calf grew and became more active the difference in distance traveled between the spring and fall calf should decrease.

Growth. Data presented by Brody (1945) and Joandet and Cartwright (1969) indicate that growth rate is essentially linear, when expressed as a percent of mature weight or as a simple regression, during the first 12 months of the bovine's life. Consequently, assuming a fairly uniform genetic base, we might expect most growth differences to be directly related to intake levels of available nutrients and to the location and mode of digestion in the case of some nutrient sources such as milk (Huber 1969) or starch (Kartchner 1972).

Effects of Milk Intake on Growth. Although it is recognized that growth-milk consumption relationships may not affect forage intake, *per se*, the effect that milk intake exerts on the calf's development is of such consequence that it is felt justified in including a discussion of it here.

It is well recognized that much of the young calf's nutrient requirements are met by milk and that much of the milk may by-pass the rumen via the esophageal groove and go directly to the abomasum (Church 1969), resulting in a more efficient utilization (as compared to ruminal fermentation) of the milk nutrients.

A number of authors have presented data relating growth rate to level of milk consumption. Gleddie and Berg (1968) found milk yield estimated in any month to be highly predictive of calf average daily gain (ADG) from birth to weaning. Similar results were reported by Christian, Hauser, and Chapman (1965) using milk production from 0 to 60 days and from 60 to 240 days. Milk yields ranged from 10 to 13 lb/day and from 7.5 to 8.5 lb/day for the two respective periods. For both periods calf ADG was highly correlated with the dam's milk production. In a Texas study (Wistrand and Riggs 1968) each additional pound of average daily milk production resulted in a 14 lb increase in calf weight at 205 days of age. Most studies have shown analogous relationships between milk intake and gain, although the degree of correlation and period of meaningful correlations vary considerably.

Furr and Nelson (1964) measured milk production in fall calving cows wintered at two levels of supplement. They found correlations to be highly significant between milk production and calf ADG to weaning in July. When the study period was broken down by weighing periods, however, the degree of correlation dropped just prior to spring green-up and again following the initial forage growth period. Milk production increased initially following the greening period and declined as summer progressed.

Melton _et al_. (1967) found a significant correlation only for the first of six monthly intervals. Howes _et al_. (1958) reported that calf gains and milk yield were correlated over the first four months of lactation, although the degree of correlation showed a consistent decline with each monthly period. The latter results agree with the findings of Gifford (1949). Other studies showing positive calf gain-milk yield correlations are those of Drennan (1971a), Drewry, Brown, and Honea (1959), Holmes, Takken, and Seifert (1968), Klett, Mason, and Riggs (1965), Knapp and Black (1941), Pope _et al_. (1963), Schwulst _et al_. (1966), Todd and Fitzhugh (1969), and Totusek and Arnett (1965).

In addition, Jeffrey, Berg, and Hardin (1971) and Neville (1962) have produced data indicating that milk yield outweighs all other environmental and animal factors studied (such as age of dam, sex, etc.) as a determinant of growth rate. In the former study, milk consumption accounted for 60% of the variation in ADG from birth to weaning, and for the latter study, 66% of the variation in 240-day weights of Hereford calves was attributed to milk. Similarly, Jeffrey and Berg (1971), Melton _et al_. (1967), and Rutledge _et al_. (1971) have shown that variations in milk composition have a relatively small effect on the rate of growth when compared to total milk yield.

Forage Intake as Related to Milk Consumption. There are relatively few papers relating forage and milk intake in the calf. National Research Council (N.R.C. 1970) recommendations do not even include requirements for the suckling calf except as they are met by the adequacy of the dam's diet for milk production. There was one study reported (Baker and Barker 1972) in which calves were fed a milk substitute at three different levels (treatments) in quantities calculated to simulate a standard lactation curve over a 240-day trial period.

Calves drinking 406 gallons of milk substitute consumed less ryegrass forage but gained at the same rate as calves receiving 333 gallons of the substitute. Calves receiving 239 gallons of substitute were apparently unable to consume sufficient forage to compensate for the lower milk intake and consequently gained less (1.86 vs. 2.23 lb/day for the other two treatments). Forage intake was positively related to liveweight and inversely related to milk consumption at equal liveweights among treatments.

Maddox (1965a) has published in tabular and schematic form the estimated energy requirements of the calf and how much of that energy must come from milk and how much from forage at monthly intervals from birth to weaning at seven months, assuming weaning weights of 300, 400, 500, and 600 lb. Howes et al. (1958), using Hereford and Brahman cows, calculated that between the second and third month following parturition the dry matter and protein supply from the milk became inadequate to maintain the same calf gains that had been obtained up to that time. Consequently, forage must of necessity provide the additional nutrients if the same growth rate were to be continued. This is similar to the conclusions of Joandet and Cartwright (1969) that calves from Hereford dams received adequate nutrients from milk alone through the second month of lactation. In contrast, Brahman x Hereford dams supplied sufficient nutrients from milk through the fourth month. Since there is little documentation of actual forage consumption in suckling calves, perhaps an approach such as the schematic presentation of Maddox (1965a) would prove useful; that is, to get an estimate of relative forage needs by looking at the pattern of milk consumption as it relates to time following calving.

Abadia and Brinks (1972) show a lactation curve for first-calf Hereford cows. The duration of lactation for these animals was considerably shorter than that reported by most other studies of a similar nature. Only 4 of 68 cows were still milking by 155 days. Production increased up to 30 days following parturition and declined steadily thereafter. In contrast, Lamond, Holmes, and Haydock (1969) found that only 14 of 62 cows showed a curvilinear lactation pattern. Forty-six cows manifested linear declines of various degrees between one and six months following calving. Gleddie and Berg (1968) also found an overall linear decline between the 30th and the 150th day of lactation when using different breeds of cattle. Final milk yield was 35% lower than the average peak production. Similarly, Melton et al. (1967) discovered an approximate linear decline in milk yield in Charolais, Angus, and Hereford cows, with yield dropping approximately 50% between days 77 and 224 of lactation. Milk yield on day 199 was only 45% of that on day 73 in a study by Drennan (1971b); and Arbuckle (1959) reported that milk production in beef cows had dropped 80% in six months, and nearly 95% in eight months. By the 10th month, 17 of 19 cows were dry. In a study of fall calving (Furr and Nelson 1964) production dropped in March and April from a January 30 measurement (80 days post calving), increased in May, and declined again until weaning in July to levels slightly below the January level.

It is obvious from these reports that the stage of lactation has a marked effect on the milk the calf will receive. In the work reported by Raleigh _et al._ (1970), spring calves averaged less than a month of age at spring turnout, whereas fall calves averaged five months or older. The dams of the fall calves would be well past their peak of lactation, whereas the spring cows would initially be near their peak. Even though Furr and Nelson (1964) have shown some recovery of milk in fall cows with the onset of spring grazing, it might be expected that total milk consumption would be substantially greater for the spring calf during the summer grazing season. Consequently, the fall calf would require more forage to meet its nutrient requirements simply on the basis of less milk available.

Efficiency of Meat Production Derived from Milk vs. Forage. In the interest of placing milk and forage intake into perspective relative to forage utilization and animal (meat) production, efficiency will be discussed here, although it is recognized that efficiency, _per se_, does not directly control forage intake. Although the gross energy of milk is more digestible than that of forage (N. R. C. 1970, Table 7), the cost in terms of forage nutrients of producing a unit of animal gain is considerably higher when derived from milk compared to that derived directly from the forage. Joandet and Cartwright (1969) stated that "The amount of TDN required to produce one kg of post-natal live weight is maximum at birth (and) decreases until a minimum is reached. . . ." The minimum point ranged from 17 to 22 months of age in this study and varied with breeding groups. A portion of the added TDN requirement at an early age could be attributed to the higher cost of gain derived from the dam's milk.

According to values presented by Maddox (1965a), only 56% of the digestible energy (DE) consumed by the cow for milk production is made available to the calf in the form of digestible milk energy; Texas work suggested a 2.5:1 ratio for conversion of feed TDN to milk (Kruse and Melton 1968). Neville (1974) found the energetic efficiency of metabolizable energy for milk production (above a cow's non-lactational requirements) to be only 34%.

Cook (1970) has reviewed some of the literature related to differential efficiencies of forage conversion to calf gain, either directly or via milk, and this will not be repeated here. The reader is referred to articles by Blaxter (1965), Gardner and Hogue (1966), Gardner, Hogue, and Bensadoun (1964), Reid (1961), and Ritzman and Benedict (1930).

In his bulletin, Cook (1970) calculated that 8.4 to 12.5 lb of TDN would be required per lb of calf gain (as part of a cow-calf unit) and 5.1 to 7.1 lb of TDN/lb of gain in a steer for animals grazing a spring-summer range. On this basis, 65 to 76% more TDN would be needed to produce a unit of calf gain compared to that for the steer. This difference in efficiency could be attributed primarily to the additional cost of maintenance for the cow as well as the greater efficiency of converting forage nutrients directly to animal gain as opposed to first converting these nutrients to milk. In a spring-fall pair comparison only the latter would apply, since both spring and fall cows would be maintained on the range.

As was brought out in the previous discussion on milk intake patterns, the fall calf would of necessity meet a greater relative proportion of its needs directly from the forage, since milk consumption levels would be lower than those of the spring calf. This would suggest a greater efficiency of utilization of forage nutrients for gain by the fall calf during the summer grazing season. This is partially supported by confinement data (Meiske et al. 1973) showing that spring calves weaned at 109 days required less TDN per unit of gain than those weaned at 205 days, although fall calves weaned at 205 days showed a slightly greater, though non-significant, efficiency compared to those weaned at 109 days.

Forage Intake by the Cow

Factors which most likely would influence differential forage intake between the spring and fall cow are relative stage of lactation (assuming similar genetic potential for milk production) and maintenance requirements (used in the broad sense of the word). Gestation needs may also be a factor affecting fall cow intake, depending upon how long the grazing season is extended in relation to the calving date.

Patterns of milk production relative to stage of lactation have been discussed in the forage-milk intake relationship section on the calf and will not be pursued further here, except to point out that if 1.78 Mcal of DE above maintenance is required to produce one Mcal of DE in the milk (Maddox 1965a), cows in the early part of the lactation cycle (spring cows) would require more energy to meet the higher lactation requirement than those which are already well along in the cycle (fall cows).

Maintenance. Using the narrow definition of the word, maintenance means no net gain or loss of body tissues (N.R.C. 1966). Under practical range conditions, maintenance implies a substantial loss and gain in body weight and condition between corresponding periods of succeeding stages (from year to year) of pregnancy, calving, lactation, and dryness (non-lactating). Although the total net effect of demands for maintenance over a 12-month calving cycle might be expected to be similar for spring and fall cows, the influence these demands have on summer forage intake would differ, since the magnitude of these demands are not being placed to the same degree at the same time for animals from the two systems.

The discussion on the calf regarding the maintenance requirement as related to body size and cost of activity apply equally well to the cow. Assuming a relatively uniform mature body size between spring and fall cows, differences in body weight would be related to changes in body weight and condition which will be discussed in the ensuing section. To the knowledge of the author there is no good information published which might suggest differences in activity patterns between spring and fall cows, although undocumented observations at the Squaw Butte Experiment Station in Oregon indicate that particularly in the early part of the grazing season the spring cow tends to travel less, preferring to forage for food near her calf, which spends much of its time resting. This is supported by the observations of Dwyer (1961) with respect to the calf's activity. However, Wagnon (1963) found that the cow used as much as 10% or more of her total distance traveled just searching out and checking on her small calf.

