



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  $19 \pm 5$  d) until weaning on October 7 ( $202 \pm 5$  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 (l/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 ( $P < .10$ ). 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 not 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  $\pm$  5 d) until weaning on October 7 (202  $\pm$  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 (l/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 ( $P<.10$ ). 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 OMI/BW (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 not 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.

## 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 pre-weaning 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 hypothalamic 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. Iusby 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 ( $\geq 4$  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  $\mu$ m) 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<sub>3</sub> 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:

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

$$\text{b.) Percentage NDF indigestibility} = 100 - \% \text{ nylon bag NDF disappearance at the approximate turnover time determined by rate of passage markers}$$

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

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

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

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:  $3.6 \times \text{OMD} = \text{Mcal metabolizable energy (ME)/kg forage}$  (Van Es, 1978) and  $\text{ME}/.82 = \text{DE}$  (NRC, 1984). Particulate turnover estimates (Grovm 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).<sup>a</sup>

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

<sup>a</sup>Monthly calf age  $\pm$  5 d; April=34, May=62, June=97, July=126, August=153, September=181 and October=202.

<sup>b</sup>Standard error; n=9.

<sup>c</sup>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.<sup>a</sup>

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

<sup>a</sup>Calf age  $\pm$  5 d; April=34, May=62, June=97, July=126, August=153, September=181 and October=202.

<sup>b</sup>n=9; Correlations without superscripts, probability  $r=0>.10$ .

<sup>c,d</sup>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.<sup>a</sup>

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

<sup>a</sup>Calf age  $\pm$  5 d; April=34, May=62, June=97, July=126, August=153, September=181 and October=202.

<sup>b</sup>n=9; Correlations without superscripts, probability  $r > .10$ .

<sup>c,d</sup>Probability  $r < .10$  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.<sup>a</sup>

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

<sup>a</sup>Calf age  $\pm$  5 d; April=34, May=62, June=97, July=126, August=153, September=181 and October=202.

<sup>b</sup>Average daily gain from birth through weaning.

<sup>c</sup>Calf weight at  $202 \pm 5$  d of age.

<sup>d</sup> $n=9$ ; Correlations without superscripts, probability  $r > 0.10$ .

<sup>e,f,g</sup>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.<sup>a</sup>

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

<sup>a</sup>Calf age  $\pm$  5 d; April=34, May=62, June=97, July=126, August=153, September=181 and October=202.

<sup>b</sup>Average daily gain from birth through weaning.

<sup>c</sup>Calf weight at 202  $\pm$  5 d of age.

<sup>d</sup>n=9; Correlations without superscripts, probability  $r=0 > .10$ .

<sup>e,f</sup>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.<sup>a</sup>

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

<sup>a</sup>Calf age  $\pm$  5 d; April=34, May=62, June=97, July=126, August=153, September=181 and October=202.

<sup>b</sup>n=9; Correlations without superscripts, probability  $r=0>.10$ .

<sup>c,d</sup>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).<sup>a</sup>

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

<sup>a</sup>Monthly calf age  $\pm$  5 d; April=37, May=65, June=107, July=135, August=163 and September=191.

<sup>b</sup>Standard error; n=9.

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

<sup>a</sup>Calf age  $\pm$  5 d; April=34, May=62, June=97, July=126, August=153, September=181 and October=202.

<sup>b</sup>n=9; Correlations without superscripts, probability  $r > 0.10$ .

<sup>c</sup>Calf age  $\pm$  5 d; April=37, May=65, June=107, July=135, August=163 and September=191.

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

<sup>a</sup>Calf age  $\pm$  5 d; April=34, May=62, June=97, July=126, August=153, September=181 and October=202.

<sup>b</sup>n=9; Coefficients without superscripts, probability  $r > .10$ .

<sup>c</sup>Calf age  $\pm$  5 d; April=37, May=65, June=107, July=135, August=163 and September=191.

<sup>d,e</sup>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:

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

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 <sup>a</sup>	.96 <sup>a</sup>	.96 <sup>a</sup>
BW	-.63 <sup>a</sup>	.96 <sup>a</sup>	.95 <sup>a</sup>
ADG	-.39 <sup>b</sup>	.41 <sup>b</sup>	.40 <sup>b</sup>
MI	1.00	-.63 <sup>a</sup>	-.63 <sup>a</sup>

<sup>ab</sup>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 <sup>a</sup>	1.00	
ADG	.04 <sup>b</sup>	.63 <sup>c</sup>	1.00

<sup>abc</sup>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.<sup>a</sup>

Month <sup>c</sup>	CP	Dietary Constituent <sup>b</sup>		NDF
		EE	ADF	
%, 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

<sup>a</sup>Extrusa samples composited each month; n=4.

