



Influence of energy or protein supplementation on forage intake of pregnant ewes grazing Montana winter range
by Kathy Jo Soder

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

A two-year winter experiment was conducted to determine the influence of either energy or protein supplementation on fecal output (FO), forage intake, blood metabolite profiles and BW change of pregnant ewes grazing winter range. Forty-eight Targhee ewes were selected for uniformity in age and BW and assigned randomly to one of six dietary treatments: 1) no supplement (CON); 2) 150 g of a corn supplement; 3) 150 g of a barley supplement (BAR) ; 4) 75 g of a soybean meal supplement (SBM); 5) 75 g of a blood meal-feather meal supplement (BM+FM); and 6) 75 g of a feather meal-urea supplement (FM+U). Dehydrated alfalfa pellets (ALF; 150 g) were substituted for the corn supplement in Year 2. Supplement intakes are expressed on a daily basis, although supplements were fed on alternate days. Two 5-d experimental periods were conducted during each winter: one in January and one in February. Period by treatment interactions were not detected ($P > .05$) for FO and forage intake in either year. Fecal DM outputs and forage intakes were similar ($P > .05$) among all supplement treatments both years. Energy and protein supplemented ewes gained more ($P < .05$) BW than CON ewes during both years. Feather meal plus urea supplemented ewes gained more ($P < .05$) BW than BAR and SBM supplemented ewes during Year 1. No differences were detected ($P > .05$) among supplemented ewes during Year 2. Supplement treatment had no effect ($P < .05$) on lamb production. A period by treatment interaction was detected ($P < .05$) for serum urea nitrogen (SUN), concentrations. Non-supplemented, SBM, BM+FM and FM+U supplemented ewes had higher ($P < .05$) SUN concentrations during Year 1. Soybean meal supplemented ewes had higher ($P < .05$) SUN concentrations than all other treatments during Period 2 of Year 2. In summary, energy or protein supplementation had no effect on FO and forage DM intake. The positive influence of supplementation on ewe BW change must have been due to factors other than the influence of supplementation on forage intake.

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MONTANA WINTER RANGE

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APPROVAL

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This thesis has been read by each member of the graduate 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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Date August 10, 1993

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ABSTRACT

A two-year winter experiment was conducted to determine the influence of either energy or protein supplementation on fecal output (FO), forage intake, blood metabolite profiles and BW change of pregnant ewes grazing winter range. Forty-eight Targhee ewes were selected for uniformity in age and BW and assigned randomly to one of six dietary treatments: 1) no supplement (CON); 2) 150 g of a corn supplement; 3) 150 g of a barley supplement (BAR); 4) 75 g of a soybean meal supplement (SBM); 5) 75 g of a blood meal-feather meal supplement (BM+FM); and 6) 75 g of a feather meal-urea supplement (FM+U). Dehydrated alfalfa pellets (ALF; 150 g) were substituted for the corn supplement in Year 2. Supplement intakes are expressed on a daily basis, although supplements were fed on alternate days. Two 5-d experimental periods were conducted during each winter: one in January and one in February. Period by treatment interactions were not detected ($P > .05$) for FO and forage intake in either year. Fecal DM outputs and forage intakes were similar ($P > .05$) among all supplement treatments both years. Energy and protein supplemented ewes gained more ($P < .05$) BW than CON ewes during both years. Feather meal plus urea supplemented ewes gained more ($P < .05$) BW than BAR and SBM supplemented ewes during Year 1. No differences were detected ($P > .05$) among supplemented ewes during Year 2. Supplement treatment had no effect ($P < .05$) on lamb production. A period by treatment interaction was detected ($P < .05$) for serum urea nitrogen (SUN) concentrations. Non-supplemented, SBM, BM+FM and FM+U supplemented ewes had higher ($P < .05$) SUN concentrations during Year 1. Soybean meal supplemented ewes had higher ($P < .05$) SUN concentrations than all other treatments during Period 2 of Year 2. In summary, energy or protein supplementation had no effect on FO and forage DM intake. The positive influence of supplementation on ewe BW change must have been due to factors other than the influence of supplementation on forage intake.

INTRODUCTION

Throughout the Intermountain region, native range provides much of the nutrients for gestating ewes during the winter because of the absence of snow cover. During this time, protein and energy concentrations of range forage are low relative to National Research Council (NRC, 1985a) requirements (Harris et al., 1989). Therefore, supplementation is an important production expense during the wintering period to offset nutrient deficiencies in the native range. Type of supplement fed varies, depending on location. Some producers feed barley as the only supplement while others supplement with .15 kg hd⁻¹ d⁻¹ of an 18 to 28% protein pellet. Van Horn et al. (1959a) reported that it was profitable to supplement gestating ewes grazing a grass foothills range in Montana two out of every three years. They concluded that increasing the protein content of the supplement improved body weight (BW) change, however, it was no more profitable to feed a high protein pellet over a high energy, low protein barley pellet. Clanton (1957) found that supplementing pregnant ewes grazing a sagebrush range in Utah with a 25% crude protein (CP) pellet improved lamb production over those fed a corn supplement or no supplement. Casper et al. (1990) stated that barley starch is more readily fermented in the rumen than corn starch. This may help explain why the corn supplemented ewes

in the Utah study had similar production responses to those not supplemented while supplementing with a barley-based pellet in the Montana experiment had increased production over those not supplemented but were similar to those supplemented with a higher level of protein. Differences in ewe production responses may also have been due to differences in forage intake; however, forage intakes were not evaluated in these early studies. Therefore, a two-year winter forage intake trial was conducted to determine the influence of energy or protein supplementation on fecal output (FO), forage intake, blood metabolite profiles, and BW change of pregnant ewes grazing Montana winter range.

LITERATURE REVIEW

Forage Intake

Performance of grazing ruminants is difficult to predict due to variation in forage intake in different grazing situations. This variation is often due to forage quality and availability; however, these interact with animal factors such as physiological state and rumen fill to determine intake. Intake regulation is a function of both short-term and long-term regulation (Mertens, 1987; Prigge et al., 1990). Short-term regulation of intake refers to within-day events that affect the frequency, size, and pattern of meals. Long-term regulation of intake refers to average daily intakes over periods of time during which animal nutrient requirements for maintenance and production are stable. Nutrient requirements of range livestock are not known because requirements can be altered by grazing activity, travel, and environmental stresses. The most critical factor in meeting nutrient requirements of a grazing ruminant is knowledge of how much it will voluntarily consume forage (Allison, 1985).

Regulation of Forage Intake

Bines (1971) suggested that one or more physiological processes exist which regulate a ruminant's forage intake

due to the fact that ruminants fed a diet of medium to high caloric density stop eating before filling their reticulo-rumen. Welch (1967) defined three mechanisms which control forage intake in ruminants: chemostatic regulation, thermostatic regulation, and physical capacity regulation. Baile and Forbes (1974) also discussed several intake-controlling mechanisms. They included humoral factors, neural transmitters, chemical and hormonal mechanisms as well as digestibility, reticulo-rumen fill, and rate of passage. Forbes (1970) proposed that a combination of these factors are responsible for intake regulation. Van Soest (1965) concluded that one single mechanism is not solely responsible for regulating forage intake.

McClymont (1957) stated that the only intrinsic stimulus facilitating phagic behavior in the grazing ruminant is total energy demand. This demand is a summation of the energy required for maintenance, growth, gestation, milk production, exercise, and environmental stress. When short term demand exceeds metabolic energy available to the animal, feeding begins. As energy is supplied beyond the level required, feeding will cease (Blaxter, 1962; Forbes, 1970). This energy balance may be governed by the hypothalamus, which "senses" various feedback signals such as rumen distention stimuli and changes in blood metabolite concentration. Journet and Remond (1976) proposed that free fatty acids may directly affect the

intake control center in the hypothalamus. Baumgardt (1970), as cited by Allison (1985), proposed that the size of the adipose cells may provide signals to the hypothalamus while Baile and Forbes (1974) suggested that there may be a hormonal control linking centers of fat accumulation to the hypothalamus. No clear evidence has been found for either of these theories (Meijs, 1981). Bines (1971) demonstrated that intake of concentrates is reduced in fat ruminants before the rumen is filled to capacity. He also concluded that since fat cows did not eat enough hay to maintain BW and thin cows ate enough of the same hay to gain BW, the existence of a physical regulator seems very likely. This suggests that a lipostatic control may at least partially account for regulation of intake. Fat accumulation around the gut reduces the ability of these organs to expand within the abdominal cavity and thus act indirectly to limit the quantity of digesta that these organs can hold (Campling, 1970; Forbes, 1970).

The major suspected chemical feedback signals regulating energy intake by ruminants on highly digestible diets without heat, cold or nutritional stress are believed to be controlled primarily by levels of available energy substrates [volatile fatty acids (VFA)], hormonal secretion and rumen pH (Baile and Forbes, 1974). Bines (1971) suggested that receptors sensitive to VFA concentrations, particularly acetate, in the rumen may occur on the lumen side of the rumen wall and in the

veins draining the rumen. Forbes (1970) proposed that the receptors sensitive to the VFA propionic acid may occur in the liver. Propionate plays a similar role in controlling feed intake of ruminants much as glucose is thought to do in monogastrics, by acting as an index of the rate of absorption of all VFA's (Forbes, 1980). Propionate is sensed by the portal vein and concentration signals are transferred via the vagus nerve to the hypothalamus. Ruminal acetate concentration has been found to play a central role in controlling meal size on range forages in particular (Waldo, 1969). Baile and Forbes (1974) proposed that the receptors sensitive to acetate are located on the lumen side of the rumen.

Baile and Forbes (1974) also stated that there is no evidence that growth hormone (GH) is a feedback signal for energy balance under normal conditions, but Forbes (1980) reported that a low insulin:GH ratio stimulates lipolysis and might be expected to occur around time of meal initiation. He suggested a link between a deficit of energy yielding metabolites (correlated by an increased secretion of GH) and the onset of feeding. Estrogens are believed to depress intake during estrus and in late pregnancy (Baile and Forbes, 1974), but whether this is an indirect or central action on the satiety center is not known. Balch and Campling (1962) stressed that the changes in feed intake associated with

hormone balance may be related to changes in metabolism.

The rapid fermentation of immature forages may produce sufficient acid to cause a drop in ruminal pH which delays cellulolytic digestion of forage cell walls, thus depressing intake (Van Soest, 1982). Thin cell walls of immature forages are not only more digestible, but are more likely to collapse upon rumination (Van Soest, 1982). Jones (1972) determined that in chemical control of feed intake, a drop in pH facilitates the absorption of VFA's across the rumen epithelium, allowing the activation point of the receptor signal to be accomplished with lower intake of immature forage. Baile and Forbes (1974) stated that feed intake is likely to be depressed when ruminal fluid pH falls below 5.5 because of the resulting rumen stasis.

In addition to the metabolic processes thought to regulate intake, there is considerable evidence that limitations of reticulo-rumen capacity can affect food intake in grazing ruminants (Balch and Campling, 1962; Baile and Forbes, 1974; Prigge et al., 1990). The bulky, fibrous nature of most range ruminant diets, and their relatively low content of digestible energy, lends emphasis to the importance of the physical effect of gut distention in limiting voluntary intake. Physical regulation of feed intake involves stretch receptors in the rumen wall (Bines, 1971). Balch and Campling (1962) found that removing swallowed hay as it entered the

reticulo-rumen exerted an immediate effect on termination of eating by cows; cows could be encouraged to eat for much longer periods of time. The converse was true if additional digesta was added to the reticulo-rumen; the cows immediately decreased hay intake. Campling (1970) had similar results; intake decreased when food was added to the reticulo-rumen through a fistula while removal of food from the rumen caused the animal to eat much longer than normal. Grovum (1979) found that when the reticulum of sheep were distended with water-filled balloons, feed intake was depressed. When the balloons were removed, the animals resumed eating. Conrad et al. (1964) concluded that in lactating dairy cows fed a diet low in digestibility, BW (which reflects reticulo-rumen capacity), passage rate of digesta and digestibility of diet appeared to regulate intake. At high digestibilities, intake appeared to be regulated by metabolism, production and diet digestibility.

Blaxter et al. (1961) showed a strong positive association between the apparent digestibility of roughages and the amount consumed by sheep. Further research has demonstrated that movement of digesta through the alimentary canal is limited by passage of digesta particles through the reticulo-rumen orifice into the omasum (Balch and Campling, 1962). They determined that particles must be of a small size to pass out of the rumen. Particles are reduced in size

primarily by mastication, rumination, digestive action of microbial fermentation in the reticulo-rumen and muscular action of the gut (Balch and Campling, 1962). The rate at which microbial fermentation occurs depends on what type and number of microorganisms exist in the reticulo-rumen (Van Soest, 1982). The number and type of rumen microbes is related to the chemical content of the ingesta (Bines, 1971). Diets with adequate protein levels usually have higher bacterial numbers than those with diets low in protein (Church, 1976). Diets that are richer in readily fermentable nutrients (higher digestibility and protein content) support greater numbers of microbes (Giescke et al., 1966). Thorley et al. (1968) found substantial differences in bacterial species composition for cows when isolated cultures were fed different rations and Church (1976) found substantial differences in isolated bacterial compositions of sheep fed either alfalfa or meadow hay.

The limitations of the reticulo-rumen to digest lower quality forage have important implications on forage intake of range animals. Winter range forage is often of low to medium digestibility and protein content (Theurer et al., 1976 as cited by Allison, 1985; Kartchner, 1981). Conrad et al. (1964) studied the feed intake rate of lactating cows fed diets varying in dry matter (DM) digestibility. They found that cows fed rations of 67% or greater DM digestibility could

increase or decrease intake to meet their energy needs while cows fed rations of less than 67% DM digestibility had intakes limited by their physical capacity to process feed. Montgomery and Baumgardt (1965) cautioned that diet digestibility should not be used alone as the criteria on which to base the "critical point" for control of intake. Factors such as physical form of ingesta, energy and protein supplements, and passage rates must also be taken into account.

Factors affecting forage intake

There are three factors that affect forage intake of grazing animals: factors related directly to the animal, factors related directly to the forage resource, and factors related to the management of the animal and forage resources (environment; Meijs, 1981; Allison, 1985).

Animal

The primary factors related to the animal are: age, body size, BW, physiological status, and condition (Meijs, 1981; Allison, 1985). Young animals require additional nutrients for growth. Energy-supplying compounds are in the greatest demand followed by proteins and various minerals and vitamins (Maynard et al., 1979). The rumen of young animals is relatively smaller than in adults, and their increased feed

requirement is usually met through increased appetite and faster turnover rate of ingesta (Hungate, 1966; Prigge et al., 1990). It may be that younger animals consume a higher quality forage, thereby causing a faster turnover rate. Horn et al. (1979) found that calves tended to select forage with higher CP and lower acid detergent fiber (ADF) and cellulose levels than did cows. Arnold (1981) as cited by Allison (1985) found five-month-old sheep consumed a diet higher in digestibility and nitrogen (N) content, and lower in fiber than that of older sheep. Lambs may be deliberately more selective when grazing, but it may also be, that with smaller jaws, they can select more precisely than older sheep.

Heavier animals will consume greater quantities of forage than lighter animals (Van Soest, 1982). Bines (1976) cited a high correlation ($r = 0.79$) between roughage DM intake and the live weight of dairy cows. Energy demands are proportional to metabolic body size ($Wkg^{0.75}$), thus energy needs per unit BW of smaller animals are greater than that for large ones (Allison, 1985). Therefore, a larger animal would have the ability to consume greater quantities of forage before reaching its reticulo-rumen capacity, when forage quality is the primary factor regulating intake. Van Soest (1982) suggested that ruminal gastrointestinal capacity is directly related to body size; that is, fill-limiting aspects of intake are linearly related to body size so that the amount of feed an animal

consumes is expressed as a percentage of body weight. Conrad et al. (1964) found that the intake of lactating cows varied in direct proportion to BW when the DM digestibility was below 66%.