<u>Changes in Body Weight and Condition</u>. Summer forage availability and quality, length of lactation, winter feeding levels, and

supplementation are some of the factors in addition to calving which can exert a considerable influence on the body weight gain-loss pattern from year to year. The single values given for lactating or dry pregnant cows in the N.R.C. (1970) recommendations are unrealistic for a cattle operation involving a winter feeding-supplementation program followed by spring-summer grazing of high quality range forage, and at best represent yearly averages. When cows are wintered at these levels prior to turning out onto spring-summer pastures they may develop excessive fattness (Jordan, Lister, and Rowlands 1968) except under severe environmental conditions (Hironaka and Peters 1969). A certain amount of winter weight loss may actually enhance longevity and production (Pinney, Stephens, and Pope 1972).

Wallace and Raleigh (1964) winter-fed mature Hereford cows 100, 74, and 50% of ad libitum intake of meadow hay with or without 1 lb of cottonseed meal daily. All animals gained weight (from 84 to 170 lb) up to calving time with those receiving higher hay levels or supplement gaining more than otherwise. In a second trial cows were full fed (N.R.C. recommendations) or limited to 60% of this level. Superimposed on these treatments were rations balanced in protein and energy, high in protein and low in energy, or low in protein and high in energy. Again, all cows gained weight up to parturition. Weight losses during the summer largely paralleled winter gains with those gaining most in the winter also losing the most in the summer, so that condition and body weight remained relatively constant from year to year. The body weight changes of fall and spring calving cows during a yearly cycle on the Squaw Butte Experiment Station are shown in graphic form in an article by Raleigh and Lesperance (1972).

Similar results were found in a four-year study by Jordan _et al._ (1968) who winter-fed silage and hay at four levels: _ad libitum_ (somewhat above 1963 N.R.C. recommendations) and at 80, 60, and 40% of _ad libitum_. At 80 or 100% of _ad libitum_ all cows gained weight during pregnancy for all years except one. Those receiving the 40 or 60% levels consistently lost weight during this time. All cows lost weight during confinement nursing prior to turning out on pasture with the greatest weight losses occurring on cows fed the lowest nutrient levels. On pasture, however, body weight gains showed an inverse relationship to winter nutritional levels and weight losses.

Hironaka and Peters (1969) fed cows at 100, 80, and 60% of 1963 N.R.C. requirements for wintering a 454 kg pregnant beef cow. Weight gains or losses on the two higher levels were greatly influenced by the severity of the winter weather conditions. Those cows on the low level consistently lost weight, although this weight was replenished during the summer grazing season, so that fall weights equaled those for cows wintered on a high plane of nutrition. At least a portion of this additional replenishing of body tissues apparently took place at the expense of milk production, since weaning weights for calves from these cows were consistently lower than for those wintered at higher nutritional planes. This phenomenon of compensatory gain on summer pasture has also been demonstrated in spring calving cows by Pinney et al. (1972).

Comparable results have been found with fall calving cows (Furr and Nelson 1964). Those cows fed a lower plane of winter nutrition with corresponding higher weight losses also gained more the following spring and summer on pasture.

It is apparent, then, that cows in comparable stages in the lactation cycle, but of differing body conditions due to different winter nutrition levels, will compensate for any excesses or deficiencies by adjusting forage intake and/or milk production. Klosterman, Sanford, and Parker (1968) have developed an equation accounting for the effect of differences in condition on maintenance: kg of $DE_{maintenance} = 130\ W_{kg}^{0.75} - (W/H - 4.0)\ 1,716$, where W/H is the weight (kg) to height (cm) ratio. However, the applicability of this equation to general situations is unknown. Although there is no published information which would suggest differences in condition between spring and fall cows, unpublished data from the Squaw Butte Experiment Station indicate that, under their management system, fall cows would require less feed to replenish their body stores than would spring cows. Average body weight at spring turnout for two recent years (1973 and 1974), including all cows having calved at least once (for a total of

265 spring cow weights and 285 fall weights), was 30 kg heavier for fall (422 kg) than for spring (392 kg) cows.

With respect to the effects of calving and lactation on body weight changes, Jordan et al. (1973) discovered that the weight of non-pregnant dry cows tended to remain relatively constant when fed hay or silage ad libitum from December to the end of July. In contrast, the cow producing a calf manifested considerable body weight changes related to calving. Body weight showed a consistent, though gradual, increase from the first of December until calving in April or May, when body weight dropped precipitously with calving, and was followed by an additional decline until the end of July.

In Oklahoma work with 32 spring calving Hereford cows (Ewing, Stephens, and Smithson 1966; Ewing et al. 1966), mean weight loss due to calving was 58.5 kg of which 34 kg, or 58.1% of the total, was due to the weight of the calf. These cows continued to lose weight until 38 to 42 days post calving. Previous fall weight was regained by 168 days postpartum. Of the 17% body weight loss from November until 28 days postpartum, 13% was due to loss at calving.

Using 409 records on Hereford cattle (Vaccaro and Dillard 1966), it was found that on the average, cows lost weight during the period from 90 days before calving to right after calving and during the first 60 days of lactation, and then gained thereafter. Mature cows producing faster gaining calves tended to have larger weight losses during the first 60 days of lactation, but gained more thereafter. Maddox (1965b) considered (based on unpublished data from the Southern Great Plains Field Station, USDA) a 15 to 20% loss of weight during a 90-day calving season to be normal for cows producing 90% calf crops and 450 lb calves at weaning.

Maintenance for Lactation. For some time there have been data available to indicate a differential maintenance requirement for lactating and dry cows. Earlier work involved primarily dairy cows. Ritzman and Benedict (1938) found the basal metabolism of lactating Holsteins to be 48% higher than in the non-lactating cows. A difference in maintenance requirements of 87% was found by Hutton (1962) in work with lactating and dry cows in New Zealand. Brody (1945) reported a 22% increase in maintenance needs due to lactation. Recently, several reports have documented increases of a similar nature in beef cattle. Schake and Riggs (1972) reported significant increases in heart and udder weights in Hereford cows following calving, and cite other work which demonstrated a 3% greater blood supply in lactating cows as compared to dry cows.

In a drylot study, Ewing *et al.* (1968) found that daily maintenance requirements for a dry open Hereford cow could be represented by DE (Mcal) = $6.861 + 0.00606\ W_{lb}$, whereas that for a lactating cow was DE (Mcal) = $6.764 + 0.0090\ W_{lb}$, or approximately a 28% increase for a 1000 lb cow. Similarly, Neville and McCullough (1969) found a 30% higher maintenance requirement for lactating Herefords compared to dry cows. The former was 178.4 kcal ME/$W_{kg}^{0.75}$/24 hours vs. 137.4 kcal ME/$W_{kg}^{0.75}$/24 hours. In a more recent study, Neville (1974) found a 41% difference in requirements, being 0.174 Mcal ME/$W_{kg}^{0.75}$/24 hours for lactating cows and 0.123 Mcal ME/ $W_{kg}^{0.75}$/24 hours for non-lactating cows.

It is clear from the literature cited above that lactation does place an additional maintenance burden on the cow, apparently on the order of 30 to 40%. Unfortunately, there appears to have been no work done to establish the effects of different levels of lactation on maintenance requirements--only between milking and dry cows. In a spring-fall calving comparison, the information reviewed above would apply directly only in an early fall calf weaning program in which the fall cow would be dry for part or all of the summer grazing season. The same can be said of any attempt to determine the total lactation effect (lactation maintenance plus milk production) on differential forage intake of cows in different stages of lactation, but grazing concurrently. There are a limited number of reports which do compare intakes of dry and lactating cows or measure intake as related to milk production levels. Only one involves grazing beef cattle, however.

In a confinement study Neville (1974) found from 67 to 93% greater metabolizable energy intakes for lactating cows compared to dry, whereas Schake and Riggs (1972) reported a more modest increase in ration intake of 34% for cows following parturition compared to those which had not yet calved. Jordan et al. (1973) published graphs showing differences between lactating and non-pregnant dry cows ranging from approximately 5 to 30% with differences in intake declining with time following calving. Current N.R.C. (1970) recommendations suggest about 65 to 70% as much metabolizable energy is needed for the dry pregnant mature cow compared to the lactating cow in the first three to four months postpartum.

In a study comparing forage intake on pasture by dry pregnant or lactating dairy cows, Dijkstra (1971) found respective DM intakes of 11.7 and 15.2 kg, the latter being 30% higher. Milk yield at the time of intake measurement averaged 18.5 kg/day.

In a Colorado grazing study (Streeter et al. 1974), forage intake and milk production were measured in four breeding groups of two to four animals each of Brown Swiss, Charolais x Angus, and two groups of Herefords. Mean DM intake for the respective groups was 14.7, 12.0, 10.5, and 10.3 kg daily, corresponding to mean 14-hour milk production of 6.0, 4.4, 4.0, and 3.0 kg. When adjusted for metabolic size ($g/W_{kg}^{0.75}$), intake for the Brown Swiss was 145 g; for Charolais x Angus, 141 g; and 125 g for the two Hereford groups, suggesting a higher requirement to meet the greater lactation demand.

Gestation. Because of the exponential type growth exhibited by the developing fetus, over half of the fetal energy is deposited during the last quarter of gestation (Maynard and Loosli 1969). Tables published by Maddox (1965a) indicate a gestation requirement amounting to 6% of maintenance by the seventh month of pregnancy in the bovine. By the eighth month this had increased to 11%; and to 20% during the last month prior to parturition.

Moe and Tyrrell (1972) suggested that the metabolizable energy required by the pregnant Holstein cow increases from 101 kcal/kg$^{0.75}$ on the first day of pregnancy (compared to the maintenance requirement of 100.8 kcal/kg$^{0.75}$ for the non-pregnant dry cow) to about 175 kcal/kg$^{0.75}$ at parturition, or about 75% above maintenance. This is considerably higher than the 20% increase suggested by Maddox (1965a). In either case the greatest burden comes during the last two to three months of pregnancy. Any significant effect on range forage intake would apply only to the fall cow, and the degree to which intake might be affected would depend on how long the cows remained on the range relative to calving time.

Although energy requirements of the fetus increase up to the day of birth (Moe and Tyrrell 1972), there is some evidence to indicate that intake by the dam may actually drop just prior to parturition (Jordan *et al.* 1973). It was suggested that this might result from a reduced rumen capacity due to the rapidly expanding fetal tissues. In this case the needs of the fetus above those which could be met by the dam's diet would of necessity come from the mother's body stores.

It is readily evident from the information reviewed that considerable work needs to be done to elucidate the various interrelations among factors influencing the forage intake by the cow-calf unit. More information is needed regarding the general requirements of the cow and calf as these relate to body condition and size, milk production, reproduction, growth, forage intake and quality, and management. Particularly where two or more major management systems are available in an area, work should be done insofar as feasible to provide comparative general and specific guidelines regarding feed requirements in order to optimize the decision making capabilities of the producer.

