Visceral mass and reticulorumen volume of differing biological types of beef cattle
by Eddie L Fredrickson

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

Abstract:
A study was conducted to determine if differences in visceral organ mass and potential reticulorumen volume occur among beef cow biological types differing in milk production potential. During 1985» 6 pregnant, 6 to 9 yr old lactating cows of 5 biological types were used. These include: Straightbred Herefords (HH) , 50% Angus-50% Hereford (AH), 25% Simmental-75% Hereford (1S3H), 50% Simmental-50% Hereford (SH) and 75% Simmental-25% Hereford (3S1H). In 1986 , 6 pregnant, 3 yr old lactating cows of 4 biological types were examined: HH, 50% Tarentaise-50% Hereford (TH), 50% Tarentaise-(25% Simmental-25% Hereford) or 50% Tarentaise-(37.5% Simmental-12.5% Hereford)(T(SH)) and 50% Charolais-(25% Simmental-25% Hereford) or 50% Charolais-(37 • 3% Simmental-12.5% Hereford) (C(SH)). In the summer of 1985 fecal organic matter output was estimated with a CrgCL dilution technique (all cows) and total fecal collections (HH and 3a1H). Total fecal collections were obtained from all cows in 1986. Esophageal fistula collections were collected each fecal collection to estimate organic matter intake (OMI). Weightiheight ratios were used to determine body condition scores, and milk production estimates were obtained using a weigh-suckle-weigh technique. Weights of the spleen, heart, lungs, kidney, kidney fat, reticulorumen weight and volume and liver were measured 5 weeks after weaning in 1 985 and at weaning in 1986. Potential reticulorumen volume was determined to be the water filled capacity at slaughter. Differences (P>.10) in reticulorumen volume or OMI were not evident either year. In 1985 liver weight was greatest (P<.10) for the 3S1H and BH, and kidney weight was higher (P<.10) for the 3S1H. Cows with larger livers and kidneys also had lower (P<.10) condition scores and kidney fat weights. During 1986 milk production at weaning was greatest (P<.10) for the T(SH) and TH. Condition scores and body fat measurements did not differ (P>.10) in 1986. Kidney and spleen weights were highest (P< .10) for the C(SH) and tended to be high for the T(SH). Differences in kidney weight could be accounted for by differences in body weight, but differences in spleen weights are not understood. Differences in organ weights in 1985 appear to reflect milk production potential, while organ weights during 1986 possibly reflect both body size and milk production potential. Further research regarding metabolic activity per unit of tissue weight may further assist in understanding differences among biological types.

VISCERAL MASS AND RETICULORUMEN VOLUME OF DIFFERING BIOLOGICAL TYPES OF BEEF CATTLE

by

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

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I would like to dedicate the efforts of the last two years to my grandparents Mr. and Mrs. Charles W. Fredrickson. These fine people have believed in me, and in my desire to pursue an education in range science. My gratitude toward them is beyond words.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF TABLES - Continued

ABSTRACT

A study was conducted to determine if differences in visceral organ mass and potential reticulorumen volume occur among beef cow biological types differing in milk production potential. During 1985, 6 pregnant, 6 to 9 yr old lactating cows of 5 biological types were used. These include: Straightbred Herefords (HH), 50% Angus-50% Hereford (AH), 25% Simmental-75% Hereford (1S3H), 50% Simmental-50% Hereford (SH) and 75% Simmental-25% Hereford (3S1H). In 1986, 6 pregnant, 3 yr old lactating cows of 4 biological types were examined: HH, 50% Tarentaise-50% Hereford (TH), 50% Tarentaise-(25% Simmental-25% Hereford) or 50% Tarentaise-(37.5% Simmental-12.5% Hereford)(T(SH)) and 50% Charolais-(25% Simmental-25% Hereford) or 50% Charolais-(37.3% Simmental-12.5% Hereford) (C(SH)). In the summer of 1985 fecal organic matter output was estimated with a Cr_2O_3 dilution technique (all cows) and total fecal collections (HH and 3S1H). Total fecal collections were obtained from all cows in 1986. Esophageal fistula collections were collected each fecal collection to estimate organic matter intake (OMI). Weight:height ratios were used to determine body condition scores, and milk production estimates were obtained using a weigh-suckle-weigh technique. Weights of the spleen, heart, lungs, kidney, kidney fat, reticulorumen weight and volume and liver were measured 5 weeks after weaning in 1985 and at weaning in 1986. Potential reticulorumen volume was determined to be the water filled capacity at slaughter. Differences ($P>.10$) in reticulorumen volume or OMI were not evident either year. In 1985 liver weight was greatest ($P<.10$) for the 3S1H and SH, and kidney weight was higher ($P<.10$) for the 3S1H. Cows with larger livers and kidneys also had lower ($P<.10$) condition scores and kidney fat weights. During 1986 milk production at weaning was greatest ($P<.10$) for the T(SH) and TH. Condition scores and body fat measurements did not differ ($P>.10$) in 1986. Kidney and spleen weights were highest ($P<.10$) for the C(SH) and tended to be high for the T(SH). Differences in kidney weight could be accounted for by differences in body weight, but differences in spleen weights are not understood. Differences in organ weights in 1985 appear to reflect milk production potential, while organ weights during 1986 possibly reflect both body size and milk production potential. Further research regarding metabolic activity per unit of tissue weight may further assist in understanding differences among biological types.

INTRODUCTION

A goal of the cow-calf operator on western rangelands is to "maximize the pounds of calf weaned per cow in the herd" (Thomas, 1986). To achieve this goal producers have introduced beef cow types with higher genetic potential for milk production and body size. Cow types with these traits often produce calves with higher weaning weights (Smith et al., 1976). However, higher producing beef cow types also have higher energy requirements (NRC, 1984). These higher requirements must be met in a rangeland environment that is often nutritionally restrictive and energetically demanding. A decline in body condition and reproductive efficiency can occur if these energy requirements are not met. This decline in reproductive efficiency is the major factor in lowering overall herd performance and makes it necessary to better understand the energetics of differing biological beef cow types because of important genotype by environmental interactions.

Approximately 70% of the metabolizable energy intake is used by the animal for maintenance (Ferrel and Jenkins, 1985). The remaining energy is used for activity, growth, and calf production. Tess et al. (1984) reported fasting heat production of maintenance was highly related to the weight of protein in the viscera of pigs. Vital organs responsible for protein turnover and ion transport such as the liver and gastrointestinal tract have proven to be of major importance. For example, liver expenditures in nonlactating dairy cows was estimated at 3,369 kcal/d, and accounted for 22.5% of total animal energy

3,369 kcal/d, and accounted for 22.5% of total animal energy expenditures (Smith and Baldwin, 1974). Therefore changes in tissue weights may be related to differences in maintenance energy expenditures between lactating and nonlactating cows. Additionally, these changes may be found in nonlactating beef cows with different lactation potentials (Ferrel and Jenkins, 1984). Information comparing these tissues between range beef cow types is unavailable. However, data of this sort may reflect differences in maintenance requirements among cow types. The first objective of this study was to measure vital organ mass of range beef cows with emphasis on more metabolically active tissues and relate any differences to beef cow types of varying forage intake and milk production.

Although many factors may limit intake of low quality roughage there is a large amounts of data which suggests the importance of gastrointestinal tract fill upon forage intake (Van Soest, 1983). If fill mechanisms limit intake of low quality forages then animals with varying intake amounts may also have differing reticulorumen capacities to accompany the increase in forage consumption. In an earlier study by Wagner et al. (1986), higher producing biological types had greater forage intakes than lower producing cow types when forage digestibilities were below 60 to 65%. A second objective was to relate potential reticulorumen volume with cow type and forage intake and to determine if reticulorumen volume varies with forage intake. These two objectives would allow us to better characterize differences among beef cow biological types and match a biological type to a specific set of environmental conditions.

LITERATURE REVIEW

Introduction

Optimal beef cow productivity from rangelands is dependant upon the energy transfer from the plant community to desired products. Specifically this means pounds of calf weaned per cow in the herd and the salvage value of the producing animals. To produce a 454 kg slaughter steer Gregory (1972) estimated that 65% of the nutrients are used to support the calf to weaning age. For the majority of producers this nutrient requirement must be met in a variety of rangeland environments, each with a unique set of attributes and constraints. Besides manipulating the plant community to achieve maximal usable solar energy in a desirable form, consideration must be given to the efficiency of energy utilization by the beef cow herd for optimal production.

Energy utilization by the producing beef cow can be partitioned into maintenance, growth, travel, gestation and lactation (Cook, 1970). However, as suggested by Koong et al. (1985) this partitioning is artificial as energy metabolism involves a complex interrelationship among all physiological processes. Because of the variability among beef cow biological types in milk production (Notter et al., 1978; Casebolt, 1984), rate of maturity (Laster et.al., 1976), body size (Smith et.al., 1976; Notter et.al., 1978), body composition (Ferrel and Jenkins, 1984), forage intake (Wagner et.al., 1986) and maintenance requirements (Ferrel and Jenkins, 1985) the extent and

interrelationship among these physiological processes must also vary. To achieve optimal production sufficient energy must be derived from the range environment to support each biological type's physiological potential. A greater understanding of the mechanisms influencing the expression of this physiological potential in relation to energy inputs required in a range environment is needed. This information may assist in identification and possible manipulation of biological types energetic demand to match the often limiting range environment.

This review of literature which addresses the study's objectives will be presented in three parts. The first part will discuss energy requirements for maintenance. The following part will address visceral organ mass and its possible relation to energetic demand differences among biological types of beef cows. The third part will examine reticulorumen volume differences among biological types as a mechanism to satisfy energetic demand when ruminal fill is limiting intake.

Maintenance Demand

When energy utilization is partitioned as suggested by Cook (1970) the energy for body stasis or maintenance requirement is approximately 70 to 75% of the total annual energy requirements (Ferrel and Jenkins, 1985). However, estimates by Ferrel and Jenkins (1985) of total annual energy requirements of differing biological types of beef cows varied considerably. These estimates of energy required for maintenance were derived from four biological types; Angus X Hereford (AHX), Charolais X

Angus or Hereford (CX), Jersey X Angus or Hereford (JX), Simmental X Angus or Hereford (SX). Each cow was nine years old, and was kept in a nonpregnant, nonlactating condition. The metabolizable energy required for maintenance was 130, 129, 145, and 160 kcal x kg $^{-.75}$ x d^{-1} for AHX, CX, JX and SX cows, respectively. Their results indicate that milk production potential and maintenance energy demand may be related for mature cows even when the physiological demand of lactation and gestation are not evident.

Research involving energy requirements among biological types has been variable. Brody (1945) did not find differences in resting metabolism between dairy and beef breeds. Klosterman et al. (1968) found no difference in efficiency among Hereford, Charolais and crossbred steers. Russel and Wright (1983) reported no difference in maintenance metabolism between Blue Grey and Hereford X Friesian cows.

