MONTANA STATE UNIVERSITY

Nutritional aspects of suckling beef calves grazing native rangeland in southwestern Montana
by Kenneth Scott Bryan

A thesis submitted in partial fulfillment of the requirements for the degree of Master of Science in Animal Science
Montana State University
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Abstract:
Production efficiency of range beef cattle herds will not be optimized until nutritional characteristics and interrelationships of both mature and adolescent bovine are learned. This study was initiated to quantify voluntary range forage intake (FI) by suckling calves and evaluate relationships among FI, milk intake (MI) and average daily gain (ADG). Five ruminally cannulated and 9 intact Angus sired steer calves and their dams grazed a 319 ha foothill grassland pasture at the Red Bluff Research Ranch near Norris, Montana, from birth (March 19 ± 5 d) until weaning on October 7 (202 ± 5 d). Milk intake was measured monthly by the weigh-suckle-weigh procedure. Intact calves were fitted with fecal collection bags monthly to determine fecal output (FO). Digesta kinetics were investigated in five periods using nylon bag techniques in conjunction with ruminal dosing of ytterbium labelled forage and cobalt ethylenediaminetetraacetic acid.

Calf body weight (BW) at birth was negatively correlated with weaning weight and preweaning ADG (r=-.75 and -.67, respectively; P<.05). Milk intake was negatively correlated with FO (r=-.63; P<.0001) over the preweaning interval. Neither MI nor FO was related to preweaning ADG. Diets selected by calves were unusually high in both fiber and protein content. Ruminal fluid output (1/h) increased from .25 in May to 1.28 in September and fluid volume (l) increased from 3.75 in May to 11.1 in August (Pc. 10). Fluid dilution rate and turnover time did not. differ. Forage organic matter intake (OMI) increased each month from .98 (May) to 2.67 kg/d (September) and OMIBW (g/kg) increased from 8.38 (May) to 12.13 (September). Ruminal digesta outflow and fill increased dramatically between June and July, however particulate passage rate and turnover time did hot differ. Forage OMI increased .08 kg for each kg reduction in fluid MI, resulting in decreased daily digestible energy intake accompanied by increased utilization efficiency.

Results from this study indicate suckling calves become active grazers and functional ruminants at approximately 100 d of age. Additionally, progress has been made towards quantifying their forage consumption and utilization.

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APPROVAL

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This thesis has been read by each member of the thesis committee and has been found to be satisfactory regarding content, English usage, format, citations, bibliographic style, and consistency, and is ready for submission to the College of Graduate Studies.

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ABSTRACT

Production efficiency of range beef cattle herds will not be optimized until nutritional characteristics and interrelationships of both mature and adolescent bovine are learned. This study was initiated to quantify voluntary range forage intake (FI) by suckling calves and evaluate relationships among FI, milk intake (MI) and average daily gain (ADG). Five ruminally cannulated and 9 intact Angus sired steer calves and their dams grazed a 319 ha foothill grassland pasture at the Red Bluff Research Ranch near Norris, Montana, from birth (March 19 ± 5 d) until weaning on October 7 (202 ± 5 d). Milk intake was measured monthly by the weigh-suckle-weigh procedure. Intact calves were fitted with fecal collection bags monthly to determine fecal output (FO). Digesta kinetics were investigated in five periods using nylon bag techniques in conjunction with ruminal dosing of ytterbium labelled forage and cobalt ethylenediaminetetraacetic acid.

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INTRODUCTION

A considerable amount of rangeland in the United States is extensively used for commercial cow-calf production. Implementing practices which improve calf growth can substantially impact livestock enterprise profits. Much research has been devoted to understanding and manipulating the cow and her ability to maximize calf growth, however little regard has been given to manipulating the calf's own growth abilities. Economical and biological efficiency is better measured by the production of the "cow-calf unit", rather than cow productivity alone.

Many breeding systems focus upon increasing calf weaning weight by increasing dam milk production, as a limitless goal. Two important questions must be answered to evaluate this rationale. First, what is the cost (in terms of nutrient intake, longevity, health, etc.) of each additional unit of milk produced? And secondly, how efficiently will each additional unit of milk be utilized by the calf? Integrally related is understanding the efficiency at which the suckling calf utilizes the forage base. In a given habitat there may be some optimal point at which milk and forage consumption meet to maximize economical return in calf performance. This relationship has not been fully investigated or described.

A few studies indicate calves may increase forage intake to offset low milk consumption, without detriment to performance. Most calf studies have utilized confinement systems to facilitate data collection. To determine milk intake, many workers hand fed milk replacer or altered lactation, which may not adequately reflect normal cow-calf relationships. Little agreement exists between findings of studies which investigated the relationship between milk and forage intake, which may be due to differing intake quantification methods and inherent differences among study location habitats. Associated studies attempted to relate pre-weaning milk intake to post-weaning performance. Again, results are inconsistent and warrant further investigation.

The intent of this study was to quantify voluntary forage intake by suckling calves in a range environment and determine relationships between milk and forage intake. Additionally, relationships between forage intake and calf performance were evaluated. Results should provide baseline data to determine efficiency for cow-calf units at differing milk production levels.

LITERATURE REVIEW

The major goal of the commercial cow-calf producer is to produce and sell pounds of beef (BIF, 1981). The first steps in this enterprise are to produce and raise a calf to weaning age (Neumann, 1977). Researchers have made detailed investigations of cow nutrition. However there is insufficient information available on the nutritional status of the suckling range calf (Maddox, 1965; Reynolds et al., 1978; Kartchner et al., 1979; Ansotegui, 1986; Abdelsamei et al., 1987). The relationship between milk and forage consumption by suckling calves remains questionable, as well as the effect of their relative intake upon their own performance (Gill, 1987).