<sup>b</sup>CP=crude protein, EE=ether extract, ADF=acid detergent fiber, and NDF=neutral detergent fiber.

<sup>c</sup>Calf age  $\pm$  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.<sup>a</sup>

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

<sup>a</sup>Calf age  $\pm$  5d; May=80, June=108, July=136, August=164 and September=192.

<sup>b-e</sup>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

digest plant material at a young age. Linear declines in NDF digestibility with advancing plant maturity reflect an increase in forage lignin content which is extremely low in potential digestibility itself, and tends to decrease microbial degradation of hemicellulose and other plant nutrients (Jung and Fahey, 1983; Akin, 1986).

Ruminal fluid outflow to the omasum increased from .25 l/h in May to 1.28 l/h in September (Table 14). The largest observed increase occurred between June (.42 l/h) and July (.87 l/h), measured at calf age 108 and 136 d, respectively. Fluid volume increased numerically with calf age, however only volume measured in August was significantly greater than the other months. Rumen dilution rate showed an increasing trend over the five months, and turnover time, which is negatively related to dilution rate, displayed a decreasing trend.

Table 14. Ruminal Fluid Kinetics of Calves by Month of Sampling.<sup>a</sup>

Variable	May	June	July	August	September	SE <sup>b</sup>
Fluid Outflow (l/h)	.25 <sup>c</sup>	.42 <sup>c</sup>	.87 <sup>de</sup>	1.12 <sup>ef</sup>	1.28 <sup>f</sup>	.13
Fluid Volume (l)	3.75 <sup>c</sup>	4.78 <sup>cd</sup>	8.95 <sup>cd</sup>	11.10 <sup>d</sup>	10.41 <sup>cd</sup>	2.65
Dilution Rate (%/h)	7.70 <sup>c</sup>	11.94 <sup>c</sup>	11.71 <sup>c</sup>	13.91 <sup>c</sup>	13.14 <sup>c</sup>	2.75
Turnover Time (h)	14.4 <sup>c</sup>	11.7 <sup>c</sup>	11.0 <sup>c</sup>	8.7 <sup>c</sup>	9.0 <sup>c</sup>	2.97

<sup>a</sup>Calf age  $\pm$  5d; May=80, June=108, July=136, August=164 and September=192.

<sup>b</sup>Standard error; n=4.

<sup>c-f</sup>Row means with different superscripts differ (P<.10).

Values obtained for rumen fluid volume from this study were intermediate to those reported by Ansotegui (1986) from 1984 and 1985. However rumen dilution rates were higher and turnover times shorter, which implies a higher ruminal outflow. Fluid volume showed a non-significant decrease from August to September. Bailey and Lawson (1981) and Ansotegui

(1986) also noted this occurrence. They hypothesized that freezing temperatures and lower mean temperature may have resulted in lower levels of water intake, thereby decreasing fluid volume; the same phenomena might have been the cause in this study. Ruminant fluid dilution rates for mature cattle commonly range from 4 to 10 %/h (Owens and Goetsch, 1986); rates reported in Table 14 are within or near that range.

Average daily forage organic matter intake (OMI; Table 15) increased each month ( $P < .10$ ) from .98 kg in May to 2.67 kg in September. These figures are lower than anticipated, as Kartchner et al. (1979), Bailey and Lawson (1981) and Abdelsamei et al. (1987) reported suckling calves consumed nearly 5 kg DM/d prior to weaning. Daily forage OMI was similar to data reported by Boggs et al. (1980) showing calf DM intake increasing from .44 kg/d in May to 3.52 kg/d in September.

Table 15. Calf Organic Matter Intake (OMI) by Sampling Period.<sup>a</sup>

Variable	May	June	July	August	September	SE <sup>b</sup>
OMI (kg/d)	.98 <sup>c</sup>	1.51 <sup>d</sup>	1.83 <sup>e</sup>	2.21 <sup>f</sup>	2.67 <sup>g</sup>	.05
OMI (g/kg BW) <sup>h</sup>	8.38 <sup>c</sup>	10.60 <sup>d</sup>	10.60 <sup>d</sup>	11.08 <sup>d</sup>	12.13 <sup>e</sup>	.05

<sup>a</sup>Calf age  $\pm$  5d; May=80, June=108, July=136, August=164 and September=192.

<sup>b</sup>Standard error; n=4 rumen cannulated and 9 intact calves.

