Fecal output of Hereford and Tarentaise beef cattle on native range
by Thomas Scott Hirsch

A thesis submitted in partial fulfillment of the requirements for the degree of Master of Science in Animal Science
Montana State University

Abstract:
Fecal output (FO) from three biological types of range cows, Tarentaise (TT), Hereford (HH)5 and Hereford x Tarentaise or Tarentaise x Hereford (HT), was estimated during five periods in a production year during 1992, 1993, and 1994. Each year, 51 cows were evaluated with 17 in each biological type. The five periods were; pregnant, nonlactating, fall grazing (Pd I); pregnant, nonlactating, winter supplemented (Pd II); lactating, spring supplemented (Pd III); lactating, early summer grazing (Pd IV); and lactating, late summer grazing (Pd V). Fecal output for each period was determined using a constant release, intraruminal, $Cr2O3$ bolus. Following a 10-d equilibrium period after bolusing, three fecal grab samples were taken 3 d apart. The average of the three samples (n = 724) was used in all statistical analyses. Data were analyzed by period using least squares analysis of variance. Main effects included year, cow age, and cow biological type. Covariates tested were cow weight (COWWT), cow body condition score (BCS), milk production (MP), calf weight (CLFWT), and calf age (CLFAGE). Nonsignificant covariates and two-way interactions were removed and a reduced model was fit to the data. Fecal output means were 2851, 3430, 3578, 3177, and 3199 g/d, respectively, for the five periods. Fecal output differences were not important ($P>.05$) for biological type, but were significant for cow age. Biological type differences in FO were significant on a per unit of body weight basis (g/kg BW) in Periods III and IV where HH had lower FO/BW than HT and TT in Pd III and TT had greater FO/BW than HT and HH (P= 06) in Pd IV. Regressions of FO on cow body condition, milk production, calf weight and calf age were not significant. The regression of FO on cow weight was significant in Pd III. Fecal output increased with cow weight ($P<.05$) during the early lactation period. Although our results show no significant differences in FO among genotypes or levels of milk production, FO differed for different cow weights at early lactation after calving. When expressing FO on a per unit body weight basis, biological type differences were detected during lactating periods. Breed group differences in FO/BW were a function of forage quality and the physiological demands on the cow.

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Thomas Scott Hirsch

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

Fecal output (FO) from three biological types of range cows, Tarentaise (TT), Hereford (HH), and Hereford x Tarentaise or Tarentaise x Hereford (HT), was estimated during five periods in a production year during 1992, 1993, and 1994. Each year, 51 cows were evaluated with 17 in each biological type. The five periods were; pregnant, nonlactating, fall grazing (Pd I); pregnant, nonlactating, winter supplemented (Pd II); lactating, spring supplemented (Pd III); lactating, early summer grazing (Pd IV); and lactating, late summer grazing (Pd V). Fecal output for each period was determined using a constant release, intraruminal, Cr_2O_3 bolus. Following a 10-d equilibrium period after bolusing, three fecal grab samples were taken 3 d apart. The average of the three samples (n = 724) was used in all statistical analyses. Data were analyzed by period using least squares analysis of variance. Main effects included year, cow age, and cow biological type. Covariates tested were cow weight (COWWT), cow body condition score (BCS), milk production (MP), calf weight (CLFWT), and calf age (CLFAGE). Nonsignificant covariates and two-way interactions were removed and a reduced model was fit to the data. Fecal output means were 2851, 3430, 3578, 3177, and 3199 g/d, respectively, for the five periods. Fecal output differences were not important ($P>.05$) for biological type, but were significant for cow age. Biological type differences in FO were significant on a per unit of body weight basis (g/kg BW) in Periods III and IV where HH had lower FO/BW than HT and TT in Pd III and TT had greater FO/BW than HT and HH ($P=.06$) in Pd IV. Regressions of FO on cow body condition, milk production, calf weight and calf age were not significant. The regression of FO on cow weight was significant in Pd III. Fecal output increased with cow weight ($P<.05$) during the early lactation period. Although our results show no significant differences in FO among genotypes or levels of milk production, FO differed for different cow weights at early lactation after calving. When expressing FO on a per unit body weight basis, biological type differences were detected during lactating periods. Breed group differences in FO/BW were a function of forage quality and the physiological demands on the cow.

CHAPTER 1

INTRODUCTION

Today, with the vast selection of beef cattle breeds and genotypic variation that exists within those breeds, producers can select biological types that are most biologically and economically efficient for their range environment. Determining forage intake of free-ranging beef cattle is an important step in evaluating genotypes that are optimal for a specific environment.

Most research in range animal evaluation is directed toward total output (body weight gain, calf production, etc.) while little attention has been given to inputs, or forage intake (Kattnig et al., 1993). With greater energy expenditures of grazing animals (Allison, 1985; Havstad and Doornbos, 1987), extrapolating data from drylot studies comparing different breeds (Ferrel and Jenkins, 1985; Jenkins and Ferrel, 1994) to range environments may not be appropriate. Range environments can be quite diverse and biological efficiency of different genotypes may change from area to area.

One method of evaluating production inputs, thus biological efficiency, is to determine fecal output (FO) as an indirect estimate of forage intake. Genotype x environmental interactions for FO are known to exist in grazing cattle (Frisch and Vercoe, 1984; Doornbos et al., 1987; Barlow et al., 1990). With further understanding of the factors that contribute to this interaction, researchers and in turn, producers can determine optimal efficiency for a particular range environment. In foothill regions in north central Montana, crossbred cows intermediate in mature weight, intermediate in milk production, and early in sexual maturity were favored (Kress et al., 1986). The objective of this study was to evaluate fecal output for different biological types (Hereford, Tarentaise, Hereford x Tarentaise) of beef cows for five periods of a production year on native range.

CHAPTER 2

LITERATURE REVIEW

Methods of Estimating Forage Intake

Information regarding intake and digestibility of range forages is critical to our understanding range livestock production and plant resources and our attempts to optimize the productivity of our rangelands (Kartchner and Campbell, 1979). Langlands (1975) stated that techniques available for studying grazing animal nutrition are characterized by relatively low precision, high labor demand, and high sensitivity to bias. Techniques that work well under one set of range conditions may be totally inadequate under others, i.e., climate and forage availability. The use of internal and external markers in estimating forage intake under grazing conditions has been extensively tested.

Forage intake is expressed as dry matter intake (DMI) or organic matter intake (OMI); either as kilograms consumed or as a percentage of body weight. Techniques in estimating forage intake fall into two categories, the ratio technique or the index procedure as described by Cordova et al.(1978):

> Index procedures generally relate level of intake or digestibility to some component in the feces through a regression equation. Ratio techniques, on the other hand, involve the calculation of digestibility and fecal output data through their ratio to an "indigestible" indicator or marker. Indicators may occur naturally in the forage (internal indicator) or may be administered in known amounts (external indicator). Internal indicators are

more frequently used for estimating digestibility, while external indicators are used more in fecal output estimates. If digestibility and fecal output are known, intake is calculated from the equation:

$$OMI = \frac{\text{Fecal organic matter output}}{\text{\% organic matter indigestibility /100}}$$

Most researchers prefer to use percent organic matter because of the relatively high ash content in range and pasture forage.

Intake can also be expressed on a dry matter basis according to the formula advocated by Pond et al.(1987):

$$\text{Voluntary intake or Dry Matter Intake} = \frac{\text{Dry Matter Output of Feces (g/d)}}{\text{1-(Dry Matter Digestibility/100)}}$$

As related before, two criteria are required for estimating forage intake; fecal output and digestibility. Fecal output in grazing trials has been determined by total fecal collection or more recently, by fecal grab sampling using external markers. Due to the high labor demand with total fecal collection, the use of an external marker such as chromium or ytterbium with fecal grab sampling has become more popular. Types and methods of external markers will be discussed later. Fecal output can be calculated by the following equation cited by Sprinkle (1992):

$$\text{FO (OM Basis)} = \frac{\text{wt. of external marker /day}}{\text{wt. recovered in feces /day}} * \text{\%OM/100}$$

Digestibility can be estimated by several techniques; 1) in situ with nylon bags in rumen cannulated cows, 2) in vitro digestion of hand clipped or extrusa samples, or 3) the use of internal markers. Questionable results occur with artificial digestion techniques as they may not accurately portray the diet of the experimental animals (Judkins et al., 1990). The researcher may select forages different from what the animal selects and each individual animal's metabolism may differ from the cannulated cow or in vitro digester. Some selection bias is eliminated, however, by collecting grazed samples from esophageal or ruminally cannulated animals running with the herd, and then analyzed for digestibility by in situ or in vitro digestion.

Since the 1960's, many pasture and range studies have coupled fecal output estimates with in vitro digestibility measurements to calculate intake (Cordova et al., 1978). In vitro digestion is most widely used for large range intake studies due to advantages of analyzing a large number of samples simultaneously, a shorter estimation time, and only small samples are required for analysis (Kartchner et al., 1979). Several researchers, however, have reported unreliable digestibility estimates with this technique because of associative effects, level of intake effects, rate of passage differences, and variation in forage composition of the diet (Judkins et al., 1990). In other words, metabolism bias and forage selection differences that can limit the effectiveness of the in vitro digestion technique.

The in situ with nylon bag technique is less preferred than other methods in estimating digestibility for range intake studies. Although this method reduces metabolism bias, results obtained in grazing trials have been quite variable. Sources of variability include origin of sample, sample weight, fineness of grind, length of time subject to digestion, and source of feed consumed by the fistulated animal (Kartchner et al., 1979).

These authors recommended that the nylon bag technique should be limited to screening forages for relative digestibility. Comparisons should be further limited to within class of forage such as grasses or legumes. In general, the nylon bag method has provided accurate estimates of digestibility on homogeneous pastures and forages, but varied results on diverse range types.

In summation, no single technique for estimating forage digestibility provides accurate estimates across all diets and feeding conditions (Judkins et al., 1990). Limitations with internal marker use in range intake studies are related to selection bias by the experimenter and metabolism bias by the in vitro techniques of digestion. Internal markers are quite effective in reducing metabolism bias, but due to limitations and implications with the current techniques available, many range intake studies rely upon in vitro digestibility estimates combined with esophageal fistulated animals or representative forage clippings.

External markers

Total fecal collection or external markers have been used to estimate fecal output (FO). Total fecal collection, when used in grazing intake studies, is very labor intensive, expensive to run, and impractical for use under some situations (Cordova et al., 1978), hence, external markers with fecal grab sampling have been more frequently used (Pond et al., 1987). Fecal collection bags and harnesses, needed for total fecal collection, have been shown to alter grazing behavior (Fisher et al., 1986).

External markers are not natural constituents of the diet, but like internal markers are not digested or absorbed (Pond et al., 1987). Two main methods have been employed with the use of external markers: (1) Daily feeding of a marker (or daily release of a constant release bolus) to achieve equilibrium concentrations in the rumen, and (2) single (pulse) dosing. As described by Paterson and Kerley (1987),

> The first technique gives only an estimate of fecal output, while the second technique can predict fecal output, rate of passage, mean retention time in the gut, and fill of undigested dry matter by employing the appropriate model.

The single (pulse) dosing method requires constant sampling over 4 to 6 d to fit a curve against marker concentration over time. Excessive diurnal variation found associated with pulse dosing has limited its reliability (Raleigh et al., 1980). Fecal samples taken every few hours may also adversely affect grazing behavior unless only very gentle animals are used (Paterson and Kerley, 1987). Due to the labor demand of the pulse dosing method, most large scale grazing trials have used steady state dosage methods (Sprinkle, 1992).

Daily administration of a known marker concentration is given over a period of 5 to 7 d prior to sampling to achieve steady state dosage (Pond et al., 1987). Fecal grab samples are then taken over a 3 to 7 d period at different times of the day to obtain a mean marker concentration (Fisher et al., 1986). Types of external markers include rare earth (Yb, La, Ce, Eu, Co, Tb, Ha) marker fiber, chelated minerals, polyethylene glycol, and various administrations of chromium sesquioxide powder (Cr_2O_3). External markers are administered either in the feed, as a supplement, in gelatin capsules fed two times daily or more recently, in constant release boluses (Pond et al.,1987).

Many problems exist with daily external marker use in range intake trials. Diurnal variation has proven to be a major problem that requires multiple fecal sampling times as well as difficulties in maintaining consistent daily marker intake (Pond et al., 1987). Daily marker administration is also very labor intensive and often not practical for large scale grazing trials (Paterson and Kerley, 1987). Grazing animals are not usually supplemented on a daily basis except when forage is limited. Multiple fecal sampling times have also shown to adversely affect grazing animal behavior which may bias results (Fisher et al., 1986).

Attempts have been made to solve or limit many of these problems, particularly in reducing daily variation of fecal marker recoveries. The continuous release bolus (CRD), as developed by Laby et al. (1984) and the infusion pump (Brandyberry et al., 1991) are two such methods. These techniques have proven quite effective in reducing diurnal variation, (Ellis et al., 1981, 1982; Laby et al., 1984; Adams et al., 1990; and Furnival et al., 1990).