Development of Intake and Rumination in the Calf

The young ruminant has a greater nutrient demand than the adult (Allison, 1985). This increased demand is met by accelerated appetite and rumen turnover (Hungate, 1966). Swanson and Harris (1958) and Roy (1980) found rumination to first occur in calves at 2 to 4 wk of age. Intakes of hay and grain have been recorded for 5 wk old calves (Swanson and Harris, 1958). Bailey and Lawson (1981) observed 30 to 60 d old calves grazing native range species and drinking water. While forage intake was of considerable quantity, milk supplied 86% of the calf's energy requirement at 44 d of age.

The occurrence and extent of rumen fermentation and digestion in the calf is comparable to mature-type function between 6 wk and 6 mo of age (Swanson and Harris, 1958), with time of first occurrence being diet dependent (Roy, 1980). Ansotegui (1986) indicated calves become forage grazers and active ruminants before 45 d of age and possess many similarities to mature ruminants with regard to organic matter intake per kg body weight (OMIBW) and digesta kinetics. Additionally, Swanson and Harris (1958) found 6 wk old calves spent nearly the same amount of time ruminating as lactating cows and heifers being fed diets of similar roughage content. Heyns (1960) reported calves reach their peak efficiency of energy intake conversion to weight gain during the second month of life.

Influence of Milk Intake upon Calf Growth

Milk Quantity vs Quality

Milk plays a vital role in calf growth. Neville (1962), Gleddie and Berg (1968) and Rutledge et al. (1971) estimated the variance in preweaning growth directly due to milk yield of the dam to range from 60 to 70%. Conversions of units of milk intake required to produce one unit of bodyweight gain have been reported between 4.5:1 and 23.5:1 (Drewery et al., 1959; Montsma, 1960; Neville, 1962; Melton et al., 1967). Heyns (1960) indicated the efficiency of milk conversion to be highest during the first 4 wk of life. It is unclear which attributes of the dam's lactation are most important. Rutledge et al. (1971) suggested milk quantity, rather than quality, is the most important influence on preweaning growth of calves. However, Christian et al. (1965) maintained that from birth to 60 d of age total butterfat and solids non-fat (SNF) are more important than milk volume. Melton et al. (1967) reported correlation coefficients between total calf gain and percentage butterfat, SNF and total solids near zero.

Milk Intake and Calf Gain

Baker et al. (1976) pointed out that prior to 3 wk of age calves are unwilling to consume solid food, therefore ensuring a strong, positive relationship between milk intake (MI) and live weight gain until this age. Research by Heyns (1960) also supports this relationship. Neville (1962) and Melton et al. (1967) found this relationship extends until about 2 mo of age. Most of these researchers reported the correlation between MI and ADG steadily decreases until weaning, however Heyns (1960) reported an increase when calves were about 6 mo of age. Melton et al. (1967) and Casebolt et al. (1983) reported correlations of .49 and .40, respectively, between total milk production and calf gain from birth to weaning. Boggs et al. (1980) noted each additional daily kilogram of milk produced by the dam increased calf adjusted 205 d weight by 7.20 kg.

Grazing Dynamics of the Suckling Calf

Extent of Grazing and Correlation with Calf Gain

Abdelsamei et al. (1987) indicated generally low forage intake values by calves until the second trimester of lactation. Boggs et al. (1980) found that from 60 to 150 d of age, grass intake of calves increased from .62 to 1.75% of body weight, with each additional kilogram per day of grass consumed yielding about .02 kg/d additional gain. Large frame calves (Charolais X Freisan) have been shown to maintain high MI without decreasing forage intake, as they approached weaning age (Wyatt et al., 1977a). Several researchers (Kartchner et al., 1979; Bailey and Lawson, 1981; Abdelsamei et al., 1987) reported daily forage intake to be approximately 5 kg DM/d prior to weaning. Bailey and Lawson (1981) stated milk satisfied 19% of calf digestible energy (DE) requirement at weaning. Boggs et al. (1980) found negative correlations between forage intake and ADG of calves up to 2 mo of age, however there was a positive correlation from 3 to 6 mo of age. Christian et al. (1965) reported significant positive correlations between creep feed intake and ADG of 2 mo old calves in drylot. Gleddie and Berg (1968) reported decreasing correlations between milk yield and calf gain as forage intake increased. Similarly, Baker et al. (1976), Wyatt et al. (1977a) and Ansotegui (1986) reported MI and forage intake to be inversely related.

Components of Diets Selected by Calves

Lusby et al. (1976) observed negative correlations between MI and forage cellulose intake of range calves. Additionally, they found forage cellulose intake to be positively correlated with calf metabolic body weight within crossbred and Holstein progeny, but not within Hereford progeny. Horn et al. (1979) reported calves select forage higher in CP and lower in ADF and cellulose than cows. Diets of calves exhibiting highest intakes were highest in CP, lowest in lignin and intermediate in NDF content. Digestibility of forage selected was found inversely related to level of N fertilization. Relationship between in vitro dry matter digestibility and calf intake was erratic. Peischel (1980) and Ansotegui (1986) reported calves selected diets higher in CP than did mature cattle.

Forage Intake Consequences of Altering Milk Production

Increasing milk production of beef cows is not without consequence. Boggs et al. (1980) showed each additional kilogram of milk produced per day will delay rebreeding by 1.4 d. Higher producing cows tend to pull nutrients into lactation at the expense of reproduction, particularly if nutrient intake is limited (Gill, 1987). Wyatt et al. (1977a) showed high MI by calves caused a 63% decrease in utilization efficiency as a result of substituting milk for forage. Ansotegui (1986) indicated a calf from a low milk producing cow will consume more forage than a calf from a high producing cow. Christian et al. (1965) and Baker et al. (1976) suggest calves receiving high milk yields may be stressed more by weaning and may require a longer adaptation period to grazing than calves receiving lesser milk quantities. The rumen of a calf from a high milk producing dam will likely be less developed than that of a calf from a less productive cow (Gill, 1987).