<sup>c-g</sup>Row means with different superscripts differ ( $P < .10$ ).

<sup>h</sup>BW=body weight.

Forage organic matter intake (g/kg BW; OMIBW) increased from May to June and again from August to September ( $P < .10$ ). Estimates of OMIBW were intermediate to those reported by Ansotegui (1986), and the extreme increases in OMIBW between July and August during both 1984 and 1985 in that study were not observed. In spite of these discrepancies, as early as June (calf age  $108 \pm 5$  d), OMIBW values were similar to estimates cited

by Kartchner (1975) and Cordova (1978) for mature beef cattle. Further, these values were higher than those observed in Hereford calves on rangeland in Oklahoma (Lusby et al., 1976).

Organic matter intake increased .08 kg ( $P < .10$ ) in response to each kg reduction in fluid MI during the study. This replacement was similar to previous research in Oklahoma and Kansas (Wyatt et al., 1977a and Boggs et al., 1980), but lower than replacements reported by Ansotegui (1986).

Extending monthly OMI over the entire preweaning period revealed these calves consumed at least 300 kg/hd. Based upon potential forage consumption by mature cows (Society for Range Management, 1974), the animal unit equivalent (AUE) of suckling calves in this study increased from .09 in May to .25 in September. Estimates of calf AUE based solely on BW would have over estimated potential intake two-fold.

Trends of ruminal digesta kinetics (Table 16) were similar to the fluid kinetics, indicating a high correlation between forage and fluid dynamics. Digesta dry matter outflow increased dramatically ( $P < .10$ ) from June (19.81 g/h) to July (42.49 g/h). Ruminal DM fill also increased significantly during the same time period. In light of significant increases in OMI each month, ruminal function changed during this period (calf age 108 to  $136 \pm 5$  d). Particulate passage rate (PPR) did not change ( $P > .10$ ), however it tended to decrease with increasing calf age. Similarly, turnover time did not differ ( $P > .10$ ) during the preweaning interval. Particulate passage rates were higher and ruminal DM fill and turnover times lower than those reported by Ansotegui (1986). As expected, PPR estimates from this study were consistently higher than estimates from mature cattle (Owens and Goetsch, 1986).

Table 16. Ruminant Digesta Kinetics of Calves by Sampling Period.<sup>a</sup>

Variable	May	June	July	August	September	SE <sup>b</sup>
Digesta Outflow (g/h)	8.63 <sup>c</sup>	19.81 <sup>c</sup>	42.49 <sup>d</sup>	48.54 <sup>d</sup>	47.11 <sup>d</sup>	7.86
Fill (g DM/kg BW) <sup>e</sup>	2.26 <sup>c</sup>	2.74 <sup>c</sup>	5.82 <sup>d</sup>	5.06 <sup>d</sup>	5.94 <sup>d</sup>	1.23
Passage Rate (%/h)	5.03 <sup>c</sup>	5.11 <sup>c</sup>	4.36 <sup>c</sup>	4.82 <sup>c</sup>	3.43 <sup>c</sup>	.70
Turnover Time (h)	25.31 <sup>c</sup>	19.85 <sup>c</sup>	23.31 <sup>c</sup>	22.41 <sup>c</sup>	30.21 <sup>c</sup>	4.26

<sup>a</sup>Calf age  $\pm$  5d; May=80, June=108, July=136, August=164 and September=192.

<sup>b</sup>Standard error; n=4.

<sup>c,d</sup>Row means with different superscripts differ (P<.10).

<sup>e</sup>DM=dry matter; BW=body weight.

Estimates of digestible energy (DE) intake by calves have been partitioned by nutrient source and are presented in Table 17. Milk intake was the primary DE source during May and June; July was the pivotal month, after which forage intake became the primary DE source. Total daily DE intake decreased throughout the summer months, likely in response to declining forage quality. However, efficiency of converting DE intake to body weight gain improved through August. The improved efficiency is probably a result of improved utilization of forage in the rumen. Forage intake accounted for 21.5% of calf daily DE intake in May and rose to 61.2% in September. In comparison, Bailey and Lawson (1981) reported calf forage intake contributing 14% of daily DE intake at 44 d of age to 81% at 160 d.

Average conversion of DE intake to BW gain was similar to values estimated from suckling calves consuming creep feed in drylot (Wyatt et al., 1977a). Efficiency of DE conversion was much better than that exhibited by suckling calves on improved fescue and fescue-legume pastures in Tennessee (Holloway et al., 1982). In that study, forage OMI contributed approximately 75% of the DE intake, while conversion

efficiency declined with increasing calf age, in contrast to the present results. These researchers found milk to be utilized more efficiently with increasing calf age.

