Supplement and forage intake for range sheep and beef cattle
by Nancy Taylor

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

Abstract:

In experiment 1,120 pregnant Targhee ewes (2-6 yr) grazing native winter range were used to determine the effects of a 25% crude protein (CP; as-fed) supplement provided in pellet or block form on supplement and forage intake and ewe bodyweight change. Ewes were group-fed 6.82 kg/day of a wheat middling-soybean meal based pellet in troughs or had ad libitum access to a cooked molasses based block. Supplement DMI and CV were greater ($P=0.001$; CV 32% (P) and 99.5% (B)) for pellet than block supplemented ewes. Younger ewes consumed less ($P<0.05$) supplement than older ewes. Treatment x pasture interactions were detected ($P<0.001$) for forage DMI and ewe bodyweight change. Forage DMl and bodyweight change were greatest ($P<0.01$) by Lowland Pellet ewes, intermediate ($P<0.01$) for Upland Block and Lowland Block ewes, and lowest ($P<0.01$) by Upland Pellet ewes. Delivery method affected individual supplement consumption. Pastures had the greatest impact on bodyweight change. In experiment 2, 32 cows individually fed chopped hay (6.97% CP) were used to determine the effects of four levels of protein supplement on forage and nutrient intake and digestibility. Eight cows were assigned to each of four treatments, which supplied 0, 100, 203, or 303 g CP in a molasses-based liquid supplement. Orts were weighed to determine forage intake. There was no effect of supplement level on hay DMI ($P>0.55$), hay DM digestibility ($P=0.98$), or hay digestible DMI ($P>=0.53$). There was a linear increase in total diet DMI ($P=0.04$) due to supplement level, but not on a % BW basis ($P=0.19$). A linear increase in total diet digestible DMI ($P<0.05$) was due to supplement intake. There was no effect ($P=0.13$) of supplement level on diet DM digestibility. There were no treatment differences ($P>0.35$) in hay nutrient intake for OM, CP, NDF, or ADF or digestibility for OM, NDF, or ADF. Total diet CP intake, CP digestibility, and digestible CP intake were all linearly increased ($P<0.001$) by supplement intake. Increasing protein supplement level had no effect on hay intake or digestibility due to high forage intakes (avg 2.6% BW), but total diet digestible DMI and CP intake were increased.

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APPROVAL

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

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Date 4/18/2001

This thesis is dedicated to my father, Dr. William L. Taylor.

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ABSTRACT

In experiment 1, 120 pregnant Targhee ewes (2-6 yr) grazing native winter range were used to determine the effects of a 25% crude protein (CP; as-fed) supplement provided in pellet or block form on supplement and forage intake and ewe bodyweight change. Ewes were group-fed 6.82 kg/day of a wheat middling-soybean meal based pellet in troughs or had *ad libitum* access to a cooked molasses based block. Supplement DMI and CV were greater ($P=0.001$; CV 32% (P) and 99.5% (B)) for pellet than block supplemented ewes. Younger ewes consumed less ($P<0.05$) supplement than older ewes. Treatment x pasture interactions were detected ($P<0.001$) for forage DMI and ewe bodyweight change. Forage DMI and bodyweight change were greatest ($P<0.01$) by Lowland Pellet ewes, intermediate ($P<0.01$) for Upland Block and Lowland Block ewes, and lowest ($P<0.01$) by Upland Pellet ewes. Delivery method affected individual supplement consumption. Pastures had the greatest impact on bodyweight change. In experiment 2, 32 cows individually fed chopped hay (6.97% CP) were used to determine the effects of four levels of protein supplement on forage and nutrient intake and digestibility. Eight cows were assigned to each of four treatments, which supplied 0, 100, 203, or 303 g CP in a molasses-based liquid supplement. Orts were weighed to determine forage intake. There was no effect of supplement level on hay DMI ($P\geq0.55$), hay DM digestibility ($P=0.98$), or hay digestible DMI ($P\geq0.53$). There was a linear increase in total diet DMI ($P=0.04$) due to supplement level, but not on a % BW basis ($P=0.19$). A linear increase in total diet digestible DMI ($P\leq0.05$) was due to supplement intake. There was no effect ($P=0.13$) of supplement level on diet DM digestibility. There were no treatment differences ($P\geq0.35$) in hay nutrient intake for OM, CP, NDF, or ADF or digestibility for OM, NDF, or ADF. Total diet CP intake, CP digestibility, and digestible CP intake were all linearly increased ($P<0.001$) by supplement intake. Increasing protein supplement level had no effect on hay intake or digestibility due to high forage intakes (avg 2.6% BW), but total diet digestible DMI and CP intake were increased.

INTRODUCTION

Seventy percent of the 93 million acres in Montana are considered rangelands or grazeable woodlands (Ross and Taylor, 1989), and the major use of these rangelands is for grazing sheep and cattle. Feed and supplement costs can be more than 50% of total costs for range livestock producers (USDA, 1994), and any practice that improves supplement or forage consumption should benefit producers.

Quantification of supplement intake and animal feeding behavior has not been adequately addressed in the literature (Bowman and Sowell, 1997). Tait and Fisher (1996) stated that there is very little published information on the variation in intake for supplements offered free-choice to grazing animals. When supplements are used to provide nutrients such as protein, wide individual intake variation is likely to have practical health implications (Kendall et al., 1983). On nutritional grounds, the usefulness of molasses blocks as carriers for urea or other additives is limited by intake variability (Lobato et al., 1980b). Bowman and Sowell (1997) stated that if animals consume less than a target amount of supplement, then the formulated nutrient intake is not received. If animals consume more than a target amount, supplementation costs are increased, and there can be potential negative impacts on forage intake and digestibility.

Forage quality is an important factor relative to forage intake and influences the effectiveness of protein supplementation. Liquid supplements are often fed to cattle grazing poor quality standing pasture, range, or crop residues (Kunkle et al., 1997). Bowman et al. (1999) concluded that cows consuming liquid supplement while grazing native range in the fall had greater forage intake and digestibility than unsupplemented cows. Moore et al. (1995), in a review of supplementation studies, found that forage crude protein (CP) concentration varied over a large range. When CP was less than about 7%, voluntary intake was low and related positively to CP, but above 7% there was little relationship between intake and CP. When the ratio of digestible organic matter (DOM) to CP was greater than 7 (indicating a deficiency of protein relative to energy), forage intake was reduced when energy or protein supplement was offered. When the ratio was less than 7 (indicating a balance between protein and digestible energy), intake was not related to the ratio of DOM to CP.

Although protein supplementation has been shown to improve forage intake and digestibility by beef cattle (Daniels et al., 1998; Earley et al., 1999), more research is needed to look at delivery methods, individual intake, and level of supplement and how that affects the utilization of forage based diets for sheep and cattle. Supplementing at a higher level than animals require would increase costs with little or no improvement in performance, forage intake or digestibility, and a lower amount than necessary might be less expensive, but could also decrease animal performance and utilization of low quality forage.

LITERATURE REVIEW

Supplement and Forage Effects on Animal Performance

There are several factors related to supplement and forage that have profound effects on animal weight gain and productivity. Initial body condition, intake (of both supplement and forage), supplement level, type or form of supplementation, and whether or not animals are consuming any supplement are all key factors in the results observed for grazing ruminants offered protein supplementation.

In a review of Montana winter range ewe nutrition research, Thomas and Kott (1995) noted that body condition entering the winter influenced ewe productivity and response to supplementation. Research showed that ewes could lose some body condition and maintain desired levels of productivity if they entered the winter in good body condition.

Crabtree and Williams (1971) reported a positive relationship between initial live weight and voluntary intake, and an additional 0.019 Mcal ME/day was consumed per kg increase in live weight. Within treatment groups, lambs consuming relatively more food also made relatively higher weight gains. Nolan et al. (1974) reported that rate of liveweight change (g/d) was significantly correlated with intake of supplement based on regression analysis from a study with 48 Hereford cows.

Warly (1994) found that average daily gain of sheep under medium (67 g CP/d) levels of protein or high (94 g CP/d) levels were significantly higher than those on low protein (40 g CP/d) diet. The author suggested that the main constraints in utilization of low quality forage by ruminants that limited animal performance were low N and high cell wall contents in the forage.

DelCurto et al. (1990a) investigated the influence of supplemental protein concentration on the intake and utilization of dormant range forage by beef cattle, and how that affected performance. These authors concluded that beef cow body condition (BC) and bodyweight (BW) losses during the winter grazing period were minimized with increasing supplemental CP concentration.

Vanzant and Cochran (1994) evaluated the effects of amount of supplemental protein from alfalfa hay on performance of cows grazing tallgrass prairie during winter. Their results indicated that improvements in performance of beef cows in moderate body condition were greater when the amount of supplemental alfalfa was increased from 405 to 607 g CP/d than when it was increased from 607 to 809 g CP/d, indicating that a moderate level of protein supplement was optimal in this situation.

