VARIATION IN SUPPLEMENT INTAKE BY GRAZING BEEF COWS

by

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Janna Jo Kincheloe

April 15, 2004

To my grandparents, with love

Eleanor and the late Wade Kincheloe

Howard and Judy Osmundson

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ABSTRACT

One hundred twenty-one pregnant Angus cross cows (3 to 9 years of age; avg. wt 636 kg ± 50 kg) grazing native range pastures (*Agropyron spicatum, Festuca idahoensis)* were used to determine effect of herd size and cow age on individual supplement intake of a hand-fed pelleted protein supplement, variation in supplement intake, individual forage intake, and performance. The study was conducted at the Montana State University Red Bluff Research Ranch near Norris, MT from October 14, 2002 to December 13, 2002. Treatment was herd size, with seventy-six cows assigned to a large herd and forty-five cows assigned to a small herd. Each herd was assigned to one of two native range pastures to achieve equal stocking rates (0.4 AU/ha). Titanium dioxide was added to the supplement at 1% as an external marker to estimate individual supplement intake. Individual fecal samples were collected on d 23, 36, 38, 40, and 61 to obtain five measurements of individual supplement intake. Forage intake was estimated using estimates of fecal output obtained using chromium boluses and *in situ* 48 h DM digestibility. Forty frames per pasture (0.25 m^2) were estimated and ten frames per pasture were hand-clipped to determine forage production and quality. Individual forage and supplement intakes were estimated and analyzed using individual animal as the experimental unit. Forage intake was higher ($P = 0.05$) for cows in the large herd vs. cows in the small herd (19.8 vs. 18.3 $kg.cow^{-1}.d^{-1}$). Herd size did not affect ADG ($P = 0.11$) between treatments (avg 1.06 kg/d gain); however, ADG was lowest ($P < 0.001$) for 3-year-old cows (0.72 kg/d) and highest for 7-year-olds (1.33 kg/d). There were no differences ($P > 0.05$) between herds for supplement intake on d 23, 38, 40, or 61; however, supplement intake on d 36 was higher ($P = 0.03$) for the large herd vs. the small herd (0.99 vs. 0.82 $kg.cow^{-1}.d^{-1}$, respectively). Average DM supplement intake was 33% lower ($P < 0.001$) for 3- and 4-yr-old cows compared to 8- and 9-yr-olds (0.72 vs. 1.07 kg/d, respectively). Supplement DMI CV was not different ($P = 0.35$) between herds (avg. 21%). Results of this study indicate that cow age may have more influence on individual supplement intake than herd size. Three-year-old cows had the lowest supplement DMI and the lowest ADG compared to all other age groups.

INTRODUCTION

Cattle producers in the Northwest are dependent on rangeland forage for the majority of their feed resources. The primary goal in a forage-based livestock production system is to obtain maximum animal performance while effectively utilizing the forage resource base. Providing supplements to range cattle during times of low forage quality or quantity can improve forage utilization and increase animal performance in a cost-efficient manner (Kunkle et al., 2000).

Protein is generally the first limiting nutrient for beef cattle grazing low-quality native range, and numerous researchers have shown increases in forage intake and digestibility due to protein supplementation (Langlands and Donald, 1978; Moore et al, 1995; Bowman et al., 1999). When the availability of low-quality forage is limiting, energy supplements are often necessary to meet nutrient requirements of grazing cattle. Positive effects of energy supplementation include higher energy intake and increased animal performance (Caton and Dhuyvetter, 1997).

In order for supplementation programs to be effective, each animal must consume the target amount of supplement to ensure desired nutrient intake of protein, energy, vitamins, and/or minerals. However, individual supplement intake may vary with animal preferences, supplement palatability and formulation, delivery method, social interactions, and forage availability (Bowman and Sowell, 1997). Variation in individual supplement intake may explain some of the inconsistent responses to supplementation.

Common measures of variation include the coefficient of variation (CV) for individual supplement intake, proportion of non-feeders (animals consuming little or no supplement), and proportion of animals consuming target supplement intake. A summary of studies by Bowman and Sowell (1997) reported an average CV for individual supplement consumption of 79% for blocks, 60% for liquids, and 41% for dry supplements. The percentage of non-feeders was 14% for blocks, 23% for liquids, and 15% for dry supplements across a range of animals, environments, and supplement formulations.

Most literature relating to supplementation strategies has a number of limitations that make it difficult to apply results to current beef production systems. Many studies that report measurements of individual supplement intake have been conducted on sheep, whose grazing patterns and social behavior are different than those of cattle. The results of most cattle supplementation studies have been based on small animal numbers and/or small grazing units, which may not be representative of a commercial production situation. Further research is necessary to determine the causes of variation in supplement intake in order to develop strategies that result in uniform supplement consumption.

LITERATURE REVIEW

Introduction

Cattle producers in the Northwest are dependent on rangeland forage for the majority of their feed resources. Providing energy and protein supplements to range cattle during times of low forage quality and/or quantity can improve animal performance and provide increased economic returns (DelCurto et al., 2000). However, considerable year-to-year variation in response to supplementation exists due to differences in forage production and quality, varying stages of animal production, and availability of essential nutrients including protein, energy, vitamins, and minerals (Shirley, 1986; DelCurto et al., 2000).

Despite inconsistent responses, producers commonly supplement grazing cattle to achieve maximum animal performance while effectively utilizing the forage resource base. Common reasons for feeding supplements to cattle include improving forage utilization and correcting nutrient deficiencies to increase economic return (Lusby, 1990). Supplementation may be used to enhance the quality of forage-based diets, and may also serve as a forage substitute when forage availability is limiting (Bowman and Sanson, 2000).

Supplements provided to grazing animals can be classified into three general categories: 1) energy; 2) protein; and 3) minerals (Allden, 1987). This review will be limited to protein and energy supplements. In general, when forage availability is high, protein is the most beneficial type of supplement (Wright, 2001). Protein supplements improve animal performance by increasing rate of fermentation and forage intake. Additional energy supplied by the supplement also contributes to increases in production (Doyle, 1987). Energy supplements containing high levels of starch or nonstructural carbohydrates (NSC) may have adverse associative effects on cellulolytic bacteria, leading to depressed intake and utilization of forages. However, energy supplements containing high levels of structural carbohydrates have fewer negative effects on forage digestion, and may provide an economical way to meet energy requirements when the roughage supply is limited (Bowman and Sanson, 2000).