Changes in intake are largely determined by alteration in physiological requirements of the animal. Bines (1976) observed increases in feed intake of pregnant non-lactating heifers. They attributed part of this increase to pregnancy and part to growth. Gut capacity is adequate for dry ewes to meet their energy requirements from roughages until 30 d before lambing (NRC, 1987). From conception until approximately day 120 of pregnancy the abdominal wall expands to accommodate the increase in uterine volume, but after this rumen volume decreases (Forbes, 1969). Meijs (1981) suggested that the effect of early and mid-pregnancy on the forage intake of cows is not well understood. Campling (1966, as cited by Allison, 1985) reported that cows, during the last six weeks of pregnancy, reduce their roughage intake by 12 to 15%. This is generally believed to be associated with the reduction in rumen capacity due to fetal growth (Meijs, 1981; Lewis and Shelton, 1983), but Forbes (1970) suggested that the reduced intake may be partly due to hormonal changes related to pregnancy (estrogen may depress intake during late pregnancy). Increased DM intake by lactating ruminants is well documented (Journet and Remond, 1976; Campling, 1966;

Allison et al., 1985). Lactating cows increase their DM intake (DMI) 25% or more during the first months of lactation in an attempt to adjust their energy intake to their energy needs (Journet and Remond, 1976). This significant increase in intake is provided for by the hypertrophy of the alimentary tract which occurs in lactating cows (Leaver et al., 1969). Campling (1970) suggested that this hypertrophy arises from endocrine changes associated with the beginning of lactation, but the mechanism is not understood.

There are two ways that adipose tissue contributes to the homeostatic balance of energy in the ruminant. First, the rate at which adipose tissue can synthesize triglycerides seems to be limited (Forbes, 1980). As this limit is approached, receptors sensitive to excess energy will tend to depress intake. Secondly, it has been proposed that "leakage" of fatty acids from adipose cells is positively related to their size. The fatter the animal, the stronger the feedback signal on energy availability (Forbes, 1980).

Forage

Forage intake of ruminants is also affected by factors associated directly with the forage resource. There is little evidence that palatability per se affects daily feed intake, but unpalatability can certainly reduce it (McClymont, 1957). McClymont (1957) also stated that the animal can recognize

plants by senses of sight, touch, taste and smell, although there is no relationship between odor and palatability. Plant selection depends on the quantity and quality of forage species, and will change with season and utilization of the species. The amount of fiber and green leaf present are among those factors associated with the quality of forage and hence its digestibility. Grazing animals select green material in preference to dry material (Arnold and Dudzinski, 1967). The selected material is usually higher in N and lower in fiber, signifying that chemical composition may be associated with physical characteristics of selected plant parts (Arnold and Dudzinski, 1967).

Arnold and Dudzinski (1967) found that one of the forage related factors most important in explaining variation in forage intake was forage digestibility. Van Soest (1965) reported that forage digestibility appears directly related to forage cell wall content. He stated that when cell wall content is high and the proportion of cell wall constituents increases, voluntary intake declines. Corbett et al. (1963) found that a decrease in forage digestibility from 80 to 68% resulted in a 5% reduction in DMI of grazing dairy cows with more of the intake reduction occurring at lower levels of digestibility. The amount of spines, plant morphology and excessive dead growth may inhibit accessibility to otherwise preferred forage. Arnold and Dudzinski (1967) concluded in

their study that when diets between two groups of sheep at different stocking rates were similar in quality and composition, DMI of the sheep with the lower stocking rate was significantly lower due to impenetrable pasture structure and the inability of the sheep to graze efficiently.

Meijs (1981) proposed that mineral content of forage may also be a forage factor related to intake. He concluded that phosphorus forage content had a significant positive effect on intake of grazing cattle, but sodium, calcium, and magnesium did not. Finger and Werk (1973 as cited by Meijs, 1981) found a positive effect of sodium content on forage intake. The effect of mineral content of forage on intake may depend on the particular requirements and deficiencies of an individual or group of animals.

Environment/Management

There are a number of factors related to environment and animal/forage management that can influence forage intake. The quantity of forage available to a grazing animal can obviously influence the quantity of forage consumed by the animal, but the level at which availability becomes a controlling factor appears to depend on the quantity and quality of forage (Allison, 1985). Havstad et al. (1983) reported that intake values for cattle grazing a diminishing supply of crested wheatgrass (digestibility of 33 to 43%) were

not significantly different when forage availability decreased from 920 to 140 kg ha⁻¹. This study indicates that under conditions where low forage quality limits DMI, the quantity of forage available to a grazing animal may not alter daily intake.

Social interaction and behavior of ruminants may also affect forage intake (Arnold, 1970; Meijs, 1981). McClymont (1957) discussed four learning processes that determine selectivity and consequently forage intake (excluding instinctive behavior exhibited by young animals). The first is allelomimetic or mimicking behavior most often displayed as imitation of the dam. Sheep diets of dams and their daughters differed less than unrelated sheep; dam/daughter groups tend to occupy the same area within the home range and hence graze the same plant communities (Meijs, 1981). It therefore appears that the numerous groups that comprise a flock of sheep do not occupy the same nutritional environment. Secondly, habit or preference due to previous experience has an effect on selectivity when animals are presented with a diverse forage resource. Experience can have a significant effect on intake. Intake of inexperienced sheep on pasture may be depressed by 50% for as long as 10 months (Arnold and Dudzinski, 1967; Arnold, 1970;). A third learned response to grazing is an avoidance of plants producing a negative response such as intoxication. The chances of an animal

learning from such an experience are diminished when the cumulative damage is slow acting and when a large selection of plants are available. Finally, habituation can cause an animal to reduce selectivity when repeated or continued exposure to a particular feed promotes addiction (Arnold and Dudzinski, 1967). Habituation can be accelerated by a nutrient deficiency or from a positive palatability problem.

Grazing ruminants interact socially with each other, mutually causing changes in grazing time and distribution. Sheep have shown a grazing hierarchy in which the weaker ewes are forced to disperse to the poorer patches of vegetation (Hunter and Milner, 1963). Social interaction plays an important but variable role in affecting grazing time. Tribe (1950) observed that sheep supplemented with grain grazed longer when mixed with unsupplemented sheep. Holder (1962) conducted similar experiments with sheep, but found that the unsupplemented sheep tended to decrease grazing and intake to match that of the supplemented sheep. The supplemented sheep were substituting concentrate for grazing, thereby reducing forage intakes and BW gain. The unsupplemented sheep merely followed suit and grazed with the supplemented group (McClymont, 1957).

Increases in feed intake due to cold stress are necessary to maintain energy balance and body temperature (NRC, 1987). The thermoneutral zone (TNZ) is the range of effective

ambient temperatures in which the heat from normal maintenance and production functions of the animal in nonstressful situations offsets the heat lost to the environment without requiring an increase in rate of metabolic heat production (NRC, 1987). Below the lower critical temperature (defined as the lower border of the TNZ), the animal must increase its metabolic rate in order to maintain body temperature. The lower critical temperature for a ewe with a 5 cm fleece is 9° C under maintenance conditions (Blaxter, 1967).

Grazing accounts for the largest percentage of energy expenditure, and temperature and wind velocity have effects on time spent grazing (Adams, 1984a). The greater the heat loss, the greater the increase in intake; however, the animals also become less efficient (Allison, 1985; McClymont, 1957; Young, 1980). Research has also shown a depression in the ability of ruminants to digest feed during cold stress, independent of feed intake. Digestibility decreases by about 2 percentage units per 10° C drop in ambient temperature (Young, 1980). After shearing, organic matter (OM) intakes rose 42-62% in grazing sheep (Wheeler et al., 1963). The increase was explained by an accelerated rate of energy metabolism induced by cold stress (4-27° C).

Huston and Engdahl (1983) reported that during the winter months when forage is dormant, fibrous, and low in digestibility, ewes had the greatest fill, longest retention

time, and slowest flow rate. Supplementing the ewes with a concentrate and increasing the amount of concentrate from 0 to 500 g d⁻¹ tended to decrease fill, shorten rumen retention time and increase flow rate. They suggested that DMI was limited during the winter by maximum passage of undigested residues. This would support his finding that FO was greatest during the winter months and not affected by supplementation.

General Trends

Cordova et al. (1978), in a review of forage intake, reported that most estimates of intake for sheep and cattle, grazing western U.S. ranges, lie between 1 and 2.8% of BW d⁻¹. Van Dyne et al. (1980) reported cattle DMI estimated from 51 different studies which used a variety of techniques to estimate forage intake. Forage intake estimates, expressed as a percentage of BW, ranged from a low of 0.96% for cattle grazing northern desert shrub in winter to a high of 3.2% for calves grazing ryegrass and white clover pasture during the growing season. From the estimates expressed on an OM basis, they reported averages of 2.4% and 2.1% for spring and summer grazing, respectively. Forage intake is often expressed on an OM basis because of high ash content of range forage (Cordova et al., 1978). From the estimates expressed on a DM basis, they reported averages of 2.1% for both spring and summer grazing. Harris et al. (1989) reported forage DM intake

values of 1.8% BW for mature ewes supplemented with a barley-soybean meal pellet and 1.7% for non-supplemented ewes in early to mid-gestation grazing Montana winter range. The importance of supplemental energy or protein in relation to voluntary intake of forages is becoming more evident. In a review by Allison, (1985) he stated that, in general, the addition of readily available carbohydrate to a low-quality roughage diet tends to decrease voluntary intake, while addition of protein tends to increase rate of digestion and forage intake. The increase in intake is usually attributed to increasing rumen microbial activity and consequently rate of passage. This will be discussed in a later section.

Supplementation

Need for supplementation

Throughout the Intermountain Region, native range provides much of the nutrient intake for gestating ewes during the winter. However, nutrient concentrations in winter range forages are often below that required to meet the nutritional requirements of grazing livestock (Harris et al., 1989; NRC, 1987). Winter range is low in crude protein (CP) and high in neutral detergent fiber (NDF; Michalk and Saville, 1979). Crude protein content of ruminal extrusa from sheep grazing winter range averaged 7% over two years (Harris et al., 1989). The NRC (1987) recommends 9.3% CP for a 60 kg ewe during the first 15 weeks of gestation. However, establishment of CP requirements in ruminants is complicated because CP supplied to the small intestine differs from the protein supplied by the diet (Karges et al., 1992). Pregnant ewes grazing the Intermountain winter range are commonly supplemented with .15 to .23 kg of a grain based supplement containing 16 to 18% CP to offset the nutritional deficiencies of the forage (Van Dyne et al., 1964).

Van Horn et al. (1959b) indicated it was profitable to supplement ewes grazing winter range two out of every three years. He suggested that any supplement was better than no supplement at all and the harsher the winter the better the

response to supplementation. Van Horn et al. (1959b) also reported that increasing the CP content of supplements increased ewe BW gain but did not also positively influence ewe productivity.

Effect of supplementation on passage rate, digestibility and N metabolism

One important characteristic of low-quality roughage is its low CP content (Michalk and Saville, 1979). Although sheep have the ability to select high CP forage, low CP levels in pasture will affect their performance because a dietary CP deficiency is associated with relatively low voluntary feed intake (Michalk and Saville, 1979). In protein-deficient diets, microbial activity may be depressed by a deficiency in ruminal N; this limitation retards the rate of removal of OM from the rumen which, in turn, may reduce intake (Michalk and Saville, 1979; Robinson, 1982). Low-quality forage intake is also restricted by low ruminal fiber digestibility (Hovell et al., 1986) increased gastrointestinal tract retention time, or a deficiency of either absorbed protein or protein relative to energy in digestion products (Coffey et al., 1989). Harris et al. (1989) reported that metabolizable energy (ME) intake of ewes grazing Montana winter range during midpregnancy was 80% of NRC (1985a) requirements. Low-quality roughages may not satisfy microbial or animal needs; therefore, increasing the

supply of energy or CP to either the ruminal microorganisms or the small intestine may be beneficial during midpregnancy (Hoaglund et al., 1992).

Protein supplementation of livestock grazing dormant forage has been shown to improve gains and reproductive performance through changes in forage digestibility and digesta passage (Kartchner, 1981). Feeding rumen degradable CP sources increases efficiency of microbial synthesis and/or microbial flow to the small intestine compared with ruminally undegradable proteins (UDP). These improvements may be due to increased ruminal ammonia concentrations or products of protein breakdown that are required for microbial growth (Cecava et al., 1991). However, it should be noted that attempts to increase roughage digestibility by N supplementation may be limited by the encrustation of cellulose by lignin in certain roughages (Abou Akkada and El-Shazly, 1958, as cited by Lyons et al., 1970).

Caton et al. (1988) reported that supplementing with a cottonseed meal pellet (45% CP - OM basis) increased neutral detergent fiber (NDF) disappearance in steers grazing dormant rangeland over steers not supplemented. However, rate of NDF disappearance was not different between the two groups. Hannah et al. (1991) found that higher DM digestion in steers supplemented with alfalfa pellets was a result of increased

passage rate of indigestible ADF rather than increased ruminal NDF digestibility.

A portion of the CP in any feedstuff is unavailable in the rumen, and bypasses or escapes to the lower gastrointestinal tract (Dunn, 1986). The amount of UDP or escape protein varies not only between feeds, but also within feeds due to feed processing and "animal, dietary, and microbial variables" (NRC, 1985a). NRC (1985a) defined three categories of feedstuffs based on their percentage of UDP: (1) low bypass (less than 40%) including soybean meal (SBM) and sunflower meal; (2) medium bypass (40 to 60%) including cottonseed meal and dehydrated alfalfa meal; and (3) high bypass (greater than 60%) including meat meal, feather meal (FM) and blood meal (BM).

Feather meal is a commercially available bypass protein source. Thomas and Beeson (1977) reported that steers fed FM had decreased ruminal ammonia concentrations and CP digestibility compared to those fed soybean meal. No differences were observed in N retention; however, steers fed FM retained more absorbed nitrogen. Murphy et al. (1992) concluded that FM is suitable as a winter range supplement as long as rumen degradable CP requirements are first met. They found that feeding low-quality roughage (2.5% CP) to cows supplemented with FM did not meet minimal requirements for ruminal degradable N and the cows lost body weight. Miner and

Petersen (1989) found that addition of BM to a SBM supplement fed to pregnant winter-grazing beef cows enhanced NDF fermentation rate, increased ruminal volume, and decreased ruminal dilution rate. They suggested that BM increased fermentation rate by supplying a slow release of amino acids or carbon chains that stimulated microbial activity. Hoaglund et al. (1992) reported that feeding BM resulted in greater N retention, increased blood albumin, protein, glucose, and blood urea nitrogen concentrations, wool growth, and ewe BW change when ruminal microbial requirements were compared to SBM and urea. Even though ME intake was 80% of NRC (1985a) requirements, nutritional status was improved by the addition of BM, most likely related to enhanced microbial activity or to increased protein reaching the small intestine for absorption. Dhuyvetter (1991) found that beef cows grazing winter range in Montana and fed 4.5 kg of hay daily lost less BW when 13% FM was included in a SBM-based supplement. When winter range was the only roughage source, cows had the same BW losses when supplemented with SBM or 13% FM plus SBM.

Padula et al. (1992) reported that carbohydrate source influenced ruminal microbial protein production and ewe metabolism during mid-gestation. He found that ewes responded better to UDP when fed a high cellulose diet rather than a high starch diet. The high starch diets probably optimized microbial protein production, which minimized the benefit of

UDP in the small intestine. He concluded that supplements fed to ewes consuming low quality roughages should contain a high proportion of starch, and that when cellulose is the primary carbohydrate source, protein utilization is improved by feeding bypass protein. Schloesser et al. (1993) concluded that substituting SBM with BM did not enhance nutritional status of pregnant ewes, probably because the diets supplied adequate ruminal ammonia for microbial protein synthesis.

Decreased fiber digestion observed with feeding energy supplements may be due to less attachment of cellulolytic bacteria to fiber particles as ruminal pH decreases or to the preferential fermentation of nonstructural carbohydrates by ruminal bacteria (Cecava et al., 1991; Wedekind et al., 1986). Mertens and Loften (1980) suggested that starch supplementation could increase the lag time before active fermentation began by colonizing supplements before colonizing forage, which may reduce digestibility of fiber. Lag time describes the initial fermentation period when digestion does not occur or occurs at a reduced rate.