Webster et al. (1974) predicted post absorptive metabolism of Friesian steers to be proportionally 0.06 times greater than Friesain X Angus steers. Vercoe (1970) and Frisch and Vercoe (1976) determined Bos taurus (Hereford X Shorthorn and the reciprocal cross) steers had a 10 to 15% greater maintenance requirement per unit metabolic body weight (MBW) than Bos indicus X Bos taurus steers. Garrett (1971) found Holstein steers to have an 8% increase in maintenance over Hereford steers. Additional references cited by Ferrel and Jenkins (1985) suggested Bos indicus have lower metabolic requirements per unit MBW than Bos taurus. Biological types with a high milk production potential have higher maintenance requirements, when scaled to MBW, than biological types with medium milk potential. Webster (1983) felt

that fasting metabolism of cattle could be ranked according to their respective level of production; dairy cows > beef bulls > beef steers > beef heifers > Zebu.

Changes in physiological status of the mature beef cow are associated with large fluxes in energetic demand. For example, the calculated requirement of energy for maintenance is 31% higher for lactating nonpregnant Hereford cows as compared to nonlactating, nonpregnant Hereford cows (Neville and McCullough, 1969). During the last trimester of gestation when fetal growth is greatest, nutrient requirements are about 75% greater in the pregnant animal than in the nonpregnant animal (Bauman and Currie, 1980). Other energy costs associated with the postpartum interval, such as involution, also have a compounding effect with peak metabolic demands associated with early lactation.

Maintenance requirements have also been determined to decrease with decreasing body condition (Klosterman et al., 1968; Russel and Wright, 1983). In addition cows entering the winter months in poor condition in the Northern Great Plains often retained poor body condition through the winter (Adams, 1987), which often results in a subsequent decrease in reproductive performance (Bellows and Short, 1978), milk production and calf growth (Corah, 1980).

Effects of environment also cause shifts in the maintenance metabolism of beef cows. Prior exposure to cold temperatures have shown to affect resting metabolic rates. Cows kept in cold chambers with exposure of 20 C had a resting metabolic rate of approximately 70 kcal x $W^{-.75}$ x d^{-1}, whereas cows exposed to -20 C had a resting

metabolism of approximately 110 kcal x $W^{-.75}$ x d^{-1} (Young, 1975). Maintenance energy increases due to the dissipation of heat with heat stress, have been noted (Morrison, 1983).

Daily energy expenditures associated with travel and grazing for the free roaming beef cow are significantly higher than for the housed cow (Blaxter, 1962). Estimates of energy expenditures for the free roaming animal are variable. Havstad and Malechek (1982) believed this increase may be as high as 40%, while Osuji (1974) gives a range of 25 to 50%. Other estimates are as high as 100% (Osuji, 1974).

The effect of previous nutrition on fasting heat production has been demonstrated in rats (Ferrel and Koong, 1982) and sheep (Ferrel et al., 1986). A summary of these experiments by Koong et al. (1985) indicated that as previous level of nutrition was varied from low to high a corresponding increase in maintenance requirement occurred. Changes in body size did not appear to be a factor in changing the maintenance requirement, since all animals were randomly reassigned to different nutritional levels midway through the study.

Visceral Organ Mass

In order to understand the influence maintenance energy demand may have on visceral tissues it is important to remember that maintenance energy essentially represents the "cost of life" (Dale, 1984). This energy is used for circulation, respiratory function, cellular repair and replacement, membrane transport, dynamic equilibrium and many other functions at both the cellular and tissue level. Because of the

varying role of vital organs in maintenance each organ has its own energetic cost. Data presented by Baldwin et al. (1980) and others (Lobley et al., 1980; Eddelstone and Holzman, 1981; Canas et al., 1982) demonstrated that individual tissues each have a unique metabolic demand.

In work by Canas et al. (1982) heat production per gram of tissue in rats was 10 times greater in the liver than in muscle. Both the weight and resting oxidative activities of the heart, liver and intestines were greater in lactating subjects than in nonlactating animals. Furthermore, a 24% increase in maintenance energy requirements were explained by differing relative weights of the heart, kidney and liver. Studies by Eddelstone and Holtzman (1981) of tissue oxygen consumption in newborn lambs found that the liver and GI tract accounted for 15 and 11%, respectively, of the total oxygen consumed. Tess et al. (1984) determined fasting heat production was highly correlated to the weight of protein in the viscera and blood in pigs.

Garlick et al. (1976), citing other studies, stated that the metabolic rate in pigs, rats and man were highly related to protein turnover and synthesis. In his study with cattle the fractional rate of protein synthesis was greatest in the viscera. Of the viscera the liver and GI tract exhibit the greatest rate of fractional protein synthesis (Lobley et al., 1980). Muscle accounted for the majority of the protein synthesis in the whole animal. Lobley et al. (1980) believed the work of protein synthesis represents a maximum of 30% of the total animal energy expenditures. Baldwin and Smith (1975)

suggested protein metabolism accounts for 20 to 25% of liver energy expenditures.

The active movement of ions across biological membranes is another significant source of energy utilization in the viscera of cattle. Milligan and McBride (1985), describing in vitro measurements for transport of Na^+ and K^+, stated the percentage of respiration due to transport for skeletal muscle, duodenal epithelium and hepatocytes were 26 to 46%, 28 to 61%, and 18 to 54%, respectively. The nervous system and kidney had even higher cost of transporting these ions, with estimated values being 50 to 60% (Baker and Connelly, 1966) and 70% (Balaban et al., 1980), respectively. Major sites of Na^+, K^+ - ATPase activity (enzyme catalyzing the active pumping of Na^+ and K^+ across the plasma membrane) are in the kidney, liver, skeletal muscles, nervous system and duodenal epithelium. This activity increased O_2 consumption 10 to 42% for the fed animal over the fasted animal in hepatocytes (McBride and Milligan, 1985a). In a study of the liver consumption of O_2 between lactating and dry ewes, Na^+, K^+ - ATPase dependent activity accounted for 45 and 37% of the O_2 consumption rate, respectively, an increase of 22% with lactation (McBride and Milligan, 1985b). Increases in O_2 consumption by the liver, skeletal muscle and kidney of cold stressed rats were completely accounted for by Na^+, K^+ - ATPase activity (Guernsey and Stevens, 1977). It appears from these studies that energetic cost of Na^+, K^+ - ATPase activity is closely tied to physiological status.

A further indicator of visceral energetics change with physiological status is in varying blood flow rates. Blood flow rates

increase 50 to 60% to the digestive tract and to the liver with lactation in cows (Lomax and Baird, 1983). In addition there is an increasing rate of flow to the liver and GI tract with increased metabolizable energy intake (Huntington and Reynold, 1986; Lomax and Baird, 1983). This is in agreement with Sellers (1965) who found blood flow to increase with increases in volatile fatty acid production. Increased blood flow rates indicate higher O_2 consumption, greater CO_2 removal from the tissue, an increase in blood metabolites, and greater work loads involving activities such as blood purification and blood cell turnover.

Research involving changes in the organ mass of cattle and its effect on maintenance energy expenditures was probably first performed by Smith and Baldwin (1974). Citing earlier work of Barcroft (1947), Bard (1961), Linzell (1960), Neutze et al. (1968), and Wade and Bishop (1962) involving energy consumption by tissues, they determined that this might be especially true of the more metabolically active tissues. These tissues include the liver, heart, mammary and components of the gastrointestinal (GI) tract. Data from two biological types of dairy cattle, both lactating and nonlactating, demonstrated a general increase in tissue weights with lactation and in biological types with larger body size and greater lactation potential (Smith and Baldwin, 1974).

Data of organ weights in conjunction with additional data regarding tissue energy consumption were used to estimate the influence of tissue weights upon maintenance requirements between lactating and nonlactating cows (Smith and Baldwin, 1974). Increases with lactation

in the weights of the GI tract, liver, heart, mammary gland, and other components not specified increased maintenance requirements by 10% (Smith and Baldwin, 1974). The greatest changes in organ weight and percent energy consumption was noted for the mammary, GI tract, liver and heart with estimated energy consumption being 50, 22, 20 and 19% greater, respectively (Smith and Baldwin, 1974). However the greatest change in absolute energy consumption was for the liver with an increase of 851 kcal/d. In this study the liver energy expenditures accounted for 22.5% of the total animal energy expenditures in the nonlactating cow and 25.6% in the lactating cow. The mammary, GI tract, and heart represented 2.3, 7.2 and 10.0%, respectively, of the total energy expenditures for maintenance in the nonlactating animal, and 3.6, 8.4 and 11.9, respectively, in the lactating animal (Smith and Baldwin, 1974).

Active Tissues

The function of the heart is the propulsion of the blood through the circulatory system. While the heart in the adult animal can change mass in response to long term increased work loads this is generally not due to an increase in the number of cells present in the heart (Zak, 1973). Present knowledge of the heart is that myocardial cells do not regenerate in the adult animal, but that there is a enlargement of cells already differentiated. This would mean an increase in intercellular structures such as mitochondria (Zak, 1973), and therefore a greater energy demand. When the heart's workload is decreased to "normal" myocardial cells will return to normal size

(Beznak, 1969). In the case of workloads below normal atrophy of the heart can occur (Knight, 1967).

The spleen serves as a storage area for blood until such time blood is needed for other functions. Because of this function size of the spleen can vary quickly within a individual depending on the amount of blood in the spleen. The spleen is not an essential organ as other organs can assume its functions if the spleen is removed. Other functions of the spleen include; removal of aged or dead red blood corpuscles, production of lymphocytes, production of antibodies, formation of bile pigment and storage of iron (Swenson, 1983).

The energy consumption of the lungs appears to be minimal as compared to other tissues (Barcroft, 1947; as cited by Blaxter, 1962). Lung volume and diffusion surface area for gas exchange appears to be proportional to body weight (Reece, 1983). This is indicated by the tendency towards increased width and depth of the brisket with heavier biological types.

The kidney's high rate of blood flow indicates its importance to overall metabolism. The average blood flow to the kidneys of sheep and goats was measured as being 550 ml x min^{-1} x 100g tissue $^{-1}$. Blood flows for the liver and skeletal muscle are 320 and 5 ml x min^{-1} x 100g $tissue^{-1}$, respectively (Vernon and Peaker, 1983). A major kidney function is maintaining blood ion equilibrium, a significant contribution to the energy expended by these organs. The kidneys also play a role in protein metabolism, including urea conservation and excretion. Twenty percent of glycogenesis in the fasting animal is attributed to the kidney (80% in the liver). Production of glucose in

the kidney and the liver should increase substantially with lactation as glucose is a precursor for lactose. Other functions of the kidney include maintaining water balance, elimination of complex organic compounds and metabolism and secretion of endocrine substances.