Supplements are provided to grazing cattle through either hand-fed or self-fed delivery methods. Hand-fed supplements are delivered on a regular basis in fixed amounts, while self-fed supplements are generally provided *ad libitum* with intake controlled by the use of various supplement formulations, intake limiters, and delivery systems. The type of supplement offered and how it is fed have been shown to influence individual supplement intake, and variation in supplement intake can lead to inconsistent responses to supplementation (Bowman and Sowell, 1997). Factors affecting intake variation for both types of supplement delivery method include formulation and palatability, level of competition, social interactions, and forage availability (Bowman and Sowell, 1997). In addition, several studies have reported that supplement consumption may be influenced by animal-related factors such as previous experience and feeding situation (Distel et al., 1994; Dixon et al., 2001; Taylor et al., 2002). Further research is needed to determine the effects of interacting factors such as forage quality and availability, supplementation strategy, and individual intake to effectively improve beef production systems.

Protein Supplements

Protein is generally the first limiting nutrient for beef cattle grazing dormant, mature range forage or consuming low-quality hay (Lusby, 1990). A variety of protein sources are available, including oilseed meals, alfalfa cubes, and plant- and grain-based protein supplements. In addition, protein supplements may come in dry or liquid form, and can be hand-fed or self-fed. Non-protein nitrogen (NPN) compounds such as urea often supply a portion of the protein equivalent in many commercial supplements. All protein supplements provide both energy and protein, but protein supplements generally contain at least 25% CP.

Forage intake is one of the primary factors affecting performance of cattle grazing low-quality forage. Although results are not always consistent, protein supplements have been shown to improve forage intake and digestibility by animals grazing low-quality forage (Langlands and Donald, 1978; Moore et al., 1995). In a review of protein supplementation of grazing livestock, Petersen (1987) stated that enhanced forage utilization occurs in several ways. Protein supplements provide amino acids, carbon skeletons, and minerals that help satisfy microbial requirements, thereby increasing microbial growth and/or fermentation. In addition to increasing available nutrients in the rumen, protein supplements may also increase the quantity of protein at the small intestine through undegraded or bypass protein. These factors combine to increase intake through increased microbial activity and rate of passage (Allison, 1985).

McCollum and Galyean (1985) found that steers consuming prairie hay and supplemented with cottonseed meal had higher in vitro dry matter digestibility (IVDMD) and a shorter retention time (55 vs. 76 h) than unsupplemented steers. The authors speculated that these results might have reflected increases in voluntary forage intake of 4.5 g/kg body weight by supplemented steers. Bowman et al. (1999) noted a similar relationship between increases in intake and digestibility due to supplementation. They observed a 49% increase in daily forage DM intake and a 36% increase in 48 h forage in situ dry matter digestibility for cows grazing native winter range and receiving either ad libitum access to a liquid supplement feeder or a regulated amount of liquid supplement over unsupplemented cows.

The optimum protein concentration of forage supplements is not easily defined, and may depend on forage digestibility. DelCurto et al. (1990) evaluated the effects of supplemental protein level on forage intake and utilization of dormant tallgrass-prairie hay by beef steers using treatments of 1) no supplement; 2) low protein (12%) supplement; 3) moderate protein (28%) supplement; and 4) high protein (41%) supplement. Although steers receiving moderate- and high-protein supplements consumed 60% and 42% more forage, respectively, than steers receiving low-protein supplements, there were no differences between supplement protein concentrations in DM digestibility. Fike et al. (1995) conducted a similar digestion study using sixteen cannulated steers to investigate the effects of supplementing ammoniated wheat straw

(AWS) with low-, medium- and high-protein supplements (12, 20.1, and 31.7% CP, respectively). Forage DM intake increased linearly with increasing protein concentration in supplements, and a similar response was noted for digestibility of DM and NDF. Positive responses to protein supplementation were seen even though the AWS contained approximately 12% CP. The authors concluded that animals were not able to efficiently utilize nitrogen in AWS.

Köster et al. (1997) examined the effects of increasing the proportion of urea in degradable intake protein (DIP) on intake and digestibility of dormant tallgrass prairie hay. Percentages of supplemental DIP from urea were 0, 25, 50, 75, and 100%. Increasing amounts of urea did not affect total OM or N intake; however, digestible OM intake decreased ($P = 0.03$) with increasing urea, with a substantial decrease in digestion at the 100% urea level. The authors concluded that substituting urea for true protein is acceptable at low to moderate levels. Mathis et al. (2000) conducted three experiments to determine the effects of increasing the level of supplemental degradable intake protein (DIP) on forage utilization by beef steers consuming bermudagrass (8% CP), bromegrass (6% CP), or forage sorghum (4% CP). Levels of DIP supplementation were 0.041, 0.082, and 0.124% BW. Organic matter intake and digestibility increased linearly in response to increasing levels of DIP for steers fed forage sorghum, while there was no effect on OM intake or digestibility for steers fed bermudagrass. These results indicate that ability of protein supplements to increase forage utilization depends largely on forage quality characteristics, regardless of the level of protein in the supplement.

Response to supplementation may be affected by the chemical composition and physical form of supplements. DelCurto et al. (1990b) conducted a forage intake and digestibility study to compare soybean meal/sorghum grain (SBM/SG), alfalfa hay, and dehydrated alfalfa pellets (DEHY) as protein sources to a control (no supplement) treatment for beef cattle grazing dormant range forage. Protein degradation after 24-h was highest for alfalfa hay, intermediate for SBM/SG, and lowest for DEHY (44, 33, and 19%, respectively). No differences among treatment groups were reported for apparent DM digestibility; however, the DEHY supplement treatment increased forage intake by 15% over other supplement treatments.