Rittenhouse et al. (1970) reported that energy supplementation slightly depressed DMI, presumably because microorganisms preferred the readily available carbohydrate source over the forage, but that forage DM digestibility was not altered by supplementation. Also, total feed intake was increased with successive increments of energy

supplementation. The adverse associative effect of concentrate feeding on cell wall digestion in the reticulo-rumen also influences the relative importance of the sites of digestion (Doyle et al., 1988). Concentrate supplementation of oat hay fed to lambs decreased OM digestion and NDF digestion from 76% to 65% and 76 to 68%, respectively, in the reticulo-rumen, thereby increasing the importance of cell wall digestion in the large intestine.

Effect of supplementation on forage intake

In addition to improving N balance, diet digestibility, and rate of passage, supplements have been shown to affect intake of forage (Allison, 1985) and grazing activity (Adams, 1985). Milford and Minson (1965 as reviewed by Allison, 1985) found forage intake of sheep declined when dietary CP fell below 7%. However, intake and dietary CP concentrations were not highly associated when dietary CP concentration was above 7%. Apparently dietary CP below 7% did not meet the N needs of the ruminal microbial population (Van Soest, 1982).

Harris et al. (1989) used indigestible NDF as an internal marker to determine forage intake of pregnant ewes grazing Montana winter range. They reported that ewes consumed 1.6 to 2.0% of their BW daily in forage. Supplementation with .15 kg hd^{-1} daily of an 18% CP barley-based pellet had no effect on DMI over unsupplemented ewes; however, supplemented ewes had

improved nutrient retention throughout the winter and entered the lambing season in better body condition than unsupplemented ewes.

In a review, Allison (1985) indicated that evidence is accumulating on the importance of supplemental protein and energy on voluntary intake of forages. Generally it has been found that addition of readily available carbohydrates to a roughage diet decreases voluntary intake (Elliot, 1967; Allison, 1985) due to a substitution effect. Conversely, addition of protein supplements to low-quality roughage diets (below 8 to 10% CP) increases voluntary intake and digestibility (Elliot, 1967; Andrews et al., 1972; Allison, 1985). Forage intake increases due to protein supplementation are usually associated with increased rumen microbial activity and consequently increased rate of passage.

McCall (1940) enhanced digestibility and intake of a mixture of mature range grasses by feeding a protein meal supplement, but digestible energy intake was greatest when a barley supplement was fed. Cook and Harris (1968a; as cited by Allison, 1985) found that protein supplements tended to enhance intake and digestibility of winter forage by sheep and cattle, whereas energy or energy plus protein generally decreased DMI and digestion or had no effect on intake. They concluded that protein supplements tended to enhance both DMI

and digestibility of range forage, while grain supplements had a negative effect on both.

Several studies have shown that protein supplements can increase the intake of low CP feed (Clanton and Zimmerman, 1965; Cook and Harris, 1968a). Michalk and Saville (1979) reported that when CP is the limiting nutrient, protein supplements tended to enhance both palatability and digestibility of the low quality ration. Branine and Galyean (1985) reported increased passage rate, decreased turnover time and increased intake when steers grazing mature blue grama rangeland were fed .5 kg of corn hd^{-1} daily compared with steers fed no supplement or 1 kg of corn hd^{-1} daily. However, this effect is not always seen (Rittenhouse, 1970). The intake response seems to be dependent upon forage CP concentration.

Lyons et al. (1970) found that replacing barley with SBM in cattle fed barley straw (2.8% CP) increased voluntary intake. They suggested that increasing the supplement CP content increased crude fiber digestibility, thereby decreasing ruminal turnover time. Supplemental CP has a dual role in controlling voluntary intake of straw: first, in the metabolism of fermentation products at tissue level, and second, in the promotion of ruminal fermentation (Lyons et al., 1970). They concluded that cattle not supplemented were limited in intake by a primary protein deficiency at the

tissue level, rather than by the capacity of the digestive tract. When this deficiency was corrected by protein supplementation, it is probable that digestive tract capacity was the limiting factor.

Cold weather stimulates rate of passage in the reticulo-rumen (Miner, 1986), rumen volume decreases during pregnancy, and lignin and cell wall constituent contents are high in winter range forage while CP concentration is low (Cook and Harris, 1968b). Given these factors, particle size reduction of indigestible fiber in the rumen would appear to be the limiting process in removing material from the rumen and allowing further intake (Welch, 1967). The two methods of achieving particle size reduction are rumination and microbial fermentation (Dunn, 1986). Rumination is a process directly controlled by the animal in response to the fiber fraction of the forage. The time spent ruminating has shown a strong correlation to the cell wall constituent concentration of feed (Welch, 1967). Microbial fermentation relies on the activity and numbers of rumen microflora. Any factor, including all those mentioned above, that decrease microflora activity or numbers can be expected to decrease DM digestibility (Dunn, 1986). The positive effect of protein supplementation on intake may be due to a positive effect on microbial activity (Campling et al., 1962; Egan, 1965). Protein supplementation allows the optimization of microbial synthesis, microbial

numbers, and activity as the available N content of the diet increases above that available in the forage (Arias et al., 1951; Dunn, 1986).

The benefits of UDP result from an increase in essential amino acids available to the animal in the small intestine and greater true digestibility of quality proteins compared to digestibility of CP from rumen microbes (Van Soest, 1982). However, as protein bypass or escape increases, the optimization of microbial synthesis, numbers, and activity is not possible, and the positive forage intake effect seen with rumen degradable protein supplements is less likely (Dunn, 1986).

Experiments where supplemental energy (carbohydrate) was fed have generally shown a decrease in forage intake due to a substitution of the supplement for forage (Holder, 1962; Elliot, 1967; Rittenhouse et al., 1970; Bellows and Thomas, 1976; Allison, 1985). Huston (1983) reported that forage intake declined as supplemental feed (cottonseed meal-sorghum grain) increased in ewes grazing winter range, suggesting that supplement substituted for forage and passage rate of undigested residues from the rumen imposed a limitation on intake. Energy supplements have been shown to decrease the digestion of cellulose and other carbohydrates (Cook and Harris, 1968a). When feeding high energy-low protein supplements, Rittenhouse et al. (1970) reported that the lower

the quality of the forage, the lower the magnitude of the depression in voluntary intake. Michalk and Saville (1979) reported that even though energy may be inadequate in range forage, supplying carbohydrate should be done with caution since the provision of easily digested carbohydrate can depress the utilization of fiber. They recommended supplying only enough energy supplement to increase forage consumption, but not to replace it. Sultan and Loerch (1992) supported this when they concluded that the addition of 10% starch to a straw-based diet had no effect on fiber digestion, but 30% starch depressed fiber digestibility. This negative effect was due primarily to pH inhibition of fiber fermentation.

Studies where combinations of energy and protein were fed are inconclusive. Clanton and Zimmerman (1965) fed combinations of protein and energy to cows, but reported no significant differences in DM intake or digestibility when averages for supplemented groups were compared to the unsupplemented group. Turner (1985) found increased forage intake of range with 1.8 kg d⁻¹ of a 15% CP supplement, but when half that same supplement and 0.9 kg d⁻¹ of a 30% CP supplement were fed, no increase in intake over controls (no supplement) was seen. Speth et al. (1960) concluded that feeding a combination of energy and protein in a supplement was the most effective way to maintain cow BW when the

quantity and quality of the range forage was poor during the winter period.

Kartchner (1981) supplied a protein and an energy supplement to grazing cows during two successive winters. The first winter was mild with readily available forage; no intake advantages were noted for either supplement. The second winter was more severe; intake and DM digestibility were enhanced by protein supplement, but depressed with energy supplement. They concluded that providing a CP supplement to range cattle grazing a mixed shrub-grass vegetation during the winter enhanced DM intake and digestibility under certain conditions of forage quality and availability, such as a severe winter when grass availability was limited. His study provided an explanation for differences in response to supplementation under different range conditions.

Supplemental effects can also be affected by the timing of supplementation. Kartchner and Adams (1982) and Adams (1984b) reported that cows grazing Montana winter range that were supplemented daily gained BW and condition while those supplemented on alternate days gained less BW and lost body condition. These findings were attributed to the effects within the rumen. Alternate day feeding reduced pH and increased VFA concentrations. Lower ruminal pH reduced fiber digestion which could account for the lower weight gain.

Thomas et al. (1990a), however, found that although alternate

day supplementation of pregnant ewes grazing Montana winter range resulted in greater BW losses than ewes supplemented daily, there were no adverse effects on reproductive performance or lamb production.

Adams (1984a, 1984b) also studied the effect of time of day of supplemental feeding. Steers fed in the early afternoon spent less time grazing, but consumed more forage, and had a higher average daily gain than morning-fed steers. The author suggested that feeding supplement in the morning disrupted normal grazing activity and affected both behavior and performance. Energy supplementation during intensive grazing periods interrupt grazing time, thereby reducing forage intake and animal performance (Adams, 1985). Further, supplementation during intensive grazing bouts may increase ruminal ammonia concentrations at a time when ruminal ammonia concentrations are already increasing as a result of degradation of forage protein nitrogen (Barton et al., 1992). However, Barton et al. (1992) concluded that even though morning supplementation of cottonseed meal caused greater spikes in ruminal ammonia concentration than afternoon supplementation, no improvements in intake, digestion, or digesta kinetics were noted with time of supplementation.

The addition of small amounts of urea has been shown to stimulate intake and digestibility of extremely low quality forages (Campling et al., 1962; Egan, 1965). Campling et al.

(1962) found that urea infusions increased voluntary DMI of wheat straw by approximately 40% and OM digestibility from 41% to 60%. Bhattacharya and Pervez (1973) reported that substitution of SBM with urea did not result in any marked improvement in the digestibility of the rations containing either barley hay or wheat straw fed to sheep. Umunna (1982) reported that urea-sprayed straw (12% protein) fed to sheep improved voluntary intake and daily gains over that of untreated straw. He suggested that the added N improved the nutritional environment of the rumen which in turn would stimulate microbial proliferation and activity leading to the increased DM digestibility observed.

Effect of winter supplementation on ewe productivity

The influence of nutrition of the breeding ewe on growth and survival of progeny has long been recognized as important (Darroch et al., 1950). Several studies reported that extremes in nutrition during pregnancy affect lamb birth weight (Darroch et al., 1950; Fogarty et al., 1992). Thompson and Fraser (1939, as cited by Darroch et al., 1950) noted that the lighter birth weight lambs resulting from a low plane of ewe nutrition lacked vitality and reported that concentrate feeding one month prior to lambing corrected this effect. Darroch et al. (1950) reported that feeding .50 lb. of beet pulp pellets increased fleece weights .37 lb. over that of

non-supplemented ewes and decreased lamb mortality up to weaning thereby increasing the number of lambs weaned.

Early work by Chittenden et al. (1935) reported that production of gestating Rambouillet ewes grazing dormant winter range supplemented with either corn, cottonseed cake, or a 25% CP pellet ($.15 \text{ kg hd}^{-1}$ daily) was similar to those not supplemented. They concluded that there was no advantage to supplementation, although ewe body condition can affect supplementation response.

Harris et al. (1956) reported that supplementing pregnant ewes grazing winter desert range of Utah with 256 g hd^{-1} soybean oil meal on alternate days improved maintenance of BW, clean wool yield, and lamb crop while supplementing with 128 g hd^{-1} soybean oil meal or barley (182 or 345 g hd^{-1}) were beneficial in maintaining BW only. They concluded that ewes in good condition could lose some BW during the winter grazing season and still produce effectively. Supplementation decreased BW losses and slightly increased lamb crop; however, they concluded that it may not be economical to feed the band as a whole, but rather to separate by age and body condition.

Van Horn et al. (1959b) concluded that it was profitable to feed a moderate amount of supplement (11% CP during the first half of the winter and 30% CP during the second half) two out of three years. Supplementing with $.15 \text{ kg hd}^{-1}$ daily of a pellet (four treatments- 11%, 20%, 30% or 35% CP) reduced

the percentage of dry ewes and lambs lost from birth to weaning. The non-supplemented treatment group had the highest percentage of non-pregnant ewes, the lowest percentage of lambs weaned and lost an average of 3.0 kg of BW each winter. Increasing the supplement level from 11% to 35% increased birth weight and weaning weight of lambs; however, these measurements varied greatly from one year to the next, so environmental conditions may play a role in these responses (Van Horn et al., 1959b). Van Horn et al. (1959a) concluded that most winters it pays to feed some kind of supplement, but returns do not increase in relation to the increase in protein content of the pellet because of the greater cost for high protein supplements.

Thomas et al. (1989) reported that ewes supplemented with an 18 to 20% CP pellet on alternate days while grazing Montana winter range gained less BW and had less lambs born per ewe exposed to the ram, although no differences were detected in lambs weaned compared with those supplemented on a daily basis. They speculated that lower reproductive rate in those fed on alternate days may be related to reproductive wastage.

Thomas et al. (1990b) reported that feeding $.23 \text{ kg hd}^{-1}$ daily of a 20% CP pellet to pregnant ewes grazing winter range improved BW change and grease fleece weights over those fed $.15 \text{ kg hd}^{-1}$ daily of the same supplement. However, level of supplement had no effect on reproduction, lamb mortality, and

lamb performance. They concluded that feeding $.15 \text{ kg hd}^{-1}$ daily was satisfactory to maintain ewe BW during the winter. Wilkinson and Chestnutt (1988) recommended that some level of restriction in mid-gestation followed by a high plane of nutrition in the last few weeks leads to a maximum birth weight and lamb viability.

Thomas et al. (1992;1993) reported that supplementing gestating ewes grazing Montana winter range with either protein or energy had no effect on ewe productivity, although supplementation improved BW changes and condition score. They showed no advantage to winter supplementation but noted that mild winter conditions and high body condition score of the ewes entering the wintering period may have contributed to lack of supplementation responses.

The diet of pregnant ewes grazing winter range is influenced by diet selection, passage rate, and digestibility. Supplementation generally has a positive effect on ewe BW change, but effects on ewe productivity are inconclusive. Forage intake is influenced by environment, digestibility, and can perhaps be enhanced or inhibited by supplementation. Since environmental conditions often influence ewe response to supplementary feeding, this should be taken into consideration when selecting a winter supplement. When ewes enter the wintering period in high body condition and/or the winter is

relatively mild, supplementation may not be as critical as when the winter is harsh or ewes are in moderate to poor body condition.

Chromic oxide-continuous release bolus

The search for an indirect method to accurately measure forage intake and digestibility by grazing ruminants has been in progress for many years. Voluntary forage intake estimates are derived by measuring fecal output and diet indigestibility (Krysl et al., 1988). Chromic oxide (Cr_2O_3) has been widely used as an indigestible marker for estimating FO and hence forage intake of grazing animals (Raleigh and Kartchner, 1980; Carruthers and Bryant, 1983; Hatfield et al., 1991a). Early research with the Cr_2O_3 gelatin capsules (GC) showed diurnal variation of Cr_2O_3 excretion in the feces (Lambourne and Reardon, 1963a). They concluded that irregular excretion of Cr_2O_3 administered in GC is due primarily to the rapid passage of a large proportion of each dose through the reticulo-omasal orifice with only a relatively small proportion becoming mixed in the reticulo-rumen with the feed residues it is intended to mark. Incorporation of Cr_2O_3 in paper (Corbett et al., 1958) reduced diurnal variation; however, this form of Cr_2O_3 is not commercially available. Harrison et al. (1981) patented a controlled release device (CRD) which is retained in the rumen and releases Cr_2O_3 at a controlled and constant rate, thereby reducing the problem of diurnal variation. The CRD offers additional advantages of reduced labor, easier use of female animals,

longer sampling periods, and the possibility of preventing adverse effects on animal behavior from repeated daily dosing or from the presence of fecal bags during collections (Buntinx et al., 1992; King et al., 1992).

Diurnal Variation

A serious problem in using Cr_2O_3 as an external marker has been uneven excretion patterns (Smith and Reid, 1955; Hopper et al., 1978; Nicoll and Sherington, 1984). The first solution was the use of Cr_2O_3 impregnated paper. It was believed that the paper would flow more evenly with the digesta and less sedimentation would occur. Kiesling et al. (1969) disproved this theory, reporting that paper was no better than Cr_2O_3 GC in reducing diurnal variation of fecal grab samples. The CRD seems to have eliminated much of the variation in daily Cr_2O_3 excretion since the Cr_2O_3 is more uniformly distributed by the CRD over that of daily dosing (Ellis et al., 1981).