DelCurto et al. (1990b) found that beef cow weight changes were influenced by form or source of supplemental protein. Cows supplemented with dehydrated alfalfa pellets (DEHY) gained more weight during the first 84 days (d) of supplementation than cows supplemented with soybean meal/sorghum grain (SBM/SG) or alfalfa hay. From 84 d to calving, weight loss was over 20% greater in cows supplemented with alfalfa hay. Up to the breeding period, BW loss was least for DEHY cows, intermediate for SBM/SG supplemented cows, and greatest for alfalfa hay supplemented cows. From 182 d to trial termination (d 265), those cows previously fed alfalfa hay and SBM/SG displayed compensatory weight gain compared with cows that had been previously supplemented with DEHY.

Earley et al. (1999) found that cows supplemented with protein gained two times more weight than unsupplemented cows. Cows receiving supplement lost less body condition during a study by Daniels et al. (1998) compared with control cows.

Supplementation of ruminants generally results in improved performance and productivity, as shown by the studies discussed, but there are factors such as type and level of supplement or forage intake that will affect the amount of improvement observed, and these factors must be considered when management practices are developed.

Variation in Individual Supplement Intake

A major limitation to providing additional nutrients to grazing animals is the inability to control individual animal consumption of supplement. Experiments that have evaluated variation in individual animal supplement consumption show that some animals refuse supplements altogether, while others consume excessive amounts (Bowman and Sowell, 1997). Low intake may provide insufficient nitrogen to produce a real benefit, while a high intake, even though not sufficient to cause toxicity, may be wasteful through increased urinary nitrogen excretion (Coombe and Tribe, 1963).

Tait and Fisher (1996), in a review of current literature, stated that there is very little published information on the variation in intake of supplements offered free-choice to grazing animals, with most studies conducted using molasses feedblocks and liquids. Data from studies they reviewed indicate large day-to-day and among animal variation in the quantity of supplement consumed and the frequency with which supplement was eaten. Kunkle et al. (1997) noted that consumption of both liquid and dry self-fed supplements is variable and situation dependent. Intake depends on animals, forage, weather, water, and other factors. Many of these factors change constantly, therefore consumption changes. Average consumption of the herd can be measured but research indicates there is considerable variation in individual animal consumption within the herd, which can be a concern when delivering drugs, nutrients, energy, and protein required to improve animal performance.

Intake variability among grazing ruminants of protein and grain supplements has not been extensively studied (Coombe and Mulholland, 1983). According to Mulholland and Coombe (1979), results on response to supplements have been extremely variable, and no clear pattern has emerged from which predictions of likely production responses can be made. These authors believe this problem is in part a result of lack of information on the variation among sheep and cattle in supplement intake.

It is important to know and control individual supplement intake values. The usefulness of molasses blocks as carriers for urea or protein is limited by variability in intake (Lobato et al., 1980b) and wide individual intake variation is likely to have important practical health implications (Kendall et al., 1983). There are implications of intake variation beyond protein supplementation as well. For example, if individual energy feedblock supplement intake is highly variable, as Ducker et al. (1981) found, this may be a particular health disadvantage when feedblocks are used as a carrier for nutrients or medication such as magnesium or anthelminics. Graham et al. (1977) stated that the success of any free-choice method for bloat control depends on the proportion of animals that consume it and within or between day variations in intake.

Mulholland and Coombe (1979) found that mean intakes of urea from block or liquid supplements by sheep grazing wheat stubble were approximately equal to desired levels, although there was considerable variation among sheep. The coefficient of variation exceeded 40% in more than half the recordings of individual animal intake. Considerable intake variability among sheep persisted throughout the experiment, although there was more tendency with the liquid for the highest intakes to be well above desired levels. Intakes of block supplements were variable and often low, particularly with the mineral block which had a much harder texture than the mineral/urea block and was not eaten as readily. This data suggests that some sheep consumed more supplement than required amounts, and intake by others was lower than desired.

Lobato and Pearce (1980) measured average intake of molasses-urea blocks by 1188 grazing sheep with forage containing 2.4 to 5.9% CP. After 3 weeks, 50% of the sheep had consumed some supplement but there was wide variability between flocks in the proportion of sheep that licked the blocks and for average individual intakes. Total intake of blocks within each flock ranged from 0 to 79%. Average intakes of grazing sheep consuming the blocks ranged from 100 g/sheep-wk to 400 g/sheep-wk. Intakes of sheep confined in yards ranged from 100 to nearly 500 g/sheep-wk.

Individual dry matter intakes were measured using four groups of 16 ewes, indoors or at sparse winter grazing (Kendall et al., 1983). Ewe groups received 14 feedblock supplements competitively, eight trough supplements competitively, or two feedblock supplements individually. The variation in individual supplement intake was high, regardless of supplement type. Individual intake variation was higher outdoors than in confinement especially for self-fed blocks. Housed ewes showed a 2.5-fold range of individual intakes, which occurred with a high-intake, self-fed block after a 4-week training period. This variation expanded to over 8-fold when a low intake, harder, free-access feedblock was provided. Similar irregular patterns in total group feedblock intake were observed for grazing ewes, especially when higher intake feedblocks were provided. The authors concluded that trough supplements allowed a more uniform delivery method for energy supplements than free-access feedblocks when offered in conventional rations of 0.2 to 0.36 kg DMI per ewe per day.

A series of trials was conducted to measure the extent of individual variation in feedblock intake for ewes on upland hill farms (Ducker et al., 1981). Results showed that feedblocks did not ensure uniform intake of supplementary nutrients by grazing sheep. Nineteen percent of the ewes sampled did not consume any of the free-access feedblocks, and 36% had eaten little or no feedblock. Individual intake ranged from 0 to 1336 g\hd-d. The variation within flocks increased if there were wide differences in body condition and ewe age. The proportion of ewes not consuming feedblock varied between flocks (0 to 67%). Thirteen percent of the ewes had fecal chromium (Cr) concentrations of more than 3g/kg, indicating high levels of feedblock consumption relative to forage intake.

Forty-eight Hereford cows grazing native winter pasture in Australia were given liquid supplement in a roller drum to measure individual intake (Nolan et al., 1974). Eight cows did not consume measurable amounts of supplement and the other 40 animals consumed from 30 ml to 2.4 liters (l) per day.

Fifteen 27-month-old grazing Hereford heifers were supplemented with urea-molasses mixtures by Langlands and Donald (1978). Supplement consumption varied between animals, with a coefficient of variation of +/-37%, and 4% of the animals refused to consume the supplement.

One hundred and one Angus cows and their bull calves grazing improved summer pastures were used to determine cow and calf intake of liquid supplement and its effect on forage intake and performance (Earley et al., 1999). Two cows appeared to consume no supplement, and all of the calves consumed some supplement. There was a wide range of intake variation with supplement intake of cows ranging from 0 to 1.2 kg/d (95% CV), and calf intake ranged from 0 to 0.62 kg/d (119% CV).

Sixty crossbred 2- and 3-year old pregnant cows were assigned to one of three native range pastures by Bowman et al. (1999) to evaluate forage and supplement intake. Individual supplement DM consumption ranged from 0.002 to 2.54 kg/day. The CV of 95-150% showed a wide range in supplement intake by individual cows, and 32.5% of cows consumed only trace amounts.

When blocks are used to supplement mature pasture, the amount of block consumed by an individual animal is important, because the animal may be unable to obtain adequate nitrogen from forage alone. The studies discussed above provide evidence that there is a wide range in individual intake when pelleted, block, or liquid supplement is offered to sheep and cattle in groups, and intake variation is highest with block supplements.

Behavioral Factors in Individual Supplement Intake Variation

Many differences between animals in supplement intake are due to behavioral influences, including social dominance, age, experience, social transmission of feeding behavior, and preference for certain foods. Trough space is an additional factor that affects supplement intake.

Social dominance, body size, and bodyweight

Lobato and Beilharz (1979) and Lobato and Pearce (1978) reported that intake of supplement was correlated with liveweight. Wagnon et al. (1966) found that there was a positive correlation between social dominance and size within cattle breeds. Subordinate animals often refrained from entering a space alongside a dominant animal because the latter turned her head in threat. Weight was also found to have a significant influence on the rank attained by a cow. Wagnon concluded that variation in rank was a factor in the utilization of a self-feeder by a herd of range cows varying in age from 1-10 years during the dry forage season.

Age

Wagnon (1966) found that age was a significant factor in aiding a cow to attain rank, and there was also evidence that old age contributed to a decline in rank. They noted that hand-feeding supplements to cows resulted in many 2- and 3-year olds being driven from troughs before they had an opportunity to eat their share of feed.

Daniels et al. (1998) also reported that younger cows had lower intake when 180 crossbred cows were assigned to native range pastures during the winter to evaluate forage and supplement intake as affected by cow age. Supplement intake (as-fed) was lowest for 2-year olds (0.8 kg/d), intermediate for 3-year olds (1.2 kg/d), and greatest for 4-, 5- and 6-year olds (avg. 1.5 kg/d).