The most commonly used external marker has been chromic sesquioxide powder (Cr_2O_3), often called chromic oxide. Its advantages are relatively low cost and simple analysis via atomic absorption spectrophotometry (Paterson and Kerley, 1987). Chromic oxide's major disadvantage, as related by the same authors, is that Cr_2O_3 does not flow either with the solid or fluid fraction of the digesta and so it is subject to diurnal variation. Ellis et al. (1982) related this occurrence to sedimentation in the rumen and sporadic transfer through the gastrointestinal tract. This led to the recommendation that steady state markers, such as chromium, be given 5 d prior to sampling to achieve steady state conditions. Fecal grab samples should then be taken over 3 to 7 d at various times of the day to determine a mean fecal concentration value (Pond et al., 1987).

Methods of administering Cr_2O_3 have included mixing with a feed concentrate, chromic oxide powder administered daily via gelatin capsules, paper impregnated with Cr_2O_3 inside gelatin capsules, mordanting chromium to fiber, and in a constant release bolus. Of these methods, the last three are attempts to reduce diurnal variation in marker concentration.

Diurnal variation is the primary problem associated with the use of chromic oxide as an external marker. Diurnal variation is variation throughout the day and between days in fecal marker concentration recoveries . This daily variation can cause forage intake to be over or underestimated, depending upon time of day of sampling (Sprinkle, 1992).

An early study by Hardison and Reid (1953) compared hand-fed steers to grazing steers using 10g of Cr_2O_3 daily in a gelatin capsule for 10 d prior to sampling. With the hand-fed group, the author's found a correlation of .981 between measured forage and estimated intake using plant chromogen indicators of digestibility and fecal grab sampling.

With the grazing steers, excretion of Cr_2O_3 per unit of fecal dry matter varied with the time of day of obtaining the fecal grab sample. The chromium recoveries of the animals were either higher or lower than the hand fed group and these patterns followed the grazing patterns of the cattle throughout the day. Chromium concentrations tended to be quite high at low grazing times as there was less dilution effect due to less rumen turnover of forage.

Moran et al. (1987) compared forage intakes between lactating cows, nonlactating cows, and wethers. Lactating cows in metabolism cages dosed with Cr_2O_3 in gelatin capsules had greater diurnal variation in fecal recoveries than the nonlactating cows and wethers.

Variables that may play a role in chromic oxide's excretion patterns, as identified by Hardison and Reid (1953) were;

> degree of uniformity and time of forage intake, time of Cr_2O_3 administration, plant species and stage of growth, climatic conditions, management practices affecting grazing habits, water intake, factors affecting the motility of the gastrointestinal tract, and sex of the animal.

As mentioned earlier, attempts to reduce diurnal variation include the use of paper impregnated with Cr_2O_3, chromium mordanted fiber, and constant release boluses.

Paper impregnated with Cr_2O_3 was used because it was believed that the paper would flow more evenly with the digesta and less sedimentation would occur. This technique has received variable results (Kiesling et al., 1969, Pond et al., 1987), often finding paper no better than Cr_2O_3 in gelatin capsules in reducing diurnal variation in fecal marker recoveries (Kiesling et al., 1969).

Chromium mordanted fiber is one of the most widely used fiber markers (Pond et al., 1987), based on the same idea of chromium flowing more evenly with the digesta. According to Paterson and Kerley (1987), mordanting chromium to dietary fiber appears to be effective in allowing the marker to flow with the particulate phase. Pond et al. (1987) recommended adding chromium equal to 6 to 8% of the weight of fiber in the diet rather than the previous 12 to 14% that increased the density well beyond the untreated dietary fiber. These two methods still involve daily administration of the marker which makes nonsupplemented grazing intake trials impractical.

The constant release Cr_2O_3 bolus (CRD) has solved many of these problems associated with estimating fecal output in grazing intake trials. The CRD, developed by R.H. Laby, has largely replaced other methods of estimating fecal output in grazing trials due to the success in reducing diurnal variation (Laby et al., 1984). Many studies have reported that the constant release bolus greatly reduces diurnal variation on grazing trials in both sheep and cattle (Ellis et al., 1981, 1982; Laby et al., 1982, 1984).

Furnival et al. (1990) compared twice daily dosing with gelatin capsules to the CRD in grazing sheep. Gelatin capsules were more accurate when pooling fecal samples together over several days. However, when a single fecal grab sample was taken at a particular period and compared to a composite fecal sample in the same period, the CRD was more reliable than the gelatin capsules. The constant release Cr_2O_3 bolus was found to greatly reduce diurnal variation with the CRD having diurnal variation of $\pm$ 12.6% compared to the gelatin capsules variation of $\pm$ 29.2%.

Barlow et al. (1988) validated the release rate of the CRD by using grazing steers on three different pasture types. The release rates of the CRD were accurate across all pasture types (high, medium, and low nutritive value).

In a study by Brandyberry et al. (1991), the CRD overestimated total fecal output by 25 to 35%, but found little diurnal variation in a trial with penned cattle.

Adams et al. (1991) studied the efficacy of the CRD to estimate fecal output in two 12-d grazing trials with steers on green immature tall wheatgrass. The CRD provided an accurate estimate of daily fecal output as compared to total fecal collection, but fecal output was overestimated with dormant native plants.

Adams et al. (1991) also found that composite fecal samples varied more from total fecal collection than grab samples. They concluded that given the diurnal pattern of grazing, mixing fecal samples may not be as accurate as a single grab sample. Adams et al. (1991) recommended that due to these effects, multiple days and animals be used when using the CRD. The authors further concluded that variable effects of forage movement in the rumen of different animals may cause inconsistencies in the flow of chromium in the rumen.

Butinx et al. (1990) did not find the CRD to be a consistent predictor of estimating fecal output. The CRD consistently overestimated actual fecal output in a trial with grazing sheep.

Hatfield et al. (1990) reported the CRD to be inaccurate in 1 of 3 trials in estimating total fecal output. This study evaluated fecal output estimates of penned sheep by either using twice daily dosing with Cr_2O_3 gelatin capsules or the CRD bolus . Variation in fecal output estimates were greater using the CRD bolus than when using the twice daily dosing method. Both methods were found to over-estimate actual fecal output under pen fed conditions. The authors recommended verification of fecal outputs with total fecal collections on a subsample of animals. Several authors have also detected failure rates due to malfunctions of the CRD (Kattnig et al., 1990; Pond et al., 1990).

Kattnig et al. (1990) recommended that the optimum window for collection of fecal samples to avoid bolus failure is from day 6 to 14 of the boluse's life cycle. Regurgitation of the bolus has also been noticed particularly with animals on fibrous, bulky diets such as found on winter range (Kattnig et al., 1990). Apparently this problem can be reduced to some degree by fasting sample animals for a few hours prior to bolus administration (Sprinkle et al., 1992).

In summary, the constant release Cr_2O_3 bolus is quite effective in reducing diurnal variation, while overestimating fecal output in some cases. This overestimation can be accounted for in studies making group comparisons of fecal output on similar forage. In trials needing individual animal comparisons, the CRD would need to be calibrated for each trial or verified by total fecal collections on a subsample of animals.

Other advantages of the CRD over other external markers include a single dose and a single fecal grab sample which involves less handling of animals (Furnival et al., 1990). This method is also simple in analysis via atomic absorption spectrophotometry (Paterson and Kerley, 1987). In general, the constant release bolus minimizes labor, expense, and disturbance to grazing animals while providing accurate estimates of fecal output.

Forage Intake

Grazing Conditions

Energy expenditures and nutrient requirements for grazing animals are largely affected by the environment (Osuji, 1974). Energy expenditures for grazing can be quite substantial, as much as 45% of the total, as compared to housed animals (Havstad et al., 1981, 1986). Osuji (1974) also estimated that grazing animals can exert as much as 25 to 50% more energy than penned animals. Free-grazing, lactating cows require additional energy for grazing, travel, thermoregulation, and possibly for the extra work of handling bulky forage (Osuji, 1974).

Kronberg (1983) reported that with a 50% increase in energy expenditure for free-roaming cows, and using estimates for daily metabolic energy requirements (NRC, 1976), metabolic energy needs for free-roaming, lactating cows may be 8 to 13.8 Mcal/day greater than nongrazing cows depending on the cow's weight and level of milk production.

Coefficients of variation for forage intake by grazing cows are much higher than for penned cows (Rosiere et al., 1980). They proposed that day-to-day variation in forage intakes of 20 to 25% are natural occurrences under range conditions and may be reflected in fecal output patterns.

Forage Digestibility

For the past 30 yr, it has been well recognized that forage intake increases with forage digestibility (Huston and Pinchak (1991). Rate of passage through the reticulo-rumen has been shown to increase with digestibility, even when rumen fill remains constant (Blaxter et al., 1961).

Ellis (1978) stated that voluntary intake is limited by the capacity of the rumen and by the rate of disappearance of digesta from the rumen. This rate of disappearance is dependent upon forage digestibility. In a review by Allison (1985), most researchers have found that forage intake is limited by forage digestibility, rate of passage, physical conditions within the gut and particularly, the amount of digesta within the reticulo-rumen.

Wagner et al. (1986) found that as forage digestibility increased, intake increased as well ($P<.10$). When forage digestibility decreased from 67% to 59%, mean intake for 3/4 Simmental x 1/4 Hereford and straightbred Hereford cows decreased from 3.0 to 2.3% body weight per day, respectively. These differences in intake in relation to digestibility demonstrated that small changes in digestibility induced significant differences in intake.

Holloway et al. (1979) found similar results with cows grazing high and low quality pastures in Tennessee. Cows grazing high quality pastures consumed 1.3 kg/d more digestible DM than cows grazing low quality pastures. Similar findings were reported by Barlow et al. (1988).

However, there is a point where further increases in forage digestibility will result in zero or negative increases in forage intake. Allison (1985), in citing Hutton (1963), determined this point of decreasing forage intake exists when forage quality exceeds 70% digestibility.

In studying seasonal changes in forage intake, McCollum and Galyean, (1985), reported that,

> As the season progressed from early to late growing conditions, forage intake declined and the decline was associated with reduced forage digestibility, higher levels of GIT fill, and longer residence time of particulate and fluid digesta phases in the rumen.

Animal Factors

The primary factors driving intake in relation to the animal are cow size, body condition, and physiological status of the animal (Allison, 1985).

Cow Size and Body Condition

Nutt et al. (1980) studied the relationship of rumen capacity of mature Angus cows to body measurements, animal performance, and forage intake on pasture. Structurally large Angus cows were found to have larger rumen capacities and greater intakes than structurally small Angus cows. As a percentage of body weight, however, rumen capacity was not related to structural cow size reflecting differences in body composition of the cows studied. Milk yield was also not related to rumen capacity. Most researchers today relate intake by expressing body size in terms of metabolic body weight (MBW) (Wagner, 1985). Metabolic body weight describes the maintenance requirements of different sized animals.

Energy demands for maintenance are proportional to 0.75 power of body weight (Ferrel and Jenkins, 1985), thus, energy needs per unit weight of smaller animals are greater than larger animals (Allison, 1985). Ferrel and Jenkins (1985), citing Turner (1974), reported maintenance requirements of Hereford and Charolais cows increased in proportion to MBW implying that the two breeds did not differ in maintenance needs when scaling BW to the 0.75 power. Ferrel and Jenkins (1985), however, determined that variation among maintenance requirements were found to exist beyond size and milk production. Breed differences, therefore, in maintenance requirements were found to exist.

Ferrell and Jenkins (1985) reported that a positive relationship exists between maintenance requirements and genetic potential for measures of production (e.g., rate of growth, milk production, etc.). As a possible consequence of increased maintenance requirements, animals having genetic potential for high productivity may be at a disadvantage in more restrictive environments. Furthermore, increased maintenance requirements of higher producing animals can be largely accounted for by their increased mass of visceral organs, especially the digestive tract and liver, which have very high rates of energy expenditures (Ferrell and Jenkins, 1985).

Intake is related to body condition as well as to body size (Allison, 1985). Fatter cows have significantly smaller rumen capacities than thinner cows, thus intake was inversely related to fatness when rumen capacity was expressed in proportion to body weight (Nutt et al. 1980). Wagner (1985), citing Bines (1971), stated that increased amounts of fat within the abdominal cavity apparently reduces digestive capacity and thus, forage intake. Therefore, thin cows would be expected to consume relatively larger quantities of forage than fat cows (Holloway and Butts, 1984).

Usually body condition has an inverse relationship with milk production, calf weaning weights, and forage intake per unit of body weight (Morris and Wilton, 1976).

Montano-Bermudez et al. (1990) found that steers from high milk producing genotypes (Milking Shorthorn x Angus) and from medium milk producing genotypes (Red Poll x Angus), had more internal fat and less subcutaneous fat than lower producing (Hereford x Angus) genotypes. These high and medium milk producing cows required about 12% more energy per unit MBW than the lower milk producing cows to maintain body weight.

Holloway and Butts (1984) studied the influence of cow frame size and fatness on seasonal patterns of forage intake in Angus cows. Larger and fatter cows grazing high quality forage tended to consume more digestible energy (DE; Mcal/d) than smaller and thinner cows. As forage quality decreased, small framed cows and thinner cows tended to consume more DE (Mcal/d). Thus, at low DE concentrations, when forage intake was limited by physical factors, thinner cows consumed more forage than fatter cows.