Parker et al. (1989) determined that diurnal variation in fecal Cr concentrations using the CRD was not significant (coefficient of variation of 8.3%) in a study using sheep grazing different herbage types and levels of intake; therefore time of fecal collection was not critical. This value corresponds to the 6.2% coefficient of variation reported by Ellis et al (1981) on days 3-15 of their trial.

Diurnal variation in fecal Cr concentration is unlikely to be completely eliminated (Lambourne and Reardon, 1963b). Brandyberry et al. (1991) found little diurnal variation with the CRD, but also found that it overestimated total fecal output by 25 to 35%. This could have resulted from either overestimation of the release rate by the manufacturer or incomplete recovery of the Cr_2O_3 . Parker et al. (1989) may have overcome this problem by placing three boluses in ruminally fistulated wethers, thus minimizing bolus variation and increasing the concentration of chromic oxide in the feces (Hatfield et al., 1991b).

Furnival et al. (1990a) compared diurnal variation of Cr_2O_3 administered in a GC vs CRD. The GC was more accurate when pooling fecal samples together over several days. However, when a single fecal grab sample was taken in a particular time period and compared to a composite fecal sample in the same time period, it was found that the CRD was more reliable than the gelatin capsule. They found that the CRD had a significantly lower diurnal variation than the GC, 12.6% versus 29.2%, respectively. Lower diurnal variation with the CRD was reflected in less bias between Cr estimated fecal output and estimation of fecal output from analysis of a representative fecal sample. The CRD had lower standard deviations, therefore one sample collected daily from a CRD

dosed animal would provide a better estimate of fecal output than several daily samples collected from a GC dosed animal.

Hatfield et al. (1991a) evaluated penned sheep either dosed twice daily with Cr_2O_3 GC or administered "Captec" CRD. They did not compare single grab samples individually as Furnival et al. (1990a), but composited two rectal samples across time and day for each animal in the trial. The CRD was found to be inaccurate in 1 of 3 trials in estimating total FO and the GC was inaccurate in 2 of 3 trials. They concluded that neither method was consistently accurate in feeding trials and recommended verifying Cr_2O_3 in the feces with a subset of bagged animals.

Adams et al. (1991) reported that rectal grab samples varied less from total fecal collections than composite fecal samples in grazing steers due to diurnal variation. Both total fecal collection and CRD require multiple days and animals, and the accuracy increases with an increase in the number of days sampled. Days sampled depends on two factors: 1) number of days for which an estimate of fecal production is desired, and 2) the degree of accuracy with which fecal production is to be estimated.

CRD Release Rate

Early work completed with the CRD in sheep (Laby et al., 1984) shows that intraruminal capsule technology has the

potential to surpass existing methods of intake measurement because the uniform release of Cr_2O_3 into the rumen decreases diurnal variation of the marker in the feces when compared to gelatin capsules or Cr_2O_3 impregnated paper. However, early studies did not cover the range of environments the CRD would encounter and whether the CRD would perform similarly under different environmental conditions.

Laby et al. (1984) performed experiments with penned and grazing sheep as well as grazing cattle that were dosed with a continuous release device. In comparing actual and projected release rates, they reported correlation coefficients of .997 for grazing animals. Also, estimated fecal output equalled actual fecal output within 4%. They concluded that release rate was independent of diet, age of animal, whether the animals were penned or grazing, and whether or not the CRD was tethered in the rumen; therefore, the CRD is an accurate method of estimating fecal output.

Barlow et al. (1988) also verified the release rate of the CRD not by total fecal collection but by using 73 Hereford steers maintained on three different pasture types that were bolused and later slaughtered. They confirmed release rates by comparing the plunger travel of the CRD from the slaughtered animals across pasture types. They found the release rate to be accurate across all three pasture types (high, medium, and low nutritive value). In contrast,

Furnival et al. (1990b) concluded that there were significant differences in CRD plunger movement between pastures varying in herbage mass when they used cows grazing varying pasture types. Their data suggests a statistical relationship between plunger movement and fecal DM. They suggested that plunger rate increases as fecal DM increases. Parker et al. (1989) concluded that CRD exposed to the same environment perform similarly in sheep. They also studied the effects of herbage type and amount on the CRD release rate in crated sheep and found that plunger travel tended to increase with decreasing DM digestibility. These findings coincide with those of Furnival et al. (1990b) but directly conflict with those of Barlow et al. (1988). Perhaps the contradiction may be explained in part by a physical massaging effect on the orifice of the CRD by more fibrous feeds, causing more dissolution of the Cr_2O_3 matrix in the capsule.

Hatfield et al. (1991b) concluded that the CRD provided better estimates of fecal output in grazing wethers than in confined wethers. He suggested several explanations: first, DMI patterns of grazing animals are more constant than those of confined animals which are generally fed a specified amount of feed once daily. Second, variation in Cr_2O_3 release among animals may result from differences in the mixing action of the rumen caused by differences in diet or levels of DMI. He concluded that Cr_2O_3 should be used on a comparative basis.

only within a trial and no comparisons should be made across trials.

Buntinx et al. (1992) found that there are problems in the bolus release rate in grazing wethers. Even though the data of Parker et al. (1989) supported the use of the CRD to provide a meaningful estimate of animal intakes in a group situation, Buntinx's results indicated that even as a group, correlations between estimated and actual fecal output were not adequate for experimental purposes. They concluded that variability in estimated fecal output was greater across days than variability across animals, suggesting that the only acceptable grouping of variables was by animal, not by day. King et al. (1992) supported these findings in a study designed to evaluate the precision and accuracy of measuring fecal output by the CRD. However, they suggested that total fecal collections may be biased due to fecal losses resulting from extensive travel of the steers. They concluded that the CRD did not accurately predict fecal output, however, the precision of the CRD was acceptable and not affected by diurnal variation. Therefore, they supported Hatfield et al.'s (1991a; 1991b) conclusions that the CRD could be used to predict fecal output on a group of animals if a correction is made for actual Cr release rate using a small sub-set of animals.

Conclusions Relating to the Use of the CRD

The CRD appears to be quite effective in eliminating diurnal variation as well as minimizing stress. However, the CRD tends to overestimate FO in most cases. Despite the problem of accurately estimating FO with precision in some trials, it is a good tool to make group comparisons of FO on similar forage. The results should only be used within a trial and not compared across experiments. In cases needing accurate measurements of FO, the CRD needs to be calibrated, perhaps with the use of cannulated animals, and actual fecal collections should be obtained on a subset of animals.

EXPERIMENTAL PROCEDURE

Two forage intake experiments were conducted at the Montana State University Agricultural Experiment Station, Red Bluff Research Ranch near Norris, Montana. The first experiment was conducted from December 17, 1991 to March 7, 1992 and Experiment 2 was from December 22, 1992 to March 5, 1993. Elevations range from 1402 to 1889 m, and annual precipitation ranges from 35.5 to 43.1 cm. Weather data for each study are shown in Table 1. Vegetation is a typical foothill bunchgrass type. Bluebunch wheatgrass (Agropyron spicatum) and Idaho fescue (Festuca idahoensis) are the major grasses. Rubber rabbitbrush (Chrysothamnus nauseosus), fringed sagewort (Artemisia frigida), lupine (Lupinus spp.), milkvetch (Astragalus spp.) and western yarrow (Achillea millefolium) are commonly occurring shrubs and forbs (Harris et al., 1989).

Forty-eight Targhee ewes were selected for uniformity in age and BW each year. Following breeding, ewes were randomly allotted to one of six supplement treatments (Table 2; Table 3). Treatments during Year 1 were: 1) no supplement (CON); 2) corn supplement; 3) barley supplement (BAR); 4) soybean meal supplement (SBM); 5) blood meal plus feather meal supplement (BM+FM); and 6) feather meal plus urea supplement (FM+U). Year 2 supplements were similar to Year 1 except for

Table 1. Weather data from approximately 2 miles east of site

	Snow cover	Temperature ^a (°C)	Wind Speed ^b (kph)
1991-92^c			
Period 1			
January			
8		-13 to -3	8.6
9	Open; snow	-12 to 0	11.7
10	in	-6 to 2	16.8
11	coulees	0 to 6	8.7
12		-4 to 4	6.1
Period 2			
February			
9		-5 to 9	9.0
10		-5 to 8	4.6
11	Open; snow	-7 to 4	3.1
12	in	-7 to 3	10.5
13	coulees	-1 to 9	6.8
1992-93			
Period 1			
January			
8		-17 to -12	3.5
9	Open; snow	-28 to -16	3.5
10	in	-32 to -20	0.7
11	coulees	-24 to -15	2.1
12		-30 to -13	0.6
Period 2			
February			
6		-1 to 9	5.7
7	2 to 10	1 to 8	4.5
8	cm	-5 to 7	2.6
9	of snow	-6 to -2	2.7
10		-8 to -2	1.9

^a Temperature averages from daily low to daily high.^b Daily average.^c Minimal snow cover throughout winter.

substitution of dehydrated alfalfa pellets (ALF) for the corn supplement. Alfalfa replaced corn because no differences were detected between corn and barley during Year 1, barley is a more readily available energy source than corn in Montana and dehydrated alfalfa pellets are used as a winter supplement by some producers, but have not been evaluated in a controlled experiment.

Supplement intakes are expressed on a daily basis, although supplements were group-fed on alternate days at

Table 2. Supplement ingredient composition (dry matter basis)

Ingredient	Supplement ^a					
	Corn	ALF	BAR	SBM	BM+FM	FM+U
	-----%					
Alfalfa		100				
Barley			91.9		36.7	47.3
Corn	90.6					
Molasses, beet	2.7		2.7	5.3	5.4	5.4
Soybean meal				88.2		
Feather meal					28.0	25.3
Blood meal					18.1	6.8
Urea						3.5
Bentonite	1.8		1.8	1.8	1.8	1.8
Trace mineral salt ^b	0.4		0.4	0.4	0.5	0.5
Dicalcium phosphate	0.6		1.4	1.9		
Sodium phosphate					3.0	3.0
Sodium sulfate	1.7		2.1	2.4	3.7	4.0
Potassium chloride	0.9		1.2		2.8	2.8

^a ALF = alfalfa; BAR = barley; SBM = soybean meal; BM+FM = blood meal plus feather meal; FM+U = feather meal plus urea; corn supplement fed only in 1991-92 and alfalfa only in 1992-93; Se, 3.3 ppm in Corn, ALF and BAR supplements and 6.0 ppm in SBM, BM+FM and FM+U supplements; Vitamin A incorporated at 20,000 IU kg⁻¹ in corn and BAR and 40,000 IU kg⁻¹ in SBM, BM+FM and FM+U.

^b Composition of trace mineral salt: NaCl, 98%; Zn, .35%; Mn, .28%; Fe, .175%; Cu, .035%; I, .007%; Co, .007%.

Table 3. Supplement chemical composition and digestibility (dry matter basis)

Item	Supplement ^a					
	Corn	ALF	BAR	SBM	BM+FM	FM+U
	-----%-----					
1991-92						
CP	14.5		13.4	29.6	49.8	45.1
NDF	14.1		14.3	11.7	21.0	19.8
ADF	5.2		6.6	6.4	16.4	13.2
ADIN ^b	0.11		0.02	0.07	1.57	1.07
ME, Mcal/kg ^c	2.9		3.0	2.9	2.6	2.6
Sulfur	1.6		1.9	2.7	3.1	3.8
Ash	8.8		7.8	11.1	12.0	11.9
IVDMD	78.4		79.8	82.4	72.1	73.5
In vitro OM digestibility	73.0		70.4	66.7	79.3	80.0
1992-93						
CP		17.4	13.7	33.7	46.0	44.0
NDF		44.5	17.7	13.5	25.0	22.0
ADF		34.3	6.4	8.6	11.4	9.5
ADIN ^b		0.20	0.11	0.10		
ME, Mcal/kg ^c			3.0	2.9	2.6	2.6
Sulfur		0.3	0.4	1.0	1.4	1.2
Ash		9.9	6.1	11.1	13.4	12.8
IVDMD		53.6	80.7	74.5	75.7	79.5
In vitro OM digestibility		50.2	73.4	59.4	79.8	86.8

^a ALF = alfalfa; BAR = barley; SBM = soybean meal; BM+FM = blood meal plus feather meal; FM+U = feather meal plus urea.

^b Crude protein equivalent.

^c Calculated from NRC (1987) values.

0700h (Table 4). Alfalfa, corn and BAR supplements were fed at a rate of .33 kg hd⁻¹ on alternate days. Thomas et al. (1990b) reported that no differences were detected in ewe productivity by supplementing pregnant ewes on alternate days versus daily. Soybean meal, BM+FM and FM+U were fed at .15 kg hd⁻¹ on alternate days to provide approximately 30 g of CP

since Harris et al. (1989) determined that ewes grazing Montana winter range were deficient in CP intake by approximately 30 grams. In addition, the SBM, BM+FM and FM+U supplements cost approximately twice as much as the ALF, BAR and corn supplements, therefore we felt that for the protein supplements to be cost effective they would need to be fed at 50% of the feed intake level of the grain and ALF supplements with the same production response. Supplements for Year 1 were pelleted (0.9" diameter) while Year 2 supplements were extruded (1.1" diameter). Daily CP and ME intakes of the corn, BAR, and ALF supplements were approximately 18 g of CP during Year 1, 20 g of CP during Year 2, and .38 Mcal of ME (both years), respectively (Table 3). Daily intakes of CP and ME from the BM+FM and FM+U supplements were 28 g of CP during Year 1, 27 g of CP during Year 2, and .15 Mcal of metabolizable energy (both years), respectively. Soybean meal was formulated to be isonitrogenous and isocaloric to the BM+FM and FM+U supplements, however, SBM only provided approximately 18 g of CP during Year 1, 20 g of CP during Year 2, and .15 Mcal of ME (both years). Therefore it was isonitrogenous to the energy supplements (BAR, corn) but isocaloric to the protein supplements (BM+FM, FM+U).

Approximately 83% of the total protein in the BM+FM supplement was rumen undegradable protein (UDP) from BM and feather meal. In the FM+U supplement, approximately 75% of

Table 4. Supplement dry matter and nutrient intake by ewes

Item	Supplement ^a					
	Corn	ALF	BAR	SBM	BM+FM	FM+U
1991-92						
DM, g/d	130		130	60	60	60
Nutrient intake						
CP, g/d	18.9		17.5	17.7	29.9	27.1
ME intake, Mcal/d	0.38		0.39	0.18	0.15	0.15
1992-93						
DM, g/d		130	130	60	60	60
Nutrient intake						
CP, g/d		22.6	17.8	20.2	27.6	26.4
ME intake, Mcal/d		0.38	0.39	0.18	0.15	0.15

^a ALF = alfalfa; BAR = barley; SBM = soybean meal; BM+FM = blood meal plus feather meal; FM+U = feather meal plus urea.

the total protein was UDP from BM and FM while 13% of the total protein was from urea. Urea was incorporated to determine if increasing ruminally degradable protein enhanced forage intake.

Supplementation began approximately 120 d prior to lambing (Year 1, December 17, 1991; Year 2, December 22, 1992) and continued for approximately 84 days (year 1, March 7, 1991; year 2, March 5, 1992). All ewes were weighed on two consecutive days at the beginning of the trial and two consecutive days at the conclusion of the trial in March. Ewes were also assigned a body condition score at the beginning and conclusion of the trial. Body condition was based on a scale of 1 to 5 with a score of 1 designating an emaciated ewe and 5 designating an obese ewe (Russel et al.,

1969). Ewes were shorn at the end of the wintering period and fleece weights recorded. At the conclusion of the wintering period, ewes were managed similarly and fed 2.3 kg of alfalfa hay and .23 kg of barley grain until lambing. Following lambing, a similar quantity of hay was fed, however, ewes suckling single or twin lambs were fed .34 kg or .68 kg of barley grain, respectively, until turnout on summer range (June 1, 1992; May 29, 1993). Ewe BW and body condition scores were also recorded at turnout on summer range and at weaning (August 31, 1992). Lamb BW were recorded at birth, turnout on summer range, and at weaning. All Suffolk sired lambs were castrated.

