Abstract:
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PHYSIOLOGICAL AND BEHAVIORAL RESPONSES
OF COWS ON MONTANA FOOTHILL RANGE
TO WINTER AND SUPPLEMENT

by

Roger William Dunn

A thesis submitted in partial fulfillment
of the requirements for the degree

of

Master of Science

in

Range Science

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APPROVAL

of a thesis submitted by

Roger William Dunn

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

March 21, 1986
Date

Chairperson, Graduate Committee

Approval for the Major Department

March 21, 1986
Date

Head, Major Department

Approved for the College of Graduate Studies

March 28, 1986
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ABSTRACT

Supplementation of gestating beef cows spending the winter on range has shown benefits to cow productivity. In order to understand how these benefits operate, detailed studies of the nutritional costs for cows on winter range, and the effects of supplements, are necessary. As part of that research goal, a study was conducted in 1984 and 1985 that recorded the grazing and travel behavior, and estimated the forage intake, of gestating crossbred cows onwinter range receiving protein supplement. The rangeland available to the cows contained cool season grasses dominated by bluebunch wheatgrass (Agropyron spicatum (Pursh) Scribn. & Smith). The study pasture contained 324 hectares in the northwest foothills of the Madison Range of southwest Montana. The cows wore vibracorders and pedometers for 48 continuous days in January and February. Daily intake was estimated using the chromic oxide dilution technique. Correction factors for these estimates were derived by determining chromic oxide recovery and by comparing the estimates to total fecal collection. Cow age had a significant ($p<.05$) effect on daily grazing time, but not on daily intake. Cows receiving supplement showed significantly higher intake ($p<.05$) than unsupplemented cows, but spent the same or less time grazing. Protein supplementation seems to have lowered the nutritional cost of obtaining forage. Daily temperature swings brought about adjustments in the cows' daily grazing schedule. Severe temperature changes also brought short term reductions in daily grazing time. During these periods the cows may have been experiencing acute cold stress. No consistent correlation between grazing time, past grazing time, present temperature, and past temperature was found. This led to the conclusion that in 1984 and 1985 the cows did not experience chronic cold stress, and were not forced to re-acclimate, even though temperature varied between 8 and -26 degrees Celcius.

INTRODUCTION

In many areas of western Montana snow blows free from rangeland, and forage is accessible to cattle year round. However, the nutrient content of forage varies greatly among areas and plant species. Winter range containing mature, dormant grasses will usually be deficient in some nutrients, and is often inadequate to meet the nutrient requirements of pregnant beef cows (especially as producers try to maintain or improve cow productivity).

Nutrient supplementation for beef cows wintering on rangeland has been shown to improve cow performance with the added and directly related benefit of improved calf performance. However, the practice of nutrient supplementation can be profitable or economically wasteful. The most effective supplement for cows grazing winter forage is one that will aid the rumen microbial population in its digestion of the mature winter forage. The most efficient supplement is one that provides this digestive assistance without becomino a dietary substitute for winter forage. In order to determine the effectiveness, efficiency, and profitability of a supplement, a precise determination of the biological benenits gained with each unit of expense is required. Such determinations will provide information for designing other, more profitable supplements.

This study was a segment of an ongoing research project investigating several parameters of winter cattle nutrition including the biological benefits of supplementation. This portion of the project has concentrated on the interaction of dietary supplementation and winter forage intake. The specific objectives included (1) estimation of winter forage intake of both supplemented and unsupplemented cows in the third tromester of gestation, and (2) measurement of the behavior associated with winter forage intake of both supplemented anl unsupplemented cows in the third trimester of gestation. The study used Angus-cross cows grazing foothill rangeland typical of southwest Montana. Major grasses on the study site include bluebunch uheatgrass (Agropyron spicatum (Pursh) Scribn. & Smith), needleandthread (Stipa comata Trin. & Rupr.), Idaho fescue (Festuca idahoensis Elmer), and basin wildrye (Elymus cinereus Scribn. & Mmrr.).

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LITERATURE REVIEW

Any study of the benefits of supplementation must be limited in scope to allow solutions to be applied to a specific situation. This study was limited to crossbred cows in the last trimester of gestation (winter months), grazing native foothill rangeland in southwest Montana, and receiving a protein supplement. Each of the above limitations has an effect on two variables, intake and foraging behavior. The following literature review will deal with each limitation, their interactions, and their effects on the two variables.