Barlow et al. (1990) also found body condition to be inversely related to fecal output. Fecal output decreased as body condition scores increased for lactating cows on high and medium quality forage. A slight positive relationship with body condition on fecal output was also discovered for cows grazing low quality forages. The authors speculated the thinner animals on the low quality pastures may have been in an energy deficient state, thus allowing less energy for grazing time.

Russell and Wright (1983) reported that maintenance per unit of body size decreased with increasing body condition. Increased maintenance requirements were more of a function of greater genetic potential for milk production rather than cow weight. Dairy crosses, therefore, tend to have greater maintenance requirements as opposed to beef crosses which has been attributed to increase internal organ size (Ferrel and Jenkins, 1985).

In a study by Sprinkle et al. (1992), Hereford and Hereford X Tarentaise breed groups responded similarly to results found by Barlow et al. (1990) with increasing body condition associated with decreasing fecal output. Straightbred Tarentaise, however, did not respond as expected, with fatter cows having more fecal output than thinner cows during early lactation periods. Sprinkle et al. (1992) speculated that visual appraisal of Tarentaise cows for BCS may not provide an accurate estimate for the physiological demands or responses occurring within the Tarentaise breed group. Since Tarentaise is a high milking breed, they may mobilize more internal fat than external fat to help meet the demands of lactation.

Physiological Status

Lactation, pregnancy, and growth contribute to increased energy demands and thus, increased feed intake (Wagner, 1985).

Pregnancy

Breed group differences in forage intake for pregnant and nonlactating cows were not generally observed (Barlow et al, 1988). Rosiere et al. (1980), citing some of their earlier work, determined that pregnant cows had the same level of intake as nonpregnant heifers when voluntary consumption was expressed as %BW.

When subtracting calf weight from precalving weight, Kress et al. (1986) determined that cows actually lost maternal weight during winter in late gestation.

Winter Conditions

Reports have shown that winter grazing and/or winter feeding conditions depress forage intake (Cordova et al. 1978). Rittenhouse et al. (1970) reported winter intakes of only 50 to 58 g dry matter intake per kg of metabolic body weight of winter-range fed cattle. These intakes were less than NRC maintenance requirements (NRC, 1967).

Adverse winter conditions also affect forage intake. In a 2-yr study by Adams et al. (1986), adverse winter weather conditions (0 to -35 C) reduced grazing activity and forage intake of grazing cattle in the Northern Great Plains.

As stated by Sprinkle et al, (1992), winter forage intake during late pregnancy is often inadequate to meet the energy requirements of the cow. Compounding factors of increased fetal size and decreased rumen space of a cow in late pregnancy all contribute to decreased forage intake.

Lactation

Havstad et al. (1986) reported that intake differences among lactating cows of different biological types were related to levels of milk production. Intake was found to be 53% greater for lactating cows than for nonlactating cows grazing on medium quality pastures. Morris and Wilton (1976) found that energy requirements were 10 to 40% greater for lactating cows than for nonlactating cows.

Rosiere et al. (1980) also detected greater intakes by lactating cows. Nonlactating 2-yr-old cows consumed 67% as much forage as did lactating 2-yr-olds, when expressed relative to metabolic body weight. Nonlactating 2-yr-olds had intakes 1.4% of body weight and lactating 2-yr-olds had intakes 2.1% of body weight.

Hatfield et al. (1989) reported that forage intakes increase linearly with increased milk production. High milk producing cows (Milking Shorthorn x Angus) consumed 1.3 kg/d more forage DM than low producing cows (Hereford x Angus) and 1.4 kg/d more than medium-producing cows (Red-Poll x Angus) during early lactating periods. During late lactation periods, higher milk producing cows consumed 1.7 and 1.5 kg/d more than the low and medium milk producing cows, respectively.

Sprinkle et al. (1992) found that differences in fecal output, thus forage intake, were related to demands of milk production. As with Barlow et al. (1988), no breed group differences in FO were detected during nonlactating periods. During lactating periods, however, differences in FO were only found in early to mid-lactation.

Differences in forage intake during lactation have also been found to be dependent on forage quality. Barlow et al. (1988, 1990) found no significant differences between lactating and nonlactating cows grazing on low quality pastures (46 to 49% digestibility) during mid to late lactation. Differences were found, however, between lactating and nonlactating cows grazing high quality pasture (73 to 78% digestibility) and during early to mid-lactation on medium quality pastures (52 to 58% digestibility) with intakes 31 to 57% greater than their nonlactating counterparts.

Holloway et al. (1979) found that lactating Angus cows consumed 1.7 kg/d more DM on pastures that were 60.8% digestible than cows grazing pasture 58.3% digestible. Streeter et al. (1974) reported forage consumption of lactating cows to be as high as 3.2% of BW with increasing forage quality.

Wagner et al. (1986) stated,

> If the energy requirements or maintenance are met, then the amount of forage consumed would determine the amount of milk production. When the physical conditions limit intake, however, milk yield will more likely depend on the amount of metabolizable energy the animal can derive from fat stores (Baile and Forbes, 1974). Fat mobilization to produce milk confounds the relationship between milk yield and caloric intake. To this extent, correlation coefficients between milk yield and daily OMI intake are generally low (Bines, 1976).

Kronberg (1986) reported that lactating Herefords and crossbred cows consumed 23 to 39% more forage, respectively, than their nonlactating counterparts. When considering body weight, breed type, and lactation status as factors explaining the variation in intake, lactation status was found to be the only significant factor.

Biological Efficiency

Biological efficiency has been defined as the ability of a cow to convert feed resources to calf weight at weaning (Morris et al., 1993; Ferrel and Jenkins, 1994). Breeds of cattle can, therefore, be ranked for biological efficiency according to DMI coupled with different genetic potentials for growth and/or milk production (Ferrel and Jenkins, 1994).

Calculations for biological efficiency are often of the type proposed by Kattnig et al. (1991):

$$\text{Production Efficiency} = \frac{\text{Adjusted Calf Weaning Weight}}{\text{Mean Daily OMI}}$$

To calculate biological efficiency coupled with a reproductive measure, Doornbos et al. (1987) used the following formula:

$$\text{Biological Eff.} = \frac{\text{Adj. Calf Weaning. Wt. per Cow Exposed}}{\text{OMI}}$$

Biological efficiency of different biological types of beef cattle has been found to vary from one environment to another (Barlow et al., 1990, Sprinkle et al., 1992, Kattnig et al., 1993). As stated by Ferrel and Jenkins (1985), higher producing animals may have less of an advantage in more restrictive environments. It is generally accepted that cows with higher energy requirements for maintenance and reproduction have higher DM and energy intakes (Ferrel and Jenkins, 1985; Solis et al., 1988; DiCostanzo et al., 1990)

Ferrel and Jenkins (1994), in citing Bowden (1980), stated that if feed is supplied for normal reproduction and milk production, differences in efficiency are not observed. If, however, the availability of feed resources affect reproductive rates or if the genetic potentials for growth in the calves are limited, the potential for differences in efficiency among cattle types can be expressed.

In a recent 4-yr study by Ferrel and Jenkins (1994), differences in efficiency were expressed among 11 breeds of cattle in a drylot experiment. Breeds with greater genetic potential for growth (Pinzgauer, Braunvieh, Charolais, Limousin, Gelbvieh) tended to have higher ranks for efficiency at DMI levels greater than 6,000 kg/yr. Regarding reproductive rates, breeds with greater potential for mature size tended to have reduced reproductive rates at lower DMI, but higher rates of calving at intakes greater than 6000 kg/yr relative to moderate-sized breeds (Red Poll, Angus, Hereford). The authors reported that the primary source of variation in the reproductive rate among the breeds differing in genetic potential for mature size was attributed to the breeds response to feed energy availability.

In the final analysis, Ferrell and Jenkins (1994) determined that Red Poll and Angus or moderate-sized cows in DMI restricted environments (less than 4,000 kg/yr) had reproductivity levels that were superior, resulting in greater biological efficiency. As the DMI environment improved, these two breeds were surpassed in efficiency by breeds with greater genetic potentials for growth and lactation.

These results were similar to those found by Morris et al. (1993). In a similar trial, breed crosses with lower genetic potentials for growth or lactation were more efficient than their larger counterparts in a DMI restrictive environment. The inverse was true at a DMI nonrestrictive environment.

Van Oijen et al. (1993) compared biological efficiency of beef cattle with differing levels of milk production in a drylot experiment. In this study, the lower milk producing (Hereford x Angus) group required the least energy intake for production to weaning and slaughter. The high (Milking Shorthorn x Angus) and medium (Red Poll x Angus) milk producing groups had energy requirements 12 and 14% higher, respectively, than the lower milk producing groups under observed maintenance and reproduction. The biological efficiency of production to weaning was the highest for the lower producing, Hereford x Angus group.

These results also concur with Ferrel and Jenkins (1987) and Montano-Bermudez and Nielson (1990) in their drylot experiments. Biological types with high milk production potential have greater maintenance requirements and thus, were less biologically efficient than lower milk producing types when considering feed requirements from calf birth to calf slaughter.

Significant differences in forage intake under range conditions between different biological types were detected by Barlow et al. (1988). These differences in DMI varied with pasture type and stage of lactation. The authors reported that higher milk producing genotypes (Simmental x Hereford) and dairy crosses (Holstein x Hereford) had greater DMI on high quality pastures (57 to 78% OMD). These breed types were surpassed, however, by Brahman x Hereford crosses on low (44 to 50% OMD) and medium (52 to 61% OMD) quality pastures.

Significant differences in fecal organic matter output (FOMO) were noted in all periods of lactation between the biological types when grazing high and low quality pastures. However, when grazing medium quality pastures, differences were detected only during mid-lactation. Barlow et al. (1988) concluded that the crossbred cows had greater nutrient requirements than straightbred Hereford cows, but these differences were more of a function of higher milk yields than actual cow weight.

Holloway and Butts (1984) studied the influence of cow frame size and fatness on forage intake with Angus cows grazing different quality pastures. Large framed cows grazing higher quality fescue-clover pastures excelled in DE intake, milk production, and calf weight gain. Smaller framed cows excelled in these traits on lower quality fescue pastures. The authors speculated that on lower quality pastures, the larger framed cows were not able to consume enough forage to meet their energy needs. Fatter cows were found to be less efficient on the higher quality pastures and more efficient on the lower quality pastures. They concluded that cow body size and condition are more accurate determinants of efficiency than genetic potentials for growth and/or milk production and that these factors should be matched to respective forage environments.

Kattnig et al. (1993) compared forage intakes of various Brangus and Hereford cross cattle grazing semi-desert pastures in southern New Mexico. The authors determined that optimal biological efficiency may be achieved by using cows with lighter mature body weight.

Kattnig et al. (1993), in citing Solis et al. (1988), reported,

> Cows that have the potential to store fat are more efficient when energy is limited, whereas cows that have larger protein stores are more efficient when energy is not limited.

Under semi-desert conditions, however, energy deficiency is common. Kattnig et al. (1993) speculated that lighter cows are able to store more energy as fat more readily than heavier cows due to lower maintenance requirements.

A four year study in northern central Montana by Doornbos et al. (1987), detected no breed differences in forage intake on a high quality (65% IVOMD) or low quality (43% IVOMD) forage. During an average year, however, breed group differences in forage intake among lactating cows were 19 and 37% greater for the higher producing 1S1H and 3S1H cows, respectively, than the lower producing HH cows. The authors concluded that for ranges in northern central Montana, biological types intermediate in genetic potentials for milk production, body size, and age at puberty appeared better matched for this environment.

With continued work in northern central Montana, Sprinkle et al. (1992), detected differences in fecal output among straighbred Hereford (HH), straightbred Tarentaise, (TT) and the F_1 reciprocal (HT), but only during early to mid-lactating periods. Among the biological types tested, FO tended to be higher for TT in every period except in late lactation throughout the production year.

Sprinkle et al. (1992) summarized,

> Genotype by environmental interactions can occur during a production year, with milk production and body condition being important factors in breed group differences. During peak lactating periods, higher milking genotypes (TT) will probably have greater fecal output (and thus greater forage intake) than low milk production genotypes (HH) provided

forage resources are adequate to meet the demands of lactation. As forage quality and availability increases or decreases, milk output will change along with cow body condition. With changing forage, reranking of breed groups or fat vs. thin cows can occur (Holloway and Butts, 1984; Doornbos et al., 1987; Barlow et al., 1988).

Sprinkle et al. (1992) concurred with Ferrel and Jenkins (1985, 1987), that a maintenance cost, beyond the direct costs of lactation, is associated with improved levels of milk production. The authors summarized that milk production and body size are important factors in matching biological types to the environment.

However, there are still factors driving forage intake that may not be directly measured by milk production. Factors such as haircoat, rumen and internal organ size, fasting heat production and the animals ability to adapt to stress all contribute to the energy requirements of the animal during lactation (Sprinkle et al., 1992). These factors other than milk production can cause breed group differences in forage intake when energy resources are limited. Sprinkle et al (1992) further speculated that differences in forage intake among genotypes may not be significant in either high or severely low forage productive environments. Breed groups that are not widely divergent in their ability to adapt to these environments may not show expected forage intake differences.