Two 5-d collection periods were conducted during the winter trial; one in January and the other in February. Five days prior to and during each collection period ewes were individually penned for approximately 1 hour at 0700 h and fed their respective supplements. Ewes were maintained and group-fed their supplements between collection periods with a flock of approximately 520 western whiteface ewes that were being fed similar supplements. After supplementation, all animals were turned out onto winter range as a single group and allowed to graze for the remainder of the day.

Supplement samples were collected, ground through a 1 mm screen in a Wiley mill, and analyzed for DM, ash, CP, sulfur (AOAC, 1984), NDF, ADF (Van Soest and Wine, 1967) and ADIN

(Goering and Van Soest, 1970). Diet samples were obtained using total rumen evacuation (Lesperance et al., 1960). The evacuation steps included 1) removal of ruminal and reticulum contents and washing rumen walls with water, 2) release of animals to graze for a sufficient time period to obtain an adequate sample (90 min), 3) removal of grazed forage from the rumen, and 4) return of original ingesta into the animal. Extrusa samples were collected three times during each collection period from three ruminally fistulated ewes maintained with the flock. Fistulated and non-fistulated animals of similar history and nutritional background do not differ in grazing behavior or diet selection (Forbes and Beattie, 1987), therefore the extrusa samples were used for diet nutrient analysis. Ruminally fistulated animals were used rather than esophageally fistulated ewes due to the stressful conditions on winter range. Extrusa samples were hand-squeezed to decrease salivary contamination, frozen and later freeze-dried. Samples were then composited within ewe and period, ground through a 1 mm screen in a Wiley mill and analyzed for DM, ash, CP, sulfur (AOAC, 1984), ADIN (Goering and Van Soest, 1970), NDF, and ADF (Van Soest and Wine, 1967). Dry matter and OM digestibilities of supplements and DM and NDF digestibilities of the extrusa samples were determined in a 48-hour fermentation by the two-stage in vitro procedure of Tilley and Terry (1963). Forage samples were also hand-

clipped during Year 1, oven dried, and analyzed for DM and CP in order to compare them with the ruminal extrusa samples.

Blood samples were collected via jugular puncture (Lindsay, 1978) once during each period on a non-supplementation day. Serum samples were analyzed for total protein (PROT), creatinine (CRE), urea nitrogen (SUN), albumin (ALB), and glucose (GLU) Year 1. Year 2 serum samples were analyzed for PROT, SUN, ALB, GLU, cholesterol (CHOL), and total bilirubin (TBIL).

Total fecal output (FO) was estimated using continuous-release, chromic oxide boluses (Ellis et al., 1981). Fecal grab samples were collected from the ewes for 5 consecutive days during each period. Fecal samples were oven-dried, ground through a 1 mm screen in a Wiley mill, and composited within ewe and period. Boluses were administered 9 d before fecal collection began. Fecal grab samples were analyzed for DM, ash (AOAC, 1984) and chromium content (Fenton and Fenton, 1979). Daily FO was estimated by dividing the concentration of fecal chromium into the quantity of chromium released daily from the bolus. Fecal contributions from supplements were calculated from supplement intake and in vitro digestibility estimates. The difference between total feces and feces of supplement origin was considered the indigestible fraction of the consumed forage. Forage intake was calculated by dividing

forage FO by the fractional expression of the indigestibility (1-digestible DM) of the forage.

Ewe BW and body condition score and their changes were analyzed using the GLM procedure of SAS (1987). Main effects included supplement, type of birth and their interactions. Birth date was included as a covariate in the least squares model. The effect of supplement was tested against the residual mean square as the error term. A similar model was used for lamb traits with treatment, lamb sex and ewe age as the fixed effects. Date of birth was again the covariate in the analysis. Fecal output, forage intake, and blood metabolite concentration estimates were analyzed by multivariate analysis of variance (SAS, 1987). The repeated measures procedure was used to account for the repeated sampling of the same ewe in each period. The animal within treatment term was used to test treatment. Fixed effects included supplement, type of birth, and their interactions. Birth date was again the covariate in the analysis. All models included two-way interactions. A significance level of $P < .10$ was established for all analyses.

RESULTS

Year 1 (1991-1992)

Extrusa samples contained an average of 7.1% CP during Year 1 (Table 5). Approximately 14% of the protein was bound to the fiber fraction of the forage (ADIN 1.0% / CP 7.1%). In vitro DM and NDF digestibilities averaged 45% and 44.8%, respectively.

No period by treatment interactions were detected ($P > .10$) for forage fecal DM and OM outputs or for total fecal DM and OM outputs (Table 6). Mean forage fecal DM and OM outputs were not affected ($P > .10$) by supplementation. Forage fecal DM and OM outputs averaged 446.1 and 408.6 g d⁻¹, respectively. Total fecal DM and OM outputs were also not affected ($P > .10$) by supplementation. Total fecal DM and OM outputs averaged 464.2 and 424.8 g d⁻¹, respectively.

No period by treatment interactions were detected ($P > .10$) for forage intakes (Table 6). Mean forage DM and OM intakes were not affected ($P > .10$) by supplementation when expressed either as g per day or as a percentage of body weight. Forage DMI averaged 1115.4 g d⁻¹ and 1.56% BW while forage OMI averaged 1021.7 g d⁻¹ or 1.42% of body weight.

Initial BW were similar ($P = .68$) but final BW differed ($P < .01$) among supplement treatments (Table 7). Non-supplemented ewes lost more ($P < .05$) BW than supplemented

Table 5. Chemical composition and digestibility of ruminal extrusa collected from fistulated ewes (dry matter basis)^a

Item	Period		Mean	SE ^b
	1	2		
	-----%-----			
1991-92				
CP	7.4	6.8	7.1	0.2
NDF	62.8	62.8	62.8	0.8
ADF	45.5	47.7	46.6	0.6
ADIN ^c	1.0	1.0	1.0	0.05
Sulfur	0.10	0.11	0.11	0.02
Ash	8.3	8.5	8.4	0.2
IVDMD	46.1	43.8	45.0	0.7
In vitro NDF digestibility	45.2	44.4	44.8	0.6
1992-93				
CP	4.3	4.6	4.5	0.1
NDF	74.5	75.1	74.8	0.9
ADF	44.5	44.6	44.6	0.6
ADIN ^c	0.9	1.1	1.0	0.05
Sulfur	0.07	0.07	0.07	0.07
Ash	9.4	8.4	8.9	0.2
IVDMD	50.6	46.8	48.7	0.7
In vitro NDF digestibility	48.1	52.1	50.1	0.6

^a Collection periods were between Jan 8. and Feb. 13 in 1992 and Jan.8 and Feb. 10 in 1993.

^b SE = standard error of means; N = 32, 1991-92; N = 28, 1992-93.

^c Crude protein equivalent.

ewes. No differences were detected ($P > .10$) among ewes fed corn, BAR, SBM, and BM+FM supplements; however, FM+U supplemented ewes gained more ($P < .10$) BW than BAR or SBM supplemented ewes.

Initial body condition scores were similar ($P = .81$) among supplement treatments, but final body condition score was higher ($P < .10$) for corn, BM+FM and FM+U supplemented ewes than CON ewes (Table 7). Ewes fed the BM+FM supplement

Table 6. Effect of supplements on fecal outputs and forage DM and OM intakes
(1991-92)

Item	Supplement ^a						SE ^b	P-value ^c
	CON	Corn	BAR	SBM	BM+FM	FM+U		
Fecal DM output, g/d								
Supplement		28.1	26.3	13.2	20.9	19.9		
Forage	432.6	443.9	430.2	447.1	466.7	456.3	18.5	.73
Total	432.6	472.0	456.5	460.3	487.6	476.2	18.5	.75
Fecal OM output, g/d								
Supplement		25.6	24.2	11.7	18.4	17.5		
Forage	396.3	406.6	394.2	409.6	426.8	418.1	18.5	.70
Total	396.3	432.2	418.4	421.3	445.2	435.6	18.5	.72
Forage DM intake								
g/d	1082	1110	1076	1118	1167	1141	46.3	.75
% BW	1.55	1.50	1.51	1.59	1.64	1.54	.06	.77
Forage OM intake								
g/d	990.7	1017	985.4	1024	1069	1045	42.4	.73
% BW	1.42	1.37	1.39	1.45	1.50	1.41	.06	.76

^a CON = no supplement; BAR = barley; SBM = soybean meal; BM+FM = blood meal plus feather meal; FM+U = feather meal plus urea.

^b Standard error of the least square means.

^c Probability value for the F-test for treatment.

lost less ($P < .10$) body condition than CON and BAR supplemented ewes. No difference in body condition score changes were detected ($P > .10$) between CON ewes and corn, BAR, SBM and FM+U supplemented ewes.

Corn supplemented ewes had heavier ($P < .10$) fleece weights than CON, BAR, SBM, and BM+FM supplemented ewes (Table 7). No differences ($P > .10$) were detected among other supplement treatments.

Ewe spring BW were not different ($P = .66$) but ewe weaning BW differed ($P = .03$; Table 7). Ewes supplemented with FM+U, SBM, and BAR had higher ($P < .10$) weaning BW than CON, corn and BM+FM supplemented ewes. Ewe weaning body condition scores did not differ ($P = .16$) among supplement treatments.

No treatment differences were detected for number lambs born ($P = .74$), reared ($P = .65$) or weaned ($P = .50$) of those ewes lambing (Table 8). Lamb birth BW were affected ($P = .07$) by supplement treatments. Barley supplemented ewes tended to have lower ($P = .07$) birth BW than corn, SBM and FM+U supplemented ewes. Lamb spring (30 d) BW and weaning BW were similar ($P = .58$; $P = .22$), averaging 14.8 kg and 30.1 kg, respectively.

Supplement treatments had no effect on serum PROT ($P = .42$) or CRE ($P = .86$) concentrations (Table 9). Protein supplemented (BM+FM and U+FM), SBM supplemented, and CON ewes

Table 7. Effect of supplement on ewe body weight change, body condition, and fleece weights (1991-92)

Item	Supplement ^a						SE ^b	P-value ^c
	CON	Corn	BAR	SBM	BM+FM	FM+U		
Winter BW, kg								
Initial	71.5	73.4	71.2	70.7	71.0	72.8	1.4	.68
Final	68.2 ^f	74.5 ^{gh}	70.7 ^{fh}	70.1 ^f	71.7 ^{ghi}	75.4 ^{gi}	1.5	.01
Change ^d	-3.4 ^f	1.1 ^{hi}	-0.5 ⁱ	-0.5 ⁱ	0.7 ^{hi}	2.6 ^{gh}	1.0	.01
Body condition score ^e								
Initial	3.5	3.6	3.5	3.4	3.5	3.6	.12	.81
Final	2.7 ^f	3.3 ^{gh}	2.9 ^{fi}	3.0 ^{fhi}	3.4 ^{gi}	3.2 ^{gi}	.12	.01
Change ^d	-0.8 ^f	-0.3 ^{fg}	-0.6 ^f	-0.4 ^{fg}	-0.1 ^g	-0.4 ^{fg}	.15	.04
Fleece weight, kg	3.9 ^f	4.7 ^g	4.2 ^{fh}	3.9 ^f	4.1 ^{fi}	4.4 ^{ghi}	.16	<.01
Spring BW, kg	65.2	64.5	65.1	64.8	63.4	67.9	1.8	.66
Weaning BW, kg	63.2 ^{fh}	64.9 ^f	65.6 ^{fg}	65.5 ^{fg}	60.8 ^h	68.7 ^g	1.6	.03
Weaning condition score	2.6	2.9	3.0	3.1	2.9	3.2	.1	.16

^a CON = no supplement; BAR = barley; SBM = soybean meal; BM+FM = blood meal plus feather meal; FM+U = feather meal plus urea.

^b Standard error of the least square mean; N = 8.

^c Probability value for the F-test for treatment.

^d December 17, 1991 to March 7, 1992.

^e Numerical values are based on the following equivalent values: obese = 5, fat = 4, moderately fat = 3, slightly thin = 2, extremely thin = 1.

^{f,g,h,i} Means within rows that do not have common superscripts differ (P < .10).

Table 8. Influence of supplement on ewe reproductive rate and lamb body weights

Item	Supplement ^a						SE ^b	P-value ^c	
	CON	Corn	ALF	BAR	SBM	BM+FM			FM+U
1991-92									
Reproductive rates									
Lamb born ^d	1.6	1.9		1.7	1.7	1.8	1.9	.17	.74
Lamb reared	1.4	1.7		1.4	1.5	1.8	1.6	.21	.65
Lamb weaned ^e	1.4	1.7		1.4	1.5	1.8	1.6	.21	.50
Lamb BW, kg									
Birth	4.7 ^{fg}	5.3 ^f		4.2 ^g	5.0 ^f	4.7 ^{fg}	4.9 ^f	.26	.07
30-d	14.6	14.5		13.9	15.2	14.3	16.0	.81	.58
Weaning ^e	31.9	29.2		28.6	31.4	27.0	32.2	1.80	.22
1992-93									
Reproductive rates									
Lamb born ^d	1.4		1.4	1.2	1.2	1.3	1.4	.20	.97
Lamb reared	1.4		1.4	1.2	1.2	1.2	1.4	.20	.91
Lamb BW, kg									
Birth	4.5		5.1	5.4	5.4	5.4	5.3	.20	.28
30-d	13.5		14.1	16.4	15.5	14.3	14.2	1.10	.46

^a CON = no supplement; ALF = alfalfa; BAR = barley; SBM = soybean meal; BM+FM = blood meal plus feather meal; FM+U = feather meal plus urea.

^b Standard error of the least square means.

^c Probability for the F-test for treatment.

^d Per ewe lambing.

^e Lambs weaned in August, 1992.

had higher ($P < .03$) SUN concentrations than energy supplemented ewes (corn and BAR).

Albumin concentrations reflected ($P < .10$) a treatment by period interaction (Table 9). Ewes supplemented with BM+FM had lower ($P < .07$) serum ALB concentrations than CON, corn, BAR, and FM+U supplemented ewes during Period 1. No supplement differences were observed ($P > .10$) during Period 2. Albumin concentrations tended to decrease during Period 2 except for SBM which remained constant throughout the winter.

Glucose concentrations also reflected ($P < .10$) a treatment by period interaction (Table 9). Serum GLU concentrations were higher ($P < .02$) for SBM and corn supplemented ewes than CON, BAR, BM+FM and FM+U supplemented ewes during Period 1, but no supplement treatment differences were detected ($P = .69$) during Period 2.

Table 9. Effect of supplement on serum metabolite concentration in ewes (1991-92)

Item ^b	Supplement ^a						SE ^c	P-value ^d
	CON	Corn	BAR	SBM	BM+FM	FM+U		
PROT, g/dL	6.5	6.5	6.3	6.3	6.9	6.5	.2	.42
CRE, mg/dL	1.3	1.3	1.3	1.3	1.2	1.3	.08	.86
SUN, mg/dL	9.9 ^f	7.6 ^{gh}	7.3 ^g	9.5 ^f	9.7 ^f	9.0 ^{fh}	.55	<.01
ALB, g/dL ^e								
Period 1	3.2 ^f	3.2 ^{fh}	3.2 ^{fh}	3.0 ^{gh}	2.9 ^g	3.2 ^{fh}	.08	.06
Period 2	2.9	3.0	3.0	3.0	2.8	3.1	.09	.39
GLU, mg/dL ^e								
Period 1	66.5 ^f	75.3 ^{gh}	63.9 ^f	76.2 ^g	67.8 ^{fh}	64.0 ^f	3.11	.02
Period 2	63.2	63.8	66.6	66.6	64.9	65.2	2.07	.69

^a CON = no supplement; BAR = barley; BM+FM = blood meal plus feather meal; FM+U = feather meal plus urea.

^b PROT = total protein; CRE = creatinine; SUN = serum urea nitrogen; ALB = albumin; GLU = glucose.

^c Standard error of the least square mean.

^d Probability value for the F-test for treatment.

^e Least square means represent a significant period by treatment interaction (P < .10).

^{f,g,h} Means within rows that do not have common superscripts differ (P < .10).