Intake of Winter Forage

Forage available for winter grazing is generally of low nutritional quality. The nutrient content of grasses, forbs, and shrubs changes seasonally, with minimum levels of such important nutrients as protein, phosphorous, and carotene occuring in the winter (Cook and Harris 1950b, Marsh et al. 1959). Although grasses are usually low in protein during the winter, they may provide sufficient energy to cattle if consumed in large enough quantities (Cook and Harris 1968b, Clanton 1981). Seasonal levels of important components of grasses have been measured in Utah and Montana (Cook and Harris 1950a, 1968b; Marsh et al. 1959; Van Dyne et al. 1965). These levels are summarized in Table 1. Lignin and cellulose levels are generally higher in winter than in early summer, while other nutrient levels, especially crude protein, are lower. Along with low nutrient content, mature dormant grasses are also of low

Table 1. Seasonal composition of range grasses in eastern Montana and northern Utah.

Component	Species	Years	Time: Dec-Apr Dormant	Time: May-June Immature-bloom	Citation
Crude Protein %	Agropryon spicatum	1955-1957	2.7-3.4	10-15	VanDyne et al. 1965
	Stipa comata	1955-1960	1.9-11.2	11.3-14.7	"
	"	1948-1953	3.5-6.0	9.0-17.0	Marsh et al. 1959
	grazing sample	1948-1953	3.0-5.0	8.0-20.0	"
Lignin %	Agropyron spicatum	1955-1957	8.5-12.5	11.0-13.0	VanDyne et al. 1965
	Stipa comata	1955-1960	12.0-21.5	10.7-16.9	"
	range grass mix	1968	12.7 (Sept)	9.7	Cook and Harris 1968b
	"	1950	12.5 (Sept)	10.0	Cook and Harris 1950a
Cellulose %	Bromus carinatus	1950	49.5-49.8 (Sept)	42.7-43.1	Cook and Harris 1950b
Carotene milligram %	Agropyron spicatum	1955-1960	6.2-58.0 (Sept)	118.4-136.1	VanDyne et al. 1965
	Stipa comata	1955-1960	1.0-8.3	63.4-139.1	"
	"	1948-	0-12.5	75.0-160.0	Marsh et al. 1959

Table 1. continued

Component	Species	Years	Time: Dec-Apr Dormant	Time: May-June Immature-bloom	Citation
Carotene cont.	grazing sample	1948-1953	0-10.0	75.0-200.0	Marsh et al. 1959
Phosphorous %	Agropyron spicatum	1955-1957	0.031-0.042	0.062-0.148	VanDyne et al. 1965
	Stipa comata	1955-1960	0.021-0.118	0.104-0.230	"
	"	1948-1953	0.05-0.08	0.17-0.23	Marsh et al. 1959
	grazing sample	1948-1953	0.03-0.09	0.14-0.28	"

digestibility due to the higher levels of indigestible lignin and cellulose (Cook and Harris 1968b). A comparison of the apparent digestibility of grasses in summer and winter can be found in Table 2.

Cook and Harris (1968b) stressed the fact that the chemical contents of plants on winter range varied little over the winter months. Van Dyne and Heady (1965) found that of all chemical constituents tested for, lignin varied least over the winter grazing season.

Table 2. Apparent digestibility of grass constituents during summer and winter in Utah (from Cook and Harris 1968b).

Time	Species	Digestion Coefficient %			Digestible protein	Metabolizable energy (kcal/kg)
		Total Protein	Cellulose	Gross energy		
Summer	Agropyron intermedium	66.2	71.4	62.4	7.3	2253
	Agropyron inerme	50.1	68.7	57.0	5.2	1936
	Agropyron smithii	73.8	64.0	61.2	11.1	2028
Winter	Agropyron inerme	0.0	76.4	56.9	0.0	1991
	Agropyron smithii	6.4	70.1	64.3	0.2	2469
	Stipa comata	27.6	69.7	50.7	1.2	1647
	Oryzopsis hymenoides	6.4	69.5	45.9	0.3	1616

If cattle rely on this less digestible, less nutritious forage, more must be consumed to obtain necessary nutrient levels, and more time and energy must be expended to digest what they have consumed. Under these conditions, both the physical capacity of the reticulo-rumen and the digestive capacity of the rumen microbe population become limiting (Crampton 1952). This leads to decreased intake, because intake cannot exceed outflow from the rumen (passage rate), and outflow is dependent on how fast the animal and its microbes can break down the consumed plant material. For winter forage high in cell wall content digestion rate is slowed. This reduces outflow and leaves large amounts of food residues in the rumen in the form of a floating fiber mat (Weston 1967, Jones 1972). The rumen remains full and further intake is limited (Campling et al. 1962). Dry matter intake can increase only if an increasing amount of dry matter is digested (Conrad et al. 1964).