Determination of Voluntary Intake

The accurate determination of voluntary forage intake of animals on pasture has been a serious problem and challenge for the range nutritionist for years, both due to the importance of this type of information in range nutrition research and the difficulty in obtaining reliable data. Among the approaches utilized to estimate intake are (1) relating animal performance to intake (Davis *et al.* 1970; Knott, Hodgson, and Ellington 1934); (2) relating water intake to forage intake (Hyder 1970); (3) observing numbers of mastications in deer

(Crawford and Whelan 1973; Wallmo and Neff 1970) and in domestic livestock (Bjugstad, Crawford, and Neal 1970); (4) using fecal index techniques (McManus, Dudzinski, and Arnold 1967); (5) feeding clipped forage in conventional digestion trials (Short 1970); (6) using an agronomic approach with clipping before and after grazing to estimate herbage removal (Martin 1970); and (7) relating forage intake to fecal output and forage digestibility (excretion to indigestibility ratio). Only certain aspects of the latter three methods will be considered here.

Conventional Digestion Trial

McDonald (1968) outlines a number of possible ways in which hand feeding might vary from grazing under general conditions. However, only a few of those listed would necessarily apply in a trial to measure intake of clipped forage.

Some criticisms of the use of hand feeding to determine intake which are commonly advanced are the use of definite feeding periods (vs. continual availability under grazing conditions), lower feed intake in confinement, and the loss of the selectivity manifested by grazing animals. Wallace (1969) contended that the first two arguments are of relatively minor importance, since grazing cattle tend to establish major morning and evening grazing periods (Dwyer 1961; Wagnon 1963), similar to a twice daily feeding schedule; and lower intakes can be related to lower maintenance requirements of confined animals (Schake and Riggs 1971). The third point (loss of selectivity), it was conceded, might be a valid objection unless forages were fed which had actually been selected by the animal. Wallace (1969) and Scales et al. (1974), for example, fed cattle-grazed, esophageal fistula-collected forage to sheep in digestion and metabolism studies. It might be further argued that, in spite of lowered maintenance requirements and loss of selectivity, relative (though not absolute) intake between animals on different treatments could be established with a reasonable degree of accuracy even with machine harvested forage.

Agronomic Techniques

Clipping plots before and after grazing has been used quite extensively to measure intake and forage utilization under pasture and range conditions (Martin 1970). A major fault with this technique for measuring intake is the unaccounted losses due to such things as trampling and consumption or destruction by wildlife and insects, with resultant overestimation of forage intake. If the forage is in a growing stage, this too must be accounted for in determining intake. Several of the possible statistical problems related to this method are discussed by Sampford (1960). As with confinement feeding, this method appears to be more applicable to determining relative intake between treatments than to quantitative intake measurement.

Excretion to Indigestibility Ratio

A wide variety of techniques in various combinations have been utilized to estimate intake by the excretion to indigestibility ratio approach. The common problems faced, regardless of techniques employed, are to quantify fecal output and determine forage digestibility. Techniques utilized to arrive at estimates of fecal production and forage digestibility have been reviewed quite extensively by a number of authors, including Harris et al. (1967), Streeter (1966, 1969), Theurer (1970), and Wallace (1969).

Streeter (1966) concluded, after a rather thorough review of the literature, that chromic oxide was the best indicator for estimating fecal output. However, a recent review[1] of nearly 15 years of chromic oxide work conducted under the auspices of the Western Regional W-34 and W-94 projects (Range Livestock Nutrition) indicated that chromic oxide would not consistently give an accurate estimate of fecal production, and at best should only be used when comparing similar animals within a given set of conditions and within the same trial.

In view of the objections given for the various indicators for estimating fecal output (see discussion by Streeter 1969), such as problems in sample preparation and chemical analysis, diurnal

[1] Kartchner, R. J. 1973. Chromic oxide in range nutrition studies. Unpublished review.

variation in indicator excretion patterns, and others, total fecal collection may still be the method of choice in many situations, although it is relatively arduous and time consuming. There is evidence, too, that harnessed animals will gain less than unhindered animals (Meyer, Lofgreen, and Ittner 1956), although it may not affect intake (Raymond and Minson 1955).

With respect to determination of digestibility, a variety of indicators have been used as revealed in the aforementioned reviews. In recent years considerable attention has been given to the development of *in vitro* techniques (Van Dyne and Meyer 1964) for determining the digestibility of forages, particularly those collected via an esophageal fistula in the grazing animal (Van Dyne and Torell 1964). Of the many *in vitro* digestion procedures available (Johnson 1966), one of the most effective has been the method of Tilley and Terry (1963) in which the *in vitro* digestion is followed by a pepsin digestion. As pointed out by Van Soest, Wine, and Moore (1966), in theory the Tilley-Terry approach does not include a factor to account for the metabolic fecal DM (of animal origin) which would be excreted in an *in vivo* digestion process. The amount of DM of animal origin excreted is related to the amount of fiber in the ration (Maynard and Loosli 1969). Consequently, one might expect this fraction to increase with advancing forage maturity and thus exert an increasing influence on the predictability of apparent *in vivo* DM digestion by the *in vitro* technique. In spite of the theoretical problem just discussed, and for reasons not yet fully understood (Van Soest et al. 1966), the in vitro-acid pepsin digestion of Tilley and Terry (1963) can produce relatively high correlations with apparent in vivo DM digestibility on forages exhibiting a wide range of digestibilities (Scales et al. 1974; Tilley and Terry 1963; Van Soest et al. 1966; Wilson, Weir, and Torell 1971).

It appears, then, that for determining quantitative intake of grazing cows and calves, relatively accurate estimates could be obtained using a Tilley-Terry (1963) in vitro system in conjunction with total fecal collection. Relative intake could be effectively measured by either the conventional digestion trial with harvested forages or the agronomic method.

MATERIALS AND METHODS

Three experiments were conducted at the Squaw Butte Range Experiment Station during the summers of 1972, 1973, and 1974 (experiments 1, 2, and 3, respectively) to obtain estimates of quantitative and relative forage intake during the summer grazing season for spring and fall pairs and to obtain concurrent measurements of weight changes and milk production.

Experiment 1

Six fall and six spring calved first partum cows were confined with their calves in individual pens measuring approximately 4.5 x 12 m. A small, 1.5 x 4.5 m creep area was located at one end of each pen, and feed bunks for the cows were designed such that the calves had no access to them (Fig. 1). Consequently, the intake of each cow and each calf could be determined on an individual basis.

To obtain a quality pattern similar to that seen in range forage with advance of season, hay was harvested at intervals varying from 2 to 10 days throughout the experimental period. Hay was taken from a field of tall fescue initially; tall fescue-alfalfa from May 22 to June 19; tall fescue from June 20 to July 7; and native flood meadow from July 8 to the end of the trial on August 21. Beginning approximately July 1, all of the hay was baled. Prior to this date, the grass was

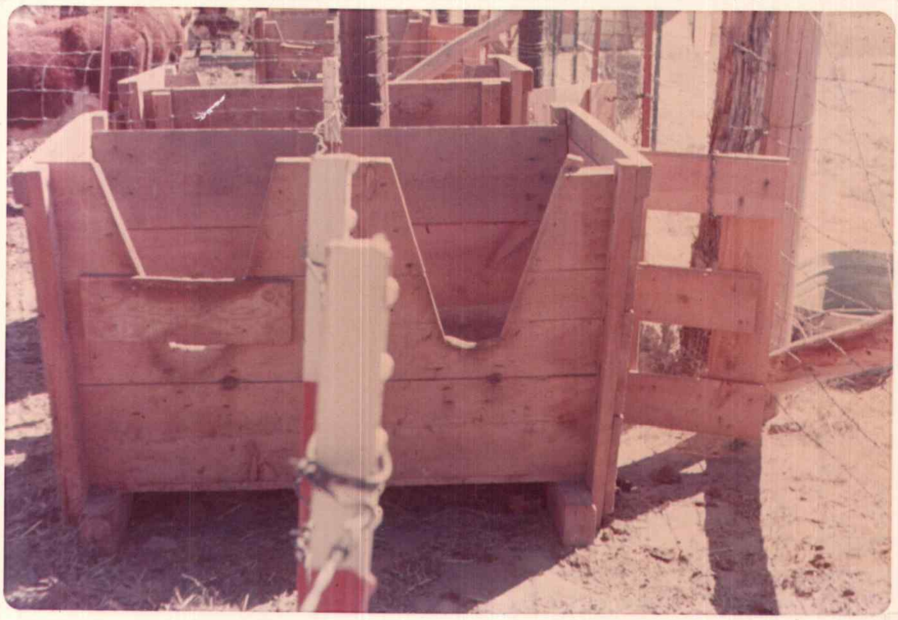

Figure 1. Feed bunks for cows and calves in experiment 1. Calf obtained hay from creep area on right.

cut, windrowed, allowed to dry for two or more days, and fed in loose form.

Measured quantities of hay were fed *ad libitum* twice daily to each animal from May 16 to August 21. A sample was taken from the hay in each bunk at each feeding and composited on a per feeding basis for dry matter (DM) determination, and refusals were weighed once a week and discarded after sampling for DM analysis. Hay samples taken for DM determination were ground, composited on a per harvest basis, and subsampled for analysis.

Cows were weighed monthly following an overnight withdrawal of food and water. Milk production was measured on three occasions between June 4 and July 8 by the calf suckling technique. Each calf was confined in the creep area at 4 p.m. The following morning at 8 a.m. the calf was weighed, allowed to suck, and weighed again in a squeeze chute apparatus mounted on a platform balance calibrated to 0.25 lb. The calf was again confined and a second measurement taken at 4 p.m. The sum of morning and afternoon differences between before and after suckling weights was taken as 24-hour milk production.

Experiment 2

Six fall and six spring multiple partum cows suckling steer calves grazed continuously on crested wheatgrass pasture from May 1 to August 31. Cows were selected to provide comparable mean weights for spring and fall treatments at spring turnout. At approximately one-month intervals for 5 to 10-day periods between May 10 and August 31, spring and fall pairs were grazed separately (by treatment) on pastures varying in area from 2.99 to 6.55 ha.

Prior to introduction of the animals into the experimental grazing areas, ten longitudinal transects were randomly located in each field, and ten points randomly located on each transect. At each point a 0.61 x 1.83 m frame was clipped, bagged, and dried. The mean sample dry weight, converted to kg/ha and multiplied by the number of ha per field, was used to estimate available forage. Following grazing, the procedure was repeated to estimate residual forage, and the difference between before and after grazing was used to estimate forage intake. An adjustment in estimated intake, based on previous data collected in prior years from the area, was made to account for rate of forage growth for the first grazing period. The forage had largely matured and exhibited little growth by the second trial, so no additional adjustments were made.

Following each grazing period, cows were weighed following an overnight withdrawal of food and water, and milk production was measured as in experiment 1 with the exception that fecal bags were worn by calves during the weighing and suckling procedures to prevent loss of feces. The weighing apparatus (Fig. 2) consisted of a chute

Figure 2. Weighing chute used for milk production determination.

with one hinged side and hung from a meat scale (0.25 lb calibration) mounted on the three-point hookup of a tractor. With a calf inside the apparatus could be quickly raised or lowered hydraulically; and when raised, the chute and calf were left suspended (Fig. 3). The hinged side produced a squeezing effect as a consequence of the animal's weight, thus restricting movement by the animal.