Year 2 (1992-1993)

Crude protein content of the extrusa was lower than in Year 1 (4.5% CP; Table 5). Approximately 22% of the protein was bound to the fiber fraction of the forage during Year 2 (ADIN 1.0% / CP 4.5%). In vitro DM and NDF digestibilities averaged 48.7% and 50.1%, respectively.

No period by treatment interactions were detected ($P > .10$) for forage fecal DM and OM outputs or for total fecal DM and OM outputs (Table 10). Mean forage fecal DM and OM outputs were not affected ($P = .40$; $P = .43$) by supplementation. Forage fecal DM and OM outputs averaged 438.5 and 399.6 g d⁻¹, respectively. Total fecal DM and OM outputs were also not affected ($P = .43$; $P = .40$) by supplementation. Total fecal DM and OM outputs averaged 461.9 and 420.4 g d⁻¹, respectively.

No period by treatment interactions were detected ($P > .10$) for forage intakes (Table 10). Mean forage DM and OM intakes (OMI) were not affected ($P = .40$) by supplementation when expressed either as g per day or as a percentage of body weight. Forage DMI averaged 907.8 g d⁻¹ or 1.26% BW while forage OMI averaged 827.9 g d⁻¹ or 1.19% of body weight.

Initial BW were similar ($P = .80$) but final BW differed ($P = .04$) among supplement treatments (Table 11). Non supplemented ewes lost more BW ($P < .10$) than supplemented

Table 10. Effect of supplements on fecal outputs and forage DM and OM intakes
(1992-93)

Item	Supplement ^a						SE ^b	P-value ^c
	CON	ALF	BAR	SBM	BM+FM	FM+U		
Fecal DM output, g/d								
Supplement		62.2	27.3	18.1	17.9	14.9		
Forage	450.9	399.0	414.9	510.0	436.0	419.9	29.0	.40
Total	450.9	461.2	442.2	528.1	453.9	434.8	29.0	.43
Fecal OM output, g/d								
Supplement		52.8	25.1	16.5	16.4	13.8		
Forage	411.5	361.9	378.4	465.1	397.6	383.2	26.4	.43
Total	411.5	414.7	403.5	481.6	414.0	397.1	26.4	.40
Forage DM intake								
g/d	933.6	826.1	858.9	1056	902.7	869.4	59.9	.40
% BW	1.32	1.17	1.20	1.44	1.25	1.18	.08	.39
Forage OM intake								
g/d	851.4	753.4	783.3	962.9	823.2	792.9	54.6	.40
% BW	1.20	1.06	1.09	1.31	1.14	1.08	.08	.39

^a CON = no supplement; ALF = alfalfa; BAR = barley; SBM = soybean meal; BM+FM = blood meal plus feather meal; FM+U = feather meal plus urea.

^b Standard error of the least square means; N = 7 for all supplement treatments except for SBM and FM+U, N = 8.

^c Probability value for the F-test for treatment.

ewes; however, no differences ($P > .10$) were detected among any of the supplemented groups.

Initial body condition scores were similar ($P = .70$) among supplement treatments, but final body condition score was higher ($P > .10$) for supplemented groups than CON ewes. No differences ($P > .10$) were detected among any of the supplemented groups. Fleece weights were similar ($P = .65$) for all supplement treatments.

Ewe spring BW and spring condition scores were similar ($P = .78$; $P = .56$; Table 8). No treatment differences were detected for number of lambs born ($P = .97$) or reared ($P = .90$). Lamb birth BW were similar ($P = .28$) for all supplement treatments. Lamb spring (30 d) BW did not differ ($P = .46$), averaging 12.4 kg.

Supplementation had no effect on serum PROT ($P = .85$) or GLU ($P = .13$) concentrations (Table 12). Serum urea nitrogen concentrations reflected ($P < .10$) a period by treatment interaction (Table 12). Supplement treatment had no effect ($P > .10$) on SUN concentrations during Period 1; however, during Period 2, SBM supplemented ewes had higher ($P < .10$) SUN concentrations than CON, ALF, BAR, BM+FM and FM+U supplemented ewes. Serum ALB concentrations were not influenced by supplement treatment ($P = .65$).

A period by treatment interaction was detected ($P < .10$) for CHOL concentrations (Table 12). Alfalfa supplemented ewes

Table 11. Effect of supplement on ewe body weight change, body condition, and fleece weights (1992-93)

Item	Supplement ^a						SE ^b	P-value ^c
	CON	ALF	BAR	SBM	BM+FM	FM+U		
Winter BW, kg								
Initial	75.1	72.0	73.0	73.5	73.2	74.9	1.7	.80
Final	66.7 ^f	69.7 ^f	70.2 ^f	73.1 ^g	71.1 ^f	72.5 ^g	1.6	<.01
Change ^d	-8.4 ^f	-2.3 ^{gh}	-2.8 ^g	-0.4 ^h	-2.1 ^{gh}	-2.4 ^{gh}	1.0	<.01
Body condition score ^e								
Initial	3.5	3.4	3.4	3.4	3.5	3.5	.06	.70
Final	2.7 ^f	2.9 ^{fh}	2.8 ^{fh}	3.1 ^{gh}	3.1 ^{gh}	3.0 ^{gh}	.14	.04
Change ^d	-0.8 ^f	-0.5 ^{gh}	-0.6 ^g	-0.3 ^h	-0.4 ^{gh}	-0.4 ^{gh}	.13	.04
Fleece weight, kg	4.0	3.9	3.9	4.2	3.7	4.0	.19	.65
Spring BW, kg	68.0	66.0	65.1	65.8	64.4	67.7	1.9	.78
Spring condition score	2.6	2.1	2.5	2.2	2.5	2.3	.2	.56

^a CON = no supplement; ALF = alfalfa; BAR = barley; SBM = soybean meal; BM+FM = blood meal plus feather meal; FM+U = feather meal plus urea.

^b Standard error of the least square mean; N = 7 for all supplement treatments except ALF and SBM, N = 8.

^c Probability value for the F-test for treatment.

^d December 22, 1992 to March 5, 1993.

^e Numerical values are based on the following equivalent values: obese = 5, fat = 4, moderately fat = 3, slightly thin = 2, extremely thin = 1.

^{f,g,h,i} Means within rows that do not have common superscripts differ (P > .10).

had lower ($P < .09$) CHOL concentrations than all other treatments during Period 1. Soybean meal supplemented ewes had higher ($P < .01$) CHOL concentrations than ALF, BM+FM, and FM+U supplemented ewes during Period 2.

Total bilirubin concentrations reflected ($P < .10$) a period and treatment interaction (Table 12). Non-supplemented ewes had higher ($P < .01$) TBIL concentrations than supplemented ewes during Period 1. During Period 2, SBM supplemented ewes had higher ($P < .01$) TBIL concentrations than all other treatments.

Table 12. Effect of supplement on serum metabolite concentration in ewes (1992-93)

Item ^b	Supplement ^a						SE ^c	P-value ^d
	CON	ALF	BAR	SBM	BM+FM	FM+U		
PROT, g/dL	6.4	6.5	6.4	6.6	6.4	6.6	.15	.85
SUN, mg/dL ^e								
Period 1	6.2	7.4	7.0	8.2	7.2	7.2	.52	.23
Period 2	8.7 ^f	8.6 ^f	8.4 ^f	12.3 ^g	7.5 ^f	7.9 ^f	.74	<.01
ALB, g/dL	3.2	3.2	3.1	3.1	3.0	3.1	.06	.65
GLU, mg/dL	65.0	62.0	60.8	66.2	61.9	62.7	2.4	.61
CHOL, mg/dL ^e								
Period 1	68.3 ^f	56.7 ^g	63.1 ^f	66.4 ^f	67.0 ^f	67.6 ^f	3.1	.09
Period 2	70.0 ^{fi}	57.1 ^{gh}	70.4 ^f	76.5 ^f	63.2 ^{hi}	61.6 ^h	2.8	<.01
TBIL, mg/dL ^e								
Period 1	0.40 ^f	0.21 ^{gh}	0.11 ^g	0.14 ^{gh}	0.12 ^{gh}	0.07 ^h	.06	<.01
Period 2	0.09 ^{fh}	0.02 ^h	0.04 ^h	0.23 ^g	0.13 ^f	0.07 ^{fh}	.03	<.01

^a CON = no supplement; ALF = alfalfa; BAR = barley; SBM = soybean meal; BM+FM = blood meal plus feather meal; FM+U = feather meal plus urea.

^b PROT = total protein; SUN = serum urea nitrogen; ALB = albumin; GLU = glucose; CHOL = cholesterol; TBIL = total bilirubin.

^c Standard error of the least square means.

^d Probability value for the F-test for treatment.

^e Least square means represent a significant period by treatment interaction (P < .10).

^{f,g,h,i} Means within rows that do not have common superscripts differ (P < .10).

DISCUSSION

Forage DMI was not affected by supplements which provided either approximately 20 g of CP and .38 Mcal of ME (corn, BAR and ALF) or approximately 28 g CP and .15 Mcal of ME (SBM, BM+FM, and FM+U). This agrees with Harris et al. (1989) who supplemented ewes in a separate study at the same location with .15 kg $\text{hd}^{-1} \text{d}^{-1}$ of a BAR-SBM supplement and found no forage intake differences between supplemented and non-supplemented ewes. They reported DMI values ranging from 971 to 1221 g d^{-1} and 1.6 to 2.0% of body weight. Our values were on the lower end of this range; this could be due to year-to-year variation or the fact that Harris et al. (1989) used internal NDF as a marker while we used an external marker, chromic oxide. However, standard errors for both methods were fairly similar; this would indicate that the variation among animals in both experiments was similar. J. E. Huston (unpublished data) also supported this observation when he concluded that supplementing goats grazing a low-quality rangeland in Texas with varying levels of UDP did not affect forage DMI, although supplements were generally additive with forage and increased total DMI and digestible dry matter.

Quantity of CP and ME provided by our supplements may not have been sufficient to enhance or decrease forage intake. Kartchner (1981) supported this observation when he found that

DMI was not affected by feeding low levels of barley to cows grazing winter range. Rittenhouse et al. (1970) determined that the influence of supplemental CP on forage DM digestibility and intake was small for cattle grazing winter range when the supplemental protein was $2.07 \text{ g kg}^{-1} \text{ BW}^{0.75}$ (converts to 50.1 g CP d^{-1} for a 70 kg ewe) or supplemental energy was below $.041 \text{ Mcal kg}^{-1} \text{ BW}^{0.75}$ (converts to $.99 \text{ Mcal d}^{-1} \text{ ME}$ for a 70 kg ewe). Huston (1983), however, found that increasing CP intake from 40 to 80 g d^{-1} and digestible DM from 75 to 240 g d^{-1} decreased forage intake of ewes from 2.2 to 2.0% of body weight. He attributed the trend for declining forage intake to substitution of supplemental feed for forage and suggested undigested residues from the rumen imposed a limitation on intake.

Variation in forage intakes between Year 1 and 2 may have been due to differences in diet quality, as shown by nutrient composition of the ruminal extrusa. Neutral detergent fiber concentration was higher during Year 2 (74.8%) than Year 1 (62.8%). However, in vitro DM and NDF digestibilities were slightly higher during Year 2. Acid detergent fiber is generally an indicator of digestibility while NDF content is more often considered an indicator of intake potential (Mertens, 1983; Church, 1988). Therefore, higher NDF content of the selected forage during Year 2 may have imposed more of a limitation on intake than in Year 1 since ADF was similar

both years. This also agrees with the observations of Harris et al. (1989) who reported ruminal extrusa NDF values slightly higher during Year 2 with a corresponding slight depression in intake over that of Year 1. Ewes in our study may also have been more selective in their grazing during Year 1 when fall re-growth was more prominent. Forage clip samples averaged 3.5 to 4% CP. The difference in CP content of the ruminal extrusa and forage clip samples was probably due to ewes selecting more green forage, lack of forbs in the extrusa samples, and possible recycling of some urea N by way of the saliva. NRC (1985b) reported that ruminants recycle approximately 25% of the dietary N intake through the saliva when consuming a diet containing 12% crude protein. Differences in winter environmental conditions may also have caused differences in forage DMI between Year 1 and 2 (Table 1). Year 1 was a mild winter with little snow cover and moderate temperatures. In contrast, Year 2 was harsher with colder temperatures and more snow cover. Grazing accounts for the greatest amount of energy expenditure, and temperature and wind velocity have effects on time spent grazing (Malechek and Smith, 1976; Adams, 1984a). Reductions in grazing time can be expected with both falling temperatures and increasing wind speed (Adams, 1984a). Also, available forage may have been much more limited during Year 2 due to snow cover, and the ewes had to spend more time and energy foraging.

Ewe BW and body condition score were positively influenced by either energy or protein supplementation, however, no production responses were observed. All ewes were fed adequately with alfalfa hay ($2.3 \text{ kg hd}^{-1} \text{ d}^{-1}$) and barley grain ($.23 \text{ kg hd}^{-1} \text{ d}^{-1}$) following removal from winter range during the last 30 days of gestation, therefore similarities in lamb production as well as ewe spring and weaning weights and condition scores were probably a result of compensatory gain after being taken off winter range. This agrees with Thomas et al. (1993) who reported on a larger group of ewes at the same location and concluded that although supplementation with energy or protein improved ewe BW, no production responses were noted, probably due to compensation in late gestation for restricted feeding on winter range. Everitt (1967) and Brink (1990) reported that pregnant ewes can compensate in late pregnancy for restricted feeding in early pregnancy. Kleemann et al. (1993) reported that supplementation during mid-pregnancy had no influence on fetal survival; nutritional intake during early and late pregnancy were more of a factor in fetal survivability.

Early work by Chittenden et al. (1935) reported that production of ewes supplemented with either corn, cottonseed cake or a 25% CP pellet was similar to ewes not supplemented. Harris et al. (1956) reported that supplementing pregnant ewes grazing winter range in Utah with 256 g d^{-1} of soybean oil meal

on alternate days improved BW maintenance, wool yield, and lamb crop while supplementing with 128 g/d of soybean oil meal or barley (182 or 345 g d⁻¹) were beneficial in maintaining BW only. They concluded that ewes in good condition could lose some BW during the winter grazing season and still produce effectively. Clanton (1957), in a study at Utah State University, found that supplementing ewes grazing a sagebrush range with a 25% protein pellet (barley and cottonseed meal) at a rate of .15 kg d⁻¹ improved kg of lamb weaned and dollar return over those supplemented with corn or not supplemented at all. Van Horn et al. (1959a) reported that increasing the energy or protein content of the supplement increased BW gain in ewes grazing winter range, however, feeding a high protein, low energy pellet did not improve lamb production over those supplemented with a high energy, low protein barley pellet. They concluded that ewe BW gain did not always translate into increased dollar return when ewes were in good body condition at the beginning of the winter.

Forage intakes were similar among treatments within each year, therefore BW and body condition score change must have been due to factors other than the influence of supplementation on forage intake, such as increased energy or protein intake in the supplemented ewes. This is supported by Hoaglund et al. (1992), who reported that supplementing ewes fed a low quality forage with SBM improved ewe nutritional

status. Addition of BM to the SBM supplement further improved ewe nutritional status, as demonstrated by improved ewe BW and body condition score changes. They concluded that improved nutritional status was probably due to enhanced microbial activity and/or increased protein reaching the small intestine.

As gestation progressed, ewes tended to lose body condition yet still gain body weight. This was probably due to the utilization of the ewe's body stores to maintain and nourish the growing fetus(es) and placental fluid.

Increased grease fleece weights in the corn supplemented ewes during Year 1 has no real biological explanation. Thomas et al. (1993), reporting on a larger set of ewes at the same location, concluded that similar supplements had no effect on fleece weights. Michalk and Saville (1979) reported that in order to obtain a grease fleece response to supplementation, the feeding trial must be at least 90 d in length and amount of supplement fed must be fairly high. Our trial length only approached the minimum 90 d length (84 d) and quantity of supplement fed was small.

Lack of PROT, CRE and ALB concentration responses were probably due to the fact that CP intake of the ewes was not limiting. These metabolites are generally not sensitive to the small quantity of protein supplied by our supplements, and

changes are more likely a result of progressing gestation (Bull et al., 1984; Miner, 1986).