Montgomery and Baumgardt (1965) stated that cattle will adjust the volume of food intake to meet physiological energy demand if rumen fill does not limit consumption. However, for cows grazing low quality winter forage rumen fill does appear to be the main factor limiting intake (Balch and Campling 1962, Grovum 1969, Journet and Remond 1976, Ellis 1978). When the digestibility of forage is less than approximately 65 percent, rumen fill is fairly continuous, and therefore continuously limiting (Jones 1972). In a review concerning forage intake by cattle, Cordova et al. (1978) reported that intake estimates in the western United States range from 1.0 to 2.8 percent of body weight or 40 to 90 g dm/kg body weight. In a previous winter study at Montana State University's Red Bluff Research Ranch, estimated forage organic matter intake ranged from 0.8 to 1.4 percent of body weight (Turner 1985). Under the fill-limiting conditions imposed by winter forage of low quality, declining availability of such forage does not appear to limit intake. Havstad et al. (1983) estimated the intake of heifers grazing forage of constant low quality, but declining availability. Heifers increased grazing time as the quantity of forage decreased, and achieved constant intake levels.

Under circumstances where rumen fill is not the main factor limiting intake, VFA (volatile fatty acids), especially acetate and propionate, appear to be important signal substances for the control of intake. Neural sensors for VFA are believed to be located in or near the rumen (Baile and Mayer 1968, Bines 1971) and in the portal vein (Baile 1969 as cited in Bines 1971). Neural signals are sent to the hypothalmus which is the center of the intake control mechanism (Conrad 1966). As VFA levels go up, intake is depressed (Bhattacharya and Warner 1968, Baile and Forbes 1974, Anil and Forbes 1977).

Kartchner and Adams (1982) found lower intake and higher rumen VFA levels in cows supplemented every other day vs. cows supplemented every day in the winter. This suggests the VFA intake mechanism is operating during the winter with a low quality roughage diet. But Jones (1972) pointed out that low quality roughage diets containing high levels of lignin are slowly digested, and rumen VFA levels may be too low in these circumstances to play a role in the control of intake. If so, other mechanisms may be involved in the results reported by Kartchner and Adams (1982). These authors suggested that rumen conditions in the cows fed grain on alternate days may have been less favorable for fiber digestion. This condition is discussed in a later section of this review.

Winter as it Affects Metabolism and Nutrition

Winter has some striking physiological and behavioral effects on cattle. Climate can affect a range cow's reproductive performance and milk production (Bellido et al. 1981). Effects of environmental stress, including the energy cost of grazing and walking, can raise an animals maintainence energy requirement 25 to 50 percent above that of animal's kept indoors (Osuji 1974). Although the effects of a cold environment are significant, they are not always excessive and do not exclude productivity (expressed by cow weight, cow condition, and fetal growth) during the winter (Webster 1970a).

The most obvious effect of the cold winter environment involves the fact that heat emission from the animal rises as the temperature drops (Blaxter and Wainman 1961). Heat is lost through radiation, conduction, and emission of water vapor (Blaxter and Wainman 1961). In fact, all physiologic responses to cold relate, directly or indirectly, to an increase in the rate of heat transfer between an animal and its environment (Christopherson and Young 1981). Webster (1970a,b) has shown that cattle may gain radiant heat from the sun during the day; however, radiant heat loss at night outweighs the gain between November and March in southern Alberta, Canada. This net radiant heat loss has an important and immediate effect. The animal must produce heat to counteract losses in order to maintain homeothermy (Young and Christopherson 1974).

Cold stress, and the animal's responses to it, vary with duration of exposure. During acute (short term) cold stress an animal conserves heat through piloerection, vasoconstriction at the skin surface, lowered respiratory rate, decreased water and food intake, and seeking shelter (Slee 1971, Young 1975a, Gonyou et al. 1979). Short term cold stress is also accompanied by massive heat production (thermogenesis) visible as shivering (Gonyou et al. 1979) and powered by free fatty acids (Young 1975a) obtained through the oxidation of adipose tissue (Blaxter and Wainman 1961).