Bowman et al. (1999) reported that 3-year old cows consumed 11% more forage DM than 2-year old cows (15.3 vs. 13.8 kg/day). Two and 3-year old cows on regulated liquid supplement and 2-year old cows with *ad libitum* access consumed less supplement DM than 3-year-old cows with unlimited access. Based on these studies, it appears that younger animals tend to have lower supplement intake due to the social dominance of older animals in the herd.

Experience/social transmission of feeding behavior

Chapple and Lynch (1986) stated that experience (age, exposure, taste aversion), and social transmission of feeding behavior (observational learning, role of mother, adult/young interactions) result in feeding behavior modification, and adult sheep may not accept new foods as readily as weaned lambs.

Lobato and Pearce (1980) reported that intake increased with time, and Lobato et al. (1980b) reported that early exposure to molasses-urea blocks increased the subsequent intake of the block by lambs, while sheep that had not been offered any supplement pre-weaning showed little or no interest in later periods. Juwarini et al. (1981) reported that experienced sheep consumed about 13% more supplemental wheat than a non-experienced group, but after 10 days, both experienced and inexperienced sheep had similar intakes.

Preference

According to Chapple and Lynch (1986), diet selection is affected by preferences related to chemical stimuli and genetics. Lobato and Beilharz (1979) suggested that intake of a molasses block depended on the individual preference of particular animals. They found it difficult to predict intake of one supplement from knowledge of intake of another, and that sheep were attracted to different supplement characteristics causing variation in individual intake.

Trough space

Arnold and Maller (1974) found that as the rate of disturbance increased and trough space per sheep decreased in a group feeding situation, a progressively greater proportion of sheep stopped competing for feed and became non-feeders. Wagnon (1966) observed that conditions for supplementation were best when cows stood close together at troughs. With only 3 feet of trough space per cow, there was less fighting and position changing while feed was still available.

Protein Supplement Effect on Forage Intake and Digestibility

Providing protein supplements to range sheep during pre- and postpartum periods can be beneficial when forage conditions are inadequate to maintain desired levels of production (Hatfield et al., 1991). One means by which protein supplementation improves performance of cattle consuming low-quality forages is through stimulation of voluntary forage intake, and positive responses to protein supplementation are often seen with forages containing less than 6-8% CP (Kartchner 1980; Allison, 1985). Ernst et al. (1975) reported that digestibility of CP was significantly improved by a supplement containing urea. According to these authors, the increased intake of low quality hay with urea supplement appeared to support the suggestion that the primary factor governing the intake of low quality hay is nitrogen level.

The effect of protein supplementation on the utilization of low quality forage was investigated by Warly et al. (1994). Forage was utilized better by sheep when supplement was given at a medium (67 g/d; MCP) level of protein than at low (40 g CP/d; LCP) or high (94 g/d; HCP) levels. Digestibility of OM in sheep given the HCP diet was significantly higher than those on the LCP diet.

Eight rumen-cannulated steers fed prairie hay *ad libitum* were used by McCollum and Galyean (1985) to determine the effect of protein supplementation on forage intake and digestibility. Treatments were: no supplement or 800 g of cottonseed meal/hd-d. In vitro rate of dry matter disappearance did not differ for supplemented compared with control but DM digestibility was greater for supplemented animals. Prairie hay intake was increased by cottonseed meal supplementation (16.9 vs 21.5 g/kg BW).

Hannah et al. (1991) reported that steers consuming dormant bluestem-range forage (2.3% CP) had increased forage intake and digestibility when supplemented with 506 g CP/d compared with 230 g CP/d or control animals. Fike et al. (1995) studied the effects of supplement CP concentration on utilization of low quality forage by cattle. Protein supplementation increased digestible DMI and forage DMI and tended to increase digestible NDF intake but did not alter apparent DM or NDF digestibility. However, DM and NDF digestibilities improved when CP concentration was increased from 240-634 g CP/d.

Daniels et al. (1998) found that forage DMI was lowest for unsupplemented cows (12.9 kg), intermediate by cows with *ad libitum* access to liquid supplement (14.8 kg), and highest by cows given regulated amounts of supplement (18.9 kg). The authors concluded that feeding liquid protein supplement increased forage intake and forage digestibility. Liquid supplementation also increased forage intake by cows and calves grazing improved forages in late summer according to Earley et al. (1999), and these authors reported that forage intake (g/kg BW) by supplemented cows and calves was 64% greater than for unsupplemented cows and calves.

Bowman et al. (1999) reported that forage 48 h DM and NDF digestibility values were greater for cows with ad libitum and regulated access to liquid protein supplement than for control animals (avg. 67.1 vs. 49.4% DM; avg. 63.7 vs. 42.7% NDF). Cows receiving regulated and ad libitum supplement consumed 49% more forage DM than control cows (avg. 16.3 vs. 11.0 kg/day). They concluded that cows consuming liquid supplement while grazing native range in the fall had greater forage intake and digestibility than unsupplemented cows.

DelCurto et al. (1990a) evaluated the influence of supplemental protein concentration on the intake and utilization of low quality (3% CP) range forage by beef cattle. Intake and utilization of dormant forage by steers were improved with increasing (112, 271, and 397 g/d) levels of CP in the supplement. Steers offered 271 and 397 g CP/d consumed 42 and 60% more forage, respectively than steers fed 112 g CP/d.

Church and Santos (1981) measured voluntary intake of cattle offered protein (SBM) and NPN supplements, and concluded that CP supplementation from SBM increased consumption of forage, but that such an increase was less likely with a liquid supplement containing NPN compounds. In addition, their results indicated that increased forage and supplement intake was not always accompanied by increases in digestibility.

Vanzant and Cochran (1994) evaluated the effects of amount of supplemental protein from alfalfa hay on intake and utilization of dormant, tallgrass-prairie forage by beef steers. Voluntary tallgrass-prairie hay intake decreased linearly but total DMI increased linearly with increased alfalfa.

The literature indicates that protein supplementation improves intake and digestibility of low quality forage for sheep and cattle in most situations. However, certain levels and sources of protein are optimal for specific production and grazing situations.

Diet quality: sheep vs. cattle

Nitrogen supplementation of ruminants grazing native pastures in late winter was examined in two experiments by Langlands and Bowles (1976). These authors noted that sheep and cattle differ in their ability to graze selectively, and therefore respond differently to supplementation. Dietary composition was not affected by supplementation but sheep selected a diet containing higher N (1.7gN/100 g OM) than steers (0.96 gN/100g OM). Differences between supplemented and unsupplemented steers were not significant but sheep selected a diet containing between 75 and 90% more N and higher digestibility than steers. Hatfield et al. (1991) also found that sheep selected higher CP diets than those reported for cattle in studies conducted by Havstad et al. (1979), and Wallace et al. (1983). Therefore, sheep and cattle may respond differently to protein supplementation due to the ability of sheep to select a higher quality diet.

Energy Supplement Effect on Forage Intake and Digestibility

When sheep and cattle consume forages as their only energy source, intake of net energy (NE) may not be adequate to meet desired rates of animal performance such as daily gain or milk production (Moore et al., 1995). In such cases, energy supplements must be provided in order to attain desired performance, but may have a negative effect on forage intake due to a substitution effect.

Sheep with high energy needs after lambing often graze pastures before nutrient intake from the grass is adequate to provide the required levels of performance expected by producers. In these circumstances a grain-based supplement is often given (Milne et al., 1981). Supplementation not only modifies the feeding behavior of grazing animals, but also significantly affects diet efficiency and performance (Avondo et al., 1995). Dove et al. (1984) reported that one factor contributing to the magnitude of performance responses in sheep is the degree of substitution between intake of pasture and intake of energy supplement by individual ewes.

Four levels of a concentrate were offered to ewe lambs receiving hay in a study by Crabtree and Williams (1971). The voluntary intakes of the forage dry matter when given alone were 242 and 451 g/d respectively, and hay intake declined linearly with increasing concentrate level. Avondo et al. (1995) also reported that forage intake was negatively correlated to the level of energy supplementation. Total dry matter intake was significantly higher in the two groups receiving a higher supplemental level. Milne et al. (1981) reported that forage intake and total OM digestibility declined linearly with increasing intake of a cereal-based supplement. There were negative linear relationships between daily OM intake of herbage and daily OM intake of supplement and between total digestibility of OM and daily OM intake of supplement.

Two concentrate supplements containing different types of carbohydrates (corn-SBM or wheat middling-SB hulls) were evaluated for effects on forage intake in growing steers (Garces-Yepez et al., 1997). Consumption of hay was lower in supplemented than control cattle, but total DM intake was higher in supplemented than in unsupplemented cattle.

DelCurto et al. (1990a) conducted three experiments to evaluate effects of supplemental protein vs. energy level on dormant forage intake and utilization by cattle. Increased levels of supplemental protein increased intake and utilization of dormant tallgrass-prairie forage (3% CP). The addition of energy at the high level of protein had no depressing effect on forage intake, but increasing supplemental energy without adequate protein availability was associated with depressed intake and digestibility.

It appears from these studies that energy supplementation may be necessary to increase performance in sheep and cattle when energy is limited in low quality forage. However, a substitution effect of energy supplement for forage may occur when concentrate amounts are increased.