Table 17. Digestible Energy (DE) Intake by Calves and Conversion to Body Weight Gain.<sup>a</sup>

Month	Forage	Milk	Total	ADG <sup>b</sup> kg	Conversion Mcal DE:kg
	Mcal DE/d				
May	2.85	10.38	13.23	.93	14.22
June	4.63	6.61	11.24	1.10	10.22
July	5.03	5.52	10.55	1.13	9.34
August	4.66	3.44	8.09	1.15	7.04
September	5.42	3.43	8.85	1.06	8.35

<sup>a</sup>Example calculation in Appendix A.

<sup>b</sup>ADG=average daily gain.

The ability of calves to compensate for reduced MI by increasing forage intake has been noted by several researchers (Wyatt et al., 1977a; Boggs et al., 1980; Ansotegui, 1986; and Wright and Russel, 1987). Le Du and Baker (1979) hypothesized that this occurrence might result in lower total energy intake by calves, as occurred in this study. In contrast to the findings of Wright and Russel (1987), decreased DE intake was accompanied by increased utilization efficiency. Perhaps the range environment presents a higher nutrient density than improved pastures, thereby allowing forage DE to be utilized more efficiently.

## IMPLICATIONS

Sound forage-animal management decisions are reliant upon complete and accurate production data. With the increasing importance of economics in the range beef cattle industry, producers are in great need of reliable estimates to improve production efficiency. Often pastures and rangelands are stocked at rates which include a buffer to account for forage which might be consumed by suckling calves. Simultaneously, these same ranchers are breeding higher milking ability into their cowherds. Application of results from this study, and similar projects to follow, can be utilized to help predict actual forage consumption by calves and to determine the "value" of additional milk production. This could lead to development of forage management schemes that will capitalize upon the calf's capability to digest forages at an early age. Perhaps in conjunction with research in the area of diet learning, it may be possible to manipulate forage intake and enable calf growth to be independent of milk intake at an earlier age, thereby decreasing cow maintenance requirements and possibly resulting in a shorter, earlier calving season.

Additionally, forage-animal management systems may need to be altered annually, dependent upon range forage availability, or inevitably, precipitation patterns. These strategies hinge upon the efficiency of milk production and utilization. Results from this study indicate that at approximately 100 d of age, calf development and growth through direct forage intake is more biologically efficient than growth via forage

consumed by a cow, converted to milk, then consumed by the calf. Assuming herd size remains relatively constant, in a year of excess, abundant forage, the economically wise decision may be to maintain high milk production, thereby utilizing large quantities of inexpensive forage at a low efficiency. In contrast, when forage availability is limited, a producer may elect to provide high quality forage to be utilized exclusively by calves and artificially limit milk production, thereby improving utilization efficiency of a higher value forage base.

It appears appropriate to assume that suckling calves which are experienced grazers will undergo less nutritional stress at weaning than calves which are heavily reliant upon milk consumption. Further, these calves should adjust more readily to forage as their sole nutrient source and will likely utilize the forage base more effectively.

## CONCLUSIONS

Findings from this study are in general agreement with several recent investigations of suckling calf nutrition which have suggested that suckling ruminants can effectively utilize a forage base. Probably the largest factor which may account for differences between results from this project and others cited in the manuscript is that this study was conducted in a range environment, rather than in a drylot or on improved pasture. This study confirms the results reported by Ansotegui (1986), indicating negative relationships between forage and milk intake by calves, and the relative non-importance of milk intake upon calf performance following peak lactation. Based upon these results, an ideal lactation curve in the study environment would increase to a peak at approximately 70 d of calf age, then decrease rapidly to a low level which can act as a supplement to forage intake. The dramatic decrease in milk production could serve as an impetus for the calves to seek non-milk nutrient sources.

It is evident that forage consumption and utilization by calves can be significant. These results, in addition to those of Ansotegui (1986) utilizing cattle of a different age and genetic base, reported comparable nutritional and intake trends of suckling calves. Replication of similar studies over years of various climatic conditions should result in a better understanding of the influence of management decisions affecting the nutritional environment upon calf growth.