Acute cold stress occurs if an animal is removed from its thermoneutral zone. This is the range of temperatures in which an animal's heat production is constant. Figure 1 shows the thermal neutral zone and the regions of thermogenesis as temperatures drop below or rise above this level.

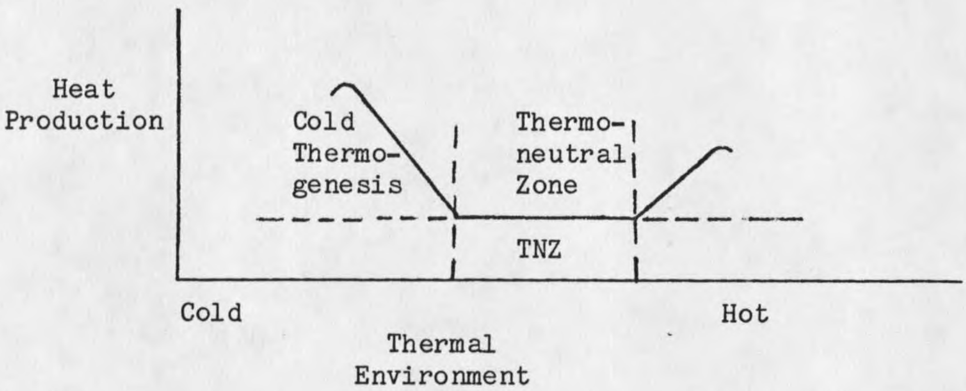

Figure 1. Heat production as related to the thermal environment of beef cattle (adapted from Young 1980).

As cold exposure continues (chronic cold stress), responses to cold change, but the increased metabolic rate continues (Slee 1971, Young and Christopherson 1974, Young 1980). Young and Christopherson (1974) reported an 8 to 40 percent rise in thermoneutral metabolic heat production during prolonged cold exposure. The new level of heat production depended on the average temperature to which animals had previously been exposed. Specifically, the average increase in thermoneutral resting heat production for each 1°C rise in average temperature to which animals had been exposed was 0.6 kcal per kg body weight$^{.75}$ per day. During prolonged cold exposure the increased metabolic rate becomes the basis for cold adaptation or acclimatization. The thermoneutral zone shifts to include the new level of heat production as seen in Figure 2.

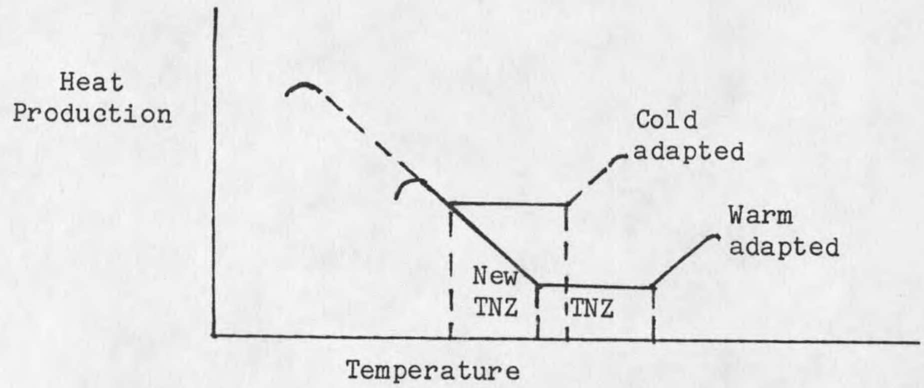

Figure 2. Heat production and cold adaptation in beef cattle (adapted from Young 1980).

Each shift in the thermoneutral zone brings a new lower critical temperature. Webster (1970a) reported that the absolute lower critical temperature for pregnant beef cows ranges from -11 to -23°C. Even though temperatures drop below -23°C in winter, cattle can usually survive these periods with acute cold responses. Young (1975b) studied a group of cows acclimatized to January temperatures approaching -25°C. When exposed to -30°C, metabolic rates increased up to 37%, but rectal temperatures decreased showing that the cows were not maintaining homeothermy.