It is evident that the decision to increase milk production of a range cow herd must be approached cautiously. Wyatt et al. (1977a) warned that the economy of increasing milk production as a means of intensification of the cow-calf enterprise will be dictated by the relationships between the resource requirements of heavier milking cows and the value of additional gains. Kartchner et al. (1979) suggested that, in light of the limitations of cattle in the range environment, further investigation into milk production and nutrient intake under range conditions should be made. Accurate knowledge of nutrient cycles in energy flow from primary producers (plants) to red meat should lead to increased biological efficiency of the cow-calf unit (Sims et al., 1975).

Control and Regulation of Voluntary Intake

Voluntary intake of the grazing ruminant is limited by 1) physical factors of the animal and plant, 2) animal physiological factors and 3) management strategies of the plant-animal interface (Allison, 1985). In early research Crampton (1957) concluded intake level is economically more important than nutritive value of forage. In an extensive review, Balch and Campling (1962) indicated voluntary intake of roughage is directly related to nutrient concentration. They also observed intake to be partially controlled by ruminal distension and nervous system function. Van Soest (1965) noted declines in voluntary intake in response to increases of cell-wall constituents (CWC) of forage. He stated fiber mass, as represented by CWC, limits intake when it reaches 50 to 60% of forage DM. Conrad (1966) maintained appetite is largely controlled by chemostatic mechanisms and thermostatic mechanisms regulate feed intake. Additionally, he suggested gut fill may also be a limiting factor. In agreement with previous findings, Baile and Forbes (1974) acknowledged the effect of ruminal fill on intake, and suggested the presence of tension receptors in the ruminant stomach. Freer (1981) cited gut fill as the primary, short-term regulator of feed intake. Voluntary intake of less digestible forages is limited by rumen volume, rumen volume occupied by undigested forage, and rate of disappearance (Balch and Campling, 1962; Ellis, 1978). Rate of disappearance is a function of passage and digestion rates (Galyean, 1987). A review by Allison (1985) identified body size and physiological status as animal related factors which influence intake level. Della-Fera and Baile (1984) and Baile and

McLaughlin (1987) indicate hypothalmic and other central nervous system regions are involved appetite control. Brain peptides, specifically opioid and cholecystokinin peptides, are involved in hunger and satiety, respectively.

Many other factors have been shown to affect voluntary intake by ruminants. McCollum and Galyean (1985), several investigations reviewed by Allison (1985), and Krysl et al. (1987) reported increased forage intakes as forage protein level was increased. Heat stress (Robertshaw, 1987), cold stress (Adams, 1986; Adams et al., 1987; Adams, 1987) and dehydration (Utley et al., 1970) also alter forage intake by cattle. Depressed feed intake results when rumen pH falls below 5.5 (Dirksen, 1970; as cited by Baile and Forbes, 1974). Intake may be limited by energy expenditures associated with grazing (Freer, 1981). During growth, animals consume more feed either in anticipation of increasing energy requirements or to satisfy existing needs (Baile and McLaughlin, 1987). Assuming abundant, good quality forage is available, intake appears to be most influenced by energy demand (Allison, 1985).

Measuring Intake

Many methods of measuring intake by livestock have been proposed, however when applied to grazing animals they are generally inaccurate, labor intensive and highly sensitive to bias (Langlands, 1975). Similarly, Holechek et al. (1982) identified the need for more precise techniques to determine nutritive value of forage consumed by livestock.

Due to the unique situations encountered by livestock in the range environment (selective grazing, accessibility, etc.) most ruminant nutrition studies utilize pen-feeding to facilitate data collection (Galyean, 1987). Agronomic techniques (clipping forage before and after grazing) for estimating forage intake have been used by Cook and Harris (1951) and Kartchner et al. (1975), however disadvantages (eg. trampling, forage regrowth, and selective grazing) were enumerated by Schneider et al. (1955) and Holechek et al. (1982).

Internal and External Markers

Researchers have utilized internal markers to estimate intake and digestibility of livestock feeds for many years. Some plant constituents used include chromogens (Reid et al., 1950), lignin (Ellis et al., 1946) and nitrogen (Gallup and Briggs, 1948). Techniques involving each of these have been used extensively, and their inherent problems reviewed by Cordova et al. (1978), Cochran et al. (1987) and Patterson and Kerley (1987). More recently researchers have used external indicators to estimate intake and passage rate. Examples of these markers, which are not natural forage constituents, include chromic oxide, ferric oxide, silver sulfide, polyethylene glycol, and preparations of chromium, cobalt, hafnium and several of the rare earth metals (Pond et al., 1987). Problems associated with marker methodologies include, but are not limited to, poor marker mixing, binding, and recovery rates (Teeter and Owens, 1983). Although no marker technique is perfect, marking fiber with rare earths is promising (Patterson and Kerley, 1987).

Total Fecal Collection

Of the techniques proposed for estimating forage intake, total fecal collection has become the standard method (Schneider et al., 1955). With this method, intake is estimated by combining determinations of digestibility of grazed forage with measurements of fecal output (Cordova et al., 1978). Digestibility estimates are determined on ingested samples collected from esophageal or ruminal fistulated livestock grazing the same range on which fecal collections were executed. The standard method for collecting extrusa from ruminally fistulated livestock is the four step rumen evacuation procedure (Lesperance et al., 1960). With this technique, contents of the rumino-reticulum are removed, the animal is released to graze a sufficient sample of forage, the grazed forage is removed and the original contents replaced. These techniques are labor intensive and time consuming (Ansotegui, 1986) and may adversely affect animal physiology and behavior (Cordova et al., 1978). Patterson and Kerley (1987) suggested that the use of tame animals for this type of research could possibly preclude some of the disadvantages.