## REFERENCES CITED

- Abdelsamei, A.H., D.G. Fox, M.L. Thonney, D.J. Duhaime and R.G. Warner. 1987. Forage intake by nursing calves. *J. Anim. Sci.* 65 (Suppl. 1):498.
- Adams, D.C. 1986. Effect of time of supplementation on performance, forage intake and grazing behavior of yearling beef steers grazing Russian wild ryegrass in the fall. *J. Anim. Sci.* 61:1037.
- Adams, D.C. 1987. Influence of weather on range livestock. *Proc. Grazing Livest. Nutr. Conf.* pp 23-29.
- Adams, D.C., R.E. Short. and B.W. Knapp. 1987. Body size and body condition effects on performance and behavior of grazing beef cows. *Nutr. Rep. Int.* 35:269.
- Akin, D.E. 1986. Chemical and biological structure of plants as related to microbial degradation of forage cell walls. In: L.P. Milligan, W.L. Grovum and A. Dobson (Ed.). *Control of Digestion and Metabolism in Ruminants.* pp. 144-145. Prentice-Hall, Englewood Cliffs, NJ.
- Allison, C.D. 1985. Factors affecting forage intake by grazing ruminants: A review. *J. Range Manage.* 38:305.
- Ansotegui, R.P. 1986. Chemical composition and digesta kinetics of diets selected and influence of milk intake on forage intake by suckling calves grazing native range. Ph.D. dissertation. New Mexico State University, Las Cruces.
- AOAC. 1980. *Official Methods of Analysis (13th Ed.)*. Association of Official Analytical Chemists. Washington, D.C.
- Baile, C.A. and C.L. McLaughlin. 1987. Mechanisms controlling feed intake in ruminants: A review. *J. Anim. Sci.* 64:915.
- Baile, C.A. and M.J. Forbes. 1974. Control of feed intake and regulation of energy balance in ruminants. *Physiol. Rev.* 54:160.
- Bailey, C.B., and J.E. Lawson. 1981. Estimated water and forage intakes in nursing calves. *Can. J. Anim. Sci.* 61:415.
- Baker, R.D. and J.M. Barker. 1978. Milk-fed calves 4. The effect of herbage allowance and milk intake upon herbage intake and performance of grazing calves. *J. Agr. Sci. (Camb.)* 90:31.

- Baker, R.D., Y.L.P. LeDu, and J.M. Barker. 1976. Milk-fed calves 1. The effect of milk intake upon the herbage intake and performance of grazing calves. *J. Agr. Sci. (Camb.)* 87:187.
- Balch, C.C. and R.C. Campling. 1962. Regulation of voluntary food intake by ruminants. *Nutr. Abstr. Rev.* 32:669.
- B.I.F. 1981. Guidelines for uniform beef improvement programs. U.S.D.A., Ext. Serv. Program Aid 1020. p 48.
- Boggs, D.L., E.F. Smith, R.R. Schalles, B.E. Brent, L.R. Corah and R.J. Pruitt. 1980. Effects of milk and forage intake on calf performance. *J. Anim. Sci.* 51:550.
- Casebolt, D.G. 1984. Lactation curves and milk production in beef cattle with varying degrees of crossbred influence. Master's thesis. Montana State University, Bozeman.
- Casebolt, D.G., D.D. Kress, D.C. Anderson and D.E. Doornbos. 1983. Lactation curves and milk production in beef cattle with varying degrees of crossbred influence. *Proc. West. Sect. Am. Soc. Anim. Sci.* 34:37.
- Christian, L.L., E.R. Hauser and A.B. Chapman. 1965. Association of preweaning and post weaning traits with weaning weight in cattle. *J. Anim. Sci.* 24:652.
- Clutter, A.C. and M.K. Nielsen. 1987. Effect of level of beef cow milk production on pre- and postweaning calf growth. *J. Anim. Sci.* 64:1313.
- Cochran, R.C., E.S. Vanzant, K.A. Jacques, M.L. Galyean, D.C. Adams and J.D. Wallace. 1987. Internal markers. *Proc. Grazing Livest. Nutr. Conf.* pp 39-46.
- Conrad, H.R. 1966. Symposium on factors influencing the voluntary intake of herbage by ruminants: Physiological and physical factors limiting feed intake. *J. Anim. Sci.* 25:227.
- Cook, C.W. and L.E. Harris. 1951. A comparison of the lignin ration technique and the chromogen method of determining digestibility and forage consumption of desert range plants by sheep. *J. Anim. Sci.* 10:565.
- Cordova, F.J., J.D. Wallace and R.D. Pieper. 1978. Forage intake by grazing livestock: A review. *J. Range Manage.* 31:430.
- Crampton, E.W. 1957. Interrelations between digestible nutrient and energy content, voluntary dry matter intake, and the overall feeding value of forages. *J. Anim. Sci.* 16:546.