Wagner et al. (1986) concluded that 60% of the variation in forage intake among five different biological types, all differing in levels of milk production, was explained by milk production. They concurred with Ferrel and Jenkins (1985), stating that animal related factors other than milk production, body weight and body condition need to be evaluated to further describe forage intake differences among genotypes. Wagner et al. (1986) suggested examining factors such as ruminal volume and organ weight and their influence on forage intake.

In a review by Ritchie (1995), he summarized that,

> High maintenance cows tend to have the following characteristics: high milk production, high visceral organ weight, high body lean mass, low body fat mass, high output, and high input. Conversely, low maintenance cows tend to be: low in milk production, low visceral organ weight, low in body lean mass, high in body fat mass, low output, and low input. All of this implies that there is a need for balance based upon the production environment and the market requirements for a given region and/or for a given farm or ranch.

Assessment of these characteristics in relation to forage intake under range environments is necessary in our understanding of the mechanisms associated with the genotype x environmental interactions that exist (Doornbos et al., 1987, Sprinkle et al., 1992, Kattnig et al., 1993). It is essential to conduct forage intake experiments to measure cow productivity in differing range environments in order to determine optimal biological efficiency and in turn, optimal economical efficiency.

CHAPTER 3

MATERIALS AND METHODS

Sampling of Cows

Each year, fifty-one 2-, 3-, 4-, and 5-yr-old pregnant range cows from the Northern Agricultural Research Center herd near Havre, Montana were randomly selected from three biological types. These biological types were straightbred Hereford (HH), straightbred Tarentaise (TT), and the F_1 reciprocal cross (HT), with 17 cows representing each group. Each breed group contained, on average, five 2-yr-old, six 3-yr-old, and six 4-yr-old or older cows. Cows that either lost a calf or failed to milk were removed from the study.

Daily fecal output (FO) was measured during five periods throughout a production year from 1992 through 1994. The five periods were pregnant, nonlactating, fall grazing (November; PdI); pregnant, nonlactating, winter supplemented (February; Pd II); lactating, spring supplemented (May; Pd III); lactating early summer grazing (June; Pd IV); and lactating, late summer grazing (September; Pd V). For each cow during each period, FO was estimated using a constant release intraruminal bolus (Captec Chrome^R, Nufarm, Auckland, NZ) of chromic oxide (Cr_2O_3). Following a 10-d equilibrium period, three fecal grab samples were taken 3 d apart. Fecal samples were then frozen and analyzed later for DM, OM, Ash and Cr_2O_3 content. From this, FO was estimated by the following formula:

$$FO\ (g/d) = \frac{Cr_2O_3\ \text{release rate}\ (g/d)}{Cr\ \text{content in feces}\ (g/g)} * \%\ OM/100$$

Each cow was bolused once in the morning of each period then retained in a drylot for several hours. If any cows regurgitated the bolus, they were rebolused immediately or removed from that period. Cows were determined to have lost a bolus by either finding a regurgitated number coded bolus or by an unreasonable fecal output estimate measured by the chromium concentration reading during laboratory analysis. Unreasonable FO estimates that were 6 standard deviations above or below (+7990.95g / -1219.16g) the mean fecal output estimate (3240.98g) were reanalyzed for chromium content. Of the 60 observations reanalyzed, 22 remained outliers (Table 18). Of the 22, 16 were removed due to large estimates of FO due to low concentrations of chromium detected in the fecal sample. These outlying observations were from either lost/regurgitated boluses or from faulty boluses whose release rates were inaccurate causing unreasonable FO estimates. All observations from these cows were, therefore, removed from that period to eliminate bias.

Management of Cattle

Grazing

During periods I, IV, and V, all cows were on pasture in the Bears Paw mountains which are characteristic of the foothill ranges of north central Montana. The area is classified in the Forest-Grassland complex of the western glaciated plains. Pasture elevation averaged 1300 m with 0 to 40% slopes. Annual precipitation was 40.5 cm in 1992, 60.7 cm in 1993, and 19.2 cm up through October in 1994 (rainfall data was only collected until the end of the study in 1994). Average annual precipitation for the area from 1982 through 1994 was about 40.2 cm. Upland vegetation was dominated by rough fescue (Festuca scabrella), Idaho fescue (Festuca idahoensis), and bluebunch wheatgrass (Agropyron spicatum) with an open overstory of ponderosa pine (Pinus ponderosa). The lowland vegetation consisted primarily of Kentucky bluegrass (Poa pratensis).

Feeding

During Period II in February, 2- and 3-yr-old cows were group fed barley hay and grass hay at 9 $kg \cdot hd^{-1} \cdot d^{-1}$ and 4-yr-old and older cows were group fed 9 $kg\,hd^{1} \cdot d^{1}$ of grass hay. After calving in Pd III, 2-yr-old cows were group fed 13.6 $kg \cdot hd^{-1} \cdot d^{-1}$ of second cutting alfalfa hay while the older cows were group fed 13.6 $kg \cdot hd^{-1} \cdot d^{-1}$ of first cutting alfalfa/grass hay mix..

Breeding and Calving

All cows were bred by artificial insemination in a 45-d breeding season while on summer pasture. Mating plans for the Foundation and Phase I cattle are represented in Tables 1 and 2. All sires were randomly assigned to breed and age of dam. Foundation cows

TABLE 1. MATING PLAN FOR FOUNDATION CATTLE TO PRODUCE PHASE I CALVES (Kress et al., 1995).

Foundation Cows[a]

	H	T
H	HH	HT
T	HT	TT

[a] H = Hereford; T = Tarentaise.

TABLE 2. MATING PLAN FOR PHASE I CATTLE TO PRODUCE PHASE II CALVES (Kress et al., 1995).

Phase I cows[a]

	HH	HT	TT
HH	1H1H	3H1T	1H1T
HT	3H1T	1H1T	3T1H
TT	1H1T	3T1H	1T1T

[a] HH = Hereford; HT = Hereford x Tarentaise; TT = Tarentaise.

were mated at random to 17 Hereford (H) and 16 Tarentaise (T) sires producing Phase I calves. The Phase I cows were then mated at random to 6 Hereford (HH), 6 Tarentaise (TT), and 6 F_1 (HT) sires producing Phase II calves. First calf heifers were bred natural service to Hereford, Tarentaise, and F_1 sires selected according to an index (I = YW - 3.2BW; Dickerson et al., 1974) and no bulls over 45 kg BW were used. Heat detection was checked by vasectomized bulls and by twice daily visual inspection. Calves were born starting late February and ending late April to early May with the average calving date in late March.

Measurements on Cattle

Cows were weighed at each fecal sampling of each period and body condition (BCS) was scored, 1 through 9 (1 = thin, 9 = obese), in the middle of each sample period. Body condition was scored by two visual appraisers and the average of the two scores and the average of the three weights within each period were used in analysis of data. Cow hip heights were taken at weaning.

Milk production (MP) was estimated during periods III, IV, and V by the weigh-suckle-weigh method (Williams et al., 1979) and converted to a 24-h basis following a 6 to 7 h separation interval.

Laboratory Procedures

Fecal Sample Analysis

Fecal samples were analyzed for dry matter (DM), organic matter (OM), and chromium content. Fecal samples were oven-dried at 60° C for 48 h and then ground in a Wiley mill with a 2 mm screen. Fecal DM and OM was estimated according to AOAC (1990) procedures. Chromium content was determined using acid digestion and spectophotometric procedures as described by Fenton and Fenton (1979), with a 2 g sample of feces. Fecal samples were analyzed by sample within period. Six fecal samples within each sample period were randomly selected and repeated to measure the accuracy of lab procedures. Repeated samples showed good accuracy with a repeatability of .873. All fecal digestion procedures used an indicator consisting of pure chromium in a flask of the acid digestion mixture. This was used as a determinant of the proper cooking length as indicated by the color change. All spectrophotometric readings were at 390 nm.

Chromium Background

Chromium contamination was tested by chromium analysis of prebolus fecal samples taken from control cows and all experimental cows. The mean FO estimate (8100.59g) from prebolus fecal samples was above 6 standard deviations from the mean FO value (3240.98g) suggesting that insignificant chromium contamination was found over the 3 year study.

Spectrophotometer Regression Line

An ultraviolet visible spectrophotometer was used to determine chromium weights in grams per gram of fecal matter. A regression line was fitted using known concentration standards of .0012, .0025, .0050, .0100, .0200, and .0250 g chromium in an acid digestion mixture diluted to 100 ml. The regression line was calculated using the Beer-Lambert Law:

$$A = a * b * c$$

where,

A = measures light absorbance of the species tested

a = a constant depending on the species tested (with Cr @ 390 nm)

b = path length of light in cm (1 cm with machine used)

c = concentration of the species in solution

With the standards used, the linear regression line was calculated assuming the following model:

$$y = b_o + b_1 x$$

with y = measured absorbance readings

b_o = calculated y intercept

b_1 = slope of the regression line

x = chromium weight

b_0 was equal to -0.0343 and b_1 was equal to 75.05 in the calculated regression equation. With these constants, chromium weights were then determined by the following formula:

$$x = A - (-0.0343) / 75.05 * \text{sample wt.}$$

Sample weight (75.05 * sample weight) was multiplied by 2 because the digested fecal samples were diluted to 1/2 the amount of the standard dilutions. The final formula was:

$$\text{Cr wt.} = A - (-0.0343) / 300.2$$

Statistical Analysis

All data for cow performance traits, cow weight (COWWT), cow body condition (BCS), calf weight (CLFWT), cow hip height (HIPHT), and milk production (MP), were analyzed by period using least squares procedures (SAS, 1987). Least squares means for COWWT and BCS were obtained for all periods while results from MP were obtained for Pds III, IV, and V, CLFWT for Pds I, III, IV, and V, and HIPHT for Pd I. The statistical model included fixed main effects for year, cow age, and breed group with all possible interactions among main effects.

Fecal output (FO) data for analysis consisted of the mean FO estimate of the three fecal samples for each cow-period-year subclass (n = 724). In the first set of analyses, data for FO were analyzed by period using least squares procedures (SAS, 1987). The statistical model included fixed main effects for year, cow age, and breed group with all possible main effect interactions. In the second set of analyses, the same model also included as covariates cow weight, cow body condition, milk production, calf weight, calf age, and cow hip height. Covariates were tested singly and in combination with other covariates. Appropriate quadratic effects and all possible two-way interactions were tested. Nonsignificant covariates ($P>.05$) and interactions ($P>.05$) were removed and a reduced model was fit. Repeated measures was not used in this analysis due to all experimental cows not being repeated every year and every period. The residual mean square, composed primarily of cow within year and breed group effects, was used to construct all F-statistics.

CHAPTER 4

RESULTS AND DISCUSSION

Cow Performance Traits

Cow Weight

Table 3 shows the least squares analyses of variance for cow weight by period.

TABLE 3. ANALYSES OF VARIANCE FOR COW WEIGHT BY PERIOD (Pr>F).

	Period				
Source	I	II	III	IV	V
Year	.0004	.7486	.1196	.0001	.0001
Cow Age	.0001	.0001	.0001	.0001	.0001
Breed	.0001	.0001	.0002	.0001	.0001
MS Error	2314	2712	2410	1810	1543
R^2	.60	.62	.58	.64	.55

Table 4 lists the cow weights by breed group and cow age for the five periods. All age groups were significantly different in all periods. Cow weights increased with age with 2-yr-olds being the lightest and 5-yr-olds being the heaviest (P<.05). Breed group differences in cow weight were found with HH and HT being significantly heavier than TT in all periods (approximately 45 kg). Hereford and HT did not differ for cow weight in any period (P>.10). Overall cow weight least squares means were 520, 515, and 476 kg for HH, HT and TT, and 510, 516, and 485 kg for 1992, 1993 and 1994, respectively.

TABLE 4. COW WEIGHTS (kg) BY PERIOD FOR BREED AND COW AGE[a].

	Period				
Breed[b]	I	II	III	IV	V
HH	519 ± 7^c	557 ± 7^c	495 ± 8^c	511 ± 7^c	517 ± 6^c
HT	518 ± 7^c	554 ± 8^c	484 ± 8^c	507 ± 7^c	511 ± 6^c
TT	479 ± 7^d	509 ± 8^d	451 ± 8^d	469 ± 7^d	476 ± 6^d
Cow Age					
2	418 ± 9^c	447 ± 11^c	393 ± 11^c	412 ± 10^c	435 ± 9^c
3	490 ± 8^d	526 ± 9^d	461 ± 9^d	487 ± 9^d	499 ± 7^d
4	536 ± 8^e	568 ± 9^e	502 ± 9^e	523 ± 8^e	527 ± 7^e
5	578 ± 6^f	618 ± 7^f	551 ± 7^f	559 ± 6^f	544 ± 5^f

[a] Least-squares means ± SE.
[b] HH = Hereford; HT = Hereford x Tarentaise; TT = Tarentaise.
[c,d,e,f] Means in column without a common superscript differ (P<.05).

Cow Hip Height

Table 5 lists the least squares analyses of variance for cow hip height, which was measured at weaning in October. Cow hip heights were not significantly different among breed groups or cow ages. Overall least squares means for cow hip height were 131.4, 132.0,

TABLE 5. ANALYSES OF VARIANCE FOR COW HIP HEIGHT (Pr>F).