Experiment 3

Six spring and six fall pairs were grazed continuously on crested wheatgrass pasture from April 22 to September 2. Six 5-day total fecal collection trials were conducted between April 29 and August 31, with a 16-day interval between periods for the first four trials and a 23-day interval between periods for the last three trials. Cows were initially selected on the basis of an approximately uniform mature body weight and ranged in age from 6 to 10 years.

A modification of the bag described by Garrigus and Rusk (1939) was used to obtain total collection from cows; and a "sheep bag,"[1] supported by a locally designed and constructed harness (Fig. 4; see also Appendix A), was used to collect feces from calves.

Bags for cows and fall calves were emptied twice daily between 6 and 8 a.m. and between 4 and 6 p.m.; only a morning collection was

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[1] Cheyenne Tent and Awning, Cheyenne, Wyoming.

Figure 3. Weighing chute used for milk production determination showing calf and chute in raised position.

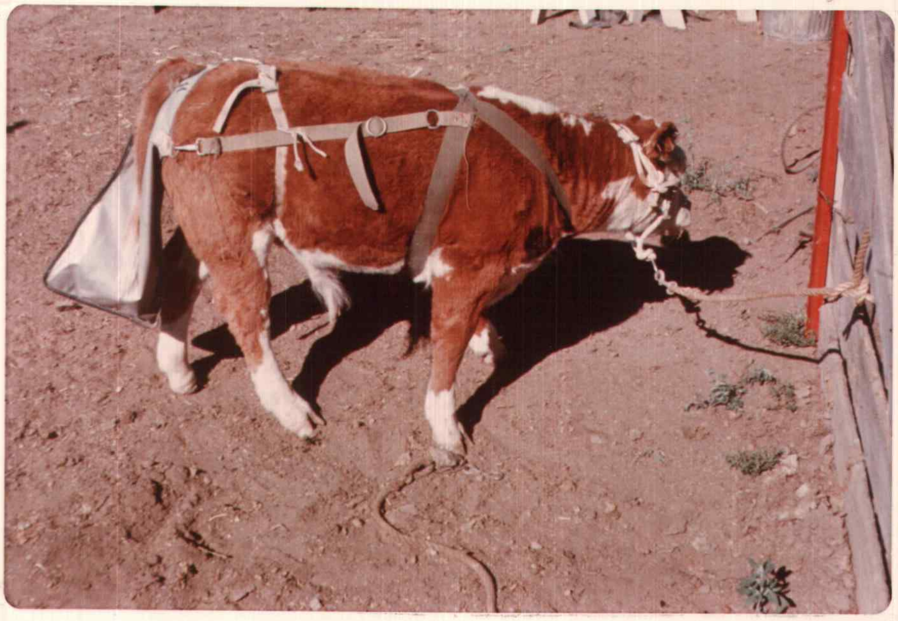

Figure 4. Fecal bag and harness used in calf fecal collection.

made from spring calves. Sampling procedures for each animal are described below. The bag (which had been tared prior to initial hook-up) and contents were weighed on a milk scale (calibrated to 0.10 lb) and contents emptied into a large bucket; the bag was re-tared and attached to the animal again immediately. (Note: for the first two trials two sets of bags were maintained for each cow, with a clean bag replacing the one removed at each collection.) Feces were stirred, a 300-450 g sample was placed in an aluminum drying pan, and the sample was immediately covered with a light-weight plastic bag to minimize moisture loss. Samples were taken to the weighing and drying facility at the station, plastic bags removed, and wet samples weighed to the nearest gram. Samples were dried in a forced draught oven at 60°C and re-weighed to determine DM content. Calf feces were subsampled, ground through a 1-mm screen in a Wiley mill, and stored in glass jars for subsequent analysis.

Because the cows were lactating, it was necessary to alter the fecal bag so that the center flap was held in an upright position (Fig. 5) rather than extending forward between the hind legs as it was designed to do (Garrigus and Rusk 1939). A double flap apparatus was designed for separation of urine and feces (Figs. 6 and 7). The inner urinary flap (appearing black in Fig. 6) was suspended between bag and animal, deflecting urine downward to the ground, whereas the outer fecal flap (light brown) extended into the bag and directed the

Figure 5. Fecal collection bag showing alterations for use with feces-urine separator flaps.

Figure 6. Feces-urine separator flaps attached to cow.

Figure 7. Feces-urine separator flaps as used with altered collection bag.

feces inward. The flaps were sewn together at the upper edges, and the dorsal edge of the combined flaps was suspended just posterior to the rectal opening but above the vulva. A 5-cm strap extending over the tail head and attaching to the flaps on either side of the rectum was used to maintain the flaps in position. Bull Cement[2] was used as an adhesive to fasten this strap securely to the animal. Additional information regarding construction and use of these flaps is found in Appendix A.

Forage samples were collected via esophageal fistula from between four and seven animals on the morning of each full day of collection (i. e., four collections per trial). The collections from all animals were composited on a daily basis, subsampled, and the subsample dried at 60°C. Dried samples for each period were ground and composited on an equal weight basis (among days) and stored for analysis. Following each collection period, all animals were weighed after an overnight withdrawal of water, and 24-hour milk production was measured as in experiment 1 using the weighing apparatus and fecal bags described for experiment 2.

Analytical Procedures

Hay and forage samples from the three experiments were

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[2] A 3M product. Obtained from Tucker Printing House, Jackson, Miss.

analyzed for crude protein using the Kjeldahl nitrogen procedure described by Black et al. (1965) and for DM digestibility by a modification of the in vitro method of Tilley and Terry (1963). Forage samples and calf fecal samples from experiment 3 were analyzed for cellulose content by a modified Crampton and Maynard (1938) procedure. The latter forage samples were also analyzed for in vitro cellulose digestibility. Details of the in vitro procedures and cellulose analysis are found in Appendices B and C. Forage samples (not from the experiments reported herein), on which in vivo digestibility had been previously determined in sheep trials, were used to correlate in vivo and in vitro digestibility values.

Intake was estimated as

$$\text{DM Intake} = \frac{\text{FRC}}{1 - \text{DRC}} \div \text{Forage RC}$$

where FRC is the fecal output of the reference component (RC; cellulose or DM) and DRC is the in vitro digestibility of the reference component expressed as a decimal.

Appropriate statistical analyses for the three experiments followed the procedures set forth by Steel and Torrie (1960). Specific probability values for treatment differences were computed by the procedure outlined by Swartzendruber (1961) using the tables of Pearson (1956).

RESULTS AND DISCUSSION

Prior to making comparisons among experiments (henceforth, experiments 1, 2, and 3 will also be referred to as E-1, E-2, and E-3, respectively), reference needs to be made to the quality of the hay or forage available to the animals in the respective experiments. The hay quality pattern in E-1 (Appendix Table 10), as measured by crude protein (CP) content and *in vitro* dry matter digestibility (IDMD), was basically as reported in earlier work at this station on meadow hay (Wallace, Rumburg, and Raleigh 1961) and in E-2 and E-3 forages (Appendix Table 11). Although the alfalfa in the May 22 to June 10 cuttings constituted a relatively minor portion of the total plant material, its presence undoubtedly increased the CP and IDMD of this hay above what might be expected from the fescue alone.

The forage qualities for E-2 and E-3 (Appendix Table 11) are not subject to direct comparison since the E-2 sample represented the total clipped forage in 1973, whereas fistulated animals were used to collect the E-3 samples in 1974. Consequently, the latter might be expected to be somewhat higher in quality, since studies have shown that grazing animals select a diet higher in quality than the total forage (Kiesling, Nelson, and Herbel 1968; Weir and Torell 1959). Differences in forage quality (clipped or grazed) can be expected to be higher where species composition is variable (Arnold *et al.* 1966) compared to a single species stand, and lower on mature compared to immature forage (Robards, Leigh, and Mulham 1967).

It is probable that much of the difference in forage quality seen between E-2 and E-3 is real and not due to sampling technique. The winter and spring of 1973 (E-2) were extremely dry with a resulting low forage production and early maturation of the forage with its concurrent decline in quality. In contrast, sufficient moisture was available in 1974 (E-3) to produce abundant forage and a delay in maturation relative to 1973.

Digestible energy (DE) values were computed on E-3 forages from IDMD values (Appendix Table 11) by applying the equation developed by Rittenhouse, Streeter, and Clanton (1971). These authors have shown that digestible DM and DE content of forages are highly correlated, the relation being expressed as kcal DE/g digestible DM = 0.18 + 0.038 x DM digestibility. For the studies reported herein, this approach probably provides the best available estimate of the forage energy content, although the validity of the DE values thus derived would be dependent on the accuracy with which *in vivo* DM digestibility was estimated by *in vitro* fermentation. An additional complication arises in the case of the suckling calf, since it is known that associative feed effects can alter the digestibility of feedstuff combinations compared to a weighted digestibility value computed from digestion coefficients determined on the component feedstuffs in separate trials. Although it has been shown that rumen function in the young calf receiving roughage as part of its diet is qualitatively similar to that of the adult with respect to overall roughage utilization and cellulolytic activity (Lengemann and Allen 1959; McCarthy and Kesler 1965) and volatile fatty acid concentrations (Lengemann and Allen 1955) by the time the calf is six to eight weeks of age, the author is unaware of any work that establishes component digestibility coefficients for milk and forage fed together.

In the interest of minimizing cow size as a factor influencing relative feed intake, consumption data for cows in E-1 and E-3 have been adjusted to apply to a common body weight within experiments on the basis of metabolic size ($W_{kg}^{0.75}$). Cows in E-1 were adjusted to a 410 kg body weight and those in E-3 to 454 kg. Unless otherwise specified, all cow intake data have been presented and discussed on an adjusted basis. Calf intake data were not adjusted.

Exact probability levels for differences between treatment means have been included where appropriate for $0.25 \geq P \geq 0.01$, following the suggestion of Swartzendruber (1961). This allows the reader to make a value judgment on the probability value under consideration, rather than being limited to the customary "less than-greater than" terminology. Considering the nature of the experimental materials and procedures involved in these studies and the inherent associated variability, it is felt that P = 0.25 is a much more realistic value for lower levels of accepted probability than the $P \leq 0.05$ so commonly used in the literature.

Since "trial" has been used to designate the day or interval of actual measurement (i. e., feed intake, milk production, and body weight), "period" will be used to designate the interval between a particular measurement or day of one trial and the corresponding measurement or day of the succeeding trial.

Calf Intake and Performance

Fall calves consumed 2.2 and 3.31 kg more ($P < 0.01$) dry feed than did spring calves in E-1 and E-3, respectively (Tables 1 and 2). Experiment 2 data did not lend themselves to partitioning intakes of cows and calves.

The pattern of intake (spring vs. fall calf) over the summer was similar for E-1 (Appendix Table 12) and E-3 (Table 2), with both studies uniformly showing large differences in relative intake. This is to be expected, in part, on the basis of calf size, since respective beginning weights for spring and fall calves were 69.7 and 160.0 kg in E-1; 64.4 and 153.8 kg in E-2; and 55.3 and 146.7 kg in E-3.