- Della-Fera, M.A. and C.A. Baile. 1984. Control of feed intake in sheep. *J. Anim. Sci.* 59:1362.
- Dirksen, G. 1970. Acidosis. In: A.T. Phillipson (Ed.). *Physiology of Digestion and Metabolism in the Ruminant.* p 612-625. Oriel Press, Newcastle, England.
- Drewery, K.J., C.J. Brown and R.S. Honea. 1959. Relationships among factors associated with mothering ability in beef cattle. *J. Anim. Sci.* 18:938.
- Ellis, G.H., G. Matrone and L.A. Maynard. 1946. A seventy-two percent  $H_2SO_4$  method for the determination of lignin and its use in animal nutrition studies. *J. Anim. Sci.* 5:285.
- Ellis, W.C. 1978. Determinants of grazed forage intake and digestibility. *J. Dairy Sci.* 61:1828.
- Ellis, W.C., C. Lascano, R. Teeter and F.N. Owens. 1980. Solute and particle flow markers. In: F.N. Owens (Ed.). *Protein Requirements for Cattle: Symposium.* pp 37-56. Oklahoma Agr. Exp. Sta. MP109.
- Freer, M. 1981. The control of food intake in grazing animals. In: F.H.W. Morley (Ed.). *Grazing Animals.* p 106. Elsevier Scientific Publishing Co., New York.
- Gallup, W.D. and H.M. Briggs. 1948. The apparent digestibility of prairie hay of variable protein content, with some observations of fecal nitrogen excretion by steers in relation to their dry matter intake. *J. Anim. Sci.* 7:110.
- Galyean, M.L. 1986. *Laboratory procedures in animal nutrition research.* New Mexico State University, Las Cruces.
- Galyean, M.L. 1987. Factors influencing the digesta flow in grazing ruminants. *Proc. Grazing Livest. Nutr. Conf.* pp 77-87.
- Gifford, W. 1953. Records-of-performance tests for beef cattle in breeding herds. *University of Arkansas Agr. Exp. Sta. Bull.* 531.
- Gill, W. 1987. Raising beef calves on pasture. *Animal Health and Nutrition.* February, 1987.
- Gleddie, V.M. and R.T. Berg. 1968. Milk production in range beef cows and its relationship to calf gains. *Can. J. Anim. Sci.* 48:323.
- Goering, H.K. and P.J. Van Soest. 1970. Forage fiber analysis. *USDA Pam.* 379.

- Grovum, W.L. and V.J. Williams. 1973. Rate of passage of digesta in sheep. 4. Passage of marker through the alimentary tract and the biological relevance of rate constants derived from the changes in concentration of marker in the faeces. *Brit. J. Nutr.* 30:313.
- Heyns, H. 1960. The growth of the Afrikaner calf in relation to the production and composition of the milk of its dam II. The milk production of the dam and growth of the calf. *S. Afr. J Agr. Sci.* 3:517.
- Holechek, J.L., M. Vavra and R.D. Pieper. 1982. Methods for determining the nutritive quality of range ruminants diets: A review. *J. Anim. Sci.* 54:363.
- Holloway, J.W., W.T. Butts, Jr., and T.L. Worley. 1982. Utilization of forage and milk energy by Angus calves grazing fescue and fescue-legume pastures. *J. Anim. Sci.* 55:1214.
- Horn, F.P., J.P. Telford, J.E. McCroskey, D.F. Stephens, J.V. Whiteman and R. Totusek. 1979. Relationship of animal performance and dry matter intake to chemical constituents of grazed forage. *J. Anim. Sci.* 49:1051.
- Hungate, R.E. 1966. *The Rumen and its Microbes.* p 414. Academic Press, New York.
- Jung, H.G. and G.C. Fahey, Jr. 1983. Nutritional implications of phenolic monomers and lignin: A review. *J. Anim. Sci.* 57:206.
- Kartchner, R.J. 1975. Forage intake and related performance criteria of spring and fall calving cow-calf pairs on summer range. Ph.D. dissertation. Oregon State University, Corvallis.
- Kartchner, R.J. and C.M. Campbell. 1979. Intake and digestibility of range forages consumed by livestock. *Montana Agr. Exp. Sta. Bull* 718.
- Kartchner, R.J., L.R. Rittenhouse and R.J. Raleigh. 1975. A comparison of methods for measuring forage intake. *Proc. West. Sect. Am. Soc. Anim. Sci.* 26:155.
- Kartchner, R.J., L.R. Rittenhouse and R.J. Raleigh. 1979. Forage and animal management implications of spring and fall calving. *J. Anim. Sci.* 48:425.
- Klett, R.H., T.R. Mason and J.K. Riggs. 1965. Milk production of beef cows and its relationship to the weaning weight of their calves. *J. Anim. Sci.* 24:586.