Effects of forage quality and availability on intake

Forage quality has a significant effect on intake for grazing sheep and cattle. Moore et al. (1995) found that forage CP concentration varied over a large range. When CP was less than 7%, voluntary intake was low and related positively to increasing CP content, but above 7% CP there was little relationship between intake and CP in the forage.

Five forages varying in quality, ranging from alfalfa to wheat straw, were fed to five beef steers with a liquid supplement (30% CP, 50% TDN, as-fed) to determine the effect of forage quality on consumption of forage and liquid supplement by beef cattle (Kellems and Church, 1981). The major contributor to reduced DM intake in this study was associated with forage quality and not with the supplement. The proportion of CP provided by the forage decreased and that provided by the supplement increased as forage quality declined.

Forage availability also has a significant effect on intake for grazing sheep and cattle. Pasture characteristics including herbage yield and plant height and the relationship of these factors with forage intake by grazing sheep were examined by Allden and Whittaker (1970). There was a close relationship between rate of intake and herbage availability. When accessibility and a reduced amount of herbage imposed limitations on the rate at which the animal was able to bite its feed, it was shown that the sheep were able to partially compensate by increasing grazing time from 6 to 13 h/day. Milne et al. (1981) also reported a significant linear relationship between herbage intake of unsupplemented animals and herbage mass available in the grazing area.

Associative Effects of Supplements

When balancing diets for ruminants, associative effects are important to recognize. Bowman and Sanson (1996) noted that these effects are sometimes ignored, and it is often assumed that each component of a balanced ration will contribute a given amount of nutrients without interfering with utilization of other feeds in the diet. This approach does not account for the effects that supplemental feed may have on fermentation of the basal forage.

Associative effects can be negative or positive. Positive associative effects are seen when supplemental protein is provided to animals consuming low protein forage and there is an increase in forage intake and/or digestibility when supplemental protein is fed. A negative effect is seen when supplement suppresses intake or digestibility of forage so that the intake of digestible nutrients is less than would be expected from the forage and supplement separately. In a review of Montana winter range ewe nutrition research, Thomas and Kott (1995) noted that forage intake was not reduced when supplements were fed at 0.2 to 0.3% of ewe BW, and Earley et al. (1999) reported a positive associative effect for cows (forage intake was increased from 14.1 to 22.3 kg/d) and calves (an increase of 3.6 kg/d) when protein supplement was offered.

DOM:CP Ratios

To ferment a low quality forage, microbes in the rumen need both energy and nitrogen, and responses to protein supplementation are due to microbial requirements for nitrogen according to Paterson et al. (1994). The requirement for N relative to the supply of available energy is also determined by the stage of growth and physiological state of the ruminant animal, according to Langlands and Bowles (1978).

A database was constructed to describe and estimate supplementation effects in nonlactating cattle consuming forage ad libitum by Moore et al. (1995, 1999). The 1999 database included 66 publications on 126 forages (73 harvested and 53 grazed) and a total of 444 comparisons between control, unsupplemented and supplement treatments. The forage digestible OM (DOM):CP ratio proposed by Moore et al. (1999) in this database is a measure of the relationship of energy to protein in a forage fed to ruminants. As stated earlier, a ratio of less than 7 indicates a balance between protein and energy and a ratio of greater than 7 represents a deficiency of protein relative to energy. The DOM:CP ratio of a forage is an excellent predictor of animal response to protein supplementation at values below 7 and above 12.

Moore et al. (1995) calculated the change in forage intake (%BW) for each of 135 comparisons by subtracting voluntary intake of forage when fed alone from voluntary intake of forage when fed with supplement. Negative values indicated that supplement depressed forage intake (substitution of supplement for forage). There was a relationship between forage intake and the forage DOM:CP ratio. When DOM and CP were balanced (<7), forage intake values were negative. When DOM and CP were moderately unbalanced (>7 and <12), forage intake values were both positive and negative. At very high DOM:CP ratios (>12) all forage intake values were positive; all types and levels of supplement increased forage intake (Figure 1).

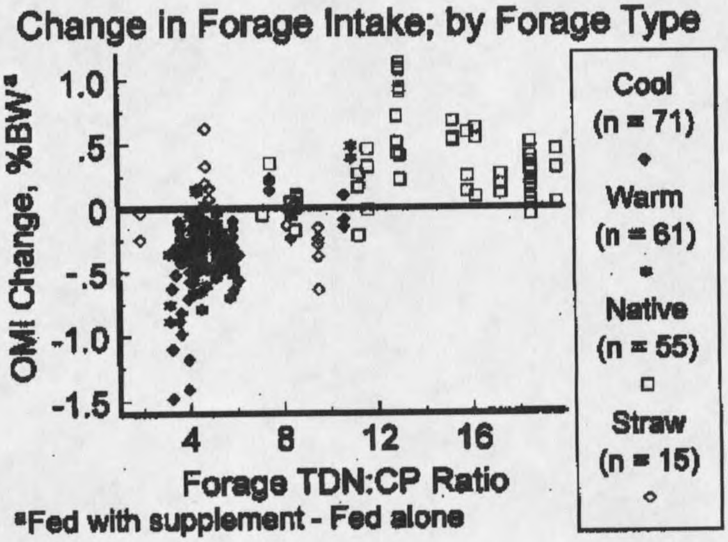

Figure 1. Change in forage intake with supplement classified by forage type (Moore et al., 1995).

Holderbaum et al. (1991) also reported a relationship between diet DOM and CP in determining animal response to NPN supplementation. Based on their herbage data, DOM to CP ratios for limpograss pastures in two years of study were 10.3 and 7.1, and despite the fact that N has been shown to be limiting for microbial synthesis when the ratio of DOM to CP in the diet exceeds 10, they found a response to nitrogen supplementation at ratios well below 10.

In a summary of the literature available on protein supplementation there are several conclusions that can be made. Response to supplementation varies due to forage quality and individual variation in supplement intake, forage intake, and digestibility. Supplement levels are not controlled in most range studies with grazing animals, which makes it difficult to determine the mechanisms of the variable results obtained. Therefore, Experiment 1 was designed to estimate individual supplement and forage intake for sheep in a range grazing situation, and Experiment 2 to measure individual supplement and forage intake for beef cows in a controlled feeding situation to identify which levels of protein supplement enhanced forage intake and digestibility.

SUPPLEMENT AND FORAGE INTAKE FOR RANGE SHEEP

Summary

Pregnant Targhee ewes (N = 120; 2-6 years of age) grazing native winter range were used to determine the effects of a 25% CP (as-fed) supplement provided in pellet (P) or block (B) form on supplement and forage intake and ewe bodyweight change. Sixty ewes receiving P were group-fed 6.82 kg/day of a wheat middling-soybean meal based pellet in troughs. Block-fed ewes had *ad libitum* access to a cooked molasses based block. The study was conducted for 41 days in southwestern Montana starting December 1, 1999. Supplement treatments were crossed over upland (U) and lowland (L) pastures on day 21. Supplement DMI was greater ($P = 0.001$) for P than B supplemented ewes. Supplement DMI CV was 32 and 99.5% for P and B ewes, respectively. Percentage of ewes consuming less than 20% of mean supplement DMI was 2 and 35% for P and B ewes, respectively. Two-year-old P ewes consumed less ($P < 0.05$) supplement than all older P ewes and 2- and 3-year-old B ewes consumed less ($P < 0.05$) supplement than 5- and 6-year-old ewes. Supplement treatment x pasture interactions were detected ($P < 0.001$) for forage DMI and ewe bodyweight change. Forage DMI and ewe bodyweight change were greatest ($P < 0.01$) by LP ewes, intermediate ($P < 0.01$) for UB and LB ewes, and

lowest ($P < 0.01$) by UP ewes. Delivery method affected individual animal consumption of supplement and younger ewes consumed less supplement. Pasture conditions and consequently forage DMI had a greater impact on ewe bodyweight change than supplement DMI or delivery method.

Introduction

A major limitation to providing additional nutrients to grazing sheep is the inability to control individual animal supplement consumption. Bowman and Sowell (1997) reported that some animals refuse supplements altogether, while others consume excessive amounts. Interpretation of data from grazing trials with supplementary feeding is difficult due to the lack of information concerning the quantity of supplement consumed by each animal in a group-feeding situation (Nolan et al., 1974). Arnold and Maller (1974) found that 1 and 7 year old sheep were least competitive when trough-fed, but few researchers have documented the effects of form of supplementation on individual supplement consumption by mixed-age groups of sheep.

Feed and supplement costs can be more than 50% of total operational costs for range livestock producers (USDA, 1994). Thomas and Kott (1995) concluded that supplementation is cost effective most winters in Montana, and Darroch et al. (1950) stated that protein supplements are cost effective when pregnant ewes need to gain bodyweight. When winter weather reduced forage intake, Thomas et al. (1993) found that protein supplements were cost effective, but these researchers did not analyze delivery method. Few studies have attempted to compare supplement delivery methods, forage intake, and ewe bodyweight change for sheep in the western United States under winter range conditions.