Source	Pr>F
Year	.0013
Cow Age	.3883
Breed	.6281
MS Error	1771
R^2	.11

and 131.2 cm for HH, HT, and TT, respectively. Cow hip heights were 130.5, 132.3, 131.3, and 132.0 cm for 2, 3, 4, and 5-yr-old cows, respectively.

Cow Body Condition

Table 6 shows the least squares analyses of variance for cow body condition by period.

TABLE 6. ANALYSES OF VARIANCE FOR BODY CONDITION SCORE (Pr>F).

	Period				
Source	I	II	III	IV	V
Year	.0001	.0001	.0001	.8245	.0001
Cow Age	.0001	.0001	.0001	.0001	.0001
Breed	.0001	.0001	.0001	.0024	.0001
MS Error	.71	.60	.47	.54	.51
R^2	.40	.37	.48	.45	.38

Table 7 lists the breed group and cow age differences in BCS by period. Breed group differences in BCS were significant over all periods with HH having greater BCS than both HT and TT except in periods II and IV where HH and HT were not different (P>.10). Tarentaise, over all periods, had the lowest body condition with HH having the highest. Cow age was significant in all periods with older cows having greater BCS than younger cows. Overall least squares means for body condition score were 5.5, 5.2, and 4.7 for HH, HT, and TT and 5.5, 5.0, and 5.0 for 1992, 1993, and 1994, respectively.

TABLE 7. BODY CONDITION SCORE (1 - 9) BY PERIOD FOR BREED AND COW AGE[a].

	Period				
Breed[b]	I	II	III	IV	V
HH	5.9 ± .11[c]	5.8 ± .11[c]	5.1 ± .11[c]	5.3 ± .11[c]	5.6 ± .12[c]
HT	5.6 ± .11[d]	5.6 ± .11[c]	4.7 ± .11[d]	5.1 ± .11[c]	5.2 ± .11[d]
TT	5.2 ± .11[e]	4.8 ± .11[d]	4.2 ± .11[e]	4.7 ± .11[d]	4.8 ± .12[e]
Cow Age					
2	5.1 ± .15[c]	5.0 ± .16[c]	4.2 ± .16[c]	4.2 ± .17[c]	4.5 ± .16[c]
3	5.3 ± .13[cd]	5.2 ± .14[c]	4.2 ± .13[c]	4.8 ± .14[d]	5.1 ± .13[d]
4	5.6 ± .13[d]	5.4 ± .13[c]	4.9 ± .13[d]	5.3 ± .13[e]	5.3 ± .12[d]
5	6.2 ± .10[e]	6.0 ± .10[d]	5.4 ± .10[e]	5.9 ± .10[f]	5.8 ± .10[e]

[a] Least-squares means ± SE.

[b] HH = Hereford; HT = Hereford x Tarentaise; TT = Tarentaise.

[c,d,e,f] Means in column without a common superscript differ (P<.05).

Milk Production

Table 8 shows the least squares analyses of variance for milk production, which was measured during periods III, IV, and V.

TABLE 8. ANALYSES OF VARIANCE FOR MILK PRODUCTION (Pr>F).

	Period		
Source	III	IV	V
Year	.0524	.0026	.0001
Cow Age	.0001	.0437	.0465
Breed	.0001	.0179	.0001
MS Error	7.56	16.51	22.12
R^2	.26	.16	.27

Table 9 represents breed group and cow age differences in milk production by period. The average age of calves during periods III, IV, and V was approximately 36 d, 67 d, and

159 d, respectively. Tarentaise and HT had significantly greater milk production than HH during early and mid-lactating periods (Pd III and IV). In late lactation (Pd V), however, all three breed groups were different with TT having the greatest milk production and HH having the lowest (P<.05). The general trend, over all lactating periods, was TT having the greatest milk production and HH having the lowest MP. The overall least squares means for milk production were 7.7, 9.9, and 10.7 kg for HH, HT, and TT, respectively. Five-yr-old cows had greater milk production than 2-yr-olds during Pd III and IV (P<.05). In late lactation (Pd V), however, 3-yr-old cows had lower milk production than the 5-yr-olds.

TABLE 9. MILK PRODUCTION (kg) BY PERIOD FOR BREED AND COW AGE[a].

	Period		
Breed[b]	III	IV	V
HH	$6.9 \pm .43^{c}$	$11.0 \pm .63^{c}$	$5.2 \pm .73^{c}$
HT	$9.4 \pm .42^{d}$	$13.0 \pm .58^{d}$	$7.2 \pm .67^{d}$
TT	$9.0 \pm .43^{d}$	$13.3 \pm .61^{d}$	$9.6 \pm .71^{e}$
Cow Age			
2	$6.8 \pm .65^{c}$	$11.1 \pm .91^{c}$	$7.2 \pm .99^{c,d}$
3	$7.6 \pm .52^{c,d}$	$12.3 \pm .74^{c,d}$	$5.6 \pm .86^{c}$
4	$9.3 \pm .50^{d,e}$	$12.5 \pm .71^{c,d}$	$7.8 \pm .82^{c,d}$
5	$10.1 \pm .39^{e}$	$14.0 \pm .56^{d}$	$8.7 \pm .65^{d}$

[a] Least-squares means ± SE.
[b] HH = Hereford; HT = Hereford x Tarentaise; TT = Tarentaise.
[c,d,e] Means in column without a common superscript differ (P<.05).

Calf Weight

Table 10 illustrates the least squares analyses of variance for calf weight by period.

TABLE 10. ANALYSES OF VARIANCE FOR CALF WEIGHT (Pr>F).

Source	Period I	III	IV	V
Year	.0001	.1391	.9070	.0001
Cow Age	.0001	.0001	.0001	.0001
Breed	.0001	.0008	.0034	.0001
MS Error	474.9	21.05	244.7	443.2
R^2	.46	.33	.23	.40

Table 11 shows calf weights by period for the three breed groups. Significant differences existed in early calf weights (Pd III) with TT having lighter calf weights the the other two breed groups. Tarentaise and HT had significantly greater calf weights, however, than HH in Pds I, IV, and V. During period I, after weaning, calf age was approximately 189 d. The HT cows may be expressing maternal heterosis resulting in heavier calf weights than the other two breed groups. Overall least squares means for calf weight were 132, 147, and

TABLE 11. CALF WEIGHT (kg) BY PERIOD FOR BREED AND COW AGE[a].

Breed[b]	Period III	IV	V	I*
HH	38.2 ± .71[c]	99.1 ± 2.4[c]	186.7 ± 3.2[c]	203.5 ± 3.3[c]
HT	40.0 ± .70[c]	110.2 ± 2.2[d]	211.2 ± 3.0[d]	226.7 ± 3.1[d]
TT	36.2 ± .72[d]	106.0 ± 2.3[d]	207.0 ± 3.2[d]	225.3 ± 3.2[d]
Cow Age				
2	34.9 ± 1.1[c]	103.0 ± 3.5[c,d]	192.7 ± 4.7[c]	205.5 ± 4.7[c]
3	36.9 ± .89[c]	95.1 ± 2.9[c]	188.0 ± 3.9[c]	204.0 ± 4.0[c]
4	39.7 ± .84[d]	108.2 ± 2.7[d,e]	208.2 ± 3.7[d]	229.1 ± 3.8[d]
5	41.1 ± .65[d]	114.1 ± 2.2[e]	217.7 ± 2.9[e]	235.3 ± 3.0[d]

[a] Least-squares means ± SE.

[b] HH = Hereford; HT = Hereford x Tarentaise; TT = Tarentaise.

* Period I = After weaning.

[c,d,e] Means in column without a common superscript differ (P<.05)

144 kg for HH, HT, and TT, respectively.

Cow age had a significant effect on differences in calf weight. Four and 5-yr-old cows had heavier ($P<.05$) calf weights than the younger cows in all periods except Pd IV. Two-yr-old cows had calf weights similar to 4-yr-olds during the peak lactation period ($P>.05$).

Fecal Output

Table 12 shows the least squares analyses of variance for fecal output (g). Year effects were very large and significant except in Pd IV.

TABLE 12. LEAST SQUARES ANOVA FOR FECAL OUTPUT (Pr>F).

			Period		
Source	I	II	III	IV	V
Year	.0001	.0010	.0001	.8245	.0001
Cow Age	.0618	.0190	.0012	.0121	.0001
Breed	.1797	.7749	.2805	.7939	.6387
MS Error	414086	614387	619299	469049	350293
R^2	.63	.17	.59	.73	.55

Table 13 contains FO (g) least squares means by period for breed group, cow age and year. Breed group had no significant effect on differences in FO in any period ($P>.05$). These results disagree with those found by Sprinkle et al. (1992), Barlow et al. (1988), Wagner et al. (1986) and Rosiere et al. (1980) where breed group differences were reported for FO during lactating periods.

Cow age had a significant effect on FO with 4 and 5-yr-olds having greater FO than the younger cows in every period except period II where 2-yr-olds were not different from older cows (P>.05). Sprinkle et al. (1992) found 2-yr-old cows with significantly greater FO than older cows only in Pd III. Year effects were significant with the general trend of 1992 showing greater FO levels during lactating periods than the other two years.

TABLE 13. LEAST-SQUARES MEANS FOR FECAL OUTPUT (g) BY PERIOD FOR BREED, COW AGE AND YEAR[a].

	Period				
Breed[b]	I	II	III	IV	V
HH	2985±91[c]	3335±111[c]	3459±122[c]	3220±106[c]	3169±91[c]
HT	2864±92[c]	3443±112[c]	3714±120[c]	3181±101[c]	3152±87[c]
TT	2745±93[c]	3366±116[c]	3509±122[c]	3279±106[c]	3061±89[c]
Cow Age					
2	2574±130[c]	3304±165[c,d]	3201+182[c]	2798±158[c]	2670±134[c]
3	2918±111[d]	3065±139[c]	3306±149[c]	3344±128[d]	3087±110[d]
4	2956±108[d]	3574±134[d]	3819±144[d]	3317±121[d]	3308±105[d,e]
5	3010±90[d]	3582±104[d]	3917±112[d]	3445±101[d]	3444±81[e]
Year					
92	2078±90[c]	3533±109[c]	4942±115[c]	4899±111[c]	3972±88[c]
93	4026±95[d]	3031±115[d]	2706±109[d]	2444±105[d]	2584±91[d]
94	2490±99[e]	3582±123[c]	3036±114[e]	2337±110[d]	2826±94[d]

[a] Least-squares means ± SE.
[b] HH = Hereford; HT = Hereford x Tarentaise; TT = Tarentaise.
[c,d,e] Means in column without a common superscript differ (P<.05).

Table 14 shows the least squares analyses of variance for fecal output on a per unit of body weight basis (g/kg; FO/BW). Again, year effects were large. The primary difference between the analysis for FO and FO/BW was that breed group was significant for FO/BW during Pds III and IV.

TABLE 14. LEAST SQUARES ANOVA FOR FECAL OUTPUT PER UNIT OF BODY WEIGHT (Pr>F).

	Period				
Source	I	II	III	IV	V
Year	.0001	.0003	.0001	.0001	.0001
Cow Age	.0829	.0005	.0595	.0900	.9044
Breed	.5173	.5557	.0222	.0082	.2702
Year*BRD	-	-	-	-	.0014
MS Error	1.91	1.48	2.47	2.22	1.42
R^2	.60	.31	.69	.78	.48

Table 15 shows least-squares means for FO/BW (g/kg) by period for breed group, cow age and year. Significant breed group differences in FO/BW were detected in periods III and IV. During early lactation, period III, HH had lower FO/BW levels than the other two breed groups. During period IV, HT had lower FO/BW than TT. Fecal output per unit of body weight for HH approached significance (P=.065) with lower FO than TT during the peak lactation period (Pd IV).

Cow age had a significant effect on FO/BW with 2-yr-olds having greater FO than the older cows in Pd II, III, and IV. This may be due to increased energy demands for growth while lactating and smaller body weight. Two-yr-olds also received a better quality supplement than older cows (59% vs 36% IVOMD, respectively) during Pd III, which could partially explain the increase in FO. Year effects on FO/BW showed 1992 having greater

TABLE 15. LEAST-SQUARES MEANS FOR FECAL OUTPUT PER UNIT OF BODY WEIGHT (g/kg) BY PERIOD FOR BREED GROUP, COW AGE AND YEAR[a].