Protein supplements containing NPN are an alternative to traditional protein sources, although plant proteins are generally more efficient in stimulating animal production (Shirley, 1986). Rush et al. (1972) compared the effects of self-fed dry and liquid supplements containing natural protein and NPN on performance of cows wintered on dormant tallgrass prairie forage. Treatments consisted of 15% and 30% all-natural protein supplements and 30% supplements with one-half of the protein equivalent provided by urea or biuret. Cows receiving the liquid supplement with NPN lost more weight than cows receiving the all-natural 30% protein supplement.

It is generally expected that protein supplements will result in increased animal performance when consuming low-quality forage; however, further research is needed to determine interactions between individual supplement consumption and supplement delivery method.

Energy Supplements

Dormant range forages often do not meet the energy requirements of grazing cattle, and energy supplements are commonly used to meet production demands. Energy supplements are typically traditional concentrate supplements such as cereal grains. In contrast to protein supplementation, research results have reported decreases in forage intake due to energy supplementation known as the substitution effect (Caton and Dhuyvetter, 1997). Horn and McCollum (1987) reviewed the mechanisms by which energy supplements decrease forage intake and utilization. Feeding energy supplements typically results in increased substrate availability and rate of fermentation, lowering rumen pH and causing shortages of ruminal ammonia. Both of these conditions lead to unfavorable conditions for cellulolytic bacteria, which may cause a reduction in forage utilization and intake. In addition, nitrogen deficiencies can cause a large substitution effect due to reduced growth of ruminal bacteria. Therefore, it is important that supplements be balanced for protein as well as energy (Horn and McCollum, 1987).

Cochran et al. (1986) conducted a 2-year study using beef cows grazing dormant mixed grass prairie to compare performance of cattle supplemented with either alfalfa cubes or a cottonseed meal-barley cake containing an equivalent amount of nitrogen. They found no differences between supplements for weight change or condition score change. Similarly, Judkins et al. (1987) found no differences between cottonseed cake and long-stem alfalfa hay in weight gain (avg. 0.24 $kg.hd^{-1}.d^{-1}$) of supplemented heifers grazing dormant winter range, while unsupplemented heifers lost weight (avg. –0.03

kg.hd^{-1}.d^{-1}). These results indicate that similar performance can be achieved with both energy and protein supplements, as long as adequate nitrogen is supplied.

Energy supplements high in non-structural carbohydrates (NSC) have been shown to negatively impact forage intake and digestion, while supplements containing high levels of structural carbohydrates can actually increase utilization of forages (Bowman and Sanson, 2000). Bowman et al. (2004) conducted a digestion study using yearling heifers and a grazing trial using 60 crossbred cows to determine the effects of increasing levels of NSC supplementation on intake and digestibility of low quality forage. Treatments for both studies were 1) control, no supplement; 2) 0.32 kg NSC; 3) 0.64 kg NSC; and 4) 0.96 kg NSC. Findings from the heifer digestion study indicated a positive response in forage intake and digestibility with low to moderate levels of NSC (0.32 and 0.64 kg) with a slight decline when a higher level of NSC was fed (0.96 kg). All treatments resulted in greater intakes and increased digestibility over the control treatment. However, in the cow grazing trial, forage and total diet intake decreased linearly (P = 0.001) with increasing level of NSC supplementation during both years of the study. The authors suggested that results may be due to differences in the DOM:CP ratio in the forages. In the digestion trial, the DOM:CP ratio was 10.3, indicating a deficiency of protein relative to energy. In this case, a positive response in forage intake due to supplementation would be expected. In the grazing trial the DOM:CP ratio was 7.1, indicating a balance between protein and energy where supplementation would negatively impact forage intake.

Current research is focused on reducing the negative associative effects that starch-containing supplements may have on fiber digestion. Bodine et al. (2000) examined the effects of adding DIP to energy supplements containing large amounts of starch on prairie hay OM intake and digestion. Treatments were dry-rolled corn at either 0 or 0.75% BW combined with one of four amounts of soybean meal to provide between 0 and 1.3 g of DIP/kg of BW. They found that feeding corn without supplemental DIP resulted in decreased forage intake and digestibility of low-quality prairie hay. The results of this study indicate that supplemental DIP may overcome negative associative effects typically observed when feeding energy supplements with low-quality forages.

Level of carbohydrates present in the diet may also affect response to energy supplementation. Garcés-Yépez et al. (1997) fed corn-soybean meal, wheat middlings, and soybean hulls at two levels (25 or 50% of projected total TDN intake) to determine effects on performance and forage intake in growing steers and total diet digestibility in sheep. In the performance trial, the authors reported that a high level of concentrate in the diet decreased intake of bermudagrass hay regardless of supplement source; however, ADG and increases in BCS were greater for cattle fed a high level of concentrate. Results of the digestion trial showed that at the high level of supplementation, soybean hulls containing highly digestible fiber had fewer negative associative effects on forage utilization than corn-soybean meal. No differences were found at the low feeding level.

DOM:CP ratio

Interactions between supplements and forages are typically responsible for animal responses to supplementation of forage-based diets. These interactions are also known as associative effects, and can be either positive or negative (Bowman and Sanson, 1996). Deviations between expected and observed performance may be due to associative effects between supplements and forages, which cause the metabolizable energy (ME) concentrations of mixed diets to be higher or lower than expected values (Moore et al., 1995).

Moore and Kunkle (1995) developed equations that estimated the effects of dry supplements on voluntary forage intake and ME concentrations of mixed diets. Moore et al. (1995, 1999) applied these equations to estimate associative effects between various types of supplements and forages.

Moore et al. (1995) calculated the change in forage intake and related effects on animal performance due to supplementation by subtracting voluntary intake of forage fed alone from voluntary intake of forage fed with supplement. They found a relationship between the ratio of energy to protein (DOM:CP) in a forage and the change in forage intake due to supplementation. When energy and nitrogen levels were balanced in the forage (DOM:CP < 7), supplementation resulted in decreased forage intake with few exceptions. When energy and nitrogen levels were unbalanced (DOM:CP between 7 and 12), forage intake was both decreased and increased by supplements. With high DOM:CP values (> 12), all types and levels of supplements increased forage intake. In general, animal gains were positively related to changes in intake, and usually occurred when the forage DOM:CP ratio was > 7. Moore et al. (1999) constructed an additional database including 66 publications and a total of 444 comparisons between an unsupplemented control treatment and a supplemented treatment to estimate the effects of supplements on gain, intake, and TDN. They reported associative effects between supplements and forages similar to those of Moore et al. (1995).