Liver functions are diverse and multifaceted. These functions include lipid metabolism, carbohydrate metabolism, protein metabolism, hormone degradation and production, bile production, blood purification and elimination of toxic substances. Major processes accounting for energetic demand have been previously mentioned. Size and weight of the liver can be severely impacted by fasting since the liver is a major site for storage of both protein and glycogen. Glycogen accounts for 2 to 8% of the wet weight of the liver depending upon the nutritional status of the animal. This reserve of glycogen can be depleted within 24 hours of fasting (Beitz and Allen, 1983). In addition, starvation or protein deficient diets can cause up to a 40% loss of liver protein with the greatest loss within the first several days of fasting (Vernon and Peaker, 1983).

Unlike other vital organs of the beef cow the rumen has received a voluminous amount of attention. In contrast to the liver, kidneys and spleen the rumen is a muscular organ. The rumen is necessary for mixing, evacuation and regurgitation contractions to facilitate passage and digestion of the ruminal contents. These contractions are continuous but vary in frequency and intensity with behavioral states of activity and rest (Ruckebusch, 1980). In a resting, post absorptive cow 6 to 8 biphasic contractions per five minute period should occur (Dziuk, 1983). A doubling of the resting rate is noted for sheep

during feeding, and the number of contractions are greater for long hay diets over cubed hay diets (Ruckebusch, 1980). The energetic demand associated with increased ruminal contractions explains in part the increased work of digestion as noted by Osuji (1973; as cited by Osuji, 1974).

Fell and Weekes (1980) discovered a close relationship between food intake and the weight of ruminal mucosa. Increased lactate and pyruvate formation which occurred during periods of peak intake rather than during peak lactation suggest that the activity of the ruminal mucosa is mediated by intake rather than metabolic demand. Most of the change in ruminal epithelial weight was due to hypertrophy of the tissue involved. However an increase in cell numbers accounted for some weight increase with a high cost of mitotic cell division, yet an increase in cell numbers was not as evident.

Intake

To meet the changing energy demands of maintenance animals must consume a corresponding amount of metabolizable energy to maintain zero, or positive energy balance (Baile and Forbes, 1974). The amount of food consumed is dependant upon attributes of the forage including nutrient and caloric density, digestibility of the feed, forage availability and physical limitations of the animal. In a range environment where feeds are often fibrous, bulky and of variable availability, the capacity of the rumen, passage rates and fatigue

restrictions associated with grazing become limiting factors of forage intake.

Numerous researchers have found increases in intake associated with the increased nutrient demand during lactation. For example, lactating crossbred cows consumed 40% more forage than nonlactating cows of the same herd (Kronberg et al., 1986). Similar differences have been found between lactating and nonlactating animals by other researchers (Dijkstra, 1971; Allison, 1985). Hodgson and Jamieson (1981) in two experiments found lactating cows (Marched calved) consumed 76 and 43% more than nonlactating animals during spring and fall, respectively. Roisere et al. (1980) found that lactating 2 year old heifers consumed 49% more forage than their nonlactating counterparts.

Forage intake has also been found to vary between biological types on summer rangelands. Kronberg et al. (1986) reported lactating straightbred Herefords (HH) and 3/4 Simmentals X 1/4 Herefords (3S1H) consumed 1.9 and 2.1% of their body weight per day (BW/d), respectively. Wagner et al. (1986) the following year, 1983, using the same biological types and rangeland as Kronberg et al. (1986) did not detect intake differences. In Wagner's study during 1983 forage digestibility was much higher, 65% in vitro organic matter digestibility (IVOMD), than that reported by Kronberg in 1982 (50%). A similar comparison of five biological types on the same rangeland as mentioned previously was made by Wagner et al. (1986) during 1984. Biological types used in this study include HH, Angus X Hereford (AH), 1/4 Simmental X 3/4 (1S3H), Hereford Simmental X Hereford (SH) and 3S1H

lactating cows. Mean forage intake for HH, AH, 1S3H, SH and 3S1H was 2.3, 2.5, 2.2, 2.6, 2.8% of BW/d, respectively, when IVOMD averaged 61%. Milk production accounted for 60% of the variation among these cows when milk production, weight:height ratios and body weight were used as covariates in a regression model.

Reticulorumen Volume

Along with an increase in reticulorumen weight caused by hypertrophy during lactation, there is an associated increase in reticulorumen volume. Tulloh (1966a) used Jersey and Jersey X Shorthorn monozygous twins to assess differences in reticulorumen volume with lactation. The weight of the digesta in the reticulorumen, and the water and air filled capacities of the reticulorumen for each lactating and nonlactating twin were obtained. Weights of both the wet and dry digesta, air filled capacity and water filled capacity were greater for lactating cows. The greatest difference occurred during mid lactation with smaller differences found during early and late lactation. Air filled capacities resulted in much the same trends as did the water filled estimations. Similar results were found in sheep (Ulyatt and Barton, 1964). Tulloh (1966b) also found the length and internal circumference of the intestinal lamina of the small and large intestine to be larger for lactating animals.

Work by Campbell and Fell (1964) found hypertrophy of the GI tract could be prevented in rats if lactating animals were fed the same amounts as nonlactating rats. This suggests intake may be a cause of

hypertrophy. However Mowatt (1973; as cited by Forbes, 1986) found a difference in reticulorumen water filled capacity between two weeks precalving and at parturition without a corresponding difference in food intake. This would suggest other influences, including hormonal control, may affect hypertrophy and reticulorumen volume.

Reticulorumen volume should also be limited by the amount of available space in the abdominal cavity. Nutt et.al. (1980) estimated ruminal volume with external markers of Angus cows with varying frame sizes. A positive relationship was found between ruminal volume and frame size. In addition cows grazing lower quality pastures had larger rumens with increased intake. This relationship was not found with animals grazing high quality pastures.

Fatigue

When the energy expenditures of seeking food, prehension and harvest become greater than the energy consumed it is likely that the animal will suffer fatigue or exhaustion. As the quantity of forage lessens there is a general increase in both bite rate (Chacon et al., 1976) and grazing time (Arnold. 1960; Scarnecchia et al., 1985). These responses are apparently a means of sustaining intake levels since animals are able to maintain intake levels with declining forage availability (Havstad et al., 1983). However, a decline in intake attributed to fatigue appears to occur when grazing time exceeds approximately 10.8 h (Scarnecchia et al., 1985) to 12.0 hours (Stobbs,

1975). Differences in the length of grazing time necessary for fatigue to occur is likely to depend upon a multiplicity of factors, such as forage density, structure and tensile strength.

MATERIALS AND METHODS

This research project was conducted during the summers of 1985 and 1986 in cooperation with the Northern Agricultural Experiment Station located near Havre, Montana. Although the research objectives for both years were the same, techniques were modified in 1986 to increase the accuracy of inferences derived from the data. Because of these changes, each year will be treated separately in this and the following section.

Methodology Used In 1985

During 1985 six pregnant and lactating animals, 6 to 9 yr old, from each of five biological types were randomly selected from the Northern Agricultural Research Center's crossbred herd. Biological types included in this study were: straightbred Hereford (HH), Angus X Hereford (AH), 1/4 Simmental X 3/4 Hereford (1S3H), Simmental X Hereford (SH) and 3/4 Simmental X 1/4 Hereford (3S1H). All calves were sired by either Havre Line 4, Polled or horned Hereford bulls. These biological types were selected to represent differences in mature size and milk production (table 1). Within these biological types the increasing Simmental influence represented a beef cow type with higher milk production and larger body size. The Angus and Hereford influence represented a smaller biological cow type with moderate milk production. Management of the herd was designed to replicate typical management practices commonly used by cow-calf producers in North

Central Montana. The overall goal of the project was to measure maternal characteristics of each biological type over a 10 year period (Kress et al., 1986).

Table 1. Traits of beef cow biological types, 1985[ab]

Cow Type	Milk Production	Body Size
HH	+	++
AH	++	++
1S3H	++	++
SH	+++	+++
3S1H	++++	++++

[a]Adapted from Kress et al. (1986).
[b]More +'s = greater milk production or body weight.

The study site was located in the Bearpaw Mountains approximately 32 km southeast of Havre, Montana. The pasture used during the study was 81 ha in size with slopes up to 40%. Elevation of the study site averages 1300 m with annual precipitation ranging from 45.7 to 50.8 cm. The site is classified by the Soil Conservation Service (1976) as a silty range site of the Forest-Grassland complex in the western glaciated plains. Dominant vegetation on the steeper slopes consists of rough fescue (Festuca scabrella), Idaho fescue (Festuca idahoensis) and bluebunch wheatgrass (Agropyron spicatum) with an open ponderosa pine (Pinus ponderosa) overstory in localized areas. The more gradual slopes were dominated by Kentucky bluegrass (Poa pratensis). The area is typical of foothill bunchgrass rangeland in Montana. The study

animals were moved to this pasture July 20, and were moved to a similar adjacent pasture on August 29. The stocking rate during the study was 1.2 ha/AUM.

Milk production was estimated on August 2 and August 21 using the weigh-suckle-weigh technique described by Williams (1979). Cow weights and hip heights were obtained after a 12 h shrink during weaning on October 1. Body condition scores were estimated based on weight:height (wt:ht) ratios . Klosterman et al. (1968) reported a high correlation between ht:wt measurements and body condition among mature cows of differing biological types. Additional body weight measurements were obtained at pre- and postbreeding, and at each milk test.

Forage organic matter intake (OMI) was estimated from both daily fecal organic matter output (FOMO) and forage IVOMD using the equation: OMI = FOMO / (1-IVOMD). During the first and third weeks of August fecal output was estimated using both total fecal collections (HH and 3S1H cows) and a Cr_2O_3 dilution technique (Raleigh, 1980; all cows). Total fecal collections were estimated using fecal collection bags and urine separation flaps (Kartchner and Campbell, 1979). Five days prior to, and during total fecal collections all cows were bolused with 10 gm of powdered Cr_2O_3 in a gelatin capsule each evening at 1800 h. On the four days of total fecal collections, collection bags were changed at 600 and 1800 h. Feces collections were weighed, sampled and frozen for later determination of dry matter, organic matter and Cr_2O_3 content (AOAC, 1980). Rectal grab samples from all cows were collected at 1800 to 1900 h and were also frozen until laboratory analysis for Cr_2O_3 content. Chromium content of the grab samples was estimated by use of

atomic absorbtion spectrometry using the procedure described by Williams et al. (1962). Samples were thawed at 40°C, and ground to less than 2mm with a Wiley mill before acid digestion of samples in preparation for atomic absorbtion spectrometry. Two forage extrusa collections using eight esophageally fistulated (HH and 3S1H) cows were collected during each fecal collection period. Extrusa collections were frozen and later freeze dried and ground through a 1mm sieve for IVOMD estimation using the Barnes modification of the Tilley and Terry technique (Harris, 1970). Rumen fluid was obtained from two rumen cannulated cows fed ad libitum grass hay. A grass hay with a known value of 55% IVOMD was used as a standard and all samples were replicated three times.