	Period				
Breed[b]	I	II	III	IV	V
HH	$5.9 \pm .20^{c}$	$6.2 \pm .22^{c}$	$7.0 \pm .25^{c}$	$6.7 \pm .24^{c,d}$	$6.3 \pm .20^{c}$
HT	$5.6 \pm .20^{c}$	$6.3 \pm .22^{c}$	$7.9 \pm .25^{d}$	$6.3 \pm .22^{c}$	$6.1 \pm .18^{c}$
TT	$5.7 \pm .21^{c}$	$6.5 \pm .23^{c}$	$7.9 \pm .26^{d}$	$7.3 \pm .25^{d}$	$6.5 \pm .22^{c}$
Cow Age					
2	$6.1 \pm .28^{c}$	$7.4 \pm .31^{c}$	$8.4 \pm .38^{c}$	$7.3 \pm .36^{c}$	$6.3 \pm .27^{c}$
3	$6.0 \pm .24^{c}$	$5.8 \pm .26^{d}$	$7.2 \pm .30^{d}$	$7.0 \pm .28^{c,d}$	$6.2 \pm .22^{c}$
4	$5.6 \pm .24^{c,d}$	$6.3 \pm .25^{d}$	$7.7 \pm .36^{c,d}$	$6.4 \pm .27^{d}$	$6.3 \pm .21^{c}$
5	$5.3 \pm .19^{d}$	$5.9 \pm .19^{d}$	$7.2 \pm .23^{d}$	$6.4 \pm .22^{d}$	$6.4 \pm .16^{c}$
Year					
92	$4.2 \pm .19^{c}$	$6.8 \pm .21^{c}$	$10.5 \pm .26^{c}$	$10.3 \pm .24^{c}$	$7.4 \pm .18^{c}$
93	$7.9 \pm .21^{d}$	$5.6 \pm .22^{d}$	$5.6 \pm .25^{d}$	$4.8 \pm .23^{d}$	$5.3 \pm .19^{d}$
94	$5.2 \pm .21^{c}$	$6.7 \pm .23^{c}$	$6.7 \pm .25^{e}$	$5.2 \pm .24^{d}$	$6.2 \pm .19^{e}$

[a] Least-squares means $\pm$ SE.
[b] HH = Hereford; HT = Hereford x Tarentaise; TT = Tarentaise.
[c,d,e] means in column without a common superscript differ (P<.05).

FO/BW levels during lactating periods than the other two years.

Table 16 lists regressions of FO on covariates from the model year, cow age and breed as the main effects. All possible main effects by covariate interactions were not significant. Each covariate was fit separately. Cow weight and calf age influenced differences in FO (P<.05) on a within breed group basis only in Pd III. Differences in FO due to calf age was primarily attributed to earlier calving dates (approximately 20 d) than the older cows. Cow body condition, milk production, calf weight, and cow hip height, however, had no significant effect on differences in FO in any period. Quadratic effects were also not significant.

The regression of FO on cow body weight was significant in Pd III, indicating that

TABLE 16. REGRESSIONS (Pr>F) OF FO (g) ON COVARIATES[a].

	Period				
Covariates	I	II	III	IV	V
Cow Weight	-1.2 (.28)	1.6 (.20)	4.9 (.0005)	-.40 (.78)	1.5(.30)
BCS	90.6 (.12)	-54.5 (.55)	156.9 (.13)	-7.6 (.93)	-100.5 (.19)
Milk Production	-	-	.16 (.99)	.73 (.96)	.65 (.96)
Calf Weight	.47 (.85)	-	27.2 (.08)	-2.5 (.53)	-.06 (.37)
Calf Age	5.8 (.25)	-	-12.8 (.04)	-6.6 (.23)	.99 (.84)
Hip Height	-5.3 (.94)	5.9 (.29)	4.7 (.99)	2.6 (.65)	-1.4 (.95)

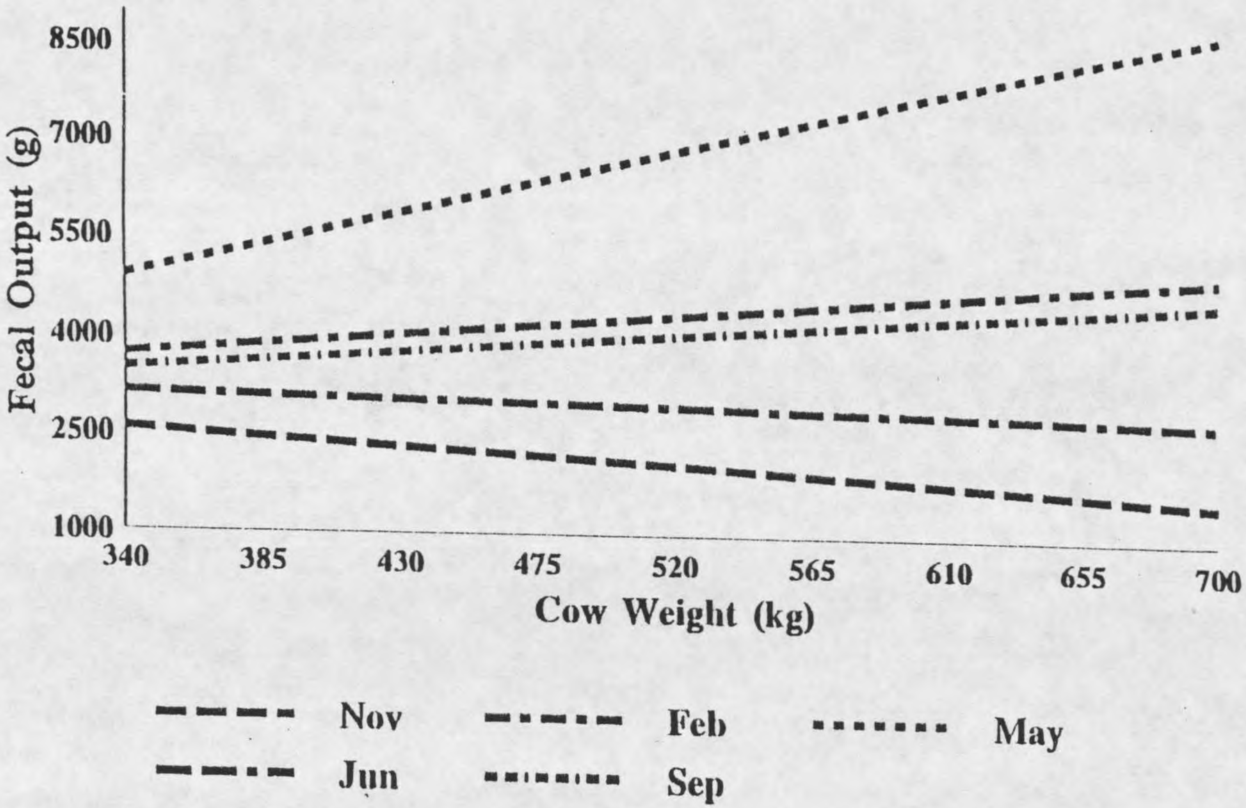
[a]Each covariate fitted separately.

FO changed along with cow weight. Figure 1 illustrates the regression of FO on cow weight by period from the model that included year, cow age, and breed as the fixed effects and cow weight as the covariate. Cow body condition was also tested in the model, but it was found insignificant and, therefore, removed.

Cow weight had a positive linear effect on FO only in Pd III, indicating that heavier cows excreted more OM than the lighter cows. Similar observations were also found by Kattnig et al. (1993), Holloway and Butts (1984), and Nutt et al. (1980) where FO increased with increasing cow weight. Regressions for Pds I, II, IV, and V were not significantly different from zero.

Fecal output trends in Pd III, after calving and at early lactation, showed that heavier cows had greater FO levels than lighter cows. Cows that have greater genetic potential to increase fat and/or weight consuming high quality forage, may have greater forage intakes which may represent the positive relationship of FO with cow weight. Holloway and Butts (1984) found that fatter cows tended to consume more forage than thinner cows during high

Figure 1. Regression of fecal output on cow weight for each of the five periods during the year (b = -1.24, 1.62, 4.88*, -0.4, and 1.47, respectively; *P<.05).



forage quality availability.

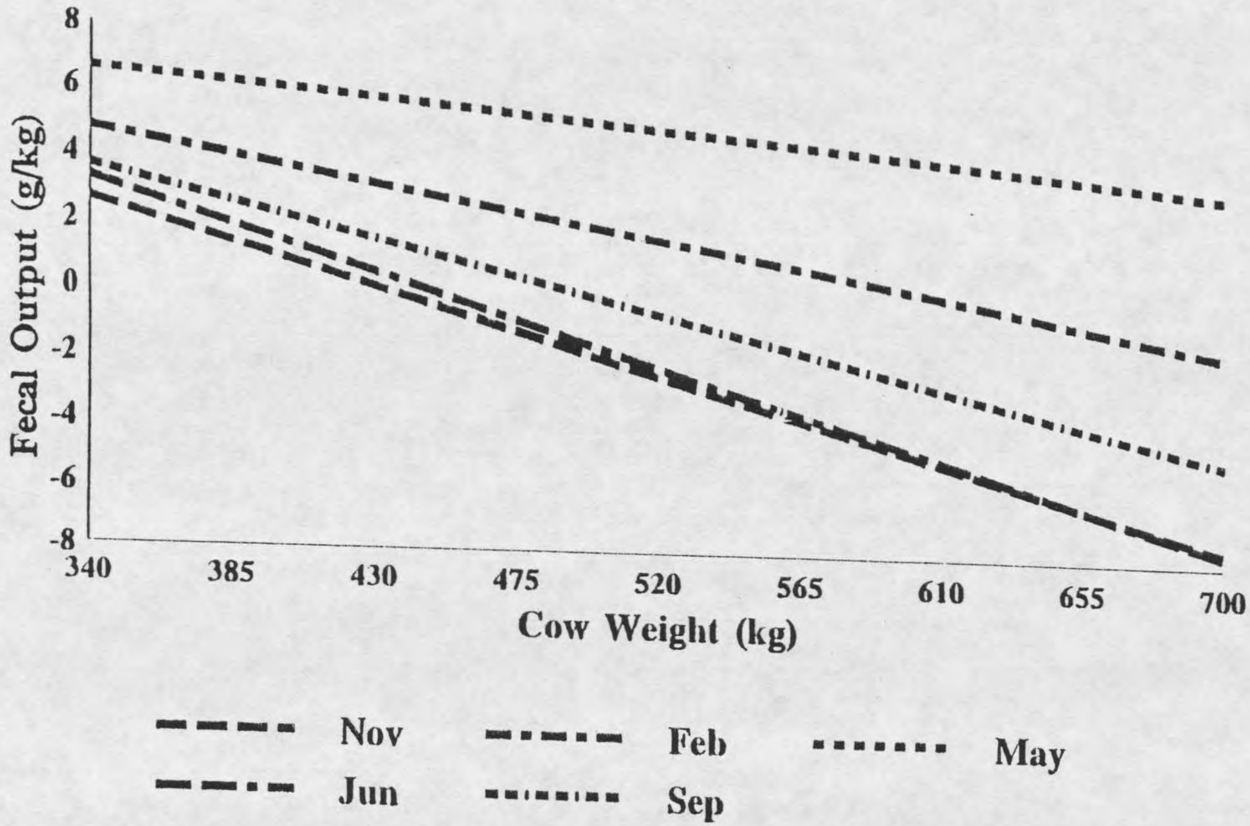
During this period, 2-yr-old cows were group fed 13.6 $kg \cdot hd^{-1} \cdot d^{-1}$ of second cutting alfalfa hay while the older cows were group fed 13.6 $kg \cdot hd^{-1} \cdot d^{-1}$ of first cutting alfalfa/grass hay mix. The correlation between cow weight and body condition was .62, therefore, heavier cows were fatter cows. During Pd III, however, all cows had significantly lower body condition scores than at other periods (Table 17).

Holloway and Butts (1984) determined that cows that were initially fat had the propensity for greater forage intake and the partitioning of nutrients went toward further fat deposition when high quality forage was available. Cows that were initially thin could not take advantage of high quality forage to increase fat cover. So for Pd III, cows that had a greater propensity to put on fat grazing high quality forages may represent the positive regression with heavier cows having greater FO levels than lighter cows.

An animal dominance factor may also attribute to the positive relationship with FO on cow weight during the early spring supplemental period. Larger cows may be more dominant over smaller cows under the controlled feeding environment. Larger cows may, therefore, have more of an opportunity to consume more hay than the smaller cows.

Figure 2 shows the regressions of FO/BW on cow weight by period from the model that included year, cow age, and breed as the fixed effects and cow weight as the covariate. Fecal output per unit of body weight was negatively related to cow weight during Pds I, II, IV, and V. Heavier cows were eating less than lighter cows per unit of body weight except after calving at early lactation. These regressions may further illustrate that energy demands are proportional to 0.75 power of body weight (Klieber, 1961), and thus energy needs per

Figure 2. Regression of fecal output per unit of body weight on cow weight for each of the five periods during the year (b = -0.01*, -0.008*, -0.004, -0.014*, and -0.01*, respectivley; *P<.05).



unit weight of smaller cows are greater than for larger cows (Allison, 1985).

Breed Group Differences in Fecal Ouput

When expressing FO on a per unit of body weight basis, significant breed group differences were detected in periods III and IV (Table 15). During early lactation, Pd III, HH had lower FO/BW levels than the other two breed groups. During Pd IV, HT had lower FO/BW than TT. Breed group differences for FO/BW approached significance (P=.065) with HH having lower FO than TT during the peak lactation period (Pd IV).

Several factors may attribute to the breed group differences detected during the lactating periods. Overall, Tarentaise appeared to have greater FO/BW levels, lower body condition scores, and greater milk production than the other two breed groups. Since TT is a maternal trait breed, increased maintenance requirements, associated with greater genetic potential for milk production, may be more an effect of greater levels of milk production than of cow weight (Ferrel and Jenkins 1985).