The objectives of this study were to: 1) determine if supplement delivery method or ewe age affected individual animal consumption of supplement; and 2) evaluate forage DMI and bodyweight change of grazing ewes either hand-fed a pelleted supplement or self-fed a cooked molasses supplement block under winter range conditions.

Materials and Methods

The study was conducted in southwestern Montana at the Red Bluff Research Ranch for 41 days from December 1, 1999 to January 10, 2000. One hundred twenty pregnant Targhee ewes (2 to 6 yrs of age) grazing winter range were randomly assigned by age to two treatments. Sixty ewes were group-fed 6.82 kg/d (114 g/ewe-d) of a 25% CP (as-fed) wheat middling-soybean meal based pelleted supplement (P, Table 1) in 4 troughs that were 3.7-m in length. The remaining 60 ewes were allowed *ad libitum* access to a 25% CP (as-fed) cooked molasses-based block supplement (B) in plastic tubs (Farmland Industries Research Farm, Kansas City, KS; Table 1). The manufacturer of the B supplement estimated average daily DMI for the block to be 114g/ewe. Both supplements contained not more than 8.0% equivalent crude protein from non-protein nitrogen.

Table 1. Composition (% DM basis unless designated as ppm) of pellet and block supplements.

Item	Pellet	Block
CP	27.0	29.3
NPN	8.0	7.9
NDF	25.1	5.7
ADF	7.0	1.2
ADL	0.3	0.4
OM	82.7	80.9
48-h DMD	77.4	86.8
Crude Fat[a]	3.65	3.51
Crude Fiber[a]	5.96	0.99
Calcium[a]	2.08	2.20
Phosphorus[a]	1.05	1.12
Magnesium[a]	0.33	0.35
Potassium[a]	1.04	5.04
Copper, ppm[a]	19.74	25.22
Iodine, ppm[a]	0.10	0.02
Cobalt, ppm[a]	0.21	0.77
Zinc, ppm[a]	126.05	31.8

[a] Values provided by manufacturer

A 133 ha upland (U) and a 61.5 ha lowland (L) pasture were used in the study (Table 2). Forage samples were collected from each pasture on October 15 and December 28 by hand-clipping 45 frames (0.25-m^2 quadrats) per pasture. The U pasture was dominated by Idaho fescue (*Festuca idahoensis*) and fringed sagewort (*Artemisia frigida*) and the L pasture was dominated by Kentucky bluegrass (*Poa pratensis*) and sedges (*Carex spp.*). Ewes were rotated once between pastures on day 21 of the study.

Table 2. Forage production, chemical composition, and DMD % (DM basis) of hand-clipped samples in Upland and Lowland pastures.[a]

	Upland pasture (133 ha)		Lowland pasture (61.5 ha)	
Item	October	December	October	December
Production, kg/ha	406	503	1,537	1,223
CP (%)	4.9	5.1	4.8	4.2
NDF (%)	61.7	61.3	57.3	62.6
ADF (%)	43.5	45.3	41.9	47.2
ADL (%)	5.2	4.7	4.6	3.6
OM (%)	91.3	92.6	90.3	92.2
48-h DMD	50.5	48.0	50.4	48.3
72-h DMD	70.3	69.8	64.2	61.2

[a] Values are means of composited samples of 45 hand-clipped frames (0.25-m^2 quadrats) per pasture

Ewes were weighed at the beginning of the study (day 0), at the time treatments were crossed over pasture (day 21), and the end of the study (day 41). Disappearance of block supplement was measured by weighing tubs on days 0, 21, and 41. Ewes on the P supplement were observed to consume all of the 6.82 kg of pellets, therefore daily disappearance of P was equal to the amount offered each day.

Thirty ewes from each treatment were dosed with sustained release chromic oxide boluses (Captec Chrome, Nufarm, Auckland, New Zealand) on day 8, and 30 different ewes from each treatment were bolused on day 28 of the trial. Fecal Cr concentration and daily Cr intake (165, 186, and 195 mg active/d for the 3 batches of boluses given to ewes) were used to estimate fecal output (FO) using the following equation:

FO, g/day = Cr marker intake / fecal Cr concentration.

Ytterbium (Yb) was added to both supplements at the time of manufacturing (2201 and 3653 ppm Yb for P and B, respectively) to estimate individual supplement intake. Fecal grab samples were collected on days 15, 17, and 20 from the first group of 30 ewes/treatment and on days 36, 38, and 41 from the second group of 30 ewes/treatment. Samples within period were composited by ewe, dried for 48 h at 60°C, ground through a 1-mm screen, and analyzed for DM (AOAC, 2000), Cr concentration by atomic absorption spectrophotometry (Ellis et al., 1982), and Yb concentration by inductively coupled plasma emission spectroscopy (Fassel, 1978). Hand-clipped forage samples from October and December were ground through a 1-mm screen, composited within pasture and month, and analyzed for CP, DM, and OM (AOAC, 1990), and for NDF, ADF, and ADL (Van Soest et al., 1991; Table 2). Forage samples were incubated *in situ* using two ruminally cannulated crossbred cows for 48 h using methods described by Bowman and Firkins (1993) to determine DM digestibility (Table 2). Estimates of forage DMI and individual supplement DMI were obtained using the following equations:

Forage DMI, g/day = FO g/day / (1 - forage 48-h DM digestibility)

Supplement DMI, g/day = (fecal Yb concentration g/g x FO g/day) /
(supplement Yb concentration g/g)

Based on mean supplement intake for each supplement treatment group, ewes were classified into four categories; non-consumers (0 to 20% of mean supplement DMI), low (21 to 50% of mean supplement DMI), average (51 to 150% of mean supplement DMI), and high consumers (>150% of mean supplement DMI).

Statistical Analysis

Supplement and forage DMI, and ewe BW change were analyzed as a 2 (block vs pelleted supplement) x 2 (upland vs lowland pasture) x 5 (2, 3, 4, 5, 6 year old ewes) factorial arrangement of treatments using the GLM procedure of SAS (SAS Inst. Inc., Cary, NC) with the individual animal as the experimental unit. Least squared means were used to compare supplement treatments, pastures, and age effects. All possible interactions were included in the model. Data were also analyzed using the CORR procedures of SAS (SAS Inst. Inc., Cary, NC) to determine the relationship between supplements and forage DMI, body weight change, and age.

Results and Discussion

Supplement intake

No pasture by supplement treatment interaction was detected for supplement DMI ($P = 0.30$). Mean supplement DMI, expressed as either g/day or % of BW was greater ($P < 0.01$) for P than B supplemented ewes (Table 3). Based on amount of P fed and manufacturer-estimated consumption of B, target intake for both supplements was 115 g/ewe-d (as-fed). Mean supplement disappearance was 114 and 54 g/ewe-d (as-fed) for P and B ewes, respectively. Mean supplement consumption based on Yb fecal concentration of each animal was 110 and 58 g/ewe-d for P and B ewes, respectively. Kendall et al. (1983) found that a greater proportion of ewes supplemented with blocks had intakes below 100 g than of ewes receiving supplement in troughs.

Table 3. Supplement intake by ewes supplemented with ad libitum access to a cooked block (B) or limit-fed a pellet (P).[a]

Item	P	B	SE	Pr > F
N	60	60		
DMI, g/day	110	58	5.6	0.001
DMI, %BW	0.15	0.07	0.01	0.001

[a] Supplement x pasture interaction, $P = 0.30$

The coefficient of variation for supplement intake was three times higher for B compared to P supplemented ewes (Table 4). Ducker et al. (1981) reported similar findings when individual intakes of supplement blocks by 2,931 grazing ewes from 15 different flocks were evaluated with a mean CV of 107%. Kendall et al. (1983) also found that free-access feedblocks tended to generate a higher CV for individual intake than trough supplements at daily DMI of less than 0.7 kg/ewe. Two percent of P supplemented ewes consumed less than 20% of mean P supplement intake compared with 35% of the B supplemented ewes (Table 4). Eighty-three percent of P ewes consumed between 51 and 150% of mean supplement intake compared with 27% for the B ewes. Ducker et al. (1981) reported that 19% of ewes did not consume any block at all, and 36% were classified as low consumers. Low supplement DMI by the B supplemented ewes is probably not as critical as the high CV and high percent of non-consumers associated with self-fed block forms of supplement. In most cases, nutrient density (i.e. CP or specific minerals) of the supplement can be increased to compensate for low intake. However, the goal of feeding the appropriate amount of supplemental nutrient to each ewe may be best achieved using a hand-fed supplement. Possibly, the gregarious nature of grazing ewes does not allow for all ewes to remain in the block supplement feeding area long enough for all ewes to consume adequate amounts of supplement. However, the fact that there were more high consumers implies that some ewes remained at the block longer and consumed more supplement.

Table 4. Average supplement intake distribution (as a percent of mean supplement intake within supplement form) for ewes supplemented with ad libitum access to a cooked block (B) or limit-fed a pellet (P) (data combined from two pastures).