In research with calves several methods of estimating forage intake have been employed. Lusby et al. (1976), Baker et al. (1976), Baker and Barker (1978), Boggs et al. (1980) and Peischel (1980) used chromium as an external marker for estimating fecal output with varying degrees of success. Total fecal collections of calves (Kartchner et al., 1979; Ansotegui, 1986) have been successful.

Estimating Milk Production

Milk intake estimates of suckling ruminants have been obtained through a variety of techniques. Researchers utilizing confined livestock have bottle-fed measured amounts of reconstituted milk replacer (Baker et al., 1976; Baker and Barker, 1978; Abdelsamei et al., 1987). Christian et al. (1965) employed a technique whereby half the udder was hand milked while the calf nursed the other half. These researchers felt the presence of the calf relaxed the cow and allowed for more complete milk letdown. Several methods of estimating milk intake involving administration of oxytocin followed by either hand or machine milking have been used (Klett et al., 1965; Melton et al., 1967; Gleddie and Berg, 1968; Lusby et al., 1976; Wyatt et al., 1977a). By far, the weigh-suckle-weigh (WSW) technique has been most extensively used (Drewery et al., 1959; Heyns, 1960a and 1960b; Neville, 1962; Rutledge et al., 1971; Reynolds et al., 1978; Kartchner et al., 1979; Boggs et al., 1980; Casebolt et al., 1983; Ansotegui, 1986). This method involves several hours when the suckling ruminant is not allowed to nurse, is then weighed and allowed to suckle, and then re-weighed. Weight gain from suckling is assumed to represent dam milk production during the separation interval. Daily milk production is then estimated by converting the WSW gain to a 24 hr period. Weigh-suckle-weigh appears to be the most appropriate and least disturbing method for use with typical grazing livestock.

EXPERIMENTAL PROCEDURE

Location and Livestock

This study was conducted at the Red Bluff Research Ranch near Norris, Montana between March 14 and October 7, 1988. Livestock were grazed on a 319 ha foothill grassland pasture (Payne, 1973) with a northwest exposure. Soil Conservation Service classification of this pasture is good condition, with vegetation composition of 65% grasses and 35% shrubs and forbs. Principal species include bluebunch wheatgrass (Agropyron spicatum), Idaho fescue (Festuca idahoensis), prairie junegrass (Koeleria pyramidata), and needle-and-thread (Stipa comata; Turner, 1985). Stocking capacity has been estimated at 1.21 ha/animal unit month (AUM; Payne, 1973); stocking rate for this study was 3.8 ha/AUM. Pasture elevation ranges from 1400 to 1900 m. Annual average precipitation in this region ranges from 350 to 406 mm (USDA-SCS, 1976) and total precipitation between 24 April and 7 October 1988 was 189 mm (C.B. Marlow, unpublished data).

Fourteen mature (≥4 yr of age) Angus X Hereford cows and their Angus-sired bull calves were selected from the Red Bluff Research Ranch cowherd based upon calving date. Calves were born between March 14 and March 24, with an average birthdate of March 19, 1988 (d 0). Five calves were ruminally cannulated on d 54. Fistulated cow-calf pairs grazed in common with the intact pairs throughout the study. All calves were castrated, branded and vaccinated in the spring concurrent with the ranch herd and were weaned at 202 d of age on October 7, 1988.

Measurement of Milk Intake

Milk production of the cows was estimated by the weigh-suckle-weigh (WSW) technique (Ansotegui, 1986) on d 34, 64, 97, 126, 153, 181 and 202. Research findings of Walker (1962) and Wyatt et al. (1977b) indicated that normal suckling frequency of calves grazing pasture is approximately four times per day, thus a six hour separation interval was considered representative of a typical suckling bout. Cows and calves were awakened at daybreak and calves were allowed to nurse their dam's until they desisted. Pairs were then trailed to a facility where cows and calves were separated and unable to suckle for a 6 h period. Calves were then weighed, released to nurse, then re-weighed. Daily milk intake (MI) was calculated by multiplying weight gain from nursing by 4.

Measurement of Fecal Output

Ninety-six hour total fecal collections from the intact calves were conducted commencing at 1200 h on d 37, 65, 107, 135, 163 and 191. Fecal output (FO) was weighed at 24 h intervals during the initial four collections and at 10 and 14 h intervals for last two collections due to increased fecal production with age. Total 96 h fecal output per calf was divided by 4 to determine average daily fecal output. Samples from each weight measurement were collected and analyzed for DM, ash (AOAC, 1980) and NDF (Goering and Van Soest, 1970).

Markers and Nylon Bags

At 0700 h on d 80, 108, 136, 164 and 192, four fistulated calves were ruminally administered 5 g Co-EDTA (Uden et al., 1978), and 50 g fiber marked with ytterbium (Yb; Galyean, 1986). Concurrently ten nylon bags (10x14 cm, pore size 44 um) containing 2 g dry, ground (2 mm screen) extrusa and two or three empty nylon bags (blanks) were placed in the rumen of each calf. Extrusa in the nylon bags was collected from the calves using the four step rumen evacuation technique (Lesperance et al., 1960) on d 68, 95, 122, 151 and 178. Rumen extrusa was composited for each collection, freeze-dried and analyzed for CP, ether extract (EE), ash (AOAC, 1980), NDF and ADF (Goering and Van Soest, 1970). Rumen fluid and fiber samples were collected at 3, 12, 24, 36, 48 and 72 h post-dosing. Fecal samples were taken at 12, 24, 36, 48 and 72 h post-dosing. At 0, 12, 24, 36, 48 and 72 h incubation, 2 nylon bags containing extrusa were removed from each calf and one blank bag was removed alternately from two calves. Nylon bags and samples were frozen immediately after collection to prevent further microbial digestion and degradation.