During the first week in November all cows were shipped to a packing plant in Butte, Montana, where weights of the liver, heart, spleen, lungs, kidneys and kidney fat were obtained. Reticulorumens were removed, emptied and stored in water until the following day when excess fat was removed from the surface. The opening to the omasum was securely stitched closed and the esophagus tied off at the cardia of the reticulorumen. Each reticulorumen was emersed in a tank of warm water and filled with water at a constant pressure until a internal pressure of 4 cm of water was achieved. The potential reticulorumen volume was then read as the change of the water in the tank (Tulloh, 1966a). Reticulorumen weights were measured after the water had drained from the tissue.

Methodolgy Used In 1986

Six pregnant, lactating 3 yr old cows each of four biological types were used as study animals during 1986. These animals were randomly selected from the Northern Agricultural Research Center's crossbred herd. Biological types included in the study were: Straightbred Hereford (HH), Tarentaise X Hereford (TH), Tarentaise X (Simmental X Hereford) (T(SH)) and Charolais X (Simmental X Hereford) (C(SH)). Within the T(SH) group three were 50% Tarentaise - 25% Simmental - 25% Hereford with the remaining three being 50% Tarentaise - 37.5% Simmental - 12.5% Hereford. The C(SH) group was also divided similarly with three animals being 50% Charolais - 25% Simmental - 25% Hereford and three being 50% Charolais - 37.5% Simmental - 12.5% Hereford. These additional sire breeds represented biological types with medium body size, high milk production (Tarentaise) and large body size with moderate milk production (Charolais; Table 2). Cows were bred to bulls of the same breeds as in 1985. Herd management was also similar during 1986 to that employed in 1985.

The study animals were pastured in a 276 ha pasture adjacent to the pasture used in the 1985 study. With the exception of the pasture size the topography and vegetation complex were very similar between years. Fifty-six cows were present on the study site from July 22 to October 1, with the stocking rate for the period being 1.2 ha/ AUM.

Milk production using the weigh-suckle-weigh technique was estimated 30 days post calving, July 18, August 22 and just prior to weaning on September 30, 1986. Cow weights after a 10 h shrink were

obtained during the last milk production test. Hip heights were measured at weaning on October 1.

Organic matter intake was estimated with total fecal collections on all cows during the last week in July, and during the last week in September. Three esophageal fistula collections were made three times during each fecal collection period using four HH animals. In addition to IVOMD analysis of extrusa, analyses of acid detergent fiber, crude protein and acid detergent lignin (AOAC, 1980) were completed as additional indicators of forage quality.

All animals were shipped to Butte, Montana, and vital organ mass data were obtained on October 9 and 10. The following day reticulorumen volume was measured. Measurements of backfat at the 12th rib interface and marbling scores of the longissimus muscle using USDA (1975) standards were made to further estimate body fat content.

Statistical Analysis

The data concerning visceral mass were analyzed as a randomized complete block design. Measured traits at slaughter within a biological type were analyzed as randomized block. Differences among biological types within a year was analyzed using least squares analysis of variance with a protected least squares difference (LSD) test for mean separation. Regression analyses were computed using Statistical Analysis System's (SAS, 1985) stepwise regression procedure.

Linear regression models with milk production and organic matter intake closest to weaning as dependent variables were computed with biological type as a main effect when one way analysis of variance determined significant differences among biological types. Regression models using the same dependent variables were calculated without biological type as a main effect. Covariates included: sex of calf, age of calf, calf weight at weaning, calf average daily gain (ADG) preceding weaning, cow weight at weaning, cow ADG preceding weaning, cow height, cow condition at weaning, spleen weight, heart weight, lung weight, liver weight, kidney weight, kidney fat weight, reticulorumen weight, total organ weight, hot carcass weight, reticulorumen volume, milk production and organic matter intake at weaning.

To identify factors influencing forage intake during a study year the data were also analyzed with a complete randomized block design. Independent variables included: biological type, date of intake measurement, a biological type X date of intake interaction, sex of calf, and calf age. Error term included cow within breed. These results are reported separately in appendix Tables 24 and 25.

RESULTS

1985

There were no differences (P>.10) in the shrunk body weights among the five biological types (Table 2). However, there were differences (P<.10) in the hot carcass weights, with the AH group having a heavier carcass. The HH and 3S1H had the lowest carcass weights with the 1S3H and SH cows being similar to either extreme.

Hip heights were also similar (P>.10) across all biological types. Body condition and kidney fat weights were lowest for the 3S1H group with the remaining biological types having equable condition scores. Kidney fat weight was also lowest (P<.05) for the 3S1H cows and highest for the AH, HH and 1S3H animals (Table 2).

Table 2. Body weight, body condition, hip height, kidney fat weight and hot carcass weight of five different beef cow biological types, 1985[a]

Biological type	Body Weight kg	Body Condition wt:ht	Hip Height cm	Kidney Fat kg	Hot Carcass kg
HH	588.24 ± 17.6	5.75 ± 0.17[b]	131.0 ± 1.73	3.10 ± 0.17[de]	276.24 ± 8.07[c]
AH	605.93 ± 14.5	6.33 ± 0.31[b]	131.2 ± 1.28	3.63 ± 0.52[d]	300.43 ± 8.93[b]
1S3H	588.47 ± 17.1	5.92 ± 0.16[b]	132.5 ± 1.89	2.44 ± 0.22[ef]	280.25 ± 6.17[bc]
SH	615.91 ± 14.2	5.75 ± 0.17[b]	134.7 ± 1.26	2.31 ± 0.15[ef]	288.26 ± 7.53[bc]
3S1H	597.39 ± 14.7	5.08 ± 0.38[c]	134.8 ± 0.70	2.14 ± 0.29[f]	269.14 ± 8.37[c]

[a] Least square means ± SE.
[bc] Means within a column with different superscript differ (P<.10).
[def] Means within a column with different superscript differ (P<.05).

Milk production did not vary (P>.10) among biological types (Table 3). However, there tended to be a increase in milk production during the second milk production test over the first test. The ratio of heifers to steer calves was 1:1, 2:1, 2:1 and 2:1 for HH, AH, 1S3H and SH cows, respectively. The 3S1H group suckled only heifer calves. Mean calf ages at weaning were 168, 178, 186, 177 and 177 days for HH, AH, 1S3H, SH and 3S1H cows, respectively. Birth weights for all biological types approximated 40 kg, and mean values for 205 d weaning weight were similar (260 kg) for all biological types except for the SH group (317 kg). Calf average daily gains (ADG) are reported in Table 4. Factors including calf sex, calf age, birth weight and calf age have been reported to influence milk production (Casebolt, 1984).

Table 3. Average daily milk production (kg/d) for five beef cow biological types, 1985[ab]

Biological type	Date		Mean
	8/2/85	8/29/85	
HH	8.73 ± 0.76	8.79 ± 0.86	8.76 ± 0.27
AH	8.71 ± 1.16	10.30 ± 1.02	9.51 ± 0.96
1S3H	7.62 ± 1.38	10.30 ± 0.75	8.96 ± 0.82
SH	8.91 ± 0.96	11.71 ± 1.37	10.21 ± 0.18
3S1H	9.98 ± 0.71	11.85 ± 0.86	10.92 ± 0.57

[a]Least square means ± SE.
[b]P>.1.

Table 4. Calf average daily gain (kg) from dams of five different beef cow biological types, 1985[a]

Biological type	Period			
	6/3 - 7/22	7/22 - 8/2	8/2 - 8/29	8/29 - 10/1
HH	.88 ± .05	1.08 ± .06[b]	1.03 ± .02	1.15 ± .02
AH	.98 ± .04	1.06 ± .07[b]	1.15 ± .05	1.10 ± .05
1S3H	.88 ± .11	1.17 ± .04[bc]	1.12 ± .04	1.15 ± .03
SH	.97 ± .05	1.28 ± .07[c]	1.19 ± .06	1.29 ± .10
3S1H	.86 ± .04	1.17 ± .09[bc]	1.12 ± .04	1.12 ± .07

[a] Least square means ± SE.
[bc] Means within a column with different superscript differ (P<.10).

Of the regression models for milk production the model with biological type as a main effect was not significant (P>.10). In the model without biological type as a main effect the weight of the lungs, kidney fat and reticulorumen accounted for 38% of the variation in milk production at weaning (Table 5).

Average daily gains during mid and late lactation (Table 6) were not different (P>.10) among biological types within a period, yet gains across periods were different. During June and the first two thirds of July all cows gained an average of 0.66 kg a day. In the following 10 days gain increased to 1.05 kg a day. Average daily gain for the study animals decreased to -0.26 kg/d during August, with weight remaining relatively constant through September.

Table 5. Stepwise regression coefficients for milk production prior to weaning, 1985

Variable	B_o	B_1
Kidney fat weight	11.2145	-1.1521**
Lung weight	11.4090	-0.9576*
Reticulorumen weight	12.7309	0.3643
MSE		4.4569
R^2		0.3805***

* P<.10.
** P<.05
***P<.01

Table 6. Average daily gain (kg) for five different beef cow biological types, 1985[ab]

Biological type	Period			
	6/3 - 7/22	7/22 - 8/2	8/2 - 8/29	8/29 - 10/1
HH	.64 ± 0.11	.69 ± 0.60	-.27 ± 0.21	-.07 ± 0.11
AH	.76 ± 0.10	.92 ± 0.51	-.29 ± 0.12	-.01 ± 0.19
1S3H	.85 ± 0.22	1.42 ± 0.52	-.05 ± 0.45	.08 ± 0.13
SH	.57 ± 0.18	.91 ± 1.05	-.24 ± 0.35	.26 ± 0.05
3S1H	.47 ± 0.11	1.29 ± 0.32	-.44 ± 0.12	-.15 ± 0.23

[a]Least squares means ± SE.
[b]P>.10.

Daily OMI (Table 7) in kg/d and as a percent of body weight (%BW) did not differ (P>.10) among cow types. There was an increase (P<.10) in intake between the two periods measured for the HH, AH and 1S3H cows. IVOMD was estimated at 43% for both intake periods.

Table 7. Organic matter intake per day (OMI/d, kg), and OMI/d as percent of body weight (%BW) for five beef cow biological types, 1985[ab]

Biological type	Date			
	8/8/85 - 8/11/85		8/21/85 - 8/25/85	
	OMI/d	OMI/d,%BW	OMI/d	OMI/d,%BW
HH	6.40 ± .13	1.07 ± .04	7.58 ± .22	1.28 ± .05
AH	7.19 ± .22	1.17 ± .02	7.71 ± .35	1.27 ± .05
1S3H	6.91 ± .22	1.15 ± .03	7.83 ± .24	1.34 ± .05
SH	7.90 ± .30	1.27 ± .04	8.02 ± .48	1.29 ± .07
3S1H	7.39 ± .60	1.21 ± .12	7.45 ± .18	1.24 ± .03

[a]Least square means ± SE.
[b]P>.10.