Item	P	B
Non-consumers (0-20% of mean intake)	2	35
Low consumers (21-50% of mean intake)	5	10
Mean consumers (51-150% of mean intake)	83	27
High consumers (>150% of mean intake)	10	28
% CV	32.0	99.5

An age x supplement treatment interaction was detected (P = 0.02) for supplement DMI (Table 5). Within age groups, P supplemented ewes consistently consumed more (P < 0.08) supplement than B ewes. Among the 5 age groups within the P supplemented ewes, 2-year old ewes consumed the lowest (P < 0.01) amount of supplement and supplement DMI did not differ (P > 0.25) among the 3 to 6 year old age groups. In the B supplemented ewes, 2-and 3-year old ewes consumed less (P < 0.05) supplement than the 5- and 6-year old ewes. Arnold and Maller (1974) reported that 50% of 1-year-old sheep were non-feeders in a competitive trough-feeding situation, while only 8% of 4-year-olds were non-feeders, suggesting that age could have an effect on supplement intake. Chapple and Lynch (1986) concluded that supplement intake could be modified by age and animal experience with supplemental feeding. The fact that younger sheep are acquiring some permanent teeth at this time could have had an effect on intake of both pellets and blocks due to supplement hardness and difficult mastication for these young ewes.

Table 5. Mean daily supplement DMI (g) during the 41-day study for ewes ages 2-6 years supplemented with ad libitum access to a cooked block (B) or limit-fed a pellet (P).[a]

Age	N	Pellets	Blocks	SE	Pr > F
2	37	71^{b}	39^{bc}	9.0	0.011
3	25	115^{c}	24^{b}	11.1	0.001
4	16	112^{c}	60^{cd}	14.6	0.008
5	27	114^{c}	88^{d}	10.9	0.077
6	13	137^{c}	76^{d}	17.5	0.008

[a] Age x supplement interaction P = 0.02

[b,c,d] Means in a column lacking a common superscript differ ($P < 0.05$)

Forage intake

Pasture by supplement treatment interactions were detected ($P < 0.01$) for forage DMI. Forage DMI by LP ewes was greater ($P < 0.01$) than by ewes on the other pasture/treatment combinations when expressed on a g/ewe-d or % BW basis (Table 6). Forage intake was lower ($P < 0.01$) by ewes on UP than those on the other pasture/treatment combinations. Forage DMI did not differ ($P = 0.60$) between UB and LB ewes. Harris et al. (1989) found that ruminally cannulated ewes grazing native winter range selected a diet of up to 7.7% CP in some years, which could influence the effectiveness of supplementation because protein generally increases intake and digestibility of range forage when crude protein content is less than 8% (Allison, 1985). Even with high selectivity, this protein level of 7.7% does not meet recommendations of 9.3% CP for a 70 kg ewe (NRC, 1985). However, Hatfield et al. (1991) reported that ewes grazing pinyon-juniper/blue grama rangelands and given a 23% CP supplement selected diets with higher CP than ewes given no supplement at all. Therefore, a combination of supplementation and selectivity could potentially improve forage DMI. Bowman et al. (1999) reported that protein supplementation increased digestibility of native forages, and Langlands and Donald (1978) reported a greater response to supplementation when animals grazed lower quality forages, but in this study, pasture conditions appeared to have more effect on forage intake than supplement type, since pellet fed ewes had both the highest (LP) and lowest (UP) forage intakes ($P < 0.01$).

Table 6. Forage intake and bodyweight change for ewes grazing upland (U) or lowland (L) pastures and supplemented with ad libitum access to a cooked block (B) or limit-fed a pellet (P).

Item	Upland Pellet	Upland Block	Lowland Pellet	Lowland Block	SE	Pr > F
N	30	30	30	30		
DMI, g/day^a	1,472^b	1,909^c	2,516^d	1,930^c	95.8	0.001
DMI, %BW^a	2.1^b	2.7^c	3.5^d	2.6^c	0.13	0.001
ADG, kg^a	-0.27^b	0.05^c	0.2^d	0.04^c	0.02	0.01
BW chg, kg^a	-5.3^b	1.0^c	3.8^d	0.5^c	0.81	0.001

^{a} Supplement x pasture interaction, $P < 0.001$

^{b,c,d} Means in a row lacking a common superscript differ ($P < 0.01$

Bowman et al. (1995) concluded that performance and forage intake by supplemented animals were confounded by pasture condition and forage quality, and interpretation of data from this study is highly dependent on the pastures that were used.

Bodyweight change and Average Daily Gain

Pasture x supplement treatment interactions were detected ($P < 0.01$) for bodyweight change and ADG. Bodyweight change and ADG were greatest ($P < 0.01$) for LP, lowest ($P < 0.01$) for UP, and intermediate ($P < 0.01$) for UB and LB ewes (Table 6). Differences among supplement treatment/pasture combinations in bodyweight change and ADG are the same as differences noted for measures of forage DMI (Table 6) indicating the impact of forage DMI on ewe bodyweight change. In addition, ADG had the higher correlation coefficient with forage DMI than other variables tested (Table 7). Coombe and Mulholland (1983) reported that during the first 4 weeks of an 11 week study, all sheep ($n = 32$) lost weight except those offered supplement blocks, and over the whole experiment, supplemented sheep lost less weight than unsupplemented sheep. Nolan et al. (1974) reported that the rate of liveweight change in supplemented heifers was significantly correlated with liquid supplement intake. However in our study, supplement DMI and ADG had an r value of 0.14 ($P = 0.12$, Table 7). Lobato et al. (1980a) reported a positive correlation between liveweight gains of sheep and individual supplement intake of oats and hay, but not molasses. In contrast, Mulholland and Coombe (1979) did not find a strong relationship between intake of a urea-molasses-mineral supplement and the rate of liveweight change in wethers. Milne et al. (1981) reported a positive linear relationship between mean liveweight gain and intake of digestible OM for grazing ewes and lambs, and reported that bodyweight change was related to both protein supplementation and available OM per hectare in the swards grazed by sheep.

Table 7. Pearson correlations coefficients (r) for all study ewes (N =120).

	Forage DMI	ADG	Supplement DMI
Age	.18 (0.05)[a]	.03 (0.78)	.36 (0.001)
Forage DMI		.53 (0.001)	.34 (0.001)
ADG			.14 (0.12)

[a] r value (P value)

DOM:CP Ratio

Moore et al. (1995) compiled data from 51 studies and concluded that animal response to supplementation depended on the ratio of digestible organic matter (DOM) to CP content of the forage. When DOM:CP was greater than 7, supplementation increased animal weight gains and forage intake. However, when DOM:CP was less than 7, weight gains could be increased, but forage intake was generally decreased. Digestible organic matter:CP for forage in the current study averaged 9.6 ([OM] / [CP content of forage] x [48-h digestibility]) across both pastures in October and December, therefore increases in weight gain as a result of increased forage intake and supplementation would be possible. Protein supplementation alone under the conditions of this research did not always increase forage intake.

INFLUENCE OF SUPPLEMENT LEVEL ON FORAGE INTAKE AND DIGESTIBILITY FOR BEEF COWS

Summary

Thirty-two pregnant crossbred cows individually fed chopped hay (6.97% CP) *ad libitum* in Calan gates were used to determine the effects of four levels of liquid supplement on forage and nutrient intake and digestibility. Eight cows were assigned by weight to one of four treatments: 0, 0.45, 0.91, or 1.36 kg (as-fed) of a molasses-based liquid supplement, which supplied 0, 100, 203, or 303 g CP daily. All four supplement levels were represented in each of eight pens. Cows were individually fed hay and supplement at 0700 daily, hay at 1600, and feed refusals were weighed each morning and evening prior to feeding to determine forage intake. There was no effect of supplement level on hay DMI (kg; $P = 0.55$, % BW; $P = 0.84$), hay DM digestibility ($P = 0.98$), or hay digestible DMI (kg; $P = 0.53$, %BW; $P = 0.78$). There was a linear increase in total diet DMI (kg; $P = 0.04$) due to supplement level, but there were no differences in total diet DMI on a % BW basis ($P = 0.19$). A linear increase in total diet digestible DMI (kg; $P = 0.004$, % BW; $P = 0.05$) was due to supplement intake. There was no effect ($P = 0.13$) of supplement level on diet DM digestibility. There were no treatment differences ($P \geq 0.35$) in hay nutrient intake for OM, CP, NDF, or ADF or digestibility for OM, NDF, or ADF on either a kg or % BW basis. Total diet CP

intake, CP digestibility, and digestible CP intake were all linearly increased ($P < 0.001$) by supplement intake. In this study, increasing CP supplement level had no effect on hay intake or digestibility, probably because forage quality as indicated by DMI as % BW (avg 2.6%) and ADG (avg 1.1 kg) was too high for supplemental CP to elicit a response, but total diet digestible DMI and CP intake were increased as supplement level increased.