Rumen fluid samples were centrifuged at 10,000 X g for 10 min and the supernatant fluid was analyzed for Co ion concentration by inductively coupled plasma spectroscopy (ICP). Fecal and rumen fiber samples were prepared by the 3M HCl/HNO_3 acid extraction method described by Ellis et al. (1980) and analyzed for Yb concentration by ICP. Nylon bag residue was analyzed to determine OM and NDF disappearance (Uden and Van Soest, 1984). Procedures of Mertens and Loften (1980) were used to estimate rates of OM and NDF disappearance. Fluid dilution rate was calculated by regressing the natural logarithm of Co ion concentration on time post-dosing. Fluid volume was estimated by dividing Co dose by extrapolated concentration at 0 h. Rumen Yb concentrations were transformed to natural logarithms and regressed on time post-dosing to determine particulate passage rate. Particulate volume was estimated by dividing Yb dose by extrapolated concentration at 0 h.

Calculation of Forage Intake

Forage and fecal NDF were used to estimate forage intake. Neutral detergent fiber was selected over OM because NDF is less apt to be affected by endogenous OM and undigested milk constituents (Ansotegui, 1986). Forage organic matter intake (OMI) was determined by:

a.) $\text{kg fecal NDF/d} = \dfrac{\text{total 96 h FO X Average \% NDF in feces}}{4}$

b.) Percentage NDF indigestibility = 100 − % nylon bag NDF disappearance at the approximate turnover time determined by rate of passage markers

c.) $\text{kg NDF intake/d} = \dfrac{\text{kg fecal NDF/d}}{\text{\% NDF indigestibility}} \times 100$

d.) $\text{kg forage OMI/d} = \dfrac{\text{kg NDF intake/d}}{\text{\% forage NDF (OM basis)}} \times 100$

e.) $\text{Forage OMI expressed as \% BW} = \dfrac{\text{forage OMI}}{\text{BW (kg)}} \times 100$

Organic matter digestibility (OMD) for each period was determined using nylon bags (Uden and Van Soest, 1984). Rate of OM disappearance was estimated by procedures described by Mertens and Loften (1980).

Digestible energy (DE) of grazed forage was estimated by two equations: 3.6 X OMD = Mcal metabolizable energy (ME)/kg forage (Van Es, 1978) and ME/.82 = DE (NRC, 1984). Particulate turnover estimates (Grovum and Williams, 1973) for these calves using Yb marked fiber were 25.31, 19.85, 23.31, 22.41 and 30.21 h in May, June, July, August and September, respectively. Thus, 24 h OMD and in situ disappearance from nylon bag analysis would be appropriate to estimate actual NDF disappearance for the months May through August and 36 h OMD and in situ disappearance used for September. A DE value of .71 Mcal DE/kg was used for fluid milk (NRC, 1971). Example calculations of Mcal DE intake/d and Mcal DE required per kg gain are presented in Appendix A.

Statistical Analysis

To facilitate identification of critical intake and performance occurrences prior to weaning, the study was analyzed as six thirty day periods beginning on d 23. Periods 1 through 6 closely parallel the months April through September, and will be referred to as such. Correlation analysis was performed using the Pearson product-moment procedure of SAS (1988). Analysis of variance for BW, ADG, MI, FO and fecal NDF output (FNDF) were conducted using the general linear model of SAS (1988), and means were separated by the Student-Newman-Keuls test. Stepwise regression analysis (SAS, 1988) of linear, quadratic and cubic functions of MI, linear and quadratic functions of FO and FNDF and period (PER; month) on monthly ADG was utilized to develop a prediction equation for calf gain. Regression analysis (SAS, 1988) was used to examine the relationship between increasing forage intake and declining MI.

RESULTS AND DISCUSSION

Calf body weight (Table 1) increased each month (P<.0001) and averaged 240.8 kg at weaning on d 202. Average daily gain (Table 1) did not differ between April, May and September nor June through August (P>.25), however ADG increased between May and June (P=.002) and decreased from September to October (P<.05). Preweaning gain averaged 1.01 kg/d. Milk intake (Table 1) did not differ between April, May and June nor between June through October (P>.18), however April and May MI were higher (P<.04) than July through October. Gifford (1953) also observed a trend of increasing ADG with calf age, accompanied by declining milk production. Numerically, MI increased to a peak in May, decreased through September and rose slightly in October.

Table 1. Least Squares Mean Monthly Calf Body Weight (BW), Average Daily Gain (ADG) and Daily Fluid Milk Intake (MI).[a]

	BW		ADG		MI	
Month	kg	SE[b]	kg/d	SE[b]	kg/d	SE[b]
April	70.23[c]	1.62	.99[cd]	.03	14.00[c]	2.24
May	96.23[d]	1.59	.93[c]	.04	14.62[c]	2.21
June	134.90[e]	1.98	1.10[de]	.03	9.31[cd]	.98
July	167.77[f]	3.05	1.13[de]	.06	7.77[d]	1.04
August	199.00[g]	3.67	1.15[e]	.03	4.84[d]	.93
September	229.87[h]	4.38	1.06[cde]	.03	4.83[d]	1.06
October	240.81[i]	4.58	.55[f]	.05	5.24[d]	1.71

[a]Monthly calf age ± 5 d; April=34, May=62, June=97, July=126, August=153, September=181 and October=202.
[b]Standard error; n=9.
[c-i]Column means with different superscripts differ (P<.05).

At the same location in 1984, Ansotegui (1986) estimated slightly higher milk intake values for July, August and September. Average MI throughout lactation was 8.68 kg/d. Clutter and Nielsen (1987) arrived at comparable milk production figures for mature crossbred beef cows of moderate milking ability. Total preweaning MI was not related (P>.70) to calf birth weight, preweaning ADG or weaning weight (WW). This is contrary to earlier research (Neville, 1962; Gleddie and Berg, 1968; Rutledge et al., 1971; Casebolt et al., 1983). Within period correlations of ADG (Table 2) can be used to identify periods of calf growth which influence growth during subsequent months. Associations were established between May and June, June and July, and August and September (P<.10). Ansotegui (1986) also reported correlations between calf ADG in August and September. April ADG was positively correlated with August ADG (P<.10). May ADG was positively associated with August (P<.10) and September ADG (P<.05). June ADG was highly correlated with both August and September ADG (P<.05). July ADG was positively correlated with October ADG (P<.10).