Serum SUN concentrations are indicative of either tissue catabolism or protein intake (Hoaglund et al., 1992). Although BM+FM, FM+U and CON ewes had elevated SUN concentrations compared to energy supplemented (corn and BAR) ewes during Year 1, BM+FM and FM+U supplemented ewes had improved BW and improved body condition scores compared to CON ewes (Year 1). This response was probably due to improved ewe nutritional status in the BM+FM and FM+U since more amino acids were probably reaching the small intestine for absorption (Hoaglund et al., 1992). Preston et al. (1965) found SUN concentrations and CP intake were highly correlated ($r = .986$). This suggests that protein supplemented ewes met their tissue N requirements (Hoaglund et al., 1992) while CON ewes probably had elevated SUN concentrations due to increased tissue catabolism. Increased SUN concentrations in SBM supplemented ewes compared to energy supplemented ewes during both years is unclear since the SBM supplement was isonitrogenous to the energy supplements both years but only contained half as much metabolizable energy.

Lower GLU concentrations in Period 2 compared to Period 1 during Year 1 was probably due to increasing fetal requirements as gestation progressed (Bull et al., 1984). Forage availability may also have decreased as the winter

progressed. In addition, there was a slight amount of snow cover during Period 2. Snow cover has been associated with reduced forage availability and reduced digestibility, the effect being greater for unsupplemented ewes than for supplemented ewes as shown by Rittenhouse et al. (1970).

The changes in CHOL and TBIL concentrations during Year 2 is unclear. Cholesterol is usually associated with lipid intake or fat mobilization. TBIL is usually associated with liver function. All ewes had similar productions both years; therefore, supplement treatments probably had no effect on liver function.

In summary, supplementation did not increase or decrease forage DMI of pregnant ewes grazing winter range, although ewes BW and body condition score were positively influenced by supplement. Improved BW and condition score were probably a result of increased energy or protein intake.

IMPLICATIONS

Alternate day supplementation with either energy or protein supplement had no effect on forage DM intake of pregnant ewes grazing winter range. Feeding levels relative to BW (.16 and .36%) were probably not high or low enough to influence forage intake. Increased BW change and reduced body condition score loss by supplemented ewes were probably due to increased nutrient intake. These results suggest that ewes should be supplemented while grazing winter range but type of supplement is not an important factor at these low feeding levels.

LITERATURE CITED

- Abou Akkada, A.R. and K. El-Shazly. 1958. Studies of the nutritive value of some common Egyptian feedstuffs. J. Agric. Sci. (Camb.) 51:157.
- Adams, D.C. 1984a. Grazing behavior and supplementation of range cattle during fall and winter periods. Field Day Report 43.
- Adams, D.C., 1984b. Time of day and interval of supplementation for beef cattle grazing fall-winter range. Proc. 35th Montana Livest. Nutr. Conf. p. 141.
- Adams, D.C. 1985. Effect of time of supplementation on performance, forage intake and grazing behavior of yearling beef steers grazing Russian wild ryegrass in the fall. J. Anim. Sci. 61:1037.
- Adams, D.C., 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 Mgmt. 44:204.
- Allison, C.D. 1985. Factors affecting forage intake by range ruminants: a review. J. Range Mgmt. 38:305.
- Andrews, R.P., J. Escuder-Volonte, M.K. Curran, and W. Holmes. 1972. The influence of supplements of energy and protein on the intake and performance of cattle fed on cereal grains. Anim. Prod. 15:167.
- AOAC. 1984. Official Methods of Analysis. (17th Ed.). Association of Official Analytical Chemists. Washington, D.C.
- Arias, C., W. Burroughs, P. Gerlaugh, and R.M. Bethke. 1951. The influence of different amounts and sources of energy upon in vitro urea utilization by rumen micro-organisms. J. Anim. Sci. 10:683.
- Arnold, G.W. and M.L. Dudzinski. 1967. Studies on the diet of the grazing animal. II. The effect of physiological status in ewes and pasture availability on herbage intake. Aust. J. Agric. Res. 18:349.
- Arnold, G.W. 1970. Regulation of food intake in grazing ruminants. In: Physiology of Digestion and Metabolism in the Ruminant. A.T. Phillipson (Ed.). Oriel Press Ltd. Newcastle.

- Arnold, G.W. 1981. Grazing behavior. In: Grazing Animals. F.H.W. Morley (Ed.). Elsevier Scientific Publ. Co., Amsterdam.
- Baile, C.A. and J.M. Forbes. 1974. Control of feed intake and regulation of energy balance in ruminants. *Physio. Rev.* 54:160.
- Balch, C.C. and R.C. Campling. 1962. Regulation of voluntary intake in ruminants. *Nut. Abst. and Rev.* 32:669.
- Barlow, R., K.J. Ellis, P.J. Williamson, P. Costigan, P.D. Stephenson, G. Rose, and P.T. Mears. 1988. Dry-matter intake of Hereford and first-cross cows by controlled release of chromic oxide on three pasture systems. *Aust. J. Agric. Sci. (Camb.)* 110:217.
- Barton, R.K., L.J. Krysl, M.B. Judkins, D.W. Holcombe, J.T. Broesder, S.A. Gunter, and S.W. Beam. 1992. Time of daily supplementation for steers grazing dormant intermediate wheatgrass pasture. *J. Anim. Sci.* 70:547.
- Baumgardt, B.R. 1970. Control of feed intake in the regulation of energy balance. In: A.T. Phillipson (Ed.). *Physiology of Digestion and Metabolism in the Ruminant*. Oriel Press. Newcastle.
- Bellows, R.A. and O.O. Thomas. 1976. Some effects of supplemental grain feeding on performance of cows and calves on range forage. *J. Range Mgmt.* 29:192.
- Bhattacharya, A.N. and E. Pervez. 1973. Effect of urea supplementation on intake and utilization of diets containing low quality roughages in sheep. *J. Anim. Sci.* 36:976.
- Bines, J.A. 1971. Metabolic and physical control of food intake in ruminants. *Proc. Nutr. Soc.* 30:116.
- Bines, J.A. 1976. Regulation of food intake in dairy cows in relation of milk production. *Livest. Prod. Sci.* 3:115.
- Blaxter, K.L., F.W. Wianman and R.S. Wilson. 1961. The regulation of food intake by sheep. *Anim. Prod.* 3:51.
- Blaxter, K.L. 1962. *The Energy Metabolism of Ruminants*. Charles C. Thomas Publ.
- Blaxter, K.L. 1967. *The Energy Metabolism of Ruminants*. Hutchinson and Co., London.

- 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.
- Branine, M.E. and M.L. Galyean. 1985. Influence of supplemental grain on forage intake, rate of passage and rumen fermentation in steers grazing summer blue grama rangeland. *Proc. West. Sec. Amer. Soc. Anim. Sci.* 36:436.
- Brink, D.R. 1990. Effects of body weight in early pregnancy on feed intake, gain, body condition in late pregnancy and lamb weights. *Small Rumin. Res.* 3:421.
- Bull, R.C., D.O. Everson, D.P. Olson, L.F. Woodard, and L.C. Anderson. 1984. Blood metabolite levels in pregnant beef heifers restricted prepartum in protein and/or energy. *Proc. West. Sec. Amer. Soc. Anim. Sci.* 35:234.
- Buntinx, S.E., K.R. Pond, D.S. Fisher, and J.C. Burns. 1992. Evaluation of the captec chrome controlled-release device for the estimation of fecal output by grazing sheep. *J. Anim. Sci.* 70:2243.
- Campling, R.C. M. Freer, and C.C. Balch. 1962. Factors affecting the voluntary intake of food by cows. *Brit. J. Nutr.* 16:115.
- Campling, R.C. 1966. The control of voluntary intake of food in cattle. *Outlook on Agr.* 6:74.
- Campling, R.C. 1970. Physical regulation of voluntary intake In: A.T. Phillipson (Ed.). *Physiology of Digestion and Metabolism in the Ruminant*. Oriel Press. Newcastle.
- Carruthers, V.R. and A.M. Bryant. 1983. Evaluation of the use of chromic oxide to estimate the feed intake of dairy cows. *N.Z.J. Agric. Res.* 26:183.
- Casper, D.P., D.J. Schingoethe, and W.A. Eisenbeisz. 1990. Response of early lactation dairy cows fed diets varying in source of nonstructural carbohydrate and crude protein. *J. Dairy Sci.* 73:1039.
- Caton, J.S., A.S. Freeman, and M.L. Galyean. 1988. Influence of protein supplementation on forage intake, in situ forage disappearance, ruminal fermentation and digesta passage rates in steers grazing dormant blue grama rangeland. *J. Anim. Sci.* 66:2262.

- Cecava, M.J., N.R. Merchen, L.L. Berger, R.I. Mackie, and G.C. Fahey, Jr. 1991. Effects of dietary energy level and protein source on nutrient digestion and ruminal nitrogen metabolism in steers. *J. Anim. Sci.* 69:2230.
- Chittendon, D.W., W.F. Dickson, and F. Barnum. 1935. Supplements on the winter range for breeding ewes. *Pro. Am. Soc. Anim. Prod.*, 159.
- Church, D.C. 1976. *Digestive Physiology and Nutrition of Ruminants*. D.C. Church Publ. 300p.
- Church, D.C. 1988. *The Ruminant Animal- Digestive Physiology and Nutrition*. Prentice Hall. Englewood Cliffs, New Jersey.
- Clanton, D.C. and D.R. Zimmerman. 1965. Protein levels in beef cow wintering rations. *Proc. West. Soc. Am. Soc. Anim. Sci.* 16:130.
- Clanton, D.C. 1957. The effect of level of nutrition on the pathology and productivity of range sheep. Ph.D. Thesis. Utah State University.
- Coffey, K.P., J.A. Paterson, C.S. Saul, L.S. Coffey, K.E. Turner, and J.G. Bowman. 1989. The influence of pregnancy and source of supplemental protein on intake, digestive kinetics and amino acid absorption by ewes. *J. Anim. Sci.* 67:1805.
- Conrad, H.R., A.D. Pratt and J.W. Hibbs. 1964. Regulation of feed intake in dairy cows. I. Change in importance of physical and physiological factors with increasing digestibility. *J. Dairy Sci.* 47:54.
- Cook, C.W. and L.E. Harris. 1968a. Effect of supplementation on intake and digestibility of range forage. *Utah Agr. Exp. Sta. Bull.* 475.
- Cook, C.W. and L.E. Harris. 1968b. Nutritive value of seasonal ranges. *Utah Agr. Exp. Sta. Bull.* 472.
- Corbett, J.L., J.F.D. Greenhalgh, P.E. Gwynn, and D. Walker. 1958. Excretion of chromium sesquioxide and polyethylene glycol by dairy cows. *Br. J. Nutr.* 12:266.
- Corbett, J.L., J.P. Langlands, and G.W. Reid. 1963. Effects of season of growth and digestibility of herbage intake by grazing dairy cows. *Anim. Prod.* 5:119.

- Cordova, F.J., J.D. Wallace, and R.D. Pieper. 1978. Forage intake by grazing livestock: a review. *J. Range Manage.* 31:430.
- Darroch, J.G., A.W. Nordskog, and J.L. Van Horn. 1950. The effect of feeding concentrates to range ewes on lamb and wool productivity. *J. Anim. Sci.* 9:431.
- Dhuyvetter, D. 1991. Reproductive efficiency of range beef cows fed differing sources of protein during gestation and differing quantities of ruminally undegradable protein prior to breeding. M.S. Thesis. Montana State University.
- Doyle, P.T., H. Dove, M. Freer, F.J. Hart, R.M. Dixon, and A.R. Egan. 1988. Effects of a concentrate supplement on the intake and digestion of a low-quality forage by lambs. *J. Agric. Sci. (Camb.)*, 111:503.
- Dunn, R.W. 1986. Physiological and behavioral responses of cows on Montana foothill range to winter and supplement. M.S. Thesis, Montana State University.
- Egan, A.R. 1965. Nutritional status and intake regulation in sheep. The relationship between improvement of nitrogen status and increase in voluntary intake of low-protein roughages by sheep. *Aust. J. Agr. Res.* 16:463.
- Elliot, R.C. 1967. Voluntary intake of low protein diets by ruminants.. 2. Intake of food by sheep. *J. Agric. Sci.* 69:383.
- Ellis, K.J., R.H. Laby, and R.G. Burns. 1981. Continuous controlled release administration of chromic oxide to sheep. *Proc. Aust. Nutr. Soc.* 6:145.
- Everitt, G.C. 1967. Residual effects of prenatal nutrition on the post-natal performance of Merino sheep. *Proc. Am. Soc. Anim. Prod.* 159.
- Fenton, T.W. and M. Fenton. 1979. An improved procedure of the determination of chromic oxide in feed and feces. *Can. J. Anim. Sci.* 59:631.
- Finger, H. and O. Werk. 1973. Ankebung des natrium-und magnesiumgehaltes der weidfutter-pflanzen und beeinflussung des futterverzehr nach dungung mit magnesia-kaimit. *Landw. Forsch;* 28II:190.

- Fogarty, N.M., D.G. Hall, and P.J. Holst. 1992. The effect of nutrition in mid pregnancy and ewe liveweight change on birth weight and management for lamb survival in highly fecund ewes. *Aust. J. Exp. Agric.* 32:1.
- Forbes, J.M. 1969. The effect of pregnancy and fatness on the volume of rumen contents in the ewe. *J. Agric. Sci. (Camb.)*. 72:119.
- Forbes, J.M. 1970. The voluntary food intake of pregnant and lactating ruminants: a review. *Br. Vet. J.* 126:1.
- Forbes, J.M. 1980. Physiological changes affecting voluntary food intake. In: *Digestive Physiology and Metabolism in Ruminants*. Y. Ruckebusch and J.P. Thirond (Eds.). AVI Publishing Co., Westport.
- Forbes, T.D.A. and M.M. Beattie. 1987. Comparative studies of ingestive behavior and diet composition in oesophageal-fistulated and non-fistulated cows and sheep. *Grass and Forage Sci.* 42:79.
- Furnival, E.P., J. L. Corbett, and M.W. Inskip. 1990a. Evaluation of controlled release devices for administration of chromium sesquioxide using fistulated grazing sheep I. Variation in marker concentration in faeces. *Aust. J. Agric. Res.* 41:969.
- Furnival, E.P. K.J. Ellis, and F.S. Pickering. 1990b. Evaluation of controlled release devices for administration of chromium sesquioxide using fistulated grazing sheep II. Variation in rate of release from the device. *Aust. J. Agric. Res.* 41:957.
- Gieske, D., M.J. Lawlor, and K. Walser-Karst. 1966. Comparative studies on the physiology of sheep fed on semi-purified or roughage-concentrate diets. 2. Microbial investigations. *Br. J. Nutr.* 20:383.
- Goering, H.K. and P.J. Van Soest. 1970. Forage fiber analysis (apparatus, reagents, procedures and some applications). *USDA Handbook No. 379*. Washington, D.C.
- Grovum, W.L. 1979. Factors affecting the voluntary intake of food by sheep 2. The role of distension and tactile input from compartments of the stomach. *Br. J. Nutr.* 42:425.

- Hannah, S.M., R.C. Cochran, E.S. Vanzant, and D.L. Harmon. 1991. Influence of protein supplementation on site and extent of digestion, forage intake, and nutrient flow characteristics in steers consuming dormant bluestem-range forage. *J. Anim. Sci.* 69:2624.
- Harris, L.E., C.W. Cook, and L.A. Stoddard. 1956. Feeding phosphorus, protein, and energy supplements to ewes on winter ranges of Utah. *Utah State Agric. Exp. Bull.* No. 398.
- Harris, K.B., V.M. Thomas, M.K. Petersen, M.J. McInerney, R.W. Kott and E. Ayers. 1989. Influence of supplementation on forage intake and nutrient retention of gestating ewes grazing winter range. *Can. J. Anim. Sci.* 69:693.
- Harrison, F.A., R.H. Laby, and J.L. Mangan. 1981. A slow-release marker capsule for studies of digestion in the sheep. *J. Physiol.* 319:1.
- Hatfield, P.G., J.W. Walker, and H.A. Glimp. 1991a. Comparing the captec bolus to chromic oxide dosed twice daily using sheep in confinement. *J. Range Mgmt.* 44:408.
- Hatfield, P.G., J.W. Walker, H.A. Glimp, and D.C. Adams. 1991b. Effect of level of intake and supplemental barley on marker estimates of fecal output using an intraruminal continuous-release chromic oxide bolus. *J. Anim. Sci.* 69:1788.
- 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.* 56:259.
- Hoaglund, C.M., V.M. Thomas, M.K. Petersen, and R.W. Kott. 1992. Effects of supplemental protein source on metabolizable energy status on nutritional status of pregnant ewes. *J. Anim. Sci.* 70:273.
- Holder, J.M. 1962. Supplementary feeding of grazing sheep-its effect on pasture intake. *Proc. Aust. Soc. Anim. Prod.* 4:154.
- Hopper, J.T., J.W. Holloway, and W.T. Butts, Jr. 1978. Animal variation in chromium sesquioxide excretion patterns of grazing cows. *J. Anim. Sci.* 46:1096.