A model including sex of calf, age of calf, milk production at weaning, calf gain prior to weaning and spleen weight as covariates accounted for 54% of the variation in OMI prior to weaning (Table 8).

Of the vital organs measured only the kidneys and the liver showed differences (P<.10; Table 9). The 3S1H group had the largest kidneys with the remaining biological types having similar kidney weights. Both SH and 3S1H had larger livers (P<.10) than the HH and 1S3H, and the AH group exhibited intermediate liver weights. When organ weights

were expressed as a percent of body weight (Table 10) the 3S1H cows had a higher percentage of their body weight as kidney weight than other biological types (P<.10). The 3S1H group also had the highest liver to body weight percentage, HH, AH, and 1S3H groups the lowest, and the SH group was intermediate. Reticulorumen volume did not differ (P>.10) among biological types (Table 11).

Table 8. Stepwise regression coefficients for organic matter intake prior to weaning, 1985

Variable	B_o	B_1
Sex of calf	7.8176	0.4519[a]*
Age of calf	7.3384	-0.0273***
Milk production prior to weaning	7.2625	-0.1032**
Calf ADG prior to weaning	9.4179	2.0522*
Spleen weight	8.9100	1.5443*
MSE		0.3091
R^2		0.5356***

[a] The class variable Sex is scored: 1=Heifer calf, 2=Steer calf.

* P<.10.
** P<.05.
***P<.01.

Table 9. Organ mass of five different beef cow biological types, 1985[a]

Biological type	Heart	Kidney	Liver	Lung	Spleen	Reticulorumen
	Kg					
HH	2.20 ± .07	1.11 ± .04[b]	5.05 ± .10[b]	4.31 ± .66	0.71 ± .05	12.95 ± .74
AH	2.20 ± .12	1.08 ± .02[b]	5.25 ± .08[bc]	3.55 ± .11	0.71 ± .02	12.83 ± .44
1S3H	2.14 ± .10	1.13 ± .04[b]	5.11 ± .22[b]	3.60 ± .17	0.71 ± .04	13.53 ± .86
SH	2.29 ± .05	1.12 ± .04[b]	5.56 ± .16[c]	4.03 ± .25	0.86 ± .08	14.90 ± .82
3S1H	2.32 ± .08	1.30 ± .10[c]	5.52 ± .09[c]	3.77 ± .27	0.86 ± .09	15.08 ± .73

[a] Least square means ± SE.
[bc] Means within a column with different superscript differ (P<.10).

Table 10. Organ mass as a percent of body weight, of five different beef cow biological types, 1985[a]

Biological type	Heart	Kidney	Liver	Lung	Spleen	Reticulorumen
	%BW					
HH	0.37 ± .002	0.19 ± .008[d]	0.86 ± .016[b]	0.73 ± .110	0.12 ± .004	2.21 ± .122
AH	0.36 ± .016	0.18 ± .004[d]	0.87 ± .024[b]	0.59 ± .020	0.12 ± .004	2.13 ± .102
1S3H	0.36 ± .012	0.19 ± .004[d]	0.87 ± .016[b]	0.61 ± .024	0.12 ± .004	2.29 ± .102
SH	0.37 ± .004	0.18 ± .004[d]	0.90 ± .016[bc]	0.66 ± .045	0.14 ± .012	2.42 ± .139
3S1H	0.39 ± .008	0.22 ± .012[e]	0.93 ± .016[c]	0.63 ± .040	0.15 ± .016	2.53 ± .110

[a] Least square means ± SE.
[bc] Means within a column with different superscript differ (P<.10).
[de] Means within a column with different superscript differ (P<.05).

Table 11. Potential reticulorumen volume of five different beef cow biological types, 1985[ab]

Biological type	Reticulorumen Volume, l
HH	58.54 ± 2.30
AH	62.29 ± 7.62
1S3H	63.78 ± 7.22
SH	80.32 ± 10.60
3S1H	68.01 ± 7.13

[a]Least square means ± SE.
[b]P>.10.

1986

Body weights for the HH, TH and T(SH) did not differ (P>.10; Table 12), yet the mean weight of the C(SH) group was 9% larger (P<.10) than the next largest group (HH). Hip heights were also taller (P<.10) for the C(SH) group, with the HH group being the shortest. In contrast, hot carcass weights did not differ (P>.10) among biological types in the study. Measurement of body fat and body condition did not yield any differences (P>.10) among biological types (Table 13).

Milk production (Table 14) was greatest (P<.10) for the T(SH) group during the first thirty days of lactation. The HH animals exhibited the lowest values (P<.10) for the second milk production test on July 18. Differences in milk production were diminished (P>.10)

Table 12. Body weight, body condition, hip height and hot carcass weight of four different beef cow biological types, 1986[a]

Biological type	Body Weight kg	Body Condition wt:ht	Hip Height cm	Hot Carcass kg
HH	516.95 ± 3.6[b]	4.05 ± 0.03	127.3 ± 0.88[d]	233.25 ± 2.84
TH	515.51 ± 17.6[b]	3.90 ± 0.09	132.0 ± 1.90[e]	244.04 ± 9.46
T(SH)	507.58 ± 4.8[b]	3.83 ± 0.04	132.7 ± 1.14[e]	230.88 ± 5.29
C(SH)	561.18 ± 23.8[c]	4.07 ± 0.13	137.5 ± 1.67[f]	255.30 ± 10.63

[a] Least square means and SE.
[bc] Means within a column with different superscript differ (P<.10).
[def] Means within a column with different superscript differ (P<.05).

Table 13. Kidney fat weight, back fat thickness and Marbling score of four different beef cow biological types, 1986[ab]

Biological type	Kidney Fat kg	Back Fat mm	Marbling score
HH	2.23 ± 0.24	1.50 ± 0.4	1.8 ± 0.18
TH	2.57 ± 0.42	1.75 ± 0.5	1.5 ± 0.22
T(SH)	1.71 ± 0.16	0.67 ± 0.2	1.3 ± 0.52
C(SH)	2.18 ± 0.25	1.00 ± 0.2	1.5 ± 0.22

[a] Least square means ± SE.
[b] P>.10.

for the test during August 22. Milk production at weaning was again higher (P<.10) for T(SH) and lowest (P<.10) for C(SH). Ratios of heifer calves to steer calves were 2:1, 1:1, 0.5:1 and 2:1 for HH, TH, T(SH) and C(SH) groups respectively. Birth weights of the calves for all biological types were near 40 kg, with the exception of the TH group (35 kg). The average age of the calves at weaning by biological type were 174, 190, 174 and 183 days for HH, TH, T(SH) and C(SH) respectively. In addition, 205 day weaning weights were 205, 224, 252 and 241 kg for HH, TH, T(SH) and C(SH), respectively. Average daily gain of the calves are listed on Table 15 for four periods from parturition to weaning.

Table 14. Average daily milk production (kg/d) for four beef cow biological types, 1986[a]

Biological type	Date			
	30 d post calving	7/18	8/22	9/30
HH	6.61 ± 0.73[b]	6.10 ± 0.36[b]	7.98 ± 0.36	5.63 ± 0.40[b]
TH	7.73 ± 0.81[b]	9.09 ± 1.01[c]	8.53 ± 0.71	7.80 ± 0.71[cd]
T(SH)	12.53 ± 2.14[c]	8.74 ± 0.78[c]	7.62 ± 1.16	8.16 ± 0.47[d]
C(SH)	8.49 ± 1.13[b]	8.41 ± 0.97[c]	8.89 ± 1.06	6.35 ± 0.95[bc]

[a] Least square means ± SE.

[bcd] Means within a column with different superscript differ (P<.10).

Table 15. Calf average daily gain (kg) from dams of four different beef cow biological types, 1986[a]

Biological type	Period			
	Birth - 30 d post calving	30 d post calving - 7/18	7/18 - 8/22	8/22 - 9/30
HH	0.72 ± .03	0.85 ± .05[b]	0.81 ± .05[b]	0.68 ± .07
TH	0.86 ± .06	0.99 ± .04[c]	0.98 ± .07[c]	0.74 ± .04
T(SH)	0.92 ± .01	1.05 ± .03[c]	1.08 ± .03[c]	0.89 ± .04
C(SH)	0.82 ± .09	1.00 ± .06[c]	1.04 ± .02[c]	0.88 ± .06

[a] Least square means ± SE.
[bc] Means within a column with different superscript differ (P<.05).

Along with biological type, sex of calf and spleen weight accounted for 65% of the variation in milk production (Table 16). When biological type was not included as a main effect sex of calf, cow ADG, body condition and hot carcass weight accounted for 52% of the variation in milk production (Table 17).

Average daily gain for the cows (Table 18) steadily increased from thirty days post calving to August 22, yet an average decrease in body weight of .95 kg/d occurred during later August and in September.

Organic matter intake did not differ among biological types (P>.10; Table 19) in either period. This was also true when intake was expressed as a percent of body weight. IVOMD for the first period was estimated at 42%, and 35% for the second period. Crude protein of the forage was 6.1% during August, and 7% in September. Acid detergent fiber was 39% and 45% in August and September respectively. Acid

Table 16. Stepwise regression coefficients for milk production at weaning, 1986

Variable	B_o	B_1
HH	13.6956	-1.8250***
TH	16.0380	0.5174
T(SH)	17.4913	1.9706***
C(SH)	14.8636	-0.6630
Sex of calf	13.3189	-2.2018[a]***
Spleen weight	7.0300	-8.4907**
MSE		1.7063
R^2		0.6546***

[a] The class variable Sex is scored: 1=Heifer calf, 2=Steer calf.

* P<.10.
** P<.05.
***P<.01.

Table 17. Stepwise regression coefficients for milk production at weaning, 1986

Variable	B_o	B_1
Sex of calf	30.3876	-1.7766*
Cow ADG	34.6805	2.5122*
Condition score	25.1204	-9.8944**
Hot carcass weight	35.0813	0.0665*
MSE		2.2258
R^2		0.5230**

[a] The class variable Sex is scored: 1=Heifer calf, 2=Steer calf.

* P<.05.
**P<.01.

Table 18. Average daily gain (kg) of four different beef cow biological types, 1986[ab]

Biological type	Period		
	30 d post calving - 7/18	7/18 - 8/22	8/22 - 9/30
HH	0.70 ± .18	0.70 ± .06	-0.79 ± .18
TH	0.71 ± .11	0.67 ± .17	-0.87 ± .09
T(SH)	0.57 ± .13	0.47 ± .13	-0.96 ± .11
C(SH)	0.63 ± .24	0.98 ± .15	-1.21 ± .11

[a]Least square means ± SE.
[b]P>.10.