Table 2. Correlation Coefficients of Average Daily Gain (ADG) between Sampling Months.[a]

	ADG						
ADG	April	May	June	July	August	Sept.	October
	r^b						
April	1.00						
May	.46	1.00					
June	.36	.62[c]	1.00				
July	.55	.55	.61[c]	1.00			
August	.65[c]	.60[c]	.69[d]	.42	1.00		
September	.36	.77[d]	.76[d]	.31	.65[c]	1.00	
October	-.01	.18	.07	.60[c]	-.00	-.31	1.00

[a]Calf age ± 5 d; April=34, May=62, June=97, July=126, August=153, September=181 and October=202.
[b]n=9; Correlations without superscripts, probability r=0>.10.
[c,d]Probability r=0<.10 and .05, respectively.

While sample size of calves in this study was not sufficiently large to explain growth relationships with regression analysis, results in Table 2 indicate that calf gain in May and June may significantly impact performance during the following months. Perhaps intake developments in May and(or) June influenced subsequent intake and performance.

Correlations of calf BW and ADG are presented in Table 3. Calf BW during the months of July through October were positively correlated with ADG for all months (P<.10) except October. June BW exhibited similar relationships, with the exception of July ADG (P>.10). While coefficients were seldom significant, calf weight at birth and in April were generally negatively associated with ADG during the subsequent months.

Table 3. Correlation Coefficients of Average Daily Gain (ADG) with Calf Body Weight (BW) by Month of Sampling.[a]

	ADG						
BW	April	May	June	July	August	Sept.	October
	r^b						
Birth	−.44	.54	$-.61^c$	$-.69^d$	−.49	−.39	−.52
April	.44	−.39	−.31	−.29	.20	−.22	−.41
May	$.80^d$	.35	.15	.11	$.65^c$	.36	−.29
June	$.81^d$	$.59^c$	$.61^c$	.38	$.85^d$	$.66^d$	−.20
July	$.83^d$	$.68^d$	$.73^d$	$.80^d$	$.79^d$	$.60^c$	.20
August	$.82^d$	$.69^d$	$.75^d$	$.75^d$	$.86^d$	$.63^c$	.17
September	$.77^d$	$.76^d$	$.80^d$	$.70^d$	$.87^d$	$.76^d$	.07
October	$.74^d$	$.77^d$	$.78^d$	$.81^d$	$.83^d$	$.66^d$	.29

[a]Calf age ± 5 d; April=34, May=62, June=97, July=126, August=153, September=181 and October=202.
[b]n=9; Correlations without superscripts, probability r=0>.10.
[c,d]Probability r=0<.10 and .05, respectively.

Relationships of preweaning ADG and WW with calf BW and monthly ADG are illustrated in Tables 4 and 5, respectively. Calf birth weight was negatively correlated with both preweaning ADG and WW (P<.05). Christian et al. (1965) reported coefficients of .52 and .62 for correlations of birth weight with preweaning ADG and WW, respectively. Additionally, Casebolt (1984) reported a positive correlation between birth weight and WW. Artificial insemination sires used in the cow herd at the Red Bluff Research Ranch have been selected for low birth weight and high yearling weight, thus the negative correlation between calf birth weight and weaning weight is believed to be a result of the breeding program. June BW was positively correlated with preweaning ADG ($P<.05$) and WW ($P<.001$). Similarly, BW values for the months July through October were highly correlated with preweaning ADG and WW ($r>.91$; $P<.001$). Average daily gain for each month except October was positively associated with preweaning ADG and WW ($P<.06$).

Table 4. Correlation Coefficients of Calf Body Weight (BW) with Preweaning Average Daily Gain and Calf Weight at Weaning.[a]

BW[a]	Preweaning ADG[b]	Weaning Weight[c]
	r^d	
Birth	-.75[e]	-.67[e]
April	-.25	-.03
May	.37	.54
June	.69[e]	.81[f]
July	.92[g]	.98[g]
August	.92[g]	.98[g]
September	.93[g]	.97[g]
October	.97[g]	1.00

[a]Calf age ± 5 d; April=34, May=62, June=97, July=126, August=153, September=181 and October=202.
[b]Average daily gain from birth through weaning.
[c]Calf weight at 202 ± 5 d of age.
[d]n=9; Correlations without superscripts, probability r=0>.10.
[e,f,g]Probability r=0<.05, .01 and .001, respectively.

Table 5. Correlation Coefficients of Monthly Average Daily Gain (ADG) with Preweaning ADG and Calf Weight at Weaning.[a]

ADG[a]	Preweaning ADG[b]	Weaning Weight[c]
	r^d	
April	.66[e]	.74[e]
May	.84[f]	.77[e]
June	.80[f]	.78[e]
July	.86[f]	.81[f]
August	.75[e]	.83[f]
September	.67[e]	.66[e]
October	.29	.38

[a]Calf age ± 5 d; April=34, May=62, June=97, July=126, August=153, September=181 and October=202.
[b]Average daily gain from birth through weaning.
[c]Calf weight at 202 ± 5 d of age.
[d]n=9; Correlations without superscripts, probability r=0>.10.
[e,f]Probability r=0<.06 and .01, respectively.

Correlation analysis of MI and ADG by month (Table 6) indicates the existence of several relationships. May MI was negatively correlated with ADG during the same month (P<.05). Milk intake measured in June was positively associated with ADG during the subsequent month (P<.05). July MI exhibited a similar relationship with August ADG (P<.10). Several other significant correlations surfaced in the analysis, however their biological interpretation is not clear.