Since these publications have been released, several researchers have utilized DOM:CP ratios in interpreting results of supplementation studies (Taylor et al., 2002; Macoon et al., 2003; Fieser and Vanzant, 2004). Taylor et al. (2002) calculated a DOM:CP ratio of 9.6 for grazed forage in a supplementation study comparing intake of pellet and block supplements by ewes. The authors found that this ratio was consistent with Moore's data in predicting an increase in forage intake and weight gain by supplemented ewes. This ratio appears to serve as a reliable predictor of animal response to supplement intake based on forage quality characteristics.

Estimating Supplement Intake by Grazing Animals

Measures of individual supplement intake are necessary to be able to critically evaluate various supplementation strategies. External markers are commonly used for determining supplement intake by individual animals. External markers are indigestible materials that are either added to the diet or administered intra-ruminally to the animal (Pond et al., 1987). These markers are used to determine digestibility, fecal output, and other measures of forage utilization in grazing animals when total fecal collection is not practical. In order to estimate supplement intake by individual animals, the marker must be administered daily to the animal in the supplement (Pond et al., 1987).

Chromic oxide is one of the most common external markers used to estimate fecal output, due to its relatively inexpensive cost and simplicity of analysis (Paterson and Kerley, 1987). Chromic oxide is not soluble in water, and does not associate with either the particulate or liquid components of rumen digesta (Pond et al., 1987), which may contribute to diurnal variation in chromium excretion. The use of a continuous release bolus is an advantage over daily dosing of chromium in terms of reduced animal handling and increased flexibility in the time of sampling (Hollingsworth et al., 1994), and researchers have reported that continuous release boluses remove problems associated with diurnal variation (Adams et al., 1991; Brandyberry et al., 1991; Momont et al., 1994).

Curtis et al. (1994) investigated the use of the rare earth element ytterbium (Yb) as a marker to estimate individual intake of lupin seed by grazing sheep. Results indicated that the recovery of Yb was independent of the level of supplement consumed, and that Yb concentrations in supplement and fecal collections can be used to predict individual supplement intake. The authors suggested the use of a second marker such as controlled release chromium capsules to estimate fecal output.

Bowman et al. (1999) validated a dual marker technique estimating both fecal output and individual supplement consumption. Twenty-eight heifers were individually fed liquid supplement marked with ytterbium chloride ($YbCl_3$) and were dosed with sustained release chromic oxide (Cr_2O_3) boluses. Their results showed a linear relationship between supplement DM intake predicted by the dual marker technique and actual supplement DM fed.

Titanium dioxide has been shown to be effective as a digestibility marker for non-ruminants; however, it has been studied little for ruminants. As stated by Titgemeyer et al. (2001), Hafez et al. (1988) observed 99% recovery of TiO_2 in fecal samples of dairy cows, although diurnal variations in excretion did occur. Titgemeyer et al. (2001) conducted three experiments to evaluate TiO_2 as a digestibility marker for cattle fed forage- and grain-based diets. They found fecal recoveries of the marker ranged from 90 to 95%; however, they did not measure excretion patterns of the marker. Although TiO_2 has not been studied as an intake marker, it has been approved for inclusion in feeds at 1% of the finished product, and is an economical alternative to ytterbium.

Variation in Supplement Intake

The positive effects of protein supplementation for cattle consuming low-quality forages are well documented, and include improvements in cow weight and body condition score, forage intake and digestibility, and pregnancy rates (Kunkle et al., 1997). However, the effectiveness of most supplementation programs is based on a target amount of supplement intake per animal. The target amount is formulated to deliver a specific amount of protein, energy, vitamins, minerals, and/or other nutrients. Potential negative impacts exist for animals consuming on either side of the target intake amount (Bowman and Sowell, 1997). The animal cannot efficiently utilize protein consumed in excess of requirements, and overconsumption of protein supplements also increases costs of supplementation. Animals consuming less than the target amount do not receive formulated nutrient amounts and therefore may exhibit no response or a negative response to supplementation.

Supplements are often used as carriers for ionophores (monensin and lasalocid) or antibiotics (chlorotetracyline, oxytetracycline, and bambermycin; Kunkle et al., 2000). Animals not consuming the target amount of medicated supplement are of special concern because specific doses of medicated ingredients are needed to maximize animal performance and avoid toxicity (Kunkle et al., 2000).

In most production situations supplement intake is measured by disappearance of supplement divided by the number of animal days, which fails to consider intake by individual animals. In addition, the majority of supplementation studies contained in the scientific literature focus on the average animal response to supplement, and supplement intake variation and individual animal performance are often not investigated.

Variation in individual supplement intake exists regardless of supplement form or delivery method, and may contribute to inconsistent responses to supplementation (Bowman and Sowell, 1997). There are several measures of individual supplement intake described in the scientific literature that can be used to quantify variation in intake. These include the coefficient of variation (CV) for individual supplement intake, proportion of non-feeders (animals consuming little or no supplement), and proportion of animals within a herd consuming target supplement intake. A number of animal- and supplement-related factors may contribute to variation in supplement intake within a herd. Increased understanding of these factors is needed to develop strategies that lead to uniform supplement consumption.

Animal-Related Factors

In a review of behavioral factors affecting acceptance of supplementary feeds, Chapple and Lynch (1986) stated that diet selection may be modified by factors such as previous experience, neophobia, age of animal, and social transmission of feeding behavior. These factors are often overlapping, and the cause of variation in supplement intake cannot always be specifically determined.

Social Interactions Social dominance hierarchies are known to exist in cattle herds, and research has shown that the presence of dominant and subordinate animals within a herd can play a role in consumption of supplement by grazing cattle (Sowell et al., 1999). Bowman and Sowell (1997) stated that dominant animals often consume large amounts of supplement and prevent other animals from consuming their share. Wagnon et al. (1966) studied social dominance relationships in a herd of 10 each of Angus, Hereford, and Shorthorn cows. A dominance hierarchy was found to exist within the herd, and individual animal rankings remained stable over the 2-year study. Ernst (1973) observed the behavior of two groups of heifers at molasses-urea lick feeders, and reported a definite social order with horned animals at the top. Relationships between low- and high-ranked animals in a herd may reduce the ability of subordinate animals to occupy certain habitat areas or access available resources such as supplement (Sowell et al., 1999).