Fall calves on pasture tended to eat more than their hay-fed counterparts, although forage DM intake was lower for spring calves on pasture (Table 2) than for those in drylot (Appendix Table 12) until the latter part of July. It is possible that the milk intake levels of

Table 1. Daily dry matter (hay) intake and performance of spring and fall pairs in drylot (experiment 1).

Item	Treatment[a] Spring (kg)	Fall (kg)	P[b]
Dry matter intake			
Cow	10.72	10.00	0.08
Calf	1.28	3.48	< 0.01
Cow + calf	12.00	13.48	< 0.01
Total feed/gain			
Calf[c]	24.38	20.16	0.20
Cow + calf[d]	14.42	11.66	0.23
Average daily milk production[e]	3.73	2.13	< 0.01

[a]Mean of six animals or pairs per treatment.

[b]Probability level at which treatment means on same line differ significantly; see Appendix Tables 13 and 16 for analyses of variance.

[c]Total kg feed (cow + calf) necessary to produce 1 kg of calf gain.

[d]Total kg feed (cow + calf) necessary to produce 1 kg of cow and calf gain.

[e]Mean of three measurements between June 4 and July 8.

Table 2. Daily forage dry matter intake (kg) by spring and fall calving cows and their calves on pasture (experiment 3).

Animal class	Treatment[a]	Trial 1	Trial 2	Trial 3	Trial 4	Trial 5	Trial 6	Trial 1-6
	Date:	4/29-5/3	5/20-5/24	6/10-6/14	7/1-7/5	7/29-8/2	8/26-8/30	4/29-8/30
Cow	Spring	12.71	17.92	11.44	10.73	9.88	9.20	11.98
	Fall	12.00	16.02	9.54	10.72	8.22	8.93	10.90
	P[b]	> 0.25	0.17	0.15	> 0.25	> 0.25	> 0.25	0.02
Calf	Spring	0.12	0.54	0.68	0.90	1.71	1.71	0.94
	Fall	2.63	4.67	3.74	3.77	5.53	5.37	4.25
	P[b]	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
Cow + calf	Spring	12.83	18.46	12.11	11.46	11.60	10.90	12.89
	Fall	14.62	20.68	13.28	14.48	13.75	14.29	15.19
	P[b]	0.18	0.08	> 0.25	< 0.01	0.25	< 0.01	< 0.01

[a]Mean of six animals or pairs per treatment.

[b]Probability level at which treatment means within trial and animal class differ significantly; see Appendix Tables 14 and 15 for analyses of variance.

the spring calves on pasture more nearly met their needs for the first two to three months than did those of the drylot calves. The latter were suckling cows two to three years of age and in their first lactation. It has been shown (Jeffery et al. 1971; Melton et al. 1967) that milk production increases through at least the first three lactations and levels off at maturity. Melton et al. (1967) found total milk production in cows five years of age or older to be 46% higher than that in two-year-olds.

Interpolating from the data in Table 2, it was estimated that total forage intake over the 119-day period in E-3 was 121 kg for spring calves vs. 527 kg for the fall treatment, corresponding to respective computed caloric intakes of 270 and 1241 Mcal of DE based on values given in Appendix Table 11.

Mean daily spring calf milk consumption in E-1 (Table 1) was somewhat greater than for the fall calf (3.73 vs. 2.13 kg; $P < 0.01$) over the five-week measurement interval. Equipment breakdown precluded additional data collection. A better overall view of this production criteria is provided by E-2 (Table 3). Milk production (consumption by calves) in E-2 consistently declined for both treatments from the first measurement on May 24 until the end of the experiment on August 31. Fall production as a percent of spring also declined steadily with the season from a high of 56% to a low of 7%, all differences being significant at $P < 0.01$. Milk production in

Table 3. Mean daily milk production by spring and fall calving cows on pasture (experiment 2).

Trial	Date	Treatment[a]	
		Spring[b] (kg)	Fall[c] (kg)
1	5/24	5.72	3.18
2	6/30	4.68	2.69
3	7/31	4.05	1.06
4	8/31	2.92	0.21
	5/24-8/31	4.34	1.78

[a]Mean of six cows per treatment.

[b, c]All treatment means on same line differ ($P \leq 0.01$); see Appendix Tables 15 and 16 for analyses of variance.

E-3 (Table 4) tended to be somewhat higher than that in E-2, persisted at rather constant levels through the fourth trial (July 6) for both treatments, and declined steadily thereafter. The earlier decline and lower production levels seen in E-2 compared to E-3 may have been due to the earlier maturation of the E-2 forage mentioned in the introduction to this discussion section.

Interpolation of the data in Table 4 gives estimates of total milk production by spring cows of 626 kg and of 294 kg for fall cows. Based on an N. R. C. (1971) value of 0.69 Mcal DE/kg of whole milk, spring calves would have consumed 432 Mcal as milk vs. 203 Mcal for fall calves.

Fall calf body weight gains exceeded (within experiment) spring gains ($P \leq 0.04$) through June for all three studies (Tables 5, 6, and 7), this time interval corresponding to the period of highest forage quality (Appendix Tables 10 and 11). Paralleling the rapid decline in forage quality in late June and July are decreases in daily gains for both treatments, as well as decreases in gain differences between treatments, so that July-August gains showed little treatment differences in E-1 (Table 5) and E-3 (Table 6). Although a like pattern was exhibited through July in E-2 (Table 7), the spring calf registered gains approaching 1 kg daily in August. This observation is difficult to explain in view of the low forage quality available (Appendix Table 11), the relatively low milk intake levels (Table 3), the results

Table 4. Spring and fall calving cow mean daily milk production and correlations with dry matter intake (experiment 3).

Trial	Date	Treatment[a] Spring (kg)	Fall (kg)	P[b]	r[c]
1	5/4	6.19	3.34	< 0.01	0.231
2	5/25	6.06	3.12	< 0.01	0.653[d]
3	6/17	6.33	3.37	< 0.01	0.654[d]
4	7/6	5.70	3.37	0.02	0.542[e]
5	8/5	4.36	1.23	< 0.01	0.498[e]
6	9/1	2.79	0.38	< 0.01	0.084
	5/4-9/1	5.24	2.47	< 0.01	

[a]Mean of six cows per treatment.

[b]Probability level at which treatment means within trials differ significantly; see Appendix Tables 15 and 16 for analyses of variance.

[c]Correlation coefficient between individual cow's adjusted feed intake and milk production within trials.

[d]$P < 0.05$.

[e]$P < 0.10$.

Table 5. Body weight gains of spring and fall calving cows and their calves in drylot (experiment 1).

Animal class	Period	Treatment[a] Spring (kg)	Fall (kg)	P[b]
Cow	5/15-6/15	26.2	27.3	> 0.25
	6/16-7/15	5.0	8.7	> 0.25
	7/16-8/22	7.8	11.2	> 0.25
	Total gain	39.0	47.2	> 0.25
Calf	5/15-6/24	15.3	29.0	0.02
	6/25-7/18	21.0	24.2	> 0.25
	7/19-8/22	13.9	14.9	> 0.25
	Total gain	50.2	68.2	0.05

[a]Mean of six animals per treatment.

[b]Probability level at which treatment means on same line differ significantly; see Appendix Table 17 for analysis of variance.

Table 6. Body weight gain (kg) of cows and calves on pasture (experiment 3).

Animal class	Treatment[a]	Trial 1	Trial 2	Trial 3	Trial 4	Trial 5	Total gain
	Date:	5/4-5/24	5/25-6/14	6/15-7/5	7/6-8/2	8/3-8/30	5/4-8/30
Cow	Spring	36.4	34.8	16.3	-5.7	-9.8	75.8
	Fall	40.7	44.8	27.8	7.6	-4.5	116.4
	P[b]	> 0.25	0.05	0.20	0.20	> 0.25	< 0.01
Calf	Spring	17.0	20.5	16.4	21.9	14.0	89.8
	Fall	26.7	35.0	21.4	23.8	11.6	118.5
	P[b]	< 0.01	< 0.01	0.04	> 0.25	> 0.25	< 0.01
Cow + calf	Spring	54.8	55.3	32.6	18.6	4.1	165.6
	Fall	64.0	78.8	49.2	31.4	7.1	231.5
	P[b]	0.21	0.01	0.12	0.17	> 0.25	< 0.01

[a]Mean of six animals or pairs per treatment.

[b]Probability level at which treatment means within period and animal class differ significantly; see Appendix Table 18 for analysis of variance.

Table 7. Body weight gains of spring and fall calving cows and their calves on pasture (experiment 2).

Animal class	Period	Treatment[a] Spring (kg)	Fall (kg)	P[b]
Cow	5/16-6/30	47.2	50.6	> 0.25
	7/ 1-7/31	7.2	18.3	0.21
	8/ 1-8/31	14.0	17.0	> 0.25
	Total gain	68.4	85.9	0.13
Calf	5/16-6/30	33.8	47.7	< 0.01
	7/ 1-7/31	22.6	26.8	> 0.25
	8/ 1-8/31	28.7	11.8	< 0.01
	Total gain	85.1	86.2	> 0.25

[a]Mean of six animals per treatment.

[b]Probability level at which treatment means on same line differ significantly; see Appendix Table 17 for analysis of variance.

obtained in E-1 and E-3 (Tables 5 and 6), and the data reported from earlier work at this station (Raleigh 1970). As a consequence of this late summer gain, total gains did not differ between treatments in E-2. However, total fall calf gains did exceed spring gains in E-1 (68.2 vs. 50.2 kg; $P = 0.05$) and in E-3 (118.5 vs. 89.8 kg; $P < 0.01$) due primarily to the advantage realized during May and June.

Energy requirements for maintenance plus gain (E-3; Table 6) were estimated using a relationship developed by Garrett, Meyer, and Lofgreen (1959): kcal DE = $76W_{lb}^{0.75}$ $(1 + 0.58 \times \text{gain}_{lb})$. The limitations of applying this equation, derived under feedlot conditions, to pasture studies are recognized. However, in the absence of adequate data of a similar type applicable to pasture conditions, this equation will be used. On this basis, spring calves required 517 Mcal of DE compared to 1155 Mcal for fall calves.

The sums of milk and forage DE intake (see estimates above for total forage and total milk DE consumption) for spring and fall calves were 702 and 1444 Mcal, respectively. However, as pointed out earlier, if significant associative feed affects were present, a summative approach as used here would be invalid. In the case of milk the complexity of the situation is increased still further considering the potential for a different digestion coefficient for milk that bypasses the rumen compared to that which undergoes ruminal fermentation. When total DE intake was calculated on the basis of total DM intake (forage + milk), estimates for spring and fall calves were 569 and 1391 Mcal, respectively. These values more closely approximate the above calculated energy requirements and are theoretically more sound than the summative values just cited, since the work of Rittenhouse et al. (1971), on the basis of whose work these DE values were calculated, showed that adding supplement to a forage diet did not alter the DM digestibility-DE relationship, but only if calculated on the total diet. The information from which the above DE intake values were derived, although based largely on computed values, suggests that the digestibility of forage and milk fed together is lower than might be expected if additivity of digestion coefficients of component feedstuffs were assumed, and this difference increases as milk intake increases relative to forage intake. If this were true, the currently accepted energy value of milk as a feedstuff for the range calf would be overestimated. Additional investigation is needed to clarify this situation.