- Krysl, L.J., M.L. Galyean, J.D. Wallace, F.T. McCollum, M.B. Judkins, M.E. Branine and J.S. Caton. 1987. Cattle nutrition on blue grama rangeland in New Mexico. New Mexico State University Agr. Exp. Sta. Bull. 727.
- Langlands, J.P. 1975. Techniques for estimating nutrient intake and its utilization by the grazing ruminant. Proc. Int. Symp. Rum. Physiol. (4th). Univ. New England Publ. Unit, Armidale S.A., Australia. pp 320-332.
- Le Du, Y.L.P. and R.D. Baker. 1979. Milk-fed calves. 5. The effect of change in milk intake upon the herbage intake and performance of grazing calves. J. Agric. Sci. (Camb.) 92:443.
- Lesperance, A.L., V.R. Bohman and D.W. Marble. 1960. Development of techniques for evaluating grazed forage. J. Dairy Sci. 43:682.
- Lusby, K.S., D.F. Stephens and R. Totusek. 1976. Effects of milk intake by nursing calves on forage intake on range and creep intake and digestibility in drylot. J. Anim. Sci. 43:1066.
- Maddox, L.A. 1965. Nutrient requirements of the cow and calf. Texas Agr. Exp. Sta. Bull. 1044.
- McCollum, F.T. and M.L. Galyean. 1985. Influence of cottonseed meal supplementation on voluntary intake, rumen fermentation and rate of passage of prairie hay in beef steers. J. Anim. Sci. 60:570.
- Melton, A.A., J.K. Riggs, L.A. Nelson and T.C. Cartwright. 1967. Milk production, composition and calf gains of Angus, Charolais and Hereford cows. J. Anim. Sci. 26:804.
- Mertens, D.R. and J.R. Loften. 1980. The effect of starch on forage fiber digestion kinetics in vitro. J. Dairy Sci. 63:1437.
- Montsma, G. 1960. Observations of milk yield and calf growth and conversion rate on three types of cattle in Ghana. Biol. Abstr. 36:7820.
- Neumann, A.L. 1977. Beef Cattle. p 3. John Wiley and Sons, New York.
- Neville, W.E. Jr. 1962. Influence of dam's milk production and other factors on 120- and 240-day weight of Hereford calves. J. Anim. Sci. 21:315.
- N.R.C. 1971. Atlas of Nutritional Data on United States and Canadian Feeds. National Academy Press. Washington, D.C.
- N.R.C. 1984. Nutrient Requirements of Beef Cattle (6th Ed.). National Academy of Press. Washington, D.C.

- Owens, F.N. and A.L. Goetsch. 1986. Digesta passage and microbial protein synthesis. In: L.P. Milligan, W.L. Grovum and A. Dobson (Ed.). Control of Digestion and Metabolism in Ruminants. pp. 196-223. Prentice-Hall, Englewood Cliffs, NJ.
- Patterson, J. and M. Kerley. 1987. Discussion of marker methodologies used in grazing experiments and digestibility of forages consumed by grazing animals. Proc. Grazing Livest. Nutr. Conf. pp 67-68.
- Payne, G.F. 1973. Vegetative rangeland types in Montana. Montana Agr. Exp. Sta. Bull. No. 671.
- Peischel, H.A. 1980. Factors affecting milk and grass consumption of calves grazing native range. Ph.D dissertation. Kansas State University, Manhattan.
- Pond, K.R., J.C. Burns and D.S. Fisher. 1987. External markers-use and methodology in grazing studies. Proc. Grazing Livest. Nutr. Conf. pp 49-53.
- Reid, J.T., P.G. Woolfolk, C.R. Richards, K.W. Kaufman, J.K. Loosli, K.L. Turk, J.I. Miller and R.E. Blaser. 1950. A new indicator method for determination of digestibility and consumption of forage by ruminants. J. Dairy Sci. 33:60.
- Reynolds, W.L., T.M. DeRouen and R.A. Bellows. 1978. Relationships of milk yield of dam to early growth rate of straightbred and crossbred calves. J. Anim. Sci. 47:584.
- Robertshaw, D. 1987. Heat stress. Proc. Grazing Livest. Nutr. Conf. pp 31-36.
- Roy, J.H.B. 1980. The Calf (4th Ed.). Buttersworth, London.
- Rutledge, J.J., O.W. Robison, W.T. Ahlschwede and J.E. Legates. 1971. Milk yield and its influence on 205-day weight of beef calves. J. Anim. Sci. 33:563.
- SAS. 1988. SAS User's Guide: Statistics. SAS Inst., Inc., Cary, NC.
- Schneider, B.H., B.K. Soni and W.E. Ham. 1955. Methods for determining consumption and digestibility of pasture forages. Washington Agr. Exp. Sta. Bull. T16.
- Sims, P.L., M.A. Cauhepe, J.L. Davidson and D.C. Edgerton. 1975. Energy dynamics of the cow-calf unit on Eastern Colorado Sandhills. Colorado Agr. Exp. Sta. Prog. Rep. PR 75-51.
- Society for Range Management. 1974. A glossary of terms used in range management. 2nd ed.