Introduction

While grazed rangelands are an inexpensive source of forage for the livestock producer, forage quality on winter range is low. Protein is usually the first limiting nutrient in dormant season range forage, and energy supplements are poorly utilized by livestock grazing protein deficient plants (Wallace, 1988). One means by which protein supplementation improves performance of cattle consuming low-quality forages is through stimulation of voluntary forage intake (Vanzant and Cochran, 1994), and positive responses to protein supplementation are expected with forages containing less than 6-8% CP (Kartchner, 1980; Allison,1985).

Liquid protein supplementation has been shown to improve forage intake and digestibility by beef cattle (Daniels et al., 1998; Earley et al., 1999), but more research is needed to look at level of supplement and how that affects the utilization of forage based diets, because there are conflicting results regarding appropriate levels of protein supplementation. Hannah (1991) and Fike (1995) reported that increasing supplement levels improved forage intake and digestibility, but on the other hand, Warly et al. (1994) and Lusby et al. (1976) observed that forage was utilized better by ruminants when supplement was given at a medium level of protein than at lower or higher levels.

Most studies are done in group-feeding situations with reduced control over supplement intake by individual animals. Supplementing at a higher level than a cow requires would increase producer costs with little or no improvement in performance, forage intake or digestibility. A lower level of supplementation than necessary might be less expensive, but may also decrease animal performance and utilization of low quality forage.

Therefore, the objective of this experiment was to determine the effect of liquid protein supplement level on forage and nutrient intake and digestibility when cows were individually fed a forage-based diet of chopped hay.

Materials and Methods

Thirty-two pregnant crossbred cows (2 years of age; average 557 kg BW; SE = 44.4) individually fed chopped hay (Table 8) *ad libitum* were used to determine the effects of four levels of liquid protein supplement on forage intake. The study was conducted for 30 d from September 25 to October 25, 2000. Cows were weighed at the beginning and end of the study. Eight animals were assigned to one of four treatments; 1) 0, 2) 0.45, 3) 0.91, or 4) 1.36 kg (as-fed) of a 38.4% CP (DM basis) liquid supplement (Table 9; Nutra Lix, Billings, MT) which supplied 0, 100, 203, or 303 g CP daily. This formulation included not more than 14% equivalent CP from non-protein nitrogen. Each pen contained four Calan-Broadbent gates (American Calan, Inc.; Northwood, NH). Cows given no supplement received a TM block, while supplemented cows consumed adequate amounts of minerals, which were provided in the supplement. Cows were individually fed chopped hay and supplement at 0700 and hay at 1600 each day, and feed refusals were weighed in the morning and evening prior to feeding to determine forage intake. Cows had access to free-choice water. Animals were cared for under a protocol approved by the MSU Animal Care Committee.

Table 8. Nutritional analysis of chopped hay fed to 2-yr-old beef cows in Calan gates (DM basis).

Item	Hay
DM (%)	90.2
CP (%)	6.97
NDF (%)	68.3
ADF (%)	44.4
OM (%)	96.0
48-h DMD (%)	61.9
72-h DMD (%)	66.4
DOM:CP ratio	7.0
Acid Insoluble Ash (%)	3.44

Cows were subjected to a 3-wk training period during which the Calan gates were left open for 7 d, closed for 7 d with latches taped so that animals could push gates open, then closed and latched for the final 7 d so they could be opened only with the appropriate key on each animal's neck. After a 14-d adaptation to the hay and supplement levels, there was a 7 d collection period.

Table 9. Nutritional analysis of liquid supplement (Nutra-Lix, Billings, MT) fed to 2-yr-old beef cows in Calan gates (DM basis); analysis supplied by manufacturer (except *)

Item	Supplement
DM (%)*	57.9
CP (%)*	38.4
NPN (%)	14.0
OM (%)*	86.3
Crude Fat, min (%)	3.00
Crude Fiber, max (%)	0.50
Calcium (%)	0.05-1.0
Phosphorus, min (%)	1.60
Potassium, min (%)	2.00
Magnesium, min (%)	0.80
Sulfur, min (ppm)	0.50
Cobalt, min (ppm)	2.3
Copper, min (ppm)	198
Manganese, min (ppm)	440
Zinc, min (ppm)	330
Selenium, min (ppm)	3.0
Iodine, min (ppm)	11
Iron, min (ppm)	121
Vitamin A, min (IU/lb)	40,000
Vitamin D, min (IU/lb)	10,000
Vitamin E, min (IU/lb)	50

Daily hay, orts, and supplement samples were collected for nutritional analysis of DM, OM, CP (AOAC, 2000), NDF, ADF (Van Soest et al., 1991) and AIA (4N method; Van Keulen and Young, 1977). Hay was ground to a 5-mm particle size for determination of DM, OM, 48-h, and 72-h *in situ* DM digestibility, and a 1-mm particle size for analysis of CP, NDF, ADF, and AIA. Two ruminally cannulated crossbred cows were used for estimates of *in situ* digestibility.

During the 7 d collection period, fecal grab samples were taken three times at 0800, 1200, and 1530 on three different days to account for diurnal variation in the marker (acid insoluble ash: AIA). Fecal samples were dried for 48 h in a 60° C forced air oven, and ground to pass a 1-mm screen in a Wiley mill. Fecal samples were composited for each cow on an equal dry weight basis and analyzed for DM, OM, CP (AOAC, 2000), NDF, ADF (Van Soest et al., 1991), and AIA (Van Keulen and Young, 1977).

Acid insoluble ash was used as a marker to determine fecal output (FO), after which FO and weight of feed refusals/orts were utilized with the following equations to estimate forage and nutrient intake and digestibility:

DM AIA fecal (g/g) = Fecal % AIA / 100

DM FO, kg/d = Total AIA intake (g/d) / fecal AIA concentration (g/g)

Forage DMI, kg/d = (Hay fed DM kg) – (orts DM kg)

Total diet DMI, kg/d = (Hay fed DM kg + supplement DM kg) – (orts DM kg)

Digestibility = [(intake (Hay, diet, or nutrient) DM) – DM FO kg / intake DM] * 100

Statistical Analysis

A randomized complete block design was used with pen as the block and individual animal as the experimental unit. Data were analyzed using the General Linear Model procedure of SAS (SAS Inst. Inc., Cary, NC). Treatment sums of squares were partitioned into linear, quadratic, and cubic effects, and least square means are reported.

Results and Discussion

Dry matter intake

There was no effect of supplement level on hay DMI (Tables 10 and 11; kg; $P = 0.55$, %BW; $P = 0.84$), or hay digestible DMI (Tables 12 and 13; kg; $P = 0.53$, %BW; $P = 0.79$). There was a linear increase in total diet DMI on a kg basis (Table 10; $P = 0.04$) and total diet digestible DMI (Table 12; kg, $P = 0.004$ and Table 13; % BW, $P = 0.05$) due to supplement level, but no difference in total diet DMI on a % BW basis (Table 11; $P = 0.19$). There were no treatment differences ($P \geq 0.53$) in hay nutrient intake for OM, CP, NDF, or ADF on either a kg or % BW basis (Tables 10 and 11). Total diet CP intake and digestible CP intake were all linearly increased (Tables 10, 11, and 12; $P < 0.001$) by increasing supplement intake.

Table 10. Hay and total diet intakes (DM basis) by 2-yr-old pregnant cows offered four levels of protein supplement.

	Supplement Level (g CP/d)					P-value		
Item	0	100	203	303	SE	Linear	Quad	Cubic
Hay intake								
DM, kg	14.89	14.53	14.47	15.24	0.36	0.55	0.13	0.75
OM, kg	14.31	13.96	13.91	14.64	0.34	0.55	0.13	0.75
CP, g	1042	1048	1014	1067	24.6	0.54	0.13	0.75
NDF, kg	10.23	9.99	9.95	10.47	0.24	0.55	0.13	0.75
ADF, kg	6.66	6.50	6.47	6.81	0.16	0.54	0.13	0.75
Diet intake								
DM, kg	14.89	14.79	15.00	16.02	0.36	0.04	0.13	0.75
OM, kg	14.31	14.19	14.36	15.32	0.34	0.05	0.13	0.75
CP, g	1042	1119	1216	1370	24.7	<0.001	0.13	0.74

Table 11. Hay and total diet intakes (%BW) by 2-yr-old pregnant cows offered four levels of protein supplement.

	Supplement Level (g CP/d)					P-value		
Item	0	100	203	303	SE	Linear	Quad	Cubic
Hay intake, % BW								
DM	2.65	2.64	2.62	2.69	0.09	0.84	0.64	0.81
OM	1.16	1.15	1.14	1.18	0.04	0.84	0.64	0.81
CP	0.08	0.08	0.08	0.08	<0.01	0.83	0.65	0.81
NDF	0.83	0.82	0.82	0.84	0.03	0.83	0.64	0.81
ADF	0.54	0.54	0.53	0.55	0.02	0.84	0.65	0.81
Diet intake, % BW								
DM	2.65	2.69	2.72	2.83	0.09	0.19	0.66	0.82
OM	1.16	1.17	1.18	1.23	0.04	0.23	0.65	0.82
CP	0.08	0.09	0.10	0.11	0.003	<0.001	0.74	0.84

Table 12. Hay and total diet digestible nutrient intakes by 2-yr-old pregnant cows offered four levels of protein supplement.