Wagnon (1965) examined the effect of social dominance on supplemental feeding in range cows aged 2 through 10 years. Results showed that when hand-feeding supplement in troughs, 2- and 3- year olds were driven away from the troughs before they were able to consume supplement. Variation in rank was also shown to affect intake of self-fed cottonseed meal by 4- through 10-year-old cows (Wagnon, 1965). Dominant older cows waited less time for an opportunity to eat and spent more time at the feeder than subordinate 4- and 5- year old cows. This resulted in less weight gain by the 4- and 5- year olds than the older cows (avg. 0.20 vs. 0.33 kg gain/d, respectively).

Lobato and Beilharz (1979) conducted a study to determine the relationship between social rank, body measurements (liveweight, wither height, and chest girth), and intake of three supplement types (oats, hay, and molasses block) by grazing sheep. They found that social rank was positively correlated with liveweight and chest girth. Intake of hay and oats were positively correlated with social rank, but intake of molasses block was positively correlated only with liveweight. Intakes of the three supplements were not significantly correlated, indicating that individual intakes of different supplements may be related to physical characteristics of the supplement in addition to social interactions.

Age of the animal can play a role in social interactions, and younger animals may be at a disadvantage when competing for supplement with older animals, regardless of previous experience. Sixty crossbred 2- and 3-year-old cows were used to determine the effects of liquid supplement delivery method on individual feeding behavior (Sowell et al., 1995). The CV for individual supplement intake averaged 85%, and 2-year-old cows visited the lick wheel feeders fewer days and spent less than half as much time at the feeders as the three-year-olds. Neither group of cows had previous experience with liquid supplements.

Taylor et al. (2002) used 120 ewes from 2 to 6 years of age in a study to compare intakes of pellet and block supplements. Among ewes consuming pellet supplement, 2-year-olds consumed the least amount of supplement compared to all other age categories (avg. 71.3 vs. 119.9 g/d, respectively). For block-supplemented ewes, 2- and 3-year-olds consumed the least amount of supplement, with 4-, 5-, and 6-year-olds consuming the most supplement (avg. 31.5 vs. 74.9 g/d, respectively).

Previous Experience When supplements are first introduced, many animals may exhibit reluctance to consume them. Chapple and Lynch (1986) reported that the acceptance of novel food is commonly affected by observation of other animals, thus influencing feeding behavior. Lobato and Pearce (1980a) investigated the use of behavioral management techniques in order to improve the initial acceptance and overall intake of molasses-urea blocks in confined sheep. For the first two days of the study, sheep with previous exposure to blocks were penned with inexperienced sheep to provide the opportunity for inexperienced sheep to learn from them. Additionally, sheep that were used to small areas and to frequent handling ("tame" sheep) were mixed with sheep that were used to large grazing areas and infrequent contact with man ("wild" sheep). Experienced sheep had higher intakes than inexperienced sheep across three replications (931 vs. 697 g/group-d). "Tame" sheep had higher intakes of blocks than "wild" sheep in two of three replications (767 vs. 485 g/group-d). Over all treatments, the proportion of non-feeders decreased from 14% in the first week of study to 4% by the end of the third week. Due to inconsistent results in supplement intake across three replications, the authors concluded that further investigation of behavioral factors affecting intake variation must be conducted in order to develop successful management strategies.

Lynch et al. (1983) exposed unweaned lambs to wheat at different ages either with or without their mothers and measured acceptance to wheat post-weaning. They found that weaned lambs that had been previously exposed to wheat in the presence of their mothers ate more than three times as much wheat than lambs exposed to wheat without their mothers. In addition, daily wheat consumption and rate of intake increased throughout the trial for all lambs regardless of exposure time. These results indicate that maternal influences and previous exposure to supplements are important in determining subsequent feeding behavior and acceptance of feeds.

An experiment was conducted to determine whether experience with molasses-urea blocks prior to weaning would improve intake of blocks post-weaning in sheep (Lobato et al., 1980a). At two research locations, Lobato et al. (1980a) found that lambs previously offered blocks began consuming blocks immediately and increased intake rapidly, while lambs with no exposure to blocks did not consume supplement for the first week of study, after which intake was low and variable. Although other studies have reported large variability in intake of molasses-urea blocks (Lobato and Beilharz, 1979; Lobato and Pearce, 1980b), it appears that early exposure to blocks affects intakes at a later stage.

Juwarini et al. (1981) used two groups of sheep to determine individual feed consumption of wheat grain labeled with tritiated water. One group had previously been exposed to wheat supplementation about 8 months prior to the experiment, while the other group had not been supplemented. During the first ten days of the trial, experienced sheep consumed approximately 13% more wheat than non-experienced sheep. After this point, intakes between groups were similar, although variation in supplement intake was quite large (115 g/d to 547 g/d).

Chapple et al. (1987) reported that sheep without previous exposure to feed supplements or hay failed to consume any trough-fed wheat for the initial 3 days of the experiment, with all animals accepting wheat after 12-14 days. Animals that were offered hay for 12 days prior to being offered wheat showed higher initial acceptance of wheat than animals not previously offered hay. The authors suggested that there may have been a failure to associate the trough with feed, and also possible trough-related neophobia. Therefore, it appears that it is not only the supplemental feed itself but also delivery devices that animals must become familiar with in order to accept new feeds.

Dixon et al. (2001) conducted six experiments to examine how voluntary intake of supplement and variation in supplement intake was affected by previous experience in young animals. Weaned calves that were previously exposed to concentrate supplements with their dams consumed 85, 88, and 97% of offered supplement on the first, second, and third day, while animals not experienced with supplement consumed 19, 33, and 98% of offered supplement. However, supplement intake of both groups averaged 95-100% after day 3. Results of these studies indicated that prior experience with supplements by young cattle increased initial acceptance and intake of supplement, but did not influence long-term supplement intake.