Acclimatization also involves other mechanisms as defenses against cold such as an increased heart rate which contributes to increased metabolic rate (Webster et al. 1970). Respiratory rate decreases to minimize loss of heat from water vapor; Young (1975a) reported respiratory rates in cows as low as 8 to 11 breathes per minute. Vasoconstriction at the skin surface continues, but periodic vasodilation occurs, followed by slow constriction, in order to prevent tissue damage at the extremities (Blaxter and Wainman 1961). Hair shedding is reduced, which can lead to a hair coat twice as heavy as unexposed animals (Webster et al. 1970). Cold exposure brings on a relatively dehydrated condition in exposed animals as their water consumption drops (Young 1975a). As cattle became adapted to colder temperatures, metabolic capability in response to acute cold stress increased (Slee 1971). These mechanisms combine to imply a greater energy consumption by animals acclimated to cold.

The heat conservation attempted during acute cold stress is accompanied by a drop in food intake (Webster and Young 1970, Slee 1971). The greater energy outflow that follows during chronic cold stress is accompanied by an increase in food intake above normal levels (Webster and Young 1970, Webster et al. 1970, Slee 1971, Baile and Forbes 1974, Ames and Brink 1977). The prolonged cold changes the animals physiologic and environmental circumstances. In order to maintain a constant energy balance with these changes, cattle must increase their food intake (Baile and Forbes 1974). However, the increased heat production needed during prolonged cold exposure will occur no matter what the food intake level of the animal (Blaxter and Wianman 1961, Young 1975b). This shows the importance of heat production to the animal, and supports the findings that adipose tissue is also used to fuel heat production.

Thus far, temperature alone has been discussed to indicate the degree of cold exposure. Wind can aggrevate the effect of temperature with pronounced additions to the effective thermal environment. At cold temperatures, wind will invoke higher heat production (Webster 1970a) and a higher metabolic rate (Christopherson et al. 1979). Insley and Ames (1972) determined that wind velocites under 32 km/hr removed an insulating layer of air surrounding the animal and trapped in the hair coat. Above 32 km/hr the wind also destroyed the structure of the insulating hair coat causing a second, accelerated rise in heat flow.

Cold exposure not only increases an animal's maintainence energy requirements, it also influences the digestive system of ruminants. Several studies have shown a significant decrease in DMD (dry matter digestibility) during prolonged cold exposure (Blaxter and Wainman 1961, Young and Christopherson 1974, Kennedy et al. 1976, Ames and Brink 1977). The mechanisms of this decrease in digestibility involve increased digesta flow through the rumen and lower gastrointestinal tract (Kennedy et al. 1976, Kennedy and Milligan 1978) associated with increased rumination time (Gonyou et al. 1979) and increased reticular contractions (Westra and Christopherson 1976).

The increased passage rate through the reticulorumen is partially counteracted by three responses: increased intake during prolonged cold exposure and thus an increase in the total amount of nutrients presented for digestion (Young 1981, Westra and Christopherson 1976), an increase in the apparent digestibility in the intestines (Kennedy et al. 1976), and an increase in microbial efficiency associated with the decreased turnover time (Kennedy et al. 1976). An effect of cold exposure possibly related to changes in digestibility is a decrease in rumen fluid volume (Degen and Young 1980, Kennedy et al. 1976) followed by a decrease in the volume of interstitial fluid and plasma (Degen and Young 1980).

Young (1981) and Young and Christopherson (1974) have summarized the effects of cold. They found a 16% average increase in annual feed needs caused in equal proportions by (1) a reduction in DMD, associated with increased passage rate and decreased digestive efficiency, and (2) a higher maintainence requirement, associated with increased resting metabolic rate and an increased energy requirement. These authors also discussed a "relatively minor but important effect", the need to produce heat during acute cold stress (i.e. storms) in order to maintain homeothermy.

Pregnancy as it Affects Dietary Requirements and Intake

Added to the effects of prolonged cold exposure are some important effects of late pregnancy. Since the volume of the abdominal cavity is limited, as the fetus grows and occupies more of that volume, rumen volume decreases (Grahm and Williams 1962; Forbes 1969, 1970; Bines 1971;). Although uterus volume increases steadily, Forbes (1968) found that rumen volume did not decrease until the last five weeks of pregnancy. In an experiment conducted with ewes (Forbes 1969) it was concluded that the volume of the abdominal cavity has an upper limit and that the expandable organs within the cavity must compete for that space. The three tissues most in competition are the uterus, the rumen, and deposits of abdominal fat. A decline in intake in the last weeks of pregnancy has been attributed to the rapidly expanding uterus causing a restriction on the amount of voluntary intake possible (Johnson et al. 1966, Curran et al. 1967, Forbes 1970, Bines 1971). Pregnancy did not seem to affect the volume of digesta in the lower intestinal tract (Forbes 1969).