	Supplement Level (g CP/d)					P-value		
Item	0	100	203	303	SE	Linear	Quad	Cubic
Hay digestible intake								
DM, kg	6.9	6.8	6.7	7.2	0.22	0.53	0.15	0.68
OM, kg	7.1	6.9	6.8	7.3	0.22	0.46	0.15	0.66
NDF, kg	4.3	4.2	4.1	4.5	0.19	0.55	0.27	0.55
ADF, kg	2.2	2.3	2.2	2.3	0.14	0.56	0.99	0.62
Diet digestible intake								
DM, kg	6.9	7.1	7.2	7.9	0.22	0.004	0.15	0.69
OM, kg	7.1	7.1	7.3	8.0	0.22	0.006	0.15	0.66
CP, g	386	458	561	679	15.2	<0.001	0.14	0.82

Table 13. Hay and total diet digestible nutrient intakes (% BW) by 2-yr-old pregnant cows offered four levels of protein supplement.

	Supplement Level					P-value		
Item	0	100	203	303	SE	Linear	Quad	Cubic
Hay digestible intake, %BW								
DM	1.25	1.24	1.22	1.27	0.03	0.79	0.57	0.75
OM	1.26	1.26	1.24	1.29	0.03	0.74	0.57	0.75
NDF	0.77	0.78	0.75	0.79	0.02	0.76	0.61	0.62
ADF	0.39	0.41	0.40	0.41	0.01	0.70	0.77	0.66
Diet digestible intake, %BW								
DM	1.25	1.29	1.32	1.42	0.03	0.05	0.59	0.77
OM	1.26	1.30	1.32	1.42	0.03	0.07	0.59	0.76

In a study by Lusby et al. (1976), cows received a moderate (average 470 g CP/d) level of protein supplement and a very high level (1660 g CP/d). Cows fed the moderate level of supplement consumed more forage dry matter than cows fed the high level. Cows grazing less palatable and less available mature winter range forage on Lusby's study decreased forage consumption with high levels of supplementation, indicating that moderate levels were sufficient. Kartchner (1980) reported that there was no improvement in forage or total DMI for cows grazing eastern Montana range containing 6.2% CP when they received 300 g CP/d compared to animals receiving no supplement. Webb et al. (1973) found no effect on intake for dairy cows offered liquid protein supplement when they were consuming 11.5% CP brome hay. Harris et al. (1989) conducted experiments in 2 consecutive years to determine the effects of protein (SBM) supplementation on forage DMI of ewes grazing Montana winter range. Supplementation had no effect on forage DM or OM intake in either year for the ewes. There appears to be an optimal level of supplementation at which intake of low quality forage (with low CP) is improved. However, in our project and those discussed above, an improvement was not seen at any level of supplementation.

Digestibility

There was no effect of supplement level on hay DM digestibility ($P = 0.98$) or total diet DM digestibility ($P = 0.14$), nor were there treatment differences ($P \geq 0.35$) in hay nutrient digestibility for OM, NDF, or ADF on either a kg or % BW basis (Table 14). Total diet CP digestibility was linearly increased ($P < 0.01$) with higher supplement intake (Table 14).

Table 14. Hay and total diet digestibilities (%) by 2-yr-old pregnant cows offered four levels of protein supplement.

	Supplement Level (g CP/d)					P-value		
Item	0	100	203	303	SE	Linear	Quad	Cubic
Hay digestibility								
DM, %	46.9	46.8	46.5	47.1	1.3	0.98	0.78	0.88
OM, %	49.5	49.5	49.2	49.9	1.3	0.87	0.78	0.86
NDF, %	42.4	42.7	41.8	42.9	1.7	0.91	0.83	0.67
ADF, %	32.9	35.1	34.4	33.8	2.1	0.86	0.52	0.75
Diet digestibility								
DM, %	46.9	47.7	48.4	49.7	1.3	0.14	0.83	0.90
OM, %	49.5	50.3	50.8	52.1	1.3	0.17	0.83	0.88
CP, %	37.1	41.0	46.2	49.6	1.4	<.01	0.84	0.64

DelCurto et al. (1990a) reported that in a Kansas study with steers grazing dormant tallgrass-prairie forage containing 2.9% CP, there was no difference in DM digestibility among CP levels (112, 271, or 397 g CP/d), and no difference in NDF digestibility between supplemented and control treatments overall, although NDF digestibility was depressed for supplemented steers offered 112 g CP/d. Kartchner (1980) reported that there was no improvement in forage or total DM digestibility for cows receiving 300 g CP/d over control animals. Fike et al. (1995) reported that supplement level did not alter apparent DM or NDF digestibility. The first increment of supplemental protein in Fike's study (240 g CP/d) decreased NDF digestibility. In our research and those discussed above, either no effect or negative effects of protein supplementation on forage digestibility were observed.

The DOM:CP ratio of the hay in our study was 7, indicating a balanced forage where we could have seen either positive or negative responses to protein supplementation. Based on previous research, it appears that when the DOM:CP ratio is between 7 and 12, there may be either an increase or decrease in forage intake when protein supplement is offered to ruminants. For example, Earley et al. (1999) saw a positive response to protein supplementation at a ratio of 8.8, but DelCurto (1990a) saw no response at 11.5. However, when the ratio is less than 7, negative response to supplement is generally observed, and when the ratio is greater than 12, an increase in forage intake would be expected when animals are supplemented. Hannah et al. (1991) used a forage with a ratio of 19.6 and saw a positive response to protein supplement. In the present study, feeding liquid protein supplement resulted in no increase in forage or nutrient intake or digestibility with a balanced DOM:CP ratio of 7 for the hay, indicating that there may be other factors at work in this range.

We calculated the degradable intake protein (DIP) content of the forage in this study and compared that to the cow's requirements (NRC, 1984), but did not find a satisfactory explanation with this approach, either. Degradable intake protein is a measure of the feed protein degraded or broken down in the rumen. The DIP requirement for a ruminant is determined by the protein needs of rumen microbes. A cow's DIP requirement ranges from 11-17% of DOM intake. For the average amount of hay consumed and assuming a requirement of 17%, the amount of DIP necessary for the cows on our study was 1500 g. The average of

14.78 kg of hay fed each day supplied 558 g of DIP, resulting in a DIP deficiency of 942 g. Even assuming that the CP in the supplement was 100% digestible, none of the 3 supplement levels (100, 203, or 303 g CP/d) that we fed in this study met the 942 g DIP requirement for the cows. While DIP is required by rumen microbes, metabolizable protein (MP) is required by the animal, and this protein is absorbed in the small intestine. The hay supplied 372 g of undegraded intake protein (UIP), which is absorbed in the intestine. According to NRC (1984), a beef cow in the second trimester of gestation requires approximately 657 g MP, which is a combination of DIP and UIP. Crude protein intake from the hay averaged 1043 g, therefore although the cows' DIP requirement for maximum microbial synthesis was not met, the crude protein requirement was met by the hay. The lack of response to supplement may be explained by the high forage intakes for these cows.

In this experiment, in order to test the effect of supplement level on forage intake and digestibility, we wanted to feed low-quality hay where we would expect to see a positive response in digestibility and intake to added CP. Our initial evaluation of forage quality of the hay fed in this study was made by using CP and NDF, and the commonly used prediction equation for intake (Intake, %BW = 120 / %NDF; Mertens, 1987). Based on this equation, we would have predicted intakes of 1.75% BW. This indicated to us that we had selected low-quality forage where we would see positive responses to supplemental CP. However, upon further analysis, the DOM:CP of 7 indicated a balanced forage where we would not expect a response in forage intake with protein supplementation according to Moore et al. (1999). Average daily gain was not affected (*P* = 0.60) by treatment (avg 1.1 kg/d). In addition, the NRC (1984) CP requirements for a 550-kg cow in the second trimester of gestation are 657 g. In our study, CP intake from the hay averaged 1,043 g. Therefore, the forage alone provided adequate CP.

SUMMARY AND IMPLICATIONS

In experiment 1, variation in supplement intake was greater and mean consumption of supplement was lower for ewes with *ad libitum* access to a self-fed block supplement than for ewes hand-fed a pelleted supplement. Younger ewes consumed less supplement than older ewes regardless of delivery method. Pasture size and forage production had more influence on forage intake and body weight change than supplement delivery methods. It appears that to achieve target intake of supplemental nutrients for individual ewes, the best delivery method is a limit-fed pellet supplement, and more variation in individual intake is observed when ewes are given *ad libitum* access to a cooked molasses-based block supplement.

In experiment 2, the forage DMI in our study averaged 2.6% BW, a level of intake that would indicate little opportunity to enhance forage intake with the addition of CP. Cows fed crested wheatgrass hay (6.97% CP) with a DOM:CP ratio of 7 showed no increase in forage intake or digestibility when supplemented with increasing levels of CP, apparently because forage quality as indicated by DMI as % BW (avg 2.6%) and ADG (avg 1.1 kg) was too high for supplemental CP to elicit a response.

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