Dixon et al. (2003) measured individual supplement intake by heifers with or without previous experience of loose mineral mix supplement (LMM) of 2 types of LMM that either included or did not include 300 g/kg cottonseed meal. The proportion of heifers not consuming supplement was 12% and the CV was 77%. In contrast to other researchers, Dixon et al. (2003) reported that previous experience by heifers led to a decrease, rather than an increase, in voluntary supplement consumption. The authors attributed this result to the development of a potential feed aversion to supplements containing high amounts of urea. Therefore, they concluded that although previous experience does influence intake and variability in intake of supplements, the type of supplement provided might also be important in influencing these factors.

Individual vs. Group Feeding Some researchers have investigated the effects of feeding animals individually as compared to a group-feeding situation. Kendall et al. (1983) compared individual supplement intake by ewes of feedblocks and trough supplements fed competitively and feedblocks fed individually. Mean intakes of feedblocks for ewes in a competitive feeding situation averaged 0.40 kg/d, while mean intakes of feedblocks for individually-fed ewes was nearly twice that at 0.73 kg/d. The authors expected that less dominant ewes would increase intake in a non-competitive situation and decrease overall intake variation. However, the average CV for supplement intake was slightly higher for individually-fed vs. group-fed ewes (42 vs. 40%, respectively). The authors concluded that dominance-subordinate interactions did not play a major role in supplement intake variation.

Foot and Russel (1973) designed an experiment to combine the effects of feeding situation with supplement allowance. Ewes were penned and fed individually, penned and fed in a group, or penned in a group and individually fed. Within each treatment, ewes were divided into two groups, one receiving a high level of supplement and the other a low level of supplement. Low supplement allowance ranged from 7 to 15 g/kg live weight and high supplement allowance from 18 to 26 g/kg. Supplement intake CV's were both approximately 25% for sheep consuming either high or low levels of supplement and fed and penned in a group. Individually fed animals had CV's of 26% for ewes consuming a low level of supplement and 13% for ewes consuming a high level of supplement (Foot and Russel, 1973).

Supplement-Related Factors

A variety of supplemental protein sources are available to producers, including oilseed by-products, soybeans and soybean meal, high quality hay, range cubes, blocks, and liquid supplements (DelCurto et al., 2000). The physical form of the supplement and the method by which it is delivered to the animal can influence variation in consumption (Bowman and Sowell, 1997). Supplement delivery methods are generally classified as self-fed or hand-fed systems. Hand-fed supplements generally include traditional dry supplements that are delivered to animals in specific amounts on a regular basis. Self-fed supplements are delivered in bulk amounts, and supplement is available for consumption on a free-choice basis (Sawyer and Mathis, 2001). Typically, feed blocks and liquid supplements are delivered in this way.

Supplement Form Mulholland and Coombe (1979) offered mineral block, mineral-urea block, molasses liquid supplement, and molasses-urea liquid supplement to grazing wethers. Average CV's for the five-week study period were lowest for mineral block at 44% and highest for molasses liquid at 64%. Coefficients of variation for mineral-urea block and molasses-urea liquid supplement were 47 and 58%, respectively. The authors found that mean intakes of supplements as estimated by direct weighing were more than twice those estimated by fecal recovery of chromium markers. This again emphasizes the importance of determining individual supplement intake through methods other than supplement disappearance.

Lobato et al. (1980b) conducted two experiments to measure variation in intake of oats, hay, and molasses-urea fed to grazing sheep. Oat grain resulted in the lowest intake variation of the three supplements, with a mean CV of 23%. The CV for hay was slightly higher at 30%, while molasses-urea blocks showed much greater variation in individual intake with a CV of 144%.

Lobato and Pearce (1980b) examined the response of sheep to molasses-urea blocks under grazing conditions and under confinement. Over 1,100 sheep from seven different flocks were used in the study. There was wide variation between flocks in the grazing study, with only 50% of all sheep consuming blocks after 3 weeks of the study. Sheep who had not licked blocks during the grazing study were confined in yards where blocks were again offered. After three weeks in confinement, 81% of sheep had begun to consume supplement. There was considerable variation in block intake, with average intake ranging from 100 to 400 $g.sheep^{-1}.week^{-1}$ in the grazing study and from 100 to 500 g.sheep^{-1}.week^{-1} in the confinement study. Some of this variability may be explained by differences in the size and shapes of paddocks and in quantity and quality of forage.

Ducker et al. (1981) conducted a series of trials to measure individual intake variation for ewes consuming three types of feedblocks. Data was collected from over 2,300 ewes on nine different farms. Old ewes (6 years of age or more) had a higher number of non-consumers than gimmers (due to lamb at 2 years of age; 23 vs. 18%, respectively.) Overall, the proportion of non-consumers averaged 19%. There was a large range in CV between flocks (46% to 231%), which authors attributed to differences in grazing area per ewe, availability of alternative feed sources, and variation between farms.

Coombe and Mulholland (1983) measured supplement intake of mature crossbred wethers grazing oat stubble and found overall CV's of 86% for molasses liquid supplement, 66% for molasses-urea liquid supplement, and 62% for urea-mineral blocks throughout the 11-week experiment. For the first 6 weeks of the experiment, the proportion of non-feeders was 50% for molasses liquid, 38% for molasses-urea liquid, and 4% for blocks. Although variation in supplement intake remained extremely high, all sheep were consuming supplement after 6 weeks.

Dove and Freer (1986) compared intakes of pelleted or unpelleted sunflower meal (SFM) by grazing lambs fed individually or in groups. Individually-fed lambs consuming pelleted SFM had the highest mean supplement intake and lowest CV compared to all other treatments (388 vs. 342 g/day and 9.9 vs. 19.6% respectively).

Taylor et al. (2002) used 120 ewes grazing native winter range to determine the effects of supplement form (pellet vs. block) on supplement intake. Sixty ewes had *ad libitum* access to a cooked molasses block, while sixty ewes received 114 $g.ewe^{-1}.d^{-1}$ of a wheat middling/SBM pellet fed in troughs. Supplements were formulated to deliver the same amounts of CP at the target intake of supplement (approximately 115 $g.ewe^{-1}.d^{-1}$). Mean supplement consumption averaged 110 and 58 $g.ewe^{-1}.d^{-1}$ for pellet- and block-supplemented ewes, respectively. The proportion of non-consumers was 33% higher for block-supplemented ewes. Coefficient of variation for supplement intake was 32% for the pellet supplement and 99.5% for the block supplement.