Campling (1966) has shown changes in intake behavior during pregnancy. Pregnant cows ate more slowly and ruminated longer than their non-pregnant monozygotic twins. This behavior resulted in a 13 percent lower hay intake for the pregnant cows.

It has also been shown that increased passage rate is a physiological side effect of late pregnancy (Grahm and Williams 1962). Although increased passage rate would tend to offset the decreased intake caused by smaller rumen volume, both factors would contribute to under nutrition in the last weeks of pregnancy.

Forbes (1970) postulated that a change in endocrine balance could also cause a depression in food intake. Estrogen in the presence of progesterone was shown to depress voluntary intake, and estrogen secretion by the placenta increases during the last third of pregnancy (Robinson 1957 as cited in Forbes 1970).

Robinson and Forbes (1967) studied the protein requirements of mature breeding ewes. A decline in intake was seen as pregnancy advanced; the decline was more pronounced on low-protein diets (5.5 percent vs. 11 percent crude protein in the entire ration). However, the efficiency of digested N utilization improved as pregnancy advanced. The intake of apparently digested N required for maximum retention efficiency decreased from 0.623 g/kg$W^{0.73}$/day at 10-12 weeks pregnant to 0.567 g/kg $W^{0.73}$/day at 18-20 weeks pregnant.

The fetus has priority for amino acids in conditions of undernutrition. The decrease in equilibrium N requirements seen in this study suggests some transfer of N from maintaince to production during pregnancy and undernutrition.

Besides using N for fetal development, the animal also experiences an increased energy requirement during pregnancy. This has been shown with measures of heat loss from pregnant and non-pregnant ewes. During the 145 days of pregnancy, pregnant ewes lost 39.5 mcal more heat than non-pregnant ewes (Brockway et al. 1963). During pregnancy the animal experiences greater nutritional needs with a decreasing ability to obtain them.

Supplementation as it Affects Winter Forage Intake

The most important and most varied supplements for cows grazing winter range are protein and energy. As discussed previously, these are often limiting in a winter range setting. A compounding factor is the fact that energy needs are met first and protein will be used for energy until it is no longer limiting (Clanton 1981).

When feeding a dietary supplement to cows on winter range, it is important to feed just that, a supplement, and not a replacement. Therefore, the supplement's effects on the intake and digestibility of the forage are most important and will be discussed here.

Several experiments have shown that protein supplement can increase the intake of low protein feed (Clanton and Zimmerman 1965, Cook and Harris 1968a, Topps 1972, Clanton 1981, Turner 1985). Branine and Galyean (1985) reported increased passage rate (and decreased turnover time) and increased intake when steers grazing mature blue grama rangeland were fed .5 kg of corn / head / day compared to steers fed no supplement and 1 kg of corn / head / day. However, this effect is not always seen (Rittenhouse 1969). The influences seem to be dependent on the concentration of crude protein in the forage. A generally accepted rule is that protein supplements will increase intake when protein levels in forage are below 8% (Allison 1985).

As has already been discussed, cold weather stimulates the rate of passage in the reticulorumen, rumen volume decreases during pregnancy, and lignin and cell wall constituent contents are high in winter forage while protein content is low. 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 1982). The two methods of achieving particle size reduction are rumination and microbial fermentation. 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 positive correlation to the cell wall constituent content of feed (Welch and Smith 1969). Microbial fermentation relies on the activity and numbers of rumen microflora. Any factor, including all those mentioned above, that decreases microflora activity or numbers can be expected to decrease DMD (Crampton 1952) and, therefore, decrease intake. The positive effect of protein supplementation on digestibilityand intake may be due toa positive effect on microbial digestion (Campling et al. 1962, Egan 1965).

Protein supplement allows the optimization of microbial synthesis, numbers, and activity as the available nitrogen content of the diet increases above that available in forage alone (Arias et al. 1951, Moir and Harris 1962, Zinn and Owens 1981).