It is to be expected that calculated requirements would be somewhat lower than measured energy intake, as seen in the above situation, since studies have shown a greater energy requirement under pasture conditions than in confinement where the maintenance figure of Garrett et al. (1959) was developed. For example, Reid, Smith, and Anderson (1958) found maintenance (basal metabolism + activity increment) to be 40% higher in dairy cows maintained on pasture compared to similar barn-fed cattle. Schake and Riggs (1971) found that beef cattle kept in confinement traveled approximately 10% as much as those on range.

Cow Intake and Performance

Spring cows consumed more hay in E-1 (Table 1) than did fall cows (10.72 vs. 10.00 kg/day; P = 0.08) and more forage (Table 2) in E-3 based on a mean of all measured intake values (11.98 vs. 10.90 kg/day; P = 0.02). Adjusted weekly intake values in E-1 (Appendix Table 12), as with forage intake by trial in E-3 (Table 2), were generally consistent in averaging higher for spring cows. The exception, seen in Appendix Table 12, was the last two weeks for drylot cows when fall intake averaged slightly higher. Although within trial differences were not all significant at the 0.25 probability level in E-3, and weekly differences in E-1 were not tested for significance, the consistent pattern seen in both studies suggests that the heavier milking spring cow can be expected to consume a higher level of forage throughout most of the summer. This is supported by the positive correlations found between forage intake and milk production in four of six trials in E-3 (Table 4).

The 332 kg difference in estimated total milk production by spring cows (626 kg) and fall cows (294 kg) in E-3 was equivalent to 229 Mcal of DE. Based on a requirement of 1.78 Mcal DE in the feed per Mcal of milk DE produced (Maddox 1965a), the spring cow would require 408 Mcal more DE in the feed than the fall cow. Dividing 408 Mcal by a weighted average value of 2.40 Mcal kg for the DE content of the forage gives an estimated difference in DM consumption of 170 kg for the 119-day period, or 1.43 kg per day. This is higher than the 1.08 kg difference determined by averaging all intake values (Table 2). A weighted average daily intake, derived by interpolation of the data in Table 2, was 12.02 and 10.76 kg for spring and fall treatments, respectively, the difference being 1.26 kg. The latter difference is higher and theoretically more reliable than the unweighted difference value cited above, and more closely approximates the calculated difference of 1.43 kg. The measured difference in forage intake (E-3) attributable to differences in milk production might be expected to be greater if spring and fall cows had gained at similar rates. However, as will be seen, fall cows did gain more, thus offsetting part of the additional intake for milk production in the spring cow.

Although differences in body weight gain in the three experiments (Tables 5, 6, and 7) were not always significant, any advantage in gain uniformly favored the fall treatment, resulting in significant total gain differences in E-2 (85.9 vs. 68.4 kg for spring; $P = 0.13$) and E-3 (116.4 vs. 75.8 kg for spring; $P < 0.01$), but not in E-1 (47.2 vs. 39.0 kg for spring; $P > 0.25$).

Cow-Calf Intake and Performance

Drylot fall pairs (E-1) consumed more ($P < 0.01$) as a daily average than did spring pairs (13.48 vs. 12.00 kg /day; Table 1) and consistently had a higher average intake by week (Appendix Table 12). Intake measured by clipping before and after grazing (Table 8; E-2) invariably averaged more for the fall treatment, the latter being 6, 19, 22, and 24% higher than for the spring treatment in trials one through four, respectively. Interpolation gave an estimated difference in total intake of 20%. Fall intake exceeded ($P \leq 0.25$) that for spring in four of six trials in E-3 (Table 2), with total mean values of 12.89 and 15.19 kg /day ($P < 0.01$) for the spring and fall treatments, respectively.

Average daily forage intake in E-3, as determined by interpolation, was 13.1 kg for spring pairs vs. 15.3 kg for fall pairs. Based on these values, 1 kg of fall calf gain (Table 6) required a total forage (cow + calf) investment of 15.4 vs. 17.4 kg for spring calf gain. Total animal gain (cow + calf; Table 6) required 7.8 kg feed/kg gain for the fall treatment compared to the 9.4 kg forage investment required per kg of spring cow-calf gain. Similar relative differences are seen in E-1 (Table 1) with approximately 17% less ($P = 0.20$) total forage required per unit of fall calf gain compared to spring (20.2 vs. 24.4 kg feed/kg gain); and fall cow-calf gain

Table 8. Daily forage dry matter intake by spring and fall pairs measured by before-and-after-grazing clipping (experiment 2).

Trial	Date	Treatment[a]				Fall/spring
		Spring (kg)	Area grazed (ha)	Fall (kg)	Area grazed (ha)	(%)
1	5/10-5/15	10.2	6.33	10.8	6.55	106
2	6/15-6/22	16.8	6.55	20.0	6.33	119
3	7/17-7/22	18.6	2.99	22.7	3.57	122
4	8/21-8/28	20.4	4.41	25.2	4.66	124

[a] Six pairs per treatment.

required 19% less feed per gain (11.7 vs. 14.4; P = 0.23) than did spring gain.

Pattern of Relative Intake

From a range management viewpoint, the time of forage harvest relative to the stage of physiological maturity of the grass plant may be of greater consequence to the continued well-being of the plant than total herbage removal (Stoddart and Smith 1955). To obtain an estimate of the grazing pressure exerted by the fall pair relative to spring, fall intake expressed as a percent of spring intake was plotted against date of harvest (Fig. 8) considering each combined intake measurement in Tables 2 and 8 and Appendix Table 12 an independent observation. Differences in relative intake were essentially linear over the four-month period. Average fall intake, as a percent above spring intake, increased from a low of 6% in early May to a high of 25% by the end of August, or an approximate 5% increase per month. During May and June, when excess grazing would be most detrimental to the forage, fall pair intake would exceed spring pair intake approximately 6 to 15%.

Regression of quantitative intake differences on date of harvest for E-1 and E-3 (Fig. 9) indicates that quantitative differences also increased in linear fashion with advance of season. Consequently,

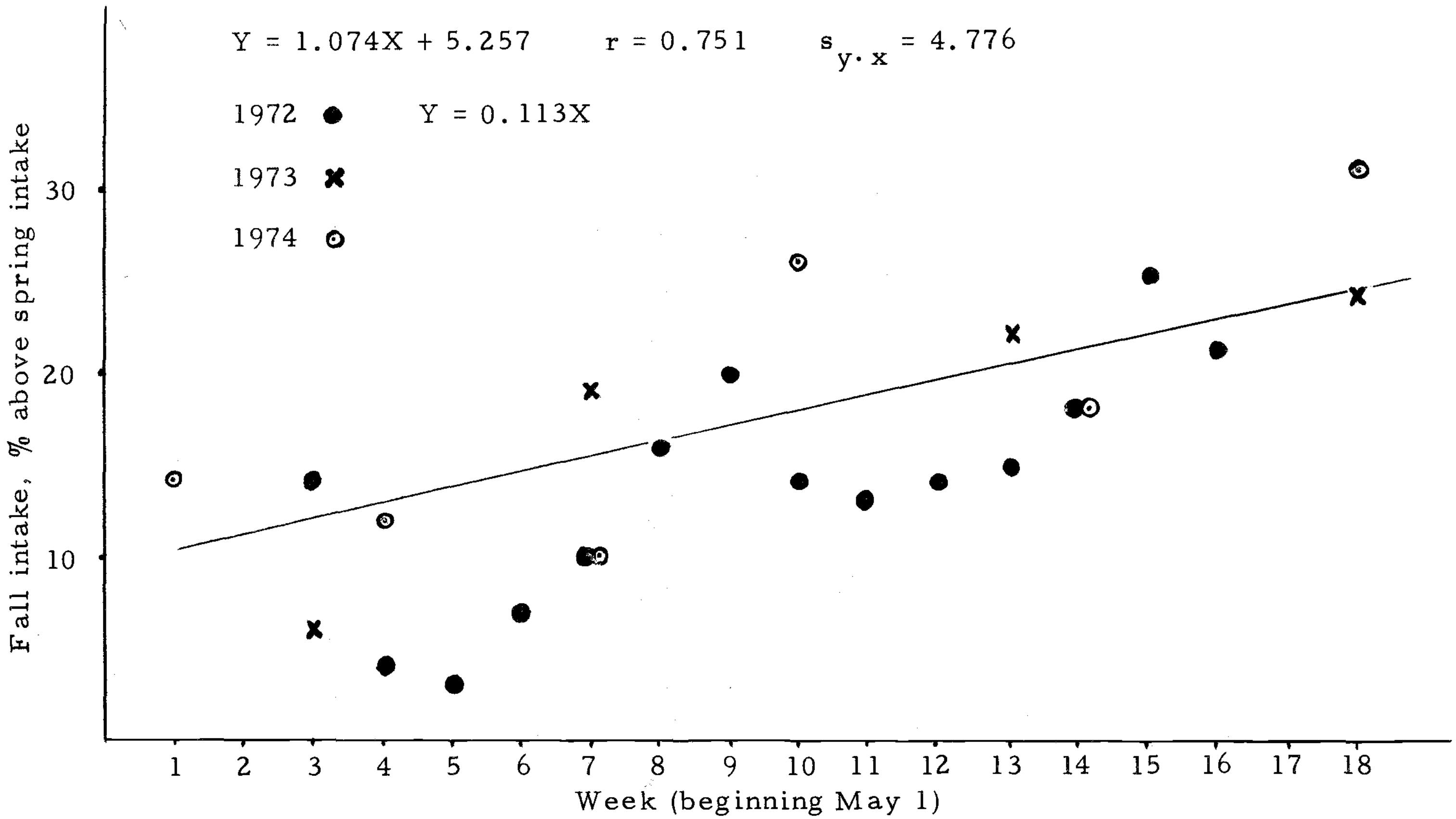

Figure 8. Increase (%) of fall pair intake above that for spring pairs with advance of season.