Table 19. Organic matter intake (kg) per day (OMI/d), and OMI/d as percent of body weight (%BW) for four beef cow biological types, 1986[ab]

Biological type	Date			
	7/24 - 7/31		9/21 - 9/29	
	OMI/d	OMI/d,%BW	OMI/d	OMI/d,%BW
HH	7.79 ± 0.66	1.43 ± 0.13	6.80 ± 0.44	1.32 ± 0.09
TH	7.68 ± 0.86	1.40 ± 0.16	7.73 ± 0.48	1.50 ± 0.08
T(SH)	7.14 ± 0.71	1.31 ± 0.14	6.70 ± 0.56	1.32 ± 0.12
C(SH)	6.93 ± 0.72	1.18 ± 0.17	8.30 ± 0.60	1.53 ± 0.10

[a]Least square means ± SE.
[b]P>.10.

detergent lignin was 5.2% in both August and September. Sex of calf, calf age, cow ADG prior to weaning and kidney weight accounted for 62% of the variation for OMI (Table 20).

Table 20. Stepwise regression coefficients for organic matter intake at weaning, 1986

Variable	B_0	B_1
Sex of calf	5.2052	-0.9491[a]**
Age of calf	6.1002	-0.0499***
Cow ADG prior to weaning	7.6757	1.5256**
Kidney weight	-2.2535	8.4036***
MSE		0.8578
R^2		0.6199***

[a] The class variable Sex is scored: 1=Heifer calf, 2=Steer calf.

* P<.10.
** P<.05.
***P<.01.

The kidneys proved to be larger (P<.05) in the C(SH) group than in the either the HH or TH animals, whereas the T(SH) group was similar to both extremes (Table 21). This pattern was repeated at the P<.10 level for spleen weight as well. When expressed as a %BW (Table 22) the kidney was no longer different (P>.10), however the spleen remained different without a change in rank. Differences (P>.10) in the other organ weights among biological types were not detected. Reticulorumen volume also did not vary (P>.10) among biological types (Table 23).

Table 21. Organ mass of four different beef biological cow types, 1986[a]

Biological type	Heart	Kidney	Liver	Lung	Spleen	Reticulorumen
	Kg					
HH	1.92 ± .07	0.97 ± .02[b]	5.40 ± .11	3.17 ± .18	0.60 ± .02[d]	15.27 ± 0.69
TH	1.85 ± .05	1.02 ± .03[b]	5.80 ± .18	3.02 ± .15	0.58 ± .02[d]	14.70 ± 1.04
T(SH)	1.92 ± .04	1.08 ± .04[bc]	5.68 ± .17	3.55 ± .37	0.67 ± .04[de]	15.35 ± 0.71
C(SH)	2.07 ± .05	1.21 ± .19[c]	6.00 ± .27	3.24 ± .16	0.76 ± .05[e]	16.71 ± 0.76

[a] Least square means ± SE.
[bc]Means within a column with different superscript differ (P<.10).
[de]Means within a column with different superscript differ (P<.05).

Table 22. Organ mass as a percent of body weight of four different beef cow biological types, 1986[a]

Biological type	Heart	Kidney	Liver	Lung	Spleen	Reticulorumen
	%BW					
HH	0.37 ± .012	0.19 ± .004	1.04 ± .016	0.61 ± .037	0.12 ± .004[bc]	2.95 ± .131
TH	0.36 ± .008	0.20 ± .004	1.13 ± .024	0.58 ± .020	0.11 ± .004[b]	2.84 ± .138
T(SH)	0.38 ± .002	0.21 ± .008	1.12 ± .033	0.70 ± .069	0.13 ± .008[c]	3.02 ± .131
C(SH)	0.37 ± .012	0.22 ± .016	1.07 ± .041	0.58 ± .016	0.13 ± .004[c]	2.99 ± .131

[a] Least square means ± SE.
[bc]Means within a column with different superscript differ (P<.05).

Table 23. Potential reticulorumen volume of four different beef cow biological types, 1986[a]

Biological type	Reticulorumen Volume ------ l ------
HH	63.34 ± 4.67
TH	68.37 ± 13.57
T(SH)	70.37 ± 4.52
C(SH)	80.63 ± 3.09

[a]Least square means ± SE.
[b]P>.10.

DISCUSSION

Forage Intake

Forage intake for all biological types in 1985 was substantially lower than values reported by Wagner et al. (1986) for 1983 and 1984. Wagner using the same lactating biological types and pasture reported OMI to be closer to 2.3% body weight in August, 1983, and 2.0% of body weight in August, 1984. Forage IVOMD was estimated at 59% in 1983, and 57% in 1984. Kronberg et. al. (1986) found somewhat lower OMI during 1982 using lactating HH and 3S1H on the same pasture used in 1985. They reported OMI at 1.7% of body weight for HH cows, and 1.9% for 3S1H cows. Forage digestibility for Kronberg's study was 41% in August. The increase in forage quality in 1983 and 1984 seems to account for the differences in intake over 1982, yet does not account for the much lower intake in 1985. Work by Funston (1987) may offer a possible explanation for the low 1985 intakes found. Funston (1987) using an adjacent pasture and the same biological types in 1985 recorded grazing times that exceeded fatigue limits found by Scarnecchia (1985), and approached fatigue limits found by Stobbs (1975). Overall grazing time of 11.9 hours per day suggests that fatigue rather than rumen fill limited intake. Funston felt that inadequate forage availability (due to successive drought years) was a major cause of the extended grazing times. Precipitation in 1985 was 28.74 cm, or 57% of normal, with less than 30% of the rainfall being received prior to or during the growing season. Lathrop (1985), in a companion study to Wagner et al. (1986)

recorded grazing times in 1984 and reported overall mean grazing time of 9.4 h/d. Lathrop's results suggest that fatigue was not a limiting factor to the intake values found by Wagner et al. (1986) in 1984.

Organic matter intake for the biological types studied in 1986, although higher than 1985, was also low. Overall daily grazing time was high, with grazing time estimates of the same cows within this study being 11.3 h/d (Funston, 1987). However, forage availability was approximately 1,200 kg DM/ha, which suggests that fatigue was not limiting intake (Funston, 1987). Forage digestibility in July of 1986 was similar to Kronberg et al. (1986) in August of 1982, this may mean forage reached maturity earlier in the year and continued to drop since IVOMD estimates in September, 1986 were 35%. Estimates of forage crude protein, acid detergent fiber and percent lignin are similar to other mature forages low in digestibility (Jung, et. al., 1985; White, 1983). With these low forage digestibility values it seems likely an inhibitory physical satiety response due to rumen fill occurred (Hodgson, 1985). McClymont (1967) felt that two mechanisms limit the animal from meeting nutrient demands imposed upon the animal by its genetic potential. A limitation of digestive capacity for low quality forages. And limitations due to behavioral adaption to limiting a sward conditions, which in turn modifies grazing time to offset a declining rate of intake. Increased selectivity by young inexperienced cows may explain extensive grazing times found in 1986, which also suggest that grazing behavior limited intake rather than GI fill. Selectivity for plant parts, specifically leaf over stem and green material over dead has been found to increase grazing time and depress

intake (Minson, 1981). Casual observations of the study animals in 1986 supports that a high degree of selection occurred. Even though standing biomass appeared sufficient animals spent more time grazing areas that had been previously grazed, or selected green vegetative tillers near the base of bunchgrass species. This is opposed to conditions in 1985 where standing biomass was uniformly low to the ground, and was composed of vegetative tillers. Selection during 1985 appeared minimal.

Milk Production

Milk production for all biological types was greater in 1985 than from the same biological types used by Wagner et. al. (1986) in 1984. In August 1984, Wagner et. al. (1986) found milk production ranging from 2 kg/d for 1S3H cows to a high of 8.2 kg/d for SH cows. With higher forage quality in 1984 it is possible that calves assumed a larger responsibility for nutrient intake than in 1985 or in 1986 when forage quality was low. Ansotegui (1986) found that calves increased forage intake to compensate for reduced milk intake. The opposite may also be true in that calves may increase or maintain higher milk intake levels when forages limit metabolizable energy intake because of poor forage quality.

Milk production remained high despite low, or in 1986, decreasing forage quality. Forage intake increased to some extent, yet average daily gains of the cows indicate that body condition decreased to maintain milk production. Lactation takes precedence over other

metabolic functions even to the point of metabolic dysfunction (Bauman and Currie, 1980). This is indicated by the lower carcass weights of the study animals with calves of higher weaning weights. This suggests that the carcass is a major source of nutrients for maintaining milk production. Kidney fat was also reduced in cows with higher milk production potential in 1985. These observations have been noted previously (Hammond, 1947; Botts et al. 1979). Generally, an increase in condition is expected during late lactation and during nonlactating periods if nutritional and environmental conditions are adequate (NRC, 1984).

Sex of calf was an important variable in explaining milk production for both regression models of milk production in 1986. Melton et. al. (1967) found that the daily milk production of cows rearing male calves was .58 kg above that of the cows rearing heifer calves during the 77 day postpartum period. As lactation progressed this difference diminished to .10 kg per day. Contrary to this report, Rutledge et al. (1971) noted that dams nursing heifer calves gave significantly more milk than dams nursing bull calves. Over a 205 d lactation period Hereford dams nursing heifer calves gave approximately 56 kg more milk. Results of this study would support the idea of dams with heifers giving more milk (see Table 4).

Organ mass

Differences in organ mass among biological types appear to reflect differences in milk production potential in 1985, with both body size

and milk production influencing organ mass in 1986. During 1985 both the kidneys and the livers were larger in cows with higher milk production potential. The relative size of these organs remained significant when scaled to both body weight and metabolic body weight. This was as expected since both organs are known to increase in size during lactation as opposed to a nonlactating state (Smith and Baldwin, 1974), implying differences may exist with different lactation potentials. During 1986 differences in body size seemed to account for observed differences in the kidney weights, with liver weights not being different among biological types. The significance of spleen weight on milk production (1986) and OMI (1985) is not understood.

Liver weights reported by Smith and Baldwin (1974) for a 700 kg lactating cow were 11.4 kg, nearly twice the size of the liver weights reported in tables 8 and 20. If an energy value of 370.2 kcal x kg of $tissue^{-1}$ x d^{-1} is assumed (Smith and Baldwin, 1974), then the larger liver of the SH represents a 9% increase in liver maintenance over the smallest mean liver weight (HH). A additive effect may occur if other smaller differences are considered.

During 1985 reticulorumen weight did not differ ($P>.10$) as might be expected from previous studies (Smith and Baldwin, 1974). Weight of the reticulorumen appears to be closely associated with the increase in feed intake during lactation rather than the increase in energetic demand with lactation (Campbell and Fell, 1964). Since forage intake did not differ among biological types in either year, a difference in reticulorumen weight was not expected.

Since organ weights were not obtained during lactation in 1985 they may not be similar to the differences which might of have been observed during lactation. Due to higher energy demands for lactation (NRC, 1984) organ weights may have been greater if measured earlier. Our observations do indicate that differences in organ mass exist among biological types when in a nonlactating state. Greater differences may have also been observed during peak lactation when differences in milk production are found to occur.