Crooker et al. (1991) also stated that lean body mass or protein is 9.3 times more costly to maintain than fat (192.9 vs 20.7 kcal/kg). The TT breed group consistently had lower BCS, thus less fat, and greater milk production which may represent the trends seen in greater FO/BW levels than the other two breed groups. However, on a within breed group basis, milk production had no significant effect on FO.

Similar observations were found by Thompson et al. (1983) comparing Angus x Hereford cows to dairy cross (Angus x Holstein) cows. They found that fat Angus x

Hereford cows had lower winter maintenance energy requirements as compared to dairy cross cows. Although this effect is evident with beef breeds (DiConstanzo et al., 1991), energy requirements of dairy cross breeds respond to factors other than fat mass. For the Angus x Hereford cross cows, body weight and condition were the primary factors affecting winter energy requirements. However, for the dairy cross cows, other unidentified factors accounted for the variation in energetic efficiency (Thompson et al., 1983).

Table 17 shows the distribution of body condition scores by period and breed group. Cow body condition scores were recategorized as A, B, and C (A = BCS<5; B = BCS 5 - 6; C = BCS>6) due an uneven distribution of body condition scores over the breed groups by period.

TABLE 17. DISTRIBUTION OF BODY CONDITION SCORES BY PERIOD[a] AND BREED GROUP[b].

	Period														
	I			II			III			IV			V		
BCS[c]	HH	HT	TT	HH	HT	TT	HH	HT	TT	HH	HT	TT	HH	HT	TT
A	7	5	12	5	3	16	14	21	34	13	15	14	6	9	10
B	24	38	33	30	39	31	21	22	10	20	31	33	28	38	37
C	22	10	5	17	8	1	9	2	0	13	4	0	11	3	0

[a]Number of observations.
[b]HH = Hereford; HT = Hereford x Tarentaise; TT = Tarentaise.
[c]BCS = Body Condition Score (A = <5; B = 5 - 6; C = >6).

Very few condition scores above 6 existed during lactating periods (III, IV, and V) with TT having no condition scores above 6 during all lactating periods. Since Tarentaise is a maternal trait breed, they may mobilize more fat stores to help meet the demands of lactation. Montano-Bermudez et al. (1990) found that high milk producing (Milking Shorthorn x Angus) cows with less external fat required about 12% more energy per unit of body weight than lower milk producing (Hereford x Angus) cows with greater external fat to maintain body weight.

Russel and Wright (1983) reported that maintenance per unit of body size was inversely related to cow body condition and that increased maintenance requirements were more of a function of greater genetic potential for milk production rather than cow weight. Since milk production for TT remains high into late lactation (Pd V; Table 9) and cow body condition remains low, TT may rely more on internal fat stores to meet maintenance requirements as compared to the other two breed groups. Slaughtering a subsample of cull cows and measuring internal and external fat differences may be advantageous in future research comparing Tarentaise with other biological types.

Herefords, on the other hand, appeared to have lower FO/BW levels than Tarentaise. The HH breed group consistently had greater body condition (Table 7), thus more fat, and lower levels of milk production than the other two breed groups. Nutt et al. (1980) and Reid and Robb (1977) both found that the accumulation of fat within the abdominal cavity may physically reduce rumen capacity, thus forage intake, similar to that of a developing uterus. Wagner (1985), in citing Forbes (1980), found that the build up of fat within the animal can also reduce intake chemostatically. This may be the case as seen with the HH breed group having lower FO/BW levels and greater BCS than the other two breed groups. Increasing body condition scores have been found to be inversely related to milk production and forage intake per unit of body weight (Morris and Wilton, 1976; Kress et al., 1986). However, on a within breed group basis in the present study, cow body condition had no significant effect on FO.

Genotype x environmental interactions can occur with milk production being an important factor in FO/BW breed group differences. Higher milking genotypes (TT) may have greater FO levels, thus forage intake, than low milk producing genotypes (HH) as long as forage resources are adequate to meet the demands of lactation (Sprinkle, 1992). With overall lower body condition scores exhibited in TT and greater milk production levels, intake requirements can be expected to be higher than the HH biological type. Drylot forage intake data (Ferrel and Jenkins, 1987) may not accurately reflect some breed group differences under range environments where cow body condition is likely to be less and changes in rank of breeds can occur with changes in BCS.

CHAPTER 5

SUMMARY

A 3 yr study, from 1992 through 1994, was conducted at the Northern Agricultural Research Center near Havre, Montana to compare differences in fecal output (FO) patterns from three biological types over five periods throughout a production year. The biological types were straightbred Hereford (HH), straightbred Tarentaise (TT), and the F_1 reciprocal cross (HT) with 17 cows representing each group. These biological types were chosen due to differing in levels of milk production, but similar in intermediate size.

Fecal output was estimated during five periods throughout the year. The five periods were; pregnant, non-lactating, fall pasture, after weaning (Pd I; November); pregnant, non-lactating, winter supplemented (Pd II; February); lactating, spring supplemented (Pd III; May); lactating, early summer pasture (Pd IV; June); lactating, late summer pasture (Pd V; September). Cow age was equally distributed among the breed groups.

Fecal output patterns during this 3-yr study agree with literature reports with no breed group differences detected during non-lactating periods (Sprinkle et al., 1992; Barlow et al., 1988). Breed group differences in FO were detected on a per unit of body weight basis (g/kg; FO/BW) during early and mid-lactation which agree with results of Sprinkle et al. (1992). These results indicate that breed group differences in FO/BW were a function of forage quality and the physiological demands on the cow. Doornbos et al. (1987) found that breed group differences in OMI disappeared in high quality and low quality forage years.

Milk production and calf weight had no significant effect on differences in FO within breed groups.

Breed goup differences in FO/BW were significant during periods III and IV, with TT having higher FO/BW than HH. These trends indicate that there may be a maintenance cost associated with improved milk production which producers should consider beyond the direct cost of lactation (Sprinkle, 1992; Ferrel and Jenkins, 1985). Mobilization of body fat in response to demands of lactation, as noted with the TT breed group, may be an important consideration when evaluating breed group differences.

Differences in fecal output patterns in relation to cow weight were important on a within breed group basis during early lactation. With high forage quality availability, increased energy demands, and low levels of body condition, fecal output changed with increasing cow weight. With changing forage quality and physiological status of the cow, reranking of breed groups or fat vs thin cows can occur (Sprinkle, 1992; Barlow et al., 1988; Doornbos et al., 1987; Holloway and Butts, 1984).

LITERATURE CITED

AOAC. 1980. Official Methods of Analysis (13th Ed.). Associated Official Analytical Chemists, Washington, DC.

Adams, D.C., T.C. Nelson, W.L. Reynolds, and B.W. Knapp. 1986. Winter grazing activity and forage intake of range cows in the Northern Great Plains. J. Anim Sci. 62:1240.

Adams, D.C., R.E. Short, M.M. Borman and M.D. MacNeil. 1991. Estimation of fecal output with an intra-ruminal continuous release marker device. J. Range Manage. 44:204.

Allison, C.D. 1985. Factors affecting forage intake by range ruminants: A review. J. Range Manage. 38:305.

Anderson, D.C., D. Casebolt, D.D. Kress, and D.E. Doornbos. 1986. Lactation curves and milk production in different types of beef cattle. MT AgResearch. MT Agric. Exp. Sta. Vol. 3:15.

Barlow, R., K.J. Ellis, P.J. Williamson, P. Costigan, P.D. Stephenson, G. Rose, and M.T. Mears. 1988. Dry-matter intake of Hereford and first-cross cows measured by controlled release of chromic oxide on three pasture systems. J. Agric. Sci., Camb. 110:217.

Barlow, R., K.J. Ellis, D.J McLennan, P. Costigan, and P.H. Hirst. 1990. New estimate of dry-matter intake of lactating beef cows grazing three pasture systems. J. Agric. Sci., Camb. 115:117.

Bines, J.A. 1971. Metabolic and physical control of food intake in ruminants. In: Wagner, M.W. 1985. Forage intake and milk production of rangeland beef cows with varying degrees of crossbred influence. M.S. Thesis. Montana State University, Bozeman.

Blaxter, K.L., F.W. Wainman, and R.S. Wilson. 1961. The regulation of food intake by sheep. Anim. Prod. 3:51.

Brandyberry, S.D., R.C. Cochran, E.S. Vanzant, and D.L. Harmon. 1991. Technical note: Effectiveness of different methods of continuous marker administration for estimating fecal output. J. Anim. Sci. 69:4611.

Buntinx, S.E., K.R. Pond, D.S. Fisher, J.C. Burns, and T.G. Goodwin. 1990. Prediction of total fecal output of free grazing sheep using the Captec Chrome controlled release capsule. J. Anim. Sci. 68(Suppl. 1):562. (Abstr.).

Clark, C.K. Personal Communication. November, 1994.

Cochran, R.C., D.C. Adams, J.D. Wallace, and M.L. Galyean. 1986. Predicting digestibility of different diets with internal markers: Evaluation of four potential markers. J. Anim. Sci. 63:1476.

Cochran, R.C., E.S. Vanzant, K.A. Jacques, M.L. Galyean, D.C. Adams, and J.D. Wallace. 1987. Internal Markers. p.39. Proc. Grazing Livest. Nutr. Conf., July 23-24, 1987. University of Wyoming.

Cook, C.W. and L.E. Harris. 1951. A comparison of the lignin ratio 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.

Crooker, B.A., P.T. Anderson, and P.D. Goodrich. 1991. Maintenance energy requirements and energetics of tissue deposition and mobilization in cattle. p. 1. Proc. Second Grazing Livest. Nutr. Conf., August 2-3, 1991. Oklahoma State University.

DiCostanzo A., J.C. Meiske, and S.D. Plegge. 1991. Characterization of energetically efficient and inefficient beef cows. J. Anim. Sci. 69:1337.

Dickerson, G.E. 1978. Animal size and efficiency: Basic concepts. Anim Prod. 27:367.

Doornbos D.E., K.M. Havstad, E. Fredrickson, M. Wagner, and D.D. Kress. 1987. Estimating efficiency of different biological types of cattle. Proc. West. Sec. Amer. Soc. Anim. Sci. 38:75.

Ellis, K.J., R.H. Laby, and R.G. Burns. 1981. Continuous controlled-release administration of chromic oxide to sheep. Proc. Nutr. Soc. Aust. 6:145.

Ellis, K.J., R.H. Laby, P. Costigan, K. Zirkler, and P.G. Choice. 1982. Continuous administration of chromic oxide to grazing cattle. Proc. Nutr. Soc. Aust. 7:177.

Fahey, G.C., G.A. McLaren, and J.E. Williams. 1979. Lignin digestibility by lambs fed both low quality and high quality roughages. J. Anim. Sci. 48:941.

Fahey, G.C. and H.G. Jung. 1983. Lignin as a marker in digestion studies: A review. J. Anim. Sci. 57:220.

Fenton, T.M. and W. Fenton. 1979. An improved procedure for the determination of chromic oxide in feed and feces. Can. J. Anim. Sci. 59:631.

Ferrel, C.L. and T.G. Jenkins. 1985. Cow type and the nutritional environment: Nutritional aspects. J. Anim. Sci. 61:725.

Ferrel, C.L. and T.G. Jenkins. 1987. Influence of biological types on energy requirements. p. 1. Proc. Grazing Livest. Nutr. Conf., July 23-24, 1987. University of Wyoming.

Fisher, D.S., J.C. Burns, and K.R. Pond. 1986. Sampling effects on grazing behavior in marked forage trials. Agron. Abstr. p.141.

Forbes, J.M. 1980. Hormones and metabolites in the control of food intake. In: Wagner, M.W. 1985. Forage intake and milk production of rangeland beef cows with varying degrees of crossbred influence. M.S. Thesis. Montana State University, Bozeman.

Frisch, J.E. and J.E. Vercoe. 1984. An analysis of different cattle genotypes reared in different environments. J. Agric. Sci., Camb. 103:137.

Furnival, E.P., J.L. Corbett, and M.W. Inskip. 1990. Evaluation of controlled release devices for administration of chromium sesquioxide using fistulated grazing sheep. I. Variation in marker concentration in feces. Aust. J. Agric. Res. 41:969.

Hardison, W.A. and J.T. Reid. 1953. Use of indicators in measurement of dry matter intake of grazing animals. J. Nutr. 51:35.

Hatfield, P.G., D.C. Clanton, K.M. Eskridge, and D.W. Sanson. 1989. Forage intake by lactating beef cows differing in potential for milk production. J. Anim. Sci. 67:3018.

Hatfield, P.G., J.D. Walker, and H.A. Glimp. 1991. Comparing the Captec bolus to chromic oxide dosed twice daily using sheep in confinement. J. Range Manage. 44:408.

Havstad, K.M. 1981. The energy expenditure of heifers grazing crested wheatgrass rangeland in West-Central Utah. Ph.D. Dissertation. Utah State University, Logan.

Havstad, K.M., W.J. Lathrop, E.L. Ayers, D.E. Doornbos, and D.D. Kress. 1986. MT AgResearch. MT Agric. Exp. Sta. Vol 3, Issue 2:20.