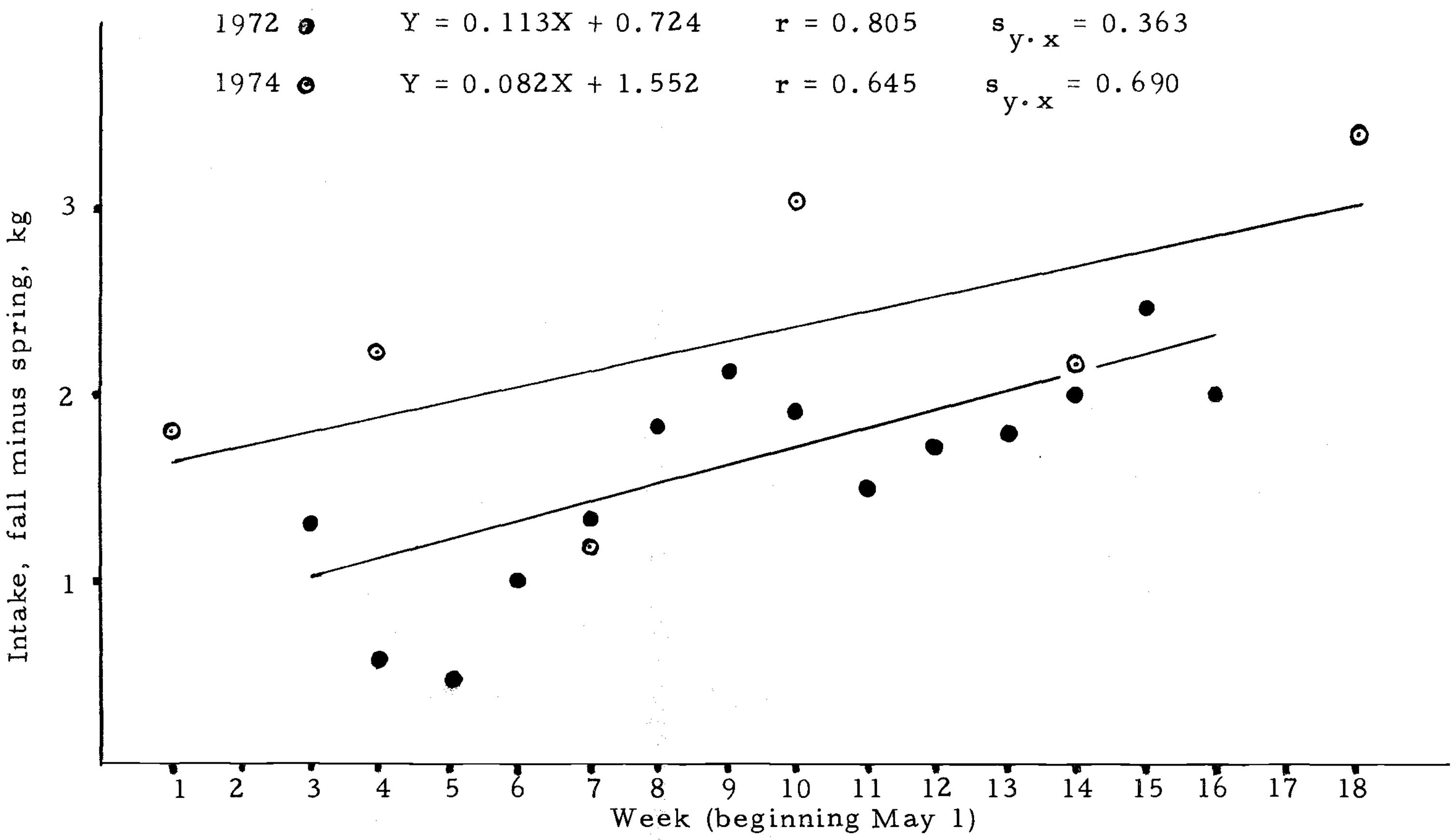

Figure 9. Relationship between difference in total intake of spring and fall pairs and advance of season.

fall pairs would consume a progressively greater amount of forage, not only on a relative basis, but also quantitatively.

On the basis of these findings, it is suggested that under the conditions of these studies fall pair numbers be reduced, relative to spring numbers, by 10 to 20% to compensate for the added grazing pressure exerted by the fall pair on the early to mid-summer forage. Such an adjustment should be taken into account in economic comparisons such as that of Raleigh et al. (1970), since there would be fewer total fall calves available for sale and fixed costs would have to be charged to fewer animals. Other studies such as those of Davis and Wheeler (1970) and Mueller and Harris (1967) might require a different adjustment factor.

Early Fall Calf Weaning

Table 9 shows adjusted intake values assuming that fall calves were weaned in late July or in early May, prior to turnout on the range. By adjusting fall intake downward to account for the quantity of feed the calf would have consumed plus the forage the dam would require to produce the indicated quantities of milk (Table 4), fall forage intake in E-3 would be equivalent to spring intake, whereas the E-1 intake was estimated at 2% higher for the fall treatment. The latter value was not adjusted to account for milk production due to insufficient data and is probably too high.

Table 9. Estimates of relative forage dry matter intake by spring and fall pairs assuming early weaning of fall calves.

Weaning date	Experiment	Spring (kg)	Fall (kg)	Fall /spring %
July[a]	1	1168	1194	102
	3	1564	1559	100
May[b]	1	1168	836	72
	3	1564	1132	72

[a]Approximately July 20.

[b]May 15 in experiment 1; May 4 in experiment 3.

An early May weaning date suggests that the dry fall cow would consume 72% as much as the spring cow and calf. Although the coincidence of values between E-1 and E-3 was fortuitous, they are in close agreement with the relative intake differences suggested by N.R.C. (1970) for the dry pregnant cow or the lactating cow in the first 3-4 months postpartum.

General Discussion and Conclusions

The current or potential fall calving operator or public grazing lands administrator has, until now, had little or no experimental evidence upon which to base a decision regarding allocation of forage resources for the fall cow and calf relative to the well-established spring calving system. The data supplied by the studies reported herein provide the first of such information.

It has been established that the fall pair will consume a greater quantity of forage on a daily basis than will the spring pair due to the greater intake of the fall calf relative to the spring calf. Offsetting for this in part is the additional intake of the spring cow, compared to her fall counterpart, required to produce a volume of milk which can be more than double that of the fall calving cow over the summer grazing season. It appears that under these conditions total fall intake will exceed that for spring by 5 to 10% in May, and this difference will increase by approximately 5% for each succeeding month through August. Quantitatively, these differences on pasture increased from 1.5 kg/day in early May to as much as 3 kg daily by late August. Based on this evidence, a 10 to 20% downward adjustment in fall animal numbers relative to spring would sufficiently compensate for the added grazing burden exerted by the larger fall calf. This approach would appear to be a more viable alternative than the blanket assessment of an animal unit to a particular age or class of cattle as pointed out by Kearl (1970).

In agreement with the contention of Raleigh (1970), there appears to be little justification for leaving the fall calf on the cow past mid- to late July. Gains were less than 0.5 kg daily, and little sustenance was obtained from the cow. Some of the fall calves would receive nothing from the latter source through all or part of August, since at least one fall cow in each of E-2 and E-3 was dry by the first of August and two or more by the end of the month. Although a mid-September vs. mid-October weaning date has been compared in spring calves (Wallace et al. 1962), the information reported herein provides the first evidence specifically related to the fall calf regarding optimum weaning time. Based on milk consumption, gain, and forage quality data, it is concluded that the current Squaw Butte Experiment Station practice of weaning fall calves in July is justified as a means of striking a balance between obtaining maximum benefit from the forage resources and optimum animal production under conditions such as are found in the high desert country of eastern Oregon. Based on the gain data presented here, it is probable that consideration should be given to an earlier (than early to mid-September) weaning date for spring calves, although in E-2 they did show gains of nearly 1 kg per day during August.

If resources are available for feeding the fall calf, a May weaning could provide numerous management alternatives related to decreasing grazing pressure on the range and/or increasing herd size (as well as a more intensive management of the calf), since the dry fall cow will consume nearly 30% less forage than the spring cow and calf.

A given quantity of forage consumed from May through August can be expected to produce more gain at a lower nutrient cost per gain if fed to the fall pair rather than the spring, in spite of the higher maintenance requirement of the fall calf. Presumably, this relates to the greater efficiency of utilizing the forage directly as opposed to the indirect route via milk. The direct utilization of high quality forage by the fall calf during the forage growing season resulted in greater gains in May and June by these animals compared to spring calves, an advantage which was maintained as total gains in two of three experiments, even though there was little difference in gain between spring and fall calves after forage quality had dropped in mid-summer.

Since these studies were conducted either in confinement or on relatively small improved pastures, an adequate estimate of forage needs to meet the travel requirement under actual range conditions was not available. Neither were data available to suggest what effect the use of spring vs. fall pairs would have in relation to a more uniform utilization of the total range, a factor which may be of some concern, since, as pointed out in the review section, the more mobile fall pair may cover a greater portion of the range, particularly during early summer, than the spring cow and calf. Both of these factors (travel requirements and area utilization) of course are highly variable, depending, among other things, on the terrain and availability of forage.

In summary, under conditions found at the Squaw Butte Experiment Station, fall pairs can be expected to consume more forage per day than spring pairs from May through August, totaling on the order of 10 to 20% higher for the fall pair over the four-month period. Intake was affected by level of milk production and calf size and was related to the body weight gain of cow and calf. It is felt that more of the type of data presented in this thesis is needed for major management systems due to the broad scope of information needed by the livestock manager on which to base decisions regarding management alternatives.

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APPENDIX A

COMMENTS ON CONSTRUCTION AND USE OF FECES-URINE SEPARATOR FLAPS AND ON CALF FECAL COLLECTION

Feces-Urine Separator Flaps

The fecal flap and tail strap (seen as light brown in Fig. 6) were made of burlap. The urinary flap (black in Fig. 6) was a "plastic burlap" sacking material coated with a rubbery substance (Flexane[1]) to improve the urine shedding capability. A set of flaps, when properly constructed, could be used for several collection periods. Sheet plastic was not suitable for flap construction due to the adhesive qualities of the plastic when wet.

Bull Cement, normally used for tagging livestock in auctions, proved to be very satisfactory for fastening the flaps to the animal. Applied with a spatula, the cement formed a tacky, fast drying, firm bond. The fecal bag could be hooked up immediately following flap attachment. To remove the flaps, the tail strap was cut just above the junction with the flaps. The tail strap was left on the animal for one to two weeks following the collection period to loosen by itself, since immediate removal of the tail strap resulted in considerable hair pulling. A new tail strap was sewed to the flaps for a subsequent trial.

A primary advantage of this apparatus compared to some other separator devices was that it was suspended independent of harness and bag. Consequently, it could continue to function efficiently even

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[1]Devcon Corporation, Danvers, Massachusetts.

when considerable shifting in bag or harness position occurred. When properly attached, the flaps provided a good to excellent collection of feces with minimal urine contamination. Most problems incurred with its use appeared in the early collection periods, due primarily to the use of inadequate materials in its construction.

Calf Fecal Collection

The fecal bags worn by the calves provided a generally excellent fecal collection. The capacity of these bags appeared to be approximately 9 to 11 kg of wet fecal material. Fall calves were approaching the point of exceeding this capacity, using a twice daily collection, by the last collection period in late August.

APPENDIX B

PROCEDURES FOR *IN VITRO* DRY MATTER DIGESTION

Modified Tilley-Terry *in vitro* Dry Matter Digestion

Inoculum Preparation

Collect whole rumen contents from rumen fistulated animal (a steer fed meadow hay in this case) and transport to laboratory in pre-warmed insulated jug. Squeeze pulp through eight layers of cheese cloth to remove rumen liquor. Suspend pulp in a volume of warmed phosphate buffer, through which carbon dioxide gas had been bubbled, equal to that of the rumen liquor. Remove phosphate buffer from pulp by squeezing through a fresh eight layers of cheese cloth and add to rumen liquor. Place solution in separatory funnel and maintain in water bath at 41-43°C until gross particulate matter separates from liquid portion. Draw off liquid portion into warmed insulated container and bubble carbon dioxide gas through it for 5-10 minutes. This constitutes the inoculum.