Reticulorumen Volume

Although possible fill limitations may have limited intake during 1986 forage intake did not vary (P>.10) among biological types. In the same respect reticulorumen volume also did not vary (P>.10) which suggests a possible relationship existed. However, further testing of this hypothesis needs to be accomplished before any definitive conclusions can be made.

General Discussion

These results suggest that assessing differences in visceral mass may lead to a better understanding of the total energetics of the lactating beef cow and assist in quantifying differences among biological types of beef cows. Several improvements in future research are suggested to better define these relationships. During this study several confounding factors may have influenced our results. Results

concerning the weight of the liver were likely to be influenced by the fasting state of the animal before exsanguination. Tissue shrink due to time in transit and to dry lot conditions before visceral weights were obtained were likely to affect liver weight. Self and Nelson (1972) found the total shrinkage in steers was approximately 7.2% when purchased from a rancher and transported from 150 to 1133 miles. A large portion of this shrink can be attributed to excretory shrink, yet any tissue shrink that occurred is likely to have its greatest effect on the weight of the liver before affecting other tissues (Haussinger and Gerok, 1986). Because of the role of the liver as a storage organ and its rapid loss of glycogen and protein (Bietz and Allen, 1983; Vernon and Peaker, 1983) the fasting and stress conditions imposed may have caused a total reduction in liver weight up to 48%. Further studies should consider in situ measurements to eliminate this error.

Stress as a result of intake estimates may provide further error in measurements of visceral organ mass. This stress may cause a negative energy balance in the animal to occur thereby affecting organ weights. In addition to the added effects of stress, the animal's normal grazing time is disrupted, having possible consequences of exacerbating the animals negative energy balance. The effects of total fecal collections on the grazing animal and the subsequent estimates need to be examined further and alternative methods tested.

Additional measurements that indicate extent and type of metabolic activity per unit of tissue weight may be helpful. Dry matter weights should increase the accuracy of measurements by limiting variation in tissue moisture levels. Protein content of the viscera coupled with

other measures of metabolic activity may prove to be a better indicator of an animal's energetic status if correlations exist. Tess (1984) suggested that total protein weight of the viscera might be a related to the energy required for maintenance of different stocks of pigs. Measurements of RNA content or enzymes responsible for transport of amino acids across the plasma membrane may be useful in determining differences in maintenance due to protein metabolism.

Baldwin and Smith (1983) estimated the effects of lactation on the activities of liver enzymes in the ruminant. These enzymatic changes associated with gluconeogenesis may vary among biological types and may be a factor in whole body energy partitioning. Assays of pertinent enzymes should be a part of future studies comparing the visceral characteristics among biological types. Regulatory mechanisms in visceral energy metabolism of ruminants are currently not known (Baldwin and Smith, 1983), but promise to further assist in understanding differences among biological types if research in this area continues.

LITERATURE CITED

Adams, D.C., R.E. Short and B.W. Knapp. 1987. Body size and body condition effects on performance and behavior of grazing beef cows. Nutr. Rep. Inter. 35:269.

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

Ansotegui, R.P., 1986. Chemical composition and rumen digesta kinetics of diets selected and influence of of milk intake on forage intake by suckling calves grazing native range. Ph.D. Dissertation, New Mexico State Univ., Las Cruces.

Arnold, G.W. 1960. The effect of quantity and quality of pasture available to sheep on their grazing behavior. Aust. J. Agr. Res. 11:1034.

Association of Official Agriculture Chemist (AOAC). 1980. Official methods of analysis (13th ed.). Assoc. Off. Agr. Chem. Washington D.C.

Baile, C.A. and J.M. Forbes. 1974. Control of feed intake and regulation of energy balance in ruminants. Physiol. Rev. 54:160

Baker, P.F. and C.M. Connelly. 1966. Some properties of the external activation site of the sodium pump in crab nerve. J. Physiol. (London) 185:270.

Balaban, R.S., S.P. Soltoff, J.M. Storey and L.J. Mandez. 1980. Improved renal cortical tubule suspension: spectrophotometric study of O_2 delivery. Amer. J. Physiol. 238:F50.

Baldwin, R.L. and N.E. Smith. 1975. Molecular control of energy metabolism. In: J.D. Sirk (Ed.) The Control of Metabolism. pp 17-34. Pennsylvania State Univ. Press, University Park.

Baldwin, R.L. and N.E. Smith. 1983. Adaptions of metabolism to various conditions: Milk production. In: P.M. Riis (Ed.), Dynamic Biochemistry of Animal Production. Elsevier Science Publishering Co. Inc. New York.

Baldwin, R.L., N.E. Smith, J. Taylor and M.Sharp. 1980. Manipulating metabolic parameters to improve growth rate and milk secretion. J. Anim. Sci. 51:1416.

Barcroft, S.J. 1947. Researches on pre-natal life. Charles C Thomas, Springfield IL.

Bard, P. 1961. O_2 uptake and tissue energy exchange. In: P. Bard (Ed.), Medical Physiology. C.V. Mosby Co., St Louis, Mo.

Bauman, D.E. and W.B. Currie. 1980. Partitioning of nutrients during pregnancy and lactation: A review of mechanisms involving homeostasis and homeorhesis. J. Dairy Sci. 63.1514.

Beitz, D.C. and R.S. Allen. 1983. Carbohydrate metabolism. In: M.J. Swenson (Ed.), Duke's Physiology of Farm Animals. Tenth ed. pp 375-385. Cornell Univ. Press. Ithica, NY.

Bellows, R.A. and R.E. Short. 1978. Effects of precalving feed level on birth weight, calving difficulty and subsequent fertility. J. Anim. Sci. 46:1522.

Beznak, M.J. 1969. Regression of cardiac hypertrophy of various origins. Can. J. Pharmacol. 47:579.

Blaxter, K.L. 1962. The Energy Metabolism of Ruminants. Charles C Thomas Publ. Springfield IL.

Botts, R.L., R.W. Hemken, and L.S. Bull. 1979. Protein reserves in the lactating dairy cow. J. Dairy Sci. 62:433.

Brody, S. 1945. Bioenergetics and Growth. Reinhold. New York, NY.

Campbell, R.M. and B.F. Fell. 1964. Gastrointestinal hypertrophy in the lactating rat and its relationship to food intake. J. Physiol. 171:90.

Canas, R., J.J. Romero and R.L. Baldwin. 1982. Maintenance energy requirements during lactation in rats. J. Nutr. 112:1876.

Casebolt, D.G. 1984. Lactation curves and milk production in beef cattle with varying degrees of crossbred influence. M.S. Thesis, Montana State Univ., Bozeman.

Chacon, E., T.H. Stobbs and R.L. Sandland. 1976. Estimation of herbage consumption by grazing cattle using measurements of grazing behaviour. J. Brit. Grassl. Soc. 31:81.

Cook, C. W. 1970. Energy Budget of the Range and Range Livestock. Colorado State Univ. Exper. Stat. Bull. TB109.

Corah, L.R. 1980. Feeding and nutrition of the beef breeding herd. In: D.C. Church (Ed.), Digestive Physiology and Nutrition of Ruminants. 2nd ed. O&C Books, Inc. Corvallis, OR.

Dale, H.E. 1984. Energy metabolism. In. R.J. Swenson (Ed.). Duke's Physiology of Farm Animals, Tenth ed. pp 423-431. Cornell Univ. Press. Ithica, NY.

Dijkstra, N.D. 1971. Feed intake by grazing dairy cows. 3. Comparison of lactating and dry pregnant cows. Neth. J. Agr. Sci. 19.257.

Dziuk, H.E. 1983. Digestion in the ruminant stomach. In. M.J. Swenson (Ed.), Duke's Physiology of Farm Animals. Tenth ed. pp 320-239. Cornell Univ. Press. Ithica, NY.

Eddelstone, D.I. and R.I. Holzman. 1981. Oxygen consumption by the gastrointestinal tract and liver in newborn lambs. Amer. J. Physiol. 240:G297.

Fell, B.F. and T.E.C. Weekes. 1980. Food intake as a mediator of adaption in the ruminal epithelium. In. Y. Ruckebusch and P. Thivends (Ed.), Digestive Physiology and Metabolism in Ruminants. MTP Press, Lancaster.

Ferrel, C.L. and T.G. Jenkins. 1984. Energy utilization by mature, nonpregnant, nonlactating cows of different types. J. Anim. Sci. 58:234.

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 L.J. Koong. 1982. Effect of previous nutrition on body composition and energy utilization of rats. Fed. Proc. 41:942. Abstr.

Ferrel, C.L., L.J. Koong and J.A. Nienaber. 1986. Effect of previous nutrition on body composition and maintenance energy cost of growing lambs. Br. J. Nutr. 56:595.

Forbes, J.M. 1986. The effects of sex hormones, pregnancy and lactation on digestion, metabolism and voluntary food intake. In: L.P. Milligan, W.L. Grovum and A. Dobson (Ed.), Control of Digestion and Metabolism in Ruminants. Prentice-Hall, Englewood Cliffs, NJ.

Frisch, J.E. and J.E. Vercoe. 1976. Maintenance requirements, fasting metabolism and body composition in different cattle breeds. In: M. Vermorel (Ed.). Energy Metabolism in Farm Animals. pp 209-212. Bussac, Clermont-Ferrand.

Funston, R.N. 1987. Grazing behavior of rangeland beef cattle differing in biological type. M.S. Thesis, Montana State Univ., Bozeman.

Garlick, P.J., T.L. Burk and R.W. Swick. 1976. Protein synthesis and RNA in tissues of the pig. Amer. J. Physiol. 230:1108.

Garrett, W.N. 1971. Energetic efficiency of beef and dairy steers. J. Anim. Sci. 32:451.

Gregory, K.E. 1972. Beef cattle type for maximum efficiency. "Putting it all together." J. Anim. Sci. 34.881.

Guernsey, D.L. and E.D. Stevens. 1977. The cell membrane sodium pump as a mechanism for increasing thermogenesis during cold acclimation in rats. Science 196:908.

Hammond, J. 1947. Animal breeding in relation to nutrition and environmental conditions. Biol. Rev. 22:195.

Harris, L.E. 1970. Nutritional research techniques for domestic and wild ruminants. Vol. I. L.E. Harris Pub., Logan, UT.

Haussinger, D. and W.Gerok. 1986. Metabolism of amino acids and ammonia. In: R.G. Thurman, F.C. Kauffman and K. Jungermann (Ed.), Regulation of Hepatic Metabolism: Intra- and Intercellular metabolism. Plenum Press. New York.

Havstad, K.M. and J.C. Malechek. 1982. Energy expenditure by heifers grazing crested wheatgrass of diminishing availability. J. Range Manage. 35:447.

Havstad, K.M., A.S. Nastis and J.C. Malechek. 1983. The voluntary forage intake of heifers grazing a diminishing supply of crested wheatgrass. J. Anim. Sci. 35:447.

Hodgson, J. and W.S. Jamieson. 1981. Variations in herbage mass and digestibility, and the grazing behavior and herbage intake of adult cattle and weaned calves. Grass and For. Sci. 36:39.