Average daily dry matter FO and FNDF are presented in Table 7. Fecal output and FNDF did not differ (P=.45) from April to May, but increased (P<.0001) each subsequent month until weaning. The greatest increase occurred from May to June (calf age 65 to 107 d), when daily FO nearly tripled and FNDF increased four-fold. Ansotegui (1986) also noted a dramatic increase in FO at a similar calf age. Indications are that forage intake became a substantial component of calf diets at this time.

It is important to note that both April and May fecal dry matter ash percentages were highly variable, ranging from 16 to 60%. The extremes in ash content are likely due to loss of metabolic mineral elements associated with occurrence of scours, as well as ingestion of non-forage material. Fecal NDF values are not reported on an ash-free basis, thus actual output may be slightly lower.

Table 6. Correlation Coefficients of Daily Fluid Milk Intake (MI) with Average Daily Gain (ADG) within Sampling Months.[a]

	MI						
ADG	April	May	June	July	August	Sept.	October
	r[b]						
April	.04	-.38	.18	.21	.22	.52	-.09
May	-.01	-.74[c]	.05	.62[d]	.12	-.03	-.39
June	.02	-.31	.56	.74[c]	.47	.22	.05
July	-.51	-.18	.72[c]	.49	.67[c]	.47	-.27
August	.02	-.49	.29	.61[d]	.04	.52	.01
September	.37	-.73[c]	.21	.43	.32	-.20	-.04
October	-.66[d]	.07	.10	.32	.09	.49	.54

[a]Calf age ± 5 d; April=34, May=62, June=97, July=126, August=153, September=181 and October=202.
[b]n=9; Correlations without superscripts, probability r=0>.10.
[c,d]Probability r=0<.05 and .10, respectively.

Table 7. Least Squares Mean Daily Calf Dry Matter Fecal Output (FO) and Fecal Neutral Detergent Fiber (FNDF).[a]

	FO		FNDF	
Month	kg/d	SE[b]	kg/d	SE[b]
April	.11[c]	.01	.04[c]	.01
May	.24[c]	.02	.08[c]	.01
June	.70[d]	.04	.31[d]	.02
July	.98[e]	.10	.53[e]	.06
August	1.69[f]	.06	.95[f]	.04
September	2.06[g]	.07	1.16[g]	.04

[a]Monthly calf age ± 5 d; April=37, May=65, June=107, July=135, August=163 and September=191.
[b]Standard error; n=9.
[c-g]Column means with different superscripts differ (P<.05).

Very few meaningful relationships were detected in the correlation analysis of monthly ADG with FO and FNDF (Table 8). Fecal output and FNDF measured during July was positively correlated with July ADG (P<.05). Additionally, July FO and FNDF were positively correlated with October ADG (P<.05). As with the correlation analysis of MI with ADG, several other relationships were significant, however biological interpretation is unclear.

Table 8. Correlation Coefficients of Average Daily Gain (ADG) with Fecal Output (FO) and Fecal Neutral Detergent Fiber (FNDF) within Sampling Months.

ADG[a]	April	May	June	July	August	September
				r^b		
				FO[c]		
April	−.24	−.16	.30	.29	−.22	.63[d]
May	.11	.16	−.14	.23	−.19	−.26
June	−.25	−.04	−.42	.29	−.28	−.15
July	−.02	−.10	.14	.76[e]	−.17	.16
August	.02	−.08	.12	.52	−.04	.00
September	−.36	.32	−.37	−.11	−.14	−.11
October	.63[d]	−.02	.39	.85[e]	.26	−.27
				FNDF[c]		
April	−.29	.03	.30	.28	−.38	.58[d]
May	.09	.13	−.20	.22	−.42	−.31
June	−.20	.21	−.48	.37	−.42	−.22
July	−.27	−.11	.09	.78[e]	−.40	.03
August	−.02	.39	.05	.55	−.21	−.09
September	−.30	.41	−.37	−.08	−.30	−.15
October	.33	−.16	.27	.83[e]	.11	−.38

[a]Calf age ± 5 d; April=34, May=62, June=97, July=126, August=153, September=181 and October=202.
[b]n=9; Correlations without superscripts, probability r=0>.10.
[c]Calf age ± 5 d; April=37, May=65, June=107, July=135, August=163 and September=191.
[d,e]Probability r=0<.10 and .05, respectively.

Correlation coefficients of monthly MI with FO and FNDF are presented in Table 9. May MI was negatively correlated with May FO and FNDF

(P<.05). Similarly, April MI was negatively correlated with July FO and FNDF (P<.05). April FO and FNDF were negatively associated with August MI (P<.10 and .05, respectively). June MI was positively related with July FNDF, however July MI was negatively correlated with August FNDF (P<.10). Both July FO and FNDF were positively associated with September MI (P<.05). Ansotegui (1986) reported a correlation of −.59 between July MI and September FO. A negative relationship existed between August FO and October MI (P<.10).

Table 9. Correlation Coefficients of Daily Fluid Milk Intake (MI) with Fecal Output (FO) and Fecal Neutral Detergent Fiber (FNDF) within Sampling Period.

MI[a]	April	May	June	July	August	September
				r[b]		
				FO[c]		
April	−.42	−.49	−.17	−.82[d]	.27	.23
May	.08	−.69[d]	−.09	.08	−.28	.03
June	−.37	−.49	−.25	.60	−.50	.12
July	.24	−.39	−.38	.45	−.48	−.53
August	−.61[e]	.11	−.19	.28	−.21	.36
September	.17	−.23	.43	.79[d]	.07	.24
October	−.53	−.37	−.53	−.30	−.62[e]	.07
				FNDF[c]		
April	−.18	−.34	−.12	−.81[d]	.35	.29
May	.15	−.59[e]	−.05	.13	−.11	.08
June	−.44	−.15	−.23	.67[e]	−.54	.04
July	.33	.02	−.49	.50	−.61[e]	−.54
August	−.80[d]	.03	−.14	.33	−.30	.26
September	.00	.22	.32	.81[d]	−.01	.17
October	−.34	.17	−.48	−.24	−.45	.19

[a]Calf age ± 5 d; April=34, May=62, June=97, July=126, August=153, September=181 and October=202.
[b]n=9; Coefficients without superscripts, probability r=0>.10.
[c]Calf age ± 5 d; April=37, May=65, June=107, July=135, August=163 and September=191.
[d,e]Probability r=0<.05 and .10, respectively.