Garossino et al. (2003) evaluated differences in feeding behavior and supplement intake between animals consuming self-fed molasses blocks and liquid-molasses supplement. They found that 70% or more animals attended the liquid supplement feeder on a daily basis vs. 40-80% attendance at the block feeder. Also, between-day variation of supplement intake was less for animals consuming liquid supplement. Target intake levels were 0.75 $kg.hd^{-1}.d^{-1}$ for the block supplement and 0.32 $kg.hd^{-1}.d^{-1}$ for the liquid supplement. Mean daily DM intake was 349 ± 690 and 330 ± 347 g per head for the block and liquid supplements, respectively. While there was larger variation in supplement intake with blocks, neither supplement resulted in achieving target intake levels. The authors suggested that due to high variation in block supplement consumption, liquid supplement may be more effective in delivering necessary nutrients and possibly health promoters, anthelmintics, and vaccines.

Dixon et al. (2003) conducted two experiments to determine individual intakes and variability in intake of various types of supplements by heifers. In Experiment 1, heifers were offered 1 of 4 supplements consisting of: 1) a restricted amount of cottonseed meal (CSM), or ad libitum amounts of 2) liquid molasses-urea supplement (M8U); 3) loose mineral mix (LMM); or 4) molasses-urea blocks (BLOCK). After 10 weeks on trial, the average CV for individual supplement intake was highest for BLOCK (83%), intermediate for LMM (71%), and lowest for CSM and M8U (28 and 26%, respectively). Proportion of non-consumers after 10 weeks was 0% for CSM and M8U, 8% for LMM, and 73% for BLOCK. In Experiment 2, heifers were offered ad libitum amounts of liquid molasses supplement containing low amounts of urea (74 g/kg), high amounts of urea (107 g/kg), monensin, or meatmeal. Variation in intake was not significantly different among the four molasses-based supplements (CV 37-58%), and all heifers consumed supplement except for one group consuming molasses-meatmeal that had 30% non-feeders.

<u>Supplement Delivery Method</u> A review of 20 supplement studies by Bowman and Sowell (1997) reported an average CV for individual supplement consumption of 41% for hand-fed supplements and 60% for self-fed supplements across a range of animals, environments, and supplement formulations. There are advantages and disadvantages for both self-fed and hand-fed delivery systems. Self-fed supplements have the potential to modify grazing distribution of cattle and decrease supplementation costs. Research suggests that cattle can be attracted to underutilized areas of pastures by providing supplements in those areas. Bailey and Welling (1999) found that forage

utilization by cattle grazing foothill rangelands was increased by approximately 17% through strategic placement of dehydrated molasses supplement blocks compared to control areas. In addition, self-fed supplements can be delivered infrequently, which can reduce labor and transportation costs (Sawyer and Mathis, 2001). However, scientific literature indicates that self-fed supplements generally result in higher variation in individual supplement intake, which may impact performance (Bowman and Sowell, 1997).

Hand-fed supplements typically have lower variation in supplement intake, which could translate to less variation in animal performance. However, this type of supplement delivery system may lead to increased labor and transportation costs, and has the potential to disrupt grazing patterns. In a review of studies investigating the influence of supplementation on grazing behavior, Krysl and Hess (1993) reported that cattle supplemented with protein grazed approximately 1.5 h/d less than unsupplemented cattle. Effects of competition may also be greater with hand-fed supplements, which could increase the proportion of non-feeders. Hand-fed supplements are typically only available for short times, which may decrease an animal's opportunity to consume supplement and increase competition for supplement (Bowman and Sowell, 1997).

Kendall (1980) found that self-fed blocks resulted in higher supplement intake variation than hand-fed concentrates. Using 14 penned heifers, individual intakes of either self-fed blocks or cubed barley/SBM supplement were measured. The CV for blocks was 57%, compared to 31% for the cubed supplement. A later study was conducted on grazing cattle, and showed higher variation in intake, although the relationship between the two supplements was similar to the first study (CV 82 vs. 55% for blocks and cubed supplement, respectively).

Kendall et al. (1983) measured individual supplement intake of blocks, block meal, and pelleted concentrate supplements for ewes either housed indoors or in small paddocks. For ewes housed indoors, CV's for individual supplement intake were 29% for high-intake blocks, 35% for barley-SBM pellets, and 50% for low-intake blocks. Ewes were also fed high-intake and low-intake feedblock meal in order to measure variation in intake without including the effects of block hardness. The average CV for feedblock meal was 31%. Grazing ewes were offered seven different types of feed blocks or equivalent amounts of concentrate DM in troughs. Supplement intake variation was higher for blocks than concentrates, with average CV's of 68 vs. 45%, respectively. Grazing ewes had higher overall individual intake variation with all types of supplement compared to ewes housed indoors. For both housed and grazing ewes, free-access blocks resulted in a higher mean CV over trough supplements (56 vs. 39%, respectively).

Grazing Merino wethers were supplemented with lupin seed either alone or with oat grain, and fed either on the ground or in a stationary feeder (Holst et al., 1994). Treatments were: 1) 600 g lupin seed fed in a lick feeder, n = 100; 2) 600 g lupin seed trailed over the ground, n = 100; 3) 600 g lupin seed fed in a lick feeder, n = 200; 4) 200 g lupin seed and 400 g oats fed in a lick feeder, n = 100. Estimated supplement intake was lower for lupin seeds when trailed on the ground vs. fed in a lick feeder (mean intake 426 vs. 573 g/hd/d), with the highest supplement intake reported for the lupin and oat mix (estimated intake 709 g/hd/d). Variation in supplement intake was lower for hand-fed vs. self-fed supplements (47 vs. 78%, respectively).