These conclusions are not supported by recent studies that have attempted to show in more detail the effects of protein supplement on N digestion and rumen microbial efficiency. Goetsch and Owens (as cited in Goetsch et al. 1984) and Goetsch et al. (1984) have reported conflicting results on the impact of protein supplement. The first study showed improved microbial efficiency (g microbial N / kg organic matter fermented) when a diet containing 12 percent CP (crude protein) was supplemented with soybean or cottonseed meal to a level providing 17 percent CP. The second study showed no such improved microbial efficiency as CP levels were increased from 9.2 to 15.1 percent. In addition, bacterial numbers and the amount of microbial N passing to the duodenum remained the same as CP in the diet rose. However, rumen protozoa numbers and ADF (acid detergent fiber) digestion increased in the second study when the basal diet was supplemented. Grummer et al. (1984) concluded that changes in rumen ammonia concentration "do not regulate protein or dry matter degradation by ruminal microbes". There remains a need for clarification of this topic. There is strong evidence showing increased intake of low quality forage when small amounts of protein supplement are provided. Studies showing evidence to the contrary may have fed diets differing to such an extent that results should not be compared.

While supplements may increase the digestible protein received from range forage, Cook and Harris (1968a) showed that there is an accompanying decrease in the digestibility of cellulose and gross energy. The cows received less metabolizable energy when range forage was supplemented.

A portion of the protein in any feedstuff is unavailable in the rumen, and bypasses or escapes to the lower gastrointestinal tract. The amount of bypass or escape protein varies not only between feeds, but also within feeds due to feed processing and "animal, dietary, and microbial variables" (NRC 1984). The NRC (1984) has suggested three categorises of feedstuffs based on their percentage of bypass protein: (1) low bypass (less than 40 percent), including soybean meal and peanut meal; (2) medium bypass (40 to 60 percent), including cottonseed meal, dehydrated alfalfa meal, corn grain, and brewers dried grains; and (3) high bypass (greater than 60 percent), including meat meal, corn gluten meal, blood meal, feather meal, and fish meal. The supplements used in this study had a soybean meal base. Cook and Harris (1968a) used the nylon bag technique to determine that a soybean meal supplement containing 48.2 percent total protein was 83.4 percent digestible in the rumen. Hume (1974) reported a similar apparent DMD for soybean meal of 83.1 percent. In his review of bypass protein, Chalupa (1975) reported that 40 to 59 percent of soybean meal protein will bypass or escape the rumen, and therefore, will be unavailable to rumen microbes.

The benefits of bypass protein result from a increase in essential amino acids available to the animal in the small intestine and greater true digestibility of quality proteins compared to the digestibility of crude protein from rumen microbes (Van Soest 1983). 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 protein supplement is less likely.

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, Campling and Murdoch 1966, Elliott 1967, Rittenhouse et al. 1970, Bellows and Thomas 1976, Merrill and Klophenstein 1984, Allison 1985). Energy supplements have been shown to decrease the digestion of cellulose and other carbohydrates (Cook and Harris 1968a).

Studies where both protein and energy are fed are inconclusive. Clanton (1981) fed combinations of protein and energy to cows, but saw no significant difference in dry matter intake or digestibility when averages for supplemented groups were compared to the control (unsupplemented) group. Raleigh and Wallace (1963) found an increase in forage intake when low levels of protein were fed regardless of energy level. When high levels of protein were fed, forage intake decreased, again, regardless of energy level. Turner (1985) found increased intake of range forage with 1.8 kg/day of a 15% protein supplement. But when half that same supplement and 0.9 kg/day of a 30% protein supplement were fed, no increase in intake over controls was seen.

Kartchner (1981) supplied a protein and an energy supplement to groups of cows during two successive winters. The first winter was mild with readily available forage, no intake advantage was gained from either supplement. The second winter was more severe and intake and DMD were enhanced by protein supplement, but depressed with energy supplement.

The effect of supplement can also be affected by the timing of supplementation. Adams (1984b) and Kartchner and Adams (1982) reported that cows fed every day gained weight and condition while those fed every other day gained less weight and lost condition. These findings were attributed to the effects within the rumen. Alternate day feeding brought reduced ph and increased VFA concentrations. Lower rumen ph brings about reduced fiber digestion which could account for the lower weight gain.

Adams (1984a,b) also studied the effect of the time of day of supplement feeding. Steers fed in the early afternoon spent less time grazing, but consumed more forage, and had a higher average daily gain than steers fed in the morning. The author postulated that feeding supplement in the morning disrupted normal grazing activity and affected both behavior and performance.

Many studies have dealt with the current and subsequent performance of cows receiving winter supplement. Cows have lost substantial amounts of body fat over the winter without adversely affecting their subsequent performance or the performance of their calves (Thompson et al. 1983, Turner 1985). But supplement level has been directly related to a cow's winter weight loss and inversely