Havstad, K.M. and D.E. Doornbos. 1987. Effect of biological type on grazing behavior and energy intake. p. 9. Proc. Grazing Livest. Nutr. Conf., July 23-24, 1987. University of Wyoming.

Holloway, J.W., W.T. Butts, J.D. Beaty, J.T. Hopper, and N.S. Hall. 1979. Forage intake and performance of lactating beef cows grazing high or low quality pasture. J. Anim. Sci. 48:692.

Holloway, J.W., R.E. Estell II, and W.T. Butts. 1981. Relationship between fecal components and forage consumption and digestibility. J. Anim. Sci. 52:836.

Holloway, J.W. and W.T. Butts. 1984. Influence of cow frame size and fatness on seasonal patterns of forage intake, performance and efficiency of Angus cow-calf pairs grazing fescue-legume or fescue pastures. J. Anim. Sci. 59:1411.

Hulsey, M.G. and R.J. Martin. 1991. Effect of varying degrees of starvation on anorexia produced by adipocyte satiety factor (ASF). FASEB J. 5:A1295.

Huston, J.E. and W.E. Pinchak. 1991. Range animal nutrition. In: R.K. Heitschmidt and J.W. Stuth (Ed.) Grazing Management: An Ecological Perspective. Timber Press, Portland.

Hutton, J.B. 1963. Studies on the nutritive value of New Zealand dairy pastures. II. Herbage intake and digestibility studies with dairy cattle. In: Allison, C.D. 1985. Factors affecting forage intake by range ruminants: A review. J. Range Manage. 38:305.

Jenkins, T.G., L.V. Cundiff, and C.L. Ferrel. 1991. Differences among breed crosses of cattle in the conversion of food energy to calf weight during preweaning interval. J. Anim. Sci. 69:2762.

Jenkins, T.G. and C.L. Ferrel. 1994. Productivity through weaning of nine breeds of cattle under varying feed availabilities: I. Initial evaluation. J. Anim. Sci. 72:2787.

Judkins, M.B., L.J. Krysl, and R.K. Barton. 1990. Estimating diet digestibility: A comparison of 11 techniques across six different diets fed to rams. J. Anim. Sci. 68:1405.

Kartchner, R.J. and C.M. Campbell. 1979. Intake and digestibility of range forages consumed by livestock. Bull. 718. Montana Ag. Exp. Sta., USDA, SEA-AR and Montana State Univ., Bozeman.

Kattnig, R.M., J.A. Winder, and A.J. Pordomingo. 1990. Efficacy of a chromium sesquioxide continuous release device in range cows. J. Anim. Sci. 68(Suppl. 1):562. (Abstr.).

Kattnig, R.M. 1991. Evaluation of range beef cattle production efficiency under semi-desert conditions. Ph.D. Dissertation. New Mexico State University, Las Cruces.

Kattnig, R.M., J.A. Winder, J.D. Wallace, and C.C. Bailey. 1993. Evaluation of biological efficiency of free-grazing beef cows under semidesert conditions. J. Anim. Sci. 17:2601.

Kress, D.D., D.E. Doornbos, D.C. Anderson, and K. Hanford. 1986. Performance of different biological types of cows: Cow traits. MT AgResearch. MT Agric. Exp. Sta. Vol 3, Issue 1:13.

Kress, D.D., D.E. Doornbos, D.C. Anderson, and K.C. Davis. 1995. Tarentaise and Hereford breed effects of cow and calf traits and estimates of individual heterosis. J. Anim. Sci. 73:2574.

Kiesling, H.E., H.A. Barry, A.B. Nelson, and C.H. Herbel. 1969. Recovery of chromic oxide administered in paper to grazing steers. J. Anim. Sci. 29:361.

Kronberg, S.L. 1983. Forage intake of Hereford and 75% Simmental-25% Hereford cows grazing Montana foothill rangeland. M.S. Thesis. Montana State University, Bozeman.

Klieber, M. 1961. The Fire of Life. An Introduction to Animal Energetics. In: Allison, C.D. 1985. Factors affecting forage intake by range ruminants: A review. J. Range Manage. 38:305.

Laby, R.H., C.A. Graham, S.R. Edwards, and B. Kautzner. 1984. A controlled release intraruminal device for the administration of fecal dry-matter markers to the grazing ruminant. Can. J. Anim. Sci. 64(Suppl.):337.

Langlands, J.P. 1975. Techniques for estimating nutrient intake and its utilization by the grazing ruminant. In: Cochran, R.C., E.S. Vanzant, K.A. Jacques, M.L. Galyean, D.C. Adams, and J.D. Wallace. 1987. Internal Markers. p. 39. Proc. Grazing Livest. Nutr. Conf., July 23-24, 1987, University of Wyoming.

Lee, G.J., K.D. Atkins, and S.I. Mortimer. 1990. Genetic and phenotypic components of feed intake by grazing sheep. Proc. 4th World Congress on Genetics to Livest. Prod. July 23-27, 1990.

Lippke, H., W.C. Ellis, and B.F. Jacobs. 1986. Recovery of indigestible fiber from feces of sheep and cattle on forage diets. J. Dairy Sci. 69:403.

McCollum, F.T. and M.L. Galyean. 1985. Cattle grazing blue grama rangeland. II. Seasonal forage intake and digesta kinetics. J. Range Manage. 38:543.

Montano-Bermudez, M., M.K. Nielson, and G.H. Deutscher. 1990. Energy requirements for maintenance of crossbred beef cattle with different genetic potential for milk. J. Anim. Sci. 68:2279.

Moran, J.B., C. Lemerle, and T.E. Trigg. 1987. Excretion patterns of chromium sesquioxide in dairy cows and sheep. J. Aus. Inst. Agric. Sci. 53(No.4):290.

Morris, J.G. and M.D. Sanchez. 1987. Energy expenditure of grazing ruminants. p. 17. Proc. Grazing Livest. Nutr. Conf., July 23-24, 1987. University of Wyoming.

Morris, C.A. and J.W. Wilton. 1976. Influence of body size on the efficiency of cows: A review. Can. J. Anim Sci. 56:613.

Morris, C.A., R.L. Baker, S.M. Hickey, D.L. Johnson, N.G. Cullen, and J.A. Wilson. 1993. Evidence of genotype by environmental interaction for reproductive and maternal traits in beef cattle. Anim. Prod. 56:69.

Nelson, M.L., L. Motjope, J.W. Finley, and S.M. Parish. 1990. Ash-free indigestible fiber as an internal marker to estimate digestibility with grazing ruminants. J. Range Manage. 43:224.

Nutt, B.G., J.W. Holloway, and W.T. Butts. 1980. Relationship of rumen capacity of mature Angus cows to body measurements, animal performance and forage consumption on pasture. J. Anim. Sci. 54:1168.

NRC. 1984. Nutrient Requirements of Beef Cattle. (6th Ed.). National Academy Press, Washington, DC.

Osuji, P.O. 1974. The physiology of eating and the energy expenditure of the ruminant at pasture. J. Range Manage. 27:437.

Paterson, J. and M. Kerley. 1987. Discussion of marker methodologies used in grazing experiments and digestibility of forages consumed by grazing ruminants. p. 67. Proc. Grazing Livest. Nutr. Conf., July 23-24, 1987. University of Wyoming.

Pond, K.R., J.C. Burns and D.S. Fisher. 1987. External markers - use and methodology in grazing studies. p. 49. Proc. Grazing Livest. Nutr. Conf., July 23-24, 1987. University of Wyoming.

Raleigh, R.J., J.R. Kartchner, and L.R. Rittenhouse. 1980. Chromic oxide in range nutrition studies. Oregon State Univ. Agr. Exp. Sta. Bull. 641. Corvallis, OR.

Reid, J.T. and J. Robb. 1977. Relationship of body composition to energy intake and energetic efficiency. J. Dairy Sci. 54:533.

Reid, J.T., P.G. Woolfolk, C.R. Richards, R.W. Kaufmann, 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 forages by ruminants. J. Dairy Sci. 33:60.

Reid, J.T. and W.K. Kennedy. 1956. Measurement of forage intake by grazing animals. Proc. Int. Grassl. Congr. 7:116.

Richards, M.W., J.C. Spitzer, and M.B. Warner. 1986. Effect of varying levels of postpartum nutrition and body condition at calving on subsequent reproduction performance in beef cattle. J. Anim. Sci. 62:300.

Ritchie, H.D. 1995. The optimum cow - What criteria must she meet? Proc. B.I.F. Conf., May 31 - June 3, 1995. Sheridan, Wyoming.

Rittenhouse, L.R., D.C. Clanton, and C.L. Streeter. 1970. Intake and digestibility of winter-range forage by cattle with or without supplements. J. Anim. Sci. 31:1215.

Rosiere, R.E., J.D. Wallace, and R.D. Pieper. 1980. Forage intake in two-year old cows and heifers grazing blue grama summer range. J. Range Manage. 33:71.

Russel, A.J.F. and J.A. Wright. 1983. Factors affecting maintenance requirements of beef cows. Anim. Prod. 37:329.

SAS. 1987. SAS User's Guide: Statistics. SAS Inst., Inc. Cary, NC.

Scales, G.H., C.L. Streeter, A.H. Denham, and G.M. Ward. 1974. A comparison of indirect methods of predicting in vivo digestibility of grazed forage. J. Anim. Sci. 38:192.

Solis, J.C., F.M. Byers, G.T. Schelling, C.R. Long, and L.W. Greene. 1988. Maintenance requirements and energetic efficiency of cows of different breed types. J. Anim. Sci. 66: 764.

Sprinkle, J.E. 1992. Fecal output of different biological types of beef cattle on native range throughout a production year. M.S. Thesis. Montana State University, Bozeman

Sprinkle, J.E., D.D. Kress, D.E. Doornbos, D.C. Anderson, M.W. Tess, R.P. Ansotegui, B.E. Olsen, and N.J. Roth. 1992. Fecal output of different biological types of beef cattle on native range throughout a production year. Proc. West. Sec. Amer. Soc. Anim. Sci. 43:31.

Streeter, C.L., C.B. Rumberg, T.H. Hall, and E.G. Siemer. 1974. Meadow forage quality, intake, and milk production of cows. J. Range Manage. 27:133.

Sunvold, G.D. and R.C. Cochran. 1991. Technical note: Evaluation of acid detergent lignin, alkaline peroxide lignin, acid insoluble ash, and indigestible acid detergent fiber as internal markers for prediction of alfalfa, bromegrass, and prairie hay digestibility by beef steers. J. Anim. Sci. 69:4951.

Thompson, W.R., J.C. Meiske, R.D. Goodrich, J.R. Rust, and F.M. Byers. 1983. Influence of body composition on energy requirements of beef cows during winter. J. Anim. Sci. 56:1241.

Thonney, M.L., B.A. Palhof, M.R. DeCarlo, D.A. Ross, N.L. Firth, R.L. Quass, D.J. Perosio, D.J. Duhaime, S.R. Rollins, and A.Y.M. Nour. 1985. Sources of variation of dry matter digestibility measured by the acid insoluble ash marker. J. Dairy Sci. 68:661.

Troelsen, J.E., 1961. Plant chromogens as an indicator in estimating the digestibility of forage crops by sheep. Can. J. Plant Sci. 41:732.

Turner, H.A. 1974. Cow size as related to energetic efficiency and partitioning of TDN for maintenance, body weight change and milk production. In: Ferrel, C.L. and T.G. Jenkins. 1985. Cow type and the nutritional environment: Nutritional aspects. J. Anim. Sci. 61:725.

Van Keulen, G.M. and B.A. Young. 1977. Evaluation of acid insoluble ash as a natural marker in ruminant digestibility studies. J. Anim. Sci. 23:1108.

Van Oijen, M., M. Montano-Bermudez, and M.K. Nielsen. 1993. Economical and biological efficiencies of beef cattle differing in level of milk production. J. Anim. Sci. 17:44.

Wagner, M.W. 1985. Forage intake and milk production of rangeland beef cows with varying degrees of crossbred influence. M.S. Thesis. Montana State University, Bozeman.

Wagner, M.W., K.M. Havstad, D.E. Doornbos, and E.L. Ayers. 1986. Forage intake and milk production of rangeland beef cows with varying degrees of crossbred influence. J. Anim. Sci. 63:1484.

Wallace, J.D., and G.M. Van Dyne. 1970. Precision of indirect methods for estimating digestibility of forage consumed by grazing cattle. J. Range Manage. 23:424.

Williams, J.H., D.C. Anderson, and D.D. Kress. 1979. Milk production in Hereford cattle. II. Physical measurements: repeatabilities and relationship with milk production. J. Anim Sci. 49:1443.

APPENDIX

TABLE 18. COWS REMOVED FROM SAMPLE PERIOD.

Cow ID	Year	Period
0070	92	III
0120	94	II
0232	92	IV
7010	92	III
7010	92	IV
7094	92	IV
7149	92	III
7149	92	IV
7158	92	IV
7192	92	IV
7209	92	I
8050	92	I
8062	92	III
8064	92	III
8064	92	V
8064	92	I
8158	92	III
8183	92	I
9120	92	III
9147	92	V
9194	92	III
9247	92	IV