Over the entire 202 d study (Table 10), calf MI was negatively correlated with age of calf (P<.0001) and ADG (P<.01). Fecal output was positively correlated with age of calf (P<.0001) and ADG (P<.01) and was negatively correlated with MI (P<.0001); correlations of FNDF with the same traits yielded comparable correlation coefficients. When observations were analyzed over monthly means (Table 11), MI was negatively correlated with FO (P<.01), however no other relationships were detected (P>.17). Stepwise regression analysis (SAS, 1988) of intake variables and calf age on monthly ADG resulted in the prediction equation:

$$ADG = .99 + .656\ FO - .190\ FO^2 - .091\ PER$$

The adjusted regression coefficient (r^2) of this model was .37. Functions of calf MI and FNDF were not used in the model (P>.10).

Table 10. Correlation Coefficients of Daily Fluid Milk Intake (MI), Fecal Output (FO) and Fecal Neutral Detergent Fiber (FNDF) with Calf Age, Body Weight (BW), Average Daily Gain (ADG) and Daily Fluid Milk Intake (MI) Over 202 Days.

	MI	FO	FNDF
		r	
AGE	-.65[a]	.96[a]	.96[a]
BW	-.63[a]	.96[a]	.95[a]
ADG	-.39[b]	.41[b]	.40[b]
MI	1.00	-.63[a]	-.63[a]

[a,b]Probability r=0<.0001 and .01, respectively; n=54.

Table 11. Correlations of Daily Fluid Milk Intake (MI), Fecal Output (FO) and Average Daily Gain (ADG) Analyzed by Monthly Means.

	MI	FO	ADG
		r	
MI	1.00		
FO	-.95[a]	1.00	
ADG	.04[b]	.63[c]	1.00

[a,b,c]Probability r=0=.0031, .9254 and .1769, respectively; n=6.

Laboratory analysis of rumen extrusa collected from calves is presented in Table 12. Composition of diets resembled expected forage nutritive content over the growing season. The high NDF percentage measured in June is probably more due to experimentation of novel foods, in this case standing forage from the previous growing season, than a representative sample of the currently growing forage species. However, the June sample did contain 16.12% CP, indicating calves simultaneously selected nutrient rich feeds. Ingesting leaves and structural tissues of woody shrub species could explain the unusual composition. Visual appraisal of extrusa from early collections indicated a more vast botanical array of constituents than the subsequent collections. Peischel (1980) and Ansotegui (1986) observed diets selected by calves high in both fibrous and proteinaceous fractions.

Table 12. Average Chemical Composition of Diets Selected by Calves.[a]

	Dietary Constituent[b]			
Month[c]	CP	EE	ADF	NDF
	%, Organic Matter Basis			
May	15.80	5.93	38.39	49.49
June	16.12	3.46	40.19	64.10
July	12.20	3.86	42.84	57.78
August	9.45	5.13	47.21	64.44
September	8.54	4.95	46.01	56.14

[a]Extrusa samples composited each month; n=4.
[b]CP=crude protein, EE=ether extract, ADF=acid detergent fiber, and NDF=neutral detergent fiber.
[c]Calf age ± 5 d; May=68, June=95, July=122, August=151, and September=178.

The decline in forage fiber content from August to September could conceivably be due to a combination of grazing fall regrowth and reduction in grass intake with a resultant increase in forb consumption (Thetford and Nelson, 1971). While the ensuing drought was not conducive to large scale forage growth, the dietary shift is the more logical explanation. Calf dietary ADF and NDF also declined from August to September in 1984 and 1985 (Ansotegui, 1986).

Average in vivo forage organic matter digestibilities for the months May through September were 70.32, 71.11, 64.46, 53.20 and 43.88%, respectively. Percentage digestibility did not differ from May through July, however declines were significant over August and September. Monthly decreases in digestibility, resulting from accumulation of structural carbohydrates in the forage base, were expected (Kartchner and Campbell, 1979).

Table 13. Average In Situ Organic Matter Disappearance (OMD) and Neutral Detergent Fiber Disappearance (NDFD) of Four Rumen Cannulated Calves by Sampling Hour within Month.[a]

Month	Sampling Hour 12	24	36	48	72
			% OMD		
May	58.34[b]	66.20[bc]	79.71[d]	75.51[cd]	82.78[d]
June	52.72[b]	69.87[c]	75.80[c]	78.64[c]	78.52[c]
July	54.25[b]	62.66[bc]	67.01[c]	71.00[c]	67.72[c]
August	32.89[b]	48.01[c]	57.77[d]	62.75[d]	64.56[d]
September	21.33[b]	35.88[c]	46.23[d]	56.78[e]	59.56[e]
			% NDFD		
May	42.71[b]	59.87[c]	70.40[c]	70.67[c]	78.47[c]
June	45.99[b]	68.58[c]	77.83[d]	82.45[d]	85.13[d]
July	43.57[b]	51.62[b]	62.61[b]	67.81[b]	64.05[b]
August	19.36[b]	36.95[c]	52.23[d]	64.54[e]	69.66[e]
September	2.66[b]	21.92[c]	29.27[c]	45.63[d]	54.05[d]

[a]Calf age ± 5d; May=80, June=108, July=136, August=164 and September=192.
[b-e]Means within rows with different superscripts differ (P<.05).

Organic matter and NDF disappearance calculated from the five nylon bag trials (Table 13) verify the ability of suckling calves to adequately