- Horn, F.P., J.P. Telford, J.E. McCroskey, D.F. Stevens, J.V. Whiteman, and R. Totuseck. 1979. Relationship of animal performance and dry matter intake to chemical constituents of grazed forage. *J. Anim. Sci.* 49:1051.
- Hovell, F.D.DeB, J.W.W. Ngambi, W.P. Barger, and D.J. Kyle. 1986. The voluntary intake of hay by sheep in relation to its digestibility in the rumen as measured by nylon bags. *Anim. Prod.* 42:111.
- Hungate, R.E. 1966. *The Rumen and its Microbes*. Academic Press, New York.
- Hunter, R.F. and C. Milner. 1963. The behavior of individual, related and groups of south country Cheviot hill sheep. *Anim. Behav.* 11:507.
- Huston, J.E. 1983. Production of fine-wool ewes on yearlong rangeland in West Texas. I. Effects of season, stage of production and supplemental feed on intake. *J. Anim. Sci.* 56:1269.
- Huston, J.E. and B.S. Engdahl. 1983. Changes in the digestive physiology of ewes fed at different levels during fall, winter, and spring. *Sheep and Goat, Wool & Mohair. CPR 4171*. P 53.
- Jones, G.M. 1972. Chemical factors and their relation to feed intake regulation in ruminants: a review. *J. Dairy Sci.* 49:856.
- Journet, M. and B. Remond. 1976. Physiological factors affecting the voluntary intake of feed by cows: a review. *Livest. Prod. Sci.* 3:129.
- Karges, K.K., T.J. Klopfenstein, V.A. Wilkerson, and D.C. Clanton. 1992. Effects of ruminally degradable and escape protein supplements on steers grazing summer native range. *J. Anim. Sci.* 70:1857.
- Kartchner, R.J. 1981. Effects of protein and energy supplementation of cows grazing native winter range forage on intake and digestibility. *J. Anim. Sci.* 51:432.
- Kartchner, R.J. and D.C. Adams. 1982. Effects of daily and alternate day feeding of grain supplements to cows grazing fall-winter range. *Proc. West. Sec. Am. Soc. Anim. Sci.* 33:308.

- Kiesling, H.E., H.A. Barry, A.B. Nelson, and C.H. Herbel.
1969. Recovery of chromic oxide administration in paper to grazing steers. J. Anim. Sci. 29:361.
- King, D.W., A.J. Pordomingo, J.D. Horton, J.L. Holechek, and J.D. Wallace. 1992. Fecal output estimates for grazing steers using total collections and a controlled-release chromic oxide device. Proc. West. Sec. Amer. Soc. Anim. Sci. 43:371.
- Kleemann, D.O., S.K. Walker, J.R.W. Walkley, R.W. Ponzoni, D.H. Smith, R.J. Grimson, and R.F. Seamark. 1993. Effect of nutrition during pregnancy on fetal growth and survival in Fec^B Booroola x South Australian Merino ewes. Theriog. 39:623.
- Krysl, L.J., M.L. Galyean, R.E. Estell, and B.F. Sowell. 1988. Estimating digestibility and faecal output in lambs using internal and external markers. J. Agric. Sci. (Camb.). 111:19.
- 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 to the grazing ruminant. Can. J. Anim. Sci. (Supp.) 64:337.
- Lambourne, L.J. and T.F. Reardon. 1963a. The use of chromium oxide to estimate the fecal output of Merinos. Aust. J. Agric. Res. 14:239.
- Lambourne, L.J. and T.F. Reardon. 1963b. The use of chromium oxide and faecal nitrogen concentration to estimate the pasture intake of Merino wethers. Aust. J. Agric. Res. 14:257.
- Leaver, J.D., R.C. Campling and W. Holmes. 1969. The effect of level of feeding on the digestibility of diets for sheep and cattle. Anim. Prod. 11:11.
- Lesperance, A.L., V.R. Bohman and D.W. Marble. 1960. Development of techniques for evaluating grazed forage. J. Dairy Sci. 43:682.
- Lewis, R. and M. Shelton. 1983. Influence of number of lambs dropped or raised on the pre- and post partum daily feed intake of Finnish Landrace and Rambouillet ewes. Sheep and Goat, Wool & Mohair. CPR 4171.

- Lindsay, D.B. 1978. The effect of feeding pattern and sampling procedure on blood parameters. In: The Use of Blood Metabolites in Animal Production. BSAP Occasional Publication Number 1. pp. 99-120. Milton Keynes, England.
- Lyons, T., P.J. Caffrey, and W.J. O'Connell. 1970. The effect of energy, protein and vitamin supplementation on the performance and voluntary intake of barley straw by cattle. Anim. Prod. 12:323.
- Malechek, J.C. and B.M. Smith. 1976. Behavior of range cows in response to winter weather. J. Range Mgmt. 29:9.
- Maynard, S.B., J.K. Loosli, H.F. Hintz, R.G. Warner. 1979. Animal Nutrition. McGraw-Hill Pub. N.Y. 602p.
- McCall, R. 1940. The digestibility of mature range grasses and range mixtures fed alone and with supplements. J. Agric. Res. 60:39.
- McClymont, G.L. 1957. Selectivity and intake in the grazing ruminant. In: Code, C.G. (Ed). Sec. 6: Alimentary Canal. Vol. I. Control of Food and Water Intake. Handbook of Physiology. Amer. Physio. Soc. Wash. D.C. 459p.
- Meijs, J.A.C. 1981. Herbage Intake by Grazing Dairy Cows. Centre for Agric. Pub. and Documentation. Wageningen, Netherlands.
- Mertens, D.R. and J.R. Lofton. 1980. The effect of starch on forage fiber digestion kinetics in vitro. J. Dairy Sci. 63:1437.
- Mertens, D.R. 1983. Using neutral detergent fiber to formulate dairy rations and estimate the net energy content of forages. Pages 60-68 in Proceedings of the Cornell Nutrition Conference, Ithaca, N.Y.
- Mertens, D.R. 1987. Predicting intake and digestibility using mathematical models of ruminal function. J. Anim. Sci. 64:1548.
- Michalk, D.L. and D.G. Saville. 1979. Supplementary feeding of range sheep. J. Range Mgmt. 32:422.
- Milford, R. and D.J. Minson. 1965. Intake of tropical pasture species. Proc. Intern'l. Grassl. Cong. 9:815.

- Miner, J.M. 1986. Bypass supplementation of grazing pregnant beef cows. MS thesis. Montana State University.
- Miner, J.M. and M.K. Petersen. 1989. The effects of ruminal escape protein or fat on ruminal characteristics of pregnant winter-grazing cows. J. Anim. Sci. 67:2782.
- Montgomery, M.J. and B.R. Baumgardt. 1965. Regulation of food intake in ruminants. II. Rations varying in energy concentration and physical form. J. Dairy Sci. 48:1623.
- Murphy, T.M., K.S. Lusby, G.W. Horn, and F.T. McCollum. 1992. The value of feather meal as a protein supplement source in winter supplements for beef cows. Prof. Anim. Scientist. 8:21.
- Nicoll, G.B. and J. Sherington. 1984. Variation in chromium excretion in suckled cows at pasture. Anim. Prod. 39:1.
- NRC. 1985a. Nutrient requirements of sheep. National Academy of Sciences-National Research Council. Washington, D.C.
- NRC. 1985b. Ruminant Nitrogen Usage. National Academy of Sciences-National Research Council. Washington, D.C.
- NRC. 1987. Predicting feed intake of food-producing animals. National Academy of Sciences-National Research Council. Washington, D.C.
- Padula, R.F., V.M. Thomas, R.W. Kott and M.K. Petersen. 1992. Influence of ruminally undegraded protein and non-structural carbohydrate on nutritional status of pregnant ewes. Sheep Res. J. 8:5.
- Parker, W.J., S.N. McCutcheon, and D.H. Carr. 1989. Effect of herbage type and level of intake on the release of chromic oxide from intraruminal controlled release capsules in sheep. N.Z.J. Agric. Res. 32:537.
- Preston, R.L., D.D. Schnakenberg, and W.H. Pfander. 1965. Protein utilization in ruminants. I. Blood urea nitrogen as affected by protein intake. J. Nutr. 86:281.
- Prigge, E.C., B.A. Stuthers, and N.A. Jacquemet. 1990. Influence of forage diets on ruminal particle size, passage of digesta, feed intake, and digestibility by steers. J. Anim. Sci. 68:4352.

- Raleigh, R.J. and R.J. Kartchner. 1980. Chromic oxide in range nutrition studies. Oregon Agr. Exp. Sta. Bull. 641.
- Rittenhouse, L.R., D.C. Clanton, and C.L. Streeter. 1970. Intake and digestibility of winter-range forage by cattle with and without supplements. J. Anim. Sci. 31: 1215.
- Robinson, J.J. 1982. Pregnancy. In: I.E. Coop (Ed.). Sheep and Goat Production. pp 103-118. Elsevier Sci. Publ. Co., Amsterdam, The Netherlands.
- Russel, A.J.F., J.M. Doney, and R.G. Gunn. 1969. Subjective assessment of body fat in live sheep. J. Agric. Sci. (Camb.) 72:451.
- SAS, 1987. SAS users guide. Statistics. SAS institute, Inc. Cary, N.C.
- Schloesser, B.J., V.M. Thomas, M.K. Petersen, R.W. Kott, and P.G. Hatfield. 1993. Effects of supplemental protein source on passage of nitrogen to the small intestine, nutritional status of pregnant ewes, and wool follicle development of progeny. J. Anim. Sci. 71:1019.
- Smith, A.M. and J.T. Reid. 1955. Use of chromic oxide as an indicator of fecal output for the purpose of determining the intake of pasture herbage by grazing cows. J. Dairy. Sci. 38:515.
- Speth, C.F., V.R. Bohman, H. Melendy, and M.A. Wade. 1960. Effect of dietary supplements on cows on a semi-desert range. J. Anim. Sci. 21:444.
- Sultan, J.I. and S.C. Loerch. 1992. Effects of protein and energy supplementation of wheat straw-based diets on site of nutrient digestion and nitrogen metabolism of lambs. J. Anim. Sci. 70:2228.
- Theurer, C.B., A.L. Lesperance, and J.D. Wallace. 1976. Botanical composition of the diet of livestock grazing native ranges. Arizona Agr. Exp. Sta. Tech. Bull. 233.
- Thomas, V.M. and W.M. Beeson. 1977. Feather meal and hair meal as protein sources for steer calves. J. Anim. Sci. 46:819.

- Thomas, V.M., E. Ayers, and R.F. Padula. 1989. Influence of day of supplementation on the performance of pregnant ewes grazing Montana winter range. Proc. West. Sec. Am. Soc. Anim. Sci. 40:475.
- Thomas, V.M., E. Ayers, C.M. Hoaglund, R.W. Kott and B. Schloesser. 1990a. Influence of day of supplementation on the production of gestating ewes grazing Montana winter range. Proc. West. Sec. Am. Soc. Anim. Sci. v. 41.
- Thomas, V.M., M.J. McInerney, E. Ayers, and R. Kott. 1990b. Influence of lasalocid and supplement level on productivity of gestating ewes grazing winter range. J. Anim. Sci. 68:1530.
- Thomas, V.M., K.J. Soder, R.W. Kott, and C.M. Schuldt. 1992. Influence of energy or protein supplementation on the production of pregnant ewe grazing winter range. Proc. West. Sec. Am. Soc. Anim. Sci. 43:374.
- Thomas, V.M., R.W. Kott, C.M. Schuldt and K.J. Soder. 1993. Influence of supplementation on the production of pregnant ewes grazing winter range. Proc. West. Sec. Am. Soc. Anim. Sci. 44:240.
- Thompson, W. and A.H. Fraser. 1939. Feeding concentrates to in-lamb ewes. The Scottish J. of Agric. 22:71.
- Thorley, C.M. E. Sharpe, and M.P. Bryant. 1968. Modification of the rumen bacteria flora by feeding cattle ground and pelleted roughage as determined with culture media with and without rumen fluid. J. Dairy Sci. 51:1811.
- Tilley, J.M.A., and R.A. Terry. 1963. A two-stage technique for the in vitro digestion of forage crops. J. Brit. Grassl. Soc. 18:104.
- Tribe, D.E. 1950. Influence of pregnancy and social facilitation on the behavior of grazing sheep. Nature. 166:74.
- Turner, M.E. 1985. The forage intake of supplemented cows grazing winter foothill rangelands of Montana. M.S. Thesis, Montana State University.
- Umunna, N.N. 1982. Utilization of poor quality roughages: response of sheep fed native hay supplemented with urea by different methods. J. Agric. Sci. (Camb.) 98:343.

- Van Dyne, G.M., O.O. Thomas, J.L. Van Horn. 1964. Diet of cattle and sheep grazing on winter range. Proc. West. Sec. Amer. Soc. Anim. Sci. 15:LXI-1-6.
- Van Dyne, G.M., N.R. Brockington, Z. Szocs, J. Duek, and C.A. Ribic. 1980. Large herbivore subsystem. In: Grassland System Analysis and Man. A.J. Brey Meyer and G.M. Van Dyne (Eds.). Internl. Biol. Prog. 19. Cambridge Univ. Press.
- Van Horn, J.L., G.F. Payne, F.S. Willson, J. Drummond, O.O. Thomas, and F.A. Branson. 1959a. Protein supplementation of range sheep. MT Agr. Exp. Sta. Bull. No. 547.
- Van Horn, J.L., O.O. Thomas, J. Drummond, A.S. Hoverland, and F.S. Willson. 1959b. Range ewe production as affected by winter feed treatments. MT Agr. Exp. Sta. Bull. No. 548.
- Van Soest, P.J. 1965. Symposium on factors influencing the voluntary intake of herbage by ruminants: voluntary intake in relation to chemical composition and digestibility. J. Anim. Sci. 24:834.
- Van Soest, P.J. and R.H. Wine. 1967. Use of detergents in the analysis of fibrous feeds. IV. Determinations of plant cell wall constituents. J. Assoc. Off. Anal. Chem. 50:50.
- Van Soest, P.J. 1982. Nutritional ecology of the Ruminant. O & B Books, Inc., Corvallis, OR.
- Waldo, D.R. 1969. Factors influencing the voluntary intake of forages. Proc. Nat. Conf. Forage Qual. Eval. Util. E-1.
- Wedekind, K.J., R.B. Muntifering, and K.B. Barker. 1986. Effects of diet concentrate level and sodium bicarbonate on site and extent of forage fiber digestion in the gastrointestinal tract of wethers. J. Anim. Sci. 62:1388.
- Welch, J.G. 1967. Appetite control in sheep by indigestible fibers. J. Anim. Sci. 26:849.
- Wheeler, J.L., T.F. Reardon, and L.J. Lambourne. 1963. The effect of pasture availability and shearing stress on herbage intake of grazing sheep. Aust. J. Agric. Res. 14:364.

Wilkinson, S.C. and D.M.B. Chestnutt. 1988. Effect of level of food intake in mid and late pregnancy on the performance of breeding ewes. Anim. Prod. 47:411.

Young, B.A. 1980. Effects of cold weather on the beef cow. Proc. 31st Annual Montana Nutritional Conference, Bozeman, MT.

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