Liquid supplements are generally considered self-fed supplements, and are common in beef production systems due to a reduction in labor and operating costs over hand-fed supplements (Sawyer and Mathis, 2001). However, feeding liquid supplements generally results in higher variation in supplement intake over hand-fed supplements. In addition, overconsumption of supplement is a concern for liquid supplements containing high amounts of non-protein nitrogen (NPN) such as urea. When the primary diet is low-quality forage, excessive NPN can have negative impacts on forage digestibility and animal performance (Köster et al., 1997; Sawyer and Mathis, 2001) and may cause urea toxicity problems in some cases (McLennan et al., 1991). Several researchers have examined delivery methods that moderate intake of liquid supplements, including intake-limiters and modifications of current supplement delivery systems.

Nolan et al. (1975) estimated individual intake of liquid supplement by 200 wethers grazing poor quality pasture. A trough containing liquid supplement contained a float system consisting of a wooden raft, which was designed to restrict animals' access to supplement and prevent overconsumption. Only 103 of the 200 sheep consumed supplement during the study, and estimated supplement intake ranged from 5 to 550 ml/day. The CV for individual supplement intake was 52%.

Entwistle and Knights (1974) fed molasses liquid supplement and molasses liquid supplement containing high and low levels of urea to grazing ewes. Troughs were equipped with wooden flotation rafts to limit the possibility of toxicity due to excess urea consumption. During the five-month study period, the mean proportion of non-consumers was 22% for molasses supplement, 15% for low urea-molasses, and 14% for high urea-molasses. Actual supplement intakes averaged 75% of supplement offered across the three treatments.

Bowman et al. (1999) compared two liquid supplement delivery systems using sixty 2- and 3-year old cows. Treatments included a control (no supplement), ad libitum access to a lick wheel liquid supplement feeder (ADLIB), and ad libitum access to a Regulate® liquid supplement feeder (REG) where supplement allowance was computer controlled. They found no effect of supplement delivery method on supplement intake; however, age of cow did influence intake. Three-year-old cows consumed more than three times as much supplement as two-year-olds. In addition, the number of cows consuming below target intake was higher for 2-year-olds than 3-year-olds (80% vs. 40%, respectively.) Sowell et al. (2003) conducted a 2-year study using the same treatments as Bowman et al. (1999) to further evaluate the influence of liquid supplement delivery method and cow age on individual supplement intake. In contrast to results reported by the previous study, Sowell et al. (2003) noted that supplement intake was higher for cows on the ADLIB vs. the REG treatment, indicating that a computer controlled supplement delivery system may be more effective in preventing overconsumption of supplement.

An experiment was conducted in two locations in Florida (Gainesville and Ona) to determine the effects of reducing the surface area of a lick wheel feeder and restricting lick wheel turning capability on liquid supplement intake in yearling heifers (Davis et al., 2003). The combination of these modifications to a standard lick wheel feeder reduced liquid supplement consumption by 40% and 23% at Gainesville and Ona, respectively.

A review of literature by Tait and Fisher (1996) stated that there is a lack of literature reporting voluntary intake of mineral supplements by individual animals. Although there are indirect ways of measuring performance of individual animals, it is difficult to measure individual mineral intake due to lack of an accurate method. Recent advances in technology such as electronic identification and computer recording systems may allow us to gain a more accurate interpretation of the causes for variation in intake.

Cockwill et al. (2000) conducted several studies to measure individual intake of free-choice mineral and molasses blocks by grazing cows and calves. In the first experiment, sixty-nine cows and calves were provided with free-choice low salt (9.8%) mineral for the first 6 days of the study and high salt (22.5%) mineral for an additional 7 days. Individual intake was measured through the use of a computerized intake system (GrowSafe Systems Ltd., Airdrie, AB). Variability in intake of low-salt mineral ranged from 0 to 974 $g.hd^{-1}.d^{-1}$ for cows and 0 to 181 $g.hd^{-1}.d^{-1}$ for calves. Increasing the level of salt reduced average mineral intake by cows; however, variation in individual intake remained high. A second experiment monitored mineral intake of high-salt (HS) and high-salt with fenbendazole (FB). Intake of mineral was similar for HS and FB (avg 113 $g.hd^{-1}.d^{-1}$); however, frequency of feeder visits and percentage of animals visiting the feeder was higher when FB was offered. The authors stated that mineral intake by 72% of cows and 78% of calves was not high enough to achieve the required dose of fenbendazole for effective parasite control, and there were two cows that consumed above the recommended dose. A third experiment used 32 pregnant cows and 26 heifers to measure individual intake of molasses blocks. Results of this study showed that although herd attendance was higher with blocks than with mineral, variability in intake remained extremely high, ranging from 0 to 1650 $g.hd^{-1}.d^{-1}$.

Garossino et al. (2001) conducted two similar studies to measure individual intake of loose mineral containing 0.55% fenbendazole by grazing steers. Mean mineral consumption was highly variable in both trials, ranging from 62 to 383 $g.hd^{-1}.d^{-1}$ in the first trial and 46 to 191 $g.hd^{-1}.d^{-1}$ in the second trial. The recommended dose for FB was 5 mg/kg of body weight. The dose actually received by individual animals varied from 1 to 4 mg/kg of body weight.

Individual animal consumption was measured for molasses blocks containing a detergent, “Teric,” to aid in prevention of bloat (Graham et al., 1977). “Teric” consumption ranged from 7.7 to 48.8 $g.hd^{-1}.d^{-1}$. The effective dose level for “Teric” was ten g/d, and estimates of block intake showed that eight of the eleven animals in the study exceeded this amount, while two animals consumed less than this amount. The remaining animal failed to consume any of the block supplements.

<u>Supplement Allowance</u> Foot et al. (1973) measured intakes of pelleted concentrate when fed in restricted amounts to ewes. Concentrate allowance was restricted to 96 $g.hd^{-1}.d^{-1}$ at the beginning of the experiment, increasing to 435 $g.hd^{-1}.d^{-1}$ at the end of the experiment. The small concentrate allowance resulted in greater variation in supplement intake when compared to the large concentrate allowance (36 vs. 16%, respectively). Foot et al. (1973) also noted that increasing the concentrate

allowance resulted in a change of ranking of individual animals in terms of individual supplement intake, indicating that social dominance may be more pronounced when larger quantities of supplement are provided.

Self-fed supplements often result in higher intake variation, even when supplement allowance