- Swanson, E.W. and J.D. Harris. 1958. Development of rumination in the young calf. *J. Dairy Sci.* 48:1768.
- Teeter, R.G. and F.N. Owens. 1983. Characteristics of water soluble markers for measuring rumen liquid volume and dilution rate. *J. Anim. Sci.* 56:717.
- Thetford, F.O. and A.B. Nelson. 1971. Botanical and chemical composition of cattle and sheep diets on pinyon-juniper grassland range. *J. Range Manage.* 24:425.
- Turner, M.E. 1985. The forage intake of supplemented cows grazing winter foothill rangelands of Montana. M.S. Thesis. Montana State Univ., Bozeman.
- Uden, P., P.E. Calucci and P.J. Van Soest. 1978. Investigation of chromium, cerium and cobalt as markers in digesta rate of passage studies. *J. Sci. Food Agr.* 40:337.
- Uden, P. and P.J. Van Soest. 1984. Investigations of the in situ bag technique and a comparison of the fermentation in heifers, sheep, ponies and rabbits. *J. Anim. Sci.* 58:213.
- Utley, P.R., N.W. Bradley and J.A. Boling. 1970. Effect of restricted water intake on feed intake, nutrient digestibility and nitrogen metabolism in steers. *J. Anim. Sci.* 31:130.
- USDA-SCS. 1976. Climax vegetation in Montana: based on soils and climate. USDA-SCS, Bozeman.
- Van Es, A.J.H. 1978. Feed evaluation for ruminants. 1. The systems in use from May 1977 onwards in the Netherlands. *Livest. Prod. Sci.* 5:331.
- Van Soest, P.J. 1965. Symposium on factors influencing the voluntary intake of herbage by ruminants: Voluntary intake in relation to chemical composition and digestibility. *J. Anim. Sci.* 24:834.
- Wright, I.A. and A.J.F. Russel. 1987. The effect of sward height on beef cow performance and on the relationship between calf milk and herbage intakes. *Anim. Prod.* 44:363.
- Walker, D.E. 1962. Suckling and grazing behaviour of beef heifers and calves. *N. Z. J. Agric. Res.* 5:331.
- Wyatt, R.D., M.B. Gould, J.V. Whiteman and R. Totusek. 1977a. Effect of milk level and biological type on calf growth and performance. *J. Anim. Sci.* 45:1138.
- Wyatt, R.D., M.B. Gould and R. Totusek. 1977b. Effects of single vs simulated twin rearing on cow and calf performance. *J. Anim. Sci.* 45:1409.

## APPENDIX

Table 18. Example Calculations of DE Intake and DE Required per Kilogram Body Weight Gain.<sup>a</sup>

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May:

24 h OMD=.6620

Grazed Forage OMI=.9721 kg/d

Fluid MI=14.6 kg

ADG=.93 kg

$3.6 \times .6620 = 2.38$  Mcal ME/kg Forage

$2.38 \text{ Mcal ME} \div .82 = 2.91$  Mcal DE/kg Forage

$2.91 \text{ Mcal DE/kg Grazed Forage} \times .9721 \text{ kg Forage} = 2.85 \text{ Mcal DE}$   
 $.71 \text{ Mcal DE/kg Milk} \times 14.6 \text{ kg Milk} = 10.38 \text{ Mcal DE}$

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13.23 Mcal DE

$13.23 \text{ Mcal DE Intake} \div .93 \text{ kg ADG} = 14.22$

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<sup>a</sup>OMD= organic matter digestibility, OMI=organic matter intake, MI=milk intake, ADG=average daily gain, ME=metabolizable energy, DE=digestible energy.

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