Sample Preparation and Incubation

Weigh 0.500 g of oven dried sample into tared 50-ml centrifuge tube. Add 2 ml of boiling water to saturate sample and add 15 ml of warmed McDougall's solution. Place tube in water bath at 39°C. Add 15 ml of inoculum. Pass a light stream of carbon dioxide gas into top of tube to drive out air and cover with rubber stopper having a 1.5-2.0 mm hole. Incubate in water bath at 39°C for 48 hr. Duplicate inoculum blanks are included with each run. Swirl tubes three to four times per day. Remove tubes, centrifuge, and decant. Add 20 ml of acid pepsin solution, stopper, and incubate at 39°C for 48 hr, swirling three to four times per day. Centrifuge, decant, and wash with distilled water. Centrifuge again, decant, and dry overnight at 100°C. Cool and weigh to determine dry matter disappearance. Digestibility is calculated as

$$\text{Dry matter digestion (\%)} = 100 \; \frac{S - (FS - R)}{S}$$

where S is the original sample weight, FS is fermented sample weight, and R is residue weight from the inoculum blank.

Reagents

Pepsin (per liter):

4 g 1:10,000 pepsin

100 ml 1N HCl

McDougall's Buffer (per liter):

9.80 g $NaHCO_3$

9.30 g $Na_2HPO_4 \cdot 12\ H_2O$

0.57 g KCl

0.47 g NaCl

0.12 g $MgSO_4 \cdot 7\ H_2O$

0.04 g $CaCl_2$ (added after others are in solution)

Phosphate Buffer (per liter):

1.059 g Na_2HPO_4 (anhydrous)

0.436 g KH_2PO_4

APPENDIX C

PROCEDURES FOR *IN VITRO* CELLULOSE DIGESTION AND CELLULOSE ANALYSIS

In vitro Cellulose Digestion and Cellulose Analysis

In vitro Digestion

The procedure for inoculum preparation and sample preparation and incubation are identical to those for *in vitro* dry matter digestion (Appendix B) through the 48-hr fermentation period, except that the centrifuge tube need not be tared. Following fermentation, the sample is centrifuged, decanted, dried, and analyzed for cellulose as described below. Cellulose digestion is determined by the same basic formula as was used in determining dry matter digestibility.

Cellulose Analysis

Weigh out 0.250 g sample of oven dried feed or feces into 50-ml centrifuge tube. Add 20 ml of reagent and place tube in boiling water for 20 minutes. Stir frequently. Remove, add 20 ml of ethanol and allow to stand for 20 minutes. Filter through asbestos pad in a Gooch crucible, washing residue thoroughly with ethanol. Dry residue for 2 hr at 100°C, cool, and weigh. Ash residue in muffle furnace at 600°C for 2 hr, cool, and weigh. Loss of weight upon ashing is cellulose.

Reagent

720 ml glacial acetic acid
180 ml distilled water
90 ml concentrated nitric acid

APPENDIX D

ANALYSES OF VARIANCE AND SUPPLEMENTARY DATA

Table 10. Crude protein (CP) content and *in vitro* dry matter digestibility (IDMD) of hay fed in experiment 1.

Date cut	CP[a] (%)	IDMD (%)	Hay type
5/15	12.12	68.0	Tall fescue
5/19	11.49	69.0	"
5/21	11.85	66.9	"
5/22	15.38	73.8	Tall fescue + alfalfa
5/27	15.18	74.7	" "
6/1	14.27	72.9	" "
6/5	13.02	66.7	" "
6/10	10.74	61.6	" "
6/19	6.56	52.9	Tall fescue
6/24	5.77	51.4	"
7/1	4.36	48.9	"
7/11	8.40	52.9	Native meadow
7/16	6.72	51.0	"
7/20	7.32	48.8	"
7/24	6.54	51.0	"
7/30	7.10	51.9	"
8/4	4.96	46.8	"
8/9	6.59	48.6	"
8/11	6.70	53.3	"

[a]Dry matter basis.

Table 11. Crude protein (CP) content and *in vitro* dry matter digestibility (IDMD) of forage samples (experiments 2 and 3) and digestible energy (DE) content (experiment 3).

Experiment	Harvest date	CP[a] (%)	IDMD (%)	DE[b] (Mcal/kg)
2	5/10-5/15	9.88	61.3	-
	6/15-6/22	6.69	52.8	-
	7/17-7/25	4.31	49.4	-
	8/21-8/28	4.62	48.1	-
3	4/29-5/3	16.81	68.0	2.76
	5/20-5/24	14.88	74.1	2.98
	6/10-6/14	13.94	65.8	2.68
	7/ 1-7/5	9.50	51.6	2.14
	7/29-8/2	7.00	49.2	2.05
	8/26-8/30	5.06	48.8	2.03

[a]Dry matter basis.

[b]Calculated from IDMD using Mcal DE/kg digestible DM = 0.18 + 0.038X, where X is dry matter digestibility (Rittenhouse *et al.* 1971).

Table 12. Daily dry matter intake by spring and fall cows and calves in drylot (experiment 1).[a]

Week beginning	Cow[b]				Calf		Cow + calf	
	Spring		Fall		Spring	Fall	Spring	Fall
	(kg)	(kg)	(kg)	(kg)	(kg)	(kg)	(kg)	(kg)
5/16	8.38	(6.89)	8.22	(7.95)	0.63	2.08	9.01	10.30
5/23	12.13	(10.00)	10.78	(10.43)	0.70	2.61	12.83	13.39
5/30	13.21	(10.87)	11.44	(11.07)	0.84	3.08	14.05	14.52
6/6	13.49	(11.08)	12.01	(11.59)	1.06	3.53	14.55	15.54
6/13	11.68	(10.28)	10.56	(10.73)	1.00	3.44	12.68	14.00
6/20	10.10	(8.83)	9.82	(9.28)	1.20	3.30	11.30	13.12
6/27	12.56	(10.97)	11.90	(12.10)	1.53	4.31	14.09	16.21
7/4	12.28	(10.71)	11.47	(11.61)	1.54	4.26	13.82	15.73
7/11	10.19	(8.98)	9.76	(10.08)	1.55	3.48	11.74	13.24
7/18	10.41	(9.16)	9.68	(9.98)	1.52	3.96	11.93	13.64
7/25	10.46	(9.21)	10.18	(10.47)	1.61	3.67	12.07	13.85
8/1	9.69	(8.52)	9.48	(9.76)	1.73	3.97	11.42	13.45
8/8	8.18	(7.21)	8.39	(8.65)	1.45	3.70	9.63	12.09
8/15	8.30	(7.34)	8.52	(8.81)	1.52	3.36	9.82	11.88

[a]Each value represents a mean of six individuals or pairs.

[b]Values in parentheses for cows represent actual measured intake; cow intake values not in parentheses represent measured intake adjusted to 410 kg body weight ($W_{kg}^{0.75}$).

Table 13. Analysis of variance for dry matter intake (DMI) and feed/gain for experiment 1.

	Mean squares for sources of variation		
	Treatment	Error	P[a]
df[b]:	1	10	
DMI, cow	1.51	0.40	0.081
DMI, calf	14.56	0.23	c
DMI, cow + calf	6.69	0.42	c
Feed/gain, calf	53.38	27.93	0.197
Feed/gain, cow + calf	22.96	13.92	0.228

[a]Probability level for significant treatment effects.

[b]df = degrees of freedom; also in Tables 14 through 18.

[c]$P < 0.010$.

Table 14. Analysis of variance for forage dry matter intake (DMI) by trial for experiment 3.

DMI	Trial		Mean squares for sources of variation		
			Treatment	Error	P[a]
		df:	1	10	
Cow	1		1.53	4.27	b
	2		10.92	4.92	0.167
	3		10.78	4.51	0.153
	4		0.00	1.44	b
	5		8.28	6.07	b
	6		0.21	1.65	b
Calf	1		18.88	0.06	c
	2		51.21	0.94	c
	3		28.24	0.14	c
	4		24.71	0.29	c
	5		43.82	0.58	c
	6		40.15	0.48	c
Cow + calf	1		9.65	4.65	0.180
	2		14.83	4.07	0.085
	3		4.13	4.82	b
	4		27.45	1.77	c
	5		13.93	9.31	0.249
	6		34.58	2.61	c

[a] Probability level for significant treatment effects.

[b] $P > 0.250$.

[c] $P < 0.010$.

Table 15. Analysis of variance for mean total milk production (MP) in experiments 2 and 3 and total forage dry matter intake (DMI) in experiment 3.

Experiment	Item		Mean squares for sources of variation				
			Treatment	Trial	T x T	Error	P[a]
		df:	1	3	3	40	
2	MP		78.39	19.24	0.54	1.02	b
		df:	1	5	5	60	
3	MP		137.84	21.92	0.33	1.56	b
	DMI, cow		20.84	106.08	2.18	3.81	0.023
	DMI, calf		201.17	8.75	1.17	0.43	b
	DMI, cow + calf		94.74	90.19	1.97	4.54	b

[a]Probability level for significant treatment effects when tested against error.

[b]$P < 0.010$.

Table 16. Analysis of variance for milk production by trial for experiments 1, 2, and 3.

Experiment	Trial	Mean squares for sources of variation: Treatment	Error	P[a]
	df:	1	10	
1		7.68	0.69	b
2	1	19.31	1.79	b
	2	11.84	1.19	b
	3	26.85	0.75	b
	4	22.00	0.04	b
3	1	24.48	1.74	b
	2	25.84	1.94	b
	3	26.22	2.33	b
	4	16.24	2.28	0.024
	5	29.33	0.69	b
	6	17.30	0.36	b

[a]Probability level for significant treatment effects.

[b]$P < 0.010$.

Table 17. Analysis of variance for body weight gains (BWG) in experiments 1 and 2.

			Mean squares for sources of variation		
Experiment	Item	Period	Treatment	Error	P[a]
		df:	1	10	
1	BWG, cow	5/15-6/15	4.08	99.02	b
		6/16-7/15	40.34	78.13	b
		7/16-8/22	33.33	197.37	b
		Total gain	200.09	294.08	b
	BWG, calf	5/15-6/24	567.74	72.15	0.019
		6/25-7/18	31.82	55.63	b
		7/19-8/22	2.91	25.71	b
		Total gain	971.82	203.58	0.054
2	BWG, cow	1	35.40	1182.74	b
		2	371.90	210.22	0.213
		3	28.00	137.58	b
		Total gain	932.81	339.78	0.128
	BWG, calf	1	579.70	39.24	c
		2	52.10	41.53	b
		3	856.90	20.46	c
		Total gain	4.09	199.14	b

[a]Probability level for significant treatment effects.

[b]$P > 0.250$.

[c]$P \leq 0.010$.

Table 18. Analysis of variance for body weight gains (BWG) of animals in experiment 3.

Item	Period	Mean squares for sources of variation: Treatment (df: 1)	Error (df: 10)	P[a]
BWG, cow	1	23.52	92.57	b
	2	296.01	58.84	0.047
	3	397.90	210.14	0.199
	4	364.10	195.96	0.203
	5	83.74	209.45	b
	Total gain	4,932.90	464.85	c
BWG, calf	1	280.33	8.90	c
	2	632.20	6.78	c
	3	77.01	13.66	0.039
	4	9.90	15.50	b
	5	16.57	39.50	b
	Total gain	2,473.94	151.26	c
BWG, cow + calf	1	250.26	140.05	0.211
	2	1,793.41	84.06	b
	3	825.02	292.72	0.124
	4	494.09	226.08	0.170
	5	25.81	354.12	b
	Total gain	13,041.62	1,035.14	c

[a]Probability level for significant treatment effects.

[b]$P > 0.250$.

[c]$P < 0.010$.