Hodgson, J. 1985. The control of herbage intake in the grazing ruminant. Proc. Nutr. Soc. 44:339.

Huntington, G.B. and P.J. Reynold. 1986. Net absorbtion of glucose, L-lactate, volatile fatty acids and nitrogenous compounds by bovine given abomasal infusions of starch or glucose. J. Dairy Sci. 69:2428.

Jung, H.G., R.W. Rice and L.J. Koong. 1985. Comparison of heifer weight gains and forage quality for continuous and short duration grazing systems. J. Range Manage. 38:144.

Kartchner, R.J. and C.M. Campbell. 1979. Intake and digestibility of range forages consumed by livestock. Montana Agr. Exp. Sta. Bull. 718.

Klosterman, E.W., L.G. Sanford and C.F. Parker. 1968. Effect of size, breed and sex upon feed efficiency of beef cattle. J. Anim. Sci. 27:242.

Knight, D.H. 1967. Pulmonary hypertension and left ventricle atrophy in dogs with spontaneous cor pulmonale. Physiologist 10:223.

Koong, L.J., C.L. Ferrel and J.A. Nienaber. 1985. Assessment of interrelationships among levels of intake and production, organ size and fasting heat production in growing animals. J. Nutr. 115:1383.

Kress, D.D., D.E. Doornbos and D. Anderson. 1986. Productivity of different biological types of beef cattle under Montana range conditions: An introduction. Montana AgResearch 3(1):1.

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

Kronberg, S.L., K.M. Havstad, E.L. Ayers and D.E. Doornbos. 1986. Influence of breed on forage intake of range beef cows. J. Range Manage. 39:421.

Laster, D.B., G.B. Smith and K.E. Gregory. 1976. Characterization of biological types of beef cattle. IV. Postweaning growth and puberty of heifers. J. Anim. Sci. 43:63.

Lathrop, W.J. 1985. Grazing behavior of rangeland beef cows differing in milk production. M.S. Thesis, Montana State Univ., Bozeman.

Linzell, J.L. 1960. Mammary-gland blood flow and oxygen, glucose and volitile fatty acid uptake in the conscious goat. J. Physiol. 153:492.

Lobley, G.E., V. Milne, J.M. Lovie, P.J. Reeds and K. Pennie. 1980. Whole body and tissue protein synthesis in cattle. Brit. J. Nutr. 43:491.

Lomax, M.A. and G.D. Baird. 1983. Blood flow and nutrient exchange across the liver and gut of the dairy cow. Effects of lactation and fasting. Brit. J. Nutr. 49:481.

McBride, B.W. and L.P. Milligan. 1985a. Effect of viability ovabain-sensitive respiration of lamb hepatocytes. Intern. J. Biochem. 17:43.

McBride, B.W. and L.P. Milligan. 1985b. Magnitude of ovabain-sensitive respiration in the liver of growing, lactating and starved sheep. Brit. J. Nutr. 54:293.

McClymont, G.L. 1967. Selectivity and intake in the grazing ruminant. In: C.G. Code (Ed.), sec. 6: Alimentary canal. Vol. I. Control of Food and Water Intake. Handbook of Physiology. Amer. Physiol. Soc. Wash. D.C.

Melton, A.A., J.K. Riggs, L.A. Nelson and T.C. Cartwright. 1967. Milk Production, composition and calf gains of Angus, Charolais and Hereford cows. J. Anim. Sci. 26:804.

Milligan, L.P. and B.W. McBride. 1985. Shifts in animal energy requirements across physiological and alimentary. Energy cost of ion pumping by animal tissues. J. Nutr. 115:1374.

Minson, D.J. 1981. Forage quality: Assessing the plant-animal complex. Proc. XIV Int. Grassl. Cong., 23-29.

Morrison, S.R. 1983. Ruminant heat stress: effect on production and means of alleviation. J. Anim. Sci. 57:1983.

National Research Council (NRC). 1984. Nutient requirements of beef cattle. 6th revised ed. National Academy Press. Washington, D.C.

Neutze, J.M., F. Wyler and A.M. Roudolf. 1968. Use of radioactive microspheres to assess distribution of cardiac output in rabbits. Amer. J. Physiol. 215:486.

Neville, W.E. and M.E. McCullough. 1969. Calculated energy requirements of lactating and nonlactating Hereford cows. J. Anim. Sci. 29:823.

Notter, D.L., L.V. Cundiff, G.M. Smith, D.B. Laster and K.E. Gregory. 1978. Characterization of biological types of cattle. VII. Milk production in young cows and transmitted and maternal effects on preweaning growth of progeny. J. Anim. Sci. 46:908.

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. 51:1168.

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

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

Reece, W.O. 1983. Respiration in mammals. In: M.J. Swenson (Ed.), Dukes Physiology of Farm Animals. Tenth ed. pp 226-254. Cornell Univ. Press. Ithica, NY.

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

Ruckebusch, Y. 1980. Motility of the ruminant stomach associated with states of sleep. In: Y. Ruckebusch and P. Thivends (Ed.), Digestive Physiology and Metabolism in Ruminants. pp 77-90. MTP Press, Lancaster.

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

Rutledge, J.J., O.W. Robinson, W.T. Ahlschwede and J.E. Legatoz. 1971. Milk yeild and its influence on 205-day weight of beef calves. J. Anim. Sci. 33:563.

SAS Institute Inc. 1985. SAS User's Guide: Statistics, 1985 Edition. Carey, NC: SAS Institute Inc., 1985. 584 p.

Scarnecchia, D.L., A.S. Nastis and J.C. Malechek. 1985. Effects of forage availability on grazing behavior of heifers. J. Range Manage. 38:177.

Self, H.L. and G. Nelson 1972. Shrinkage during shipment of feeder cattle. J. Anim. Sci. 35:489.

Sellers, A.F. 1965. Volitile fatty acid production and ruminal blood flow. In: R.W.Dougherty (Ed.), Physiology of Digestion in the Ruminant.

Smith, G.M., D.B. Laster, L.V. Cundiff and K.E. Gregory. 1976. Characterization of biological types of cattle. II. Postweaning growth and feed efficiency of steers. J. Anim. Sci. 43:37.

Smith, N.E. and R.L. Baldwin. 1974. Effects of breed, pregnancy and lactation on weight of organs and tissues in dairy cattle. J. Dairy Sci. 57:1055.

Stobbs, T.H. 1975. Factors limiting the nutritional value of grazed tropical pastures for beef and milk production. Trop. Grassl. 9:141.

Swenson,M.J. 1983. Blood circulation and the cardiovascular system. In: M.J. Swenson (Ed.), Dukes Physiology of Farm Animals. Tenth ed. pp 15-40. Cornell Univ. Press, Ithica, NY.

Taylor, St. C.S., R.B. Theissen and J. Murray. 1986. Inter-breed relationship of maintenance efficiency to milk yield in cattle. Anim. Prod. 43:37.

Tess, M.W., G.E. Dickerson, J.A. Nienaber and C.L. Ferrel. 1984. The effects of body composition on fasting heat production in pigs. J. Anim. Sci. 59:99.

Thomas, V. M. 1986. Beef Cattle Production: An Integrated Approach. Lea & Febiger. Philadelphia, PA.

Tulloh, N.M. 1966a. Physical studies of the alimentary tract of grazing cattle. III. Seasonal changes in capacity of the reticulo-rumen of dairy cattle. N.Z. J. Agri. Res. 9:252.

Tulloh, N.M. 1966b. Physical studies of the alimentary tract of grazing cattle. IV. Dimensions of the tract in lactating and non-lactating cows. N.Z. J. Agri. Res. 9:999.

Ulyatt, M.J. and R.A. Barton. 1964. The effect of body composition and weight of ingesta on the numbers of lambs reared by Romney Marsh ewes. Nature (London) 202:318.

United States Department of Agriculture (USDA) - Soil Conservation Service (SCS). 1976. Climax vegetation of Montana: based on soils and climate. USDA-SCS. Bozeman, MT.

United States Department Of Agriculture (USDA). 1975. Official United States standards for grades of carcass beef. USDA, Food Safety and Quality Service, Washington D.C.

Van Soest, P.J. 1965. Symposium on the factors influencing the voluntary intake of herbage by ruminants: Voluntary intake in relation to chemical composition and digestibility. J. Anim. Sci. 24:834.

Van Soest, P.J. 1983. Nutritional Ecology of the Ruminant. O&B Books. Corvallis, OR.

Vercoe, J.E. 1970. The fasting metabolism of Brahman, Africander and Hereford X Shorthorn cattle. Brit. J. Nutr. 24:599.

Vernon, R.G. and M.Peaker. 1983. The regulation of nutrient supply within the body. In: J.A.F. Rook and P.C. Thomas (Ed.), Nutritional Physiology of Farm Animals. pp 177-202. Longman, London and New York.

Wade, O.L. and J.M. Bishop. 1962. Cardiac output and regional blood flow. Blackwell Scientific Publications, Oxford.

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

Webster, A.J.F., J.M. Brockway and J.S. Smith. 1974. Prediction of the energy requirements for growth in beef cattle. 1. The irrelevance of fasting metabolism. Anim. Prod. 19:127.

Webster, A.J.F. 1983. Energetics of maintenance and growth. In: Girardier and M.J. Stock (Ed.), Mammalian Thermogenesis. pp 178-207. Chapman and Hall, London.

White, L.M. 1983. Seasonal changes in yield, digestibility and crude protein of vegetative and floral tillers of two grasses. J. Range Manage. 36:402.

Williams, C.H., D.S. David and O. Iismaa. 1962. The determination of chromic oxide in faeces samples by atomic absorbtion spectrometry. J. Agric. Sci. 59:381.

Williams, J.H., D.C. Anderson and D.D. Kress. 1979. Milk production in Hereford cattle. I. Effects of separation interval on weigh-suckle-weigh milk production estimates. J. Anim. Sci. 49:1438.

Young, B.A. 1975. Temperature induced changes in metabolism and body weight of cattle (Bos taurus). Can. J. Physiol. Pharmacol. 55:619.

Zak, R. 1973. Cell proliferation during cardiac growth. Am. J. Cardiol. 31:211.

APPENDIX

Table 24. Least squares analysis of variance of organic matter intake (OMI), 1985

Source	df	Mean Squares OMI (% BW/d)
Biological type	4	1.0924
OMI period	1	4.6934***
Biological type x OMI period	4	0.7110
Calf sex	1	2.6423**
Regression		
Age of calf	1	4.0640***
Body weight	1	0.5311
MSE	47	0.5483
R^2		0.4391***

* P<.10.
** P<.05.
***P<.01.

Table 25. Least squares analysis of variance of organic matter intake (OMI), 1986

Source	df	Mean Squares OMI (% BW/d)
Calf sex	1	7.5762*
Regression		
Age of calf	1	9.6802**
MSE	43	2.1154
R^2		0.1467**

* P<.10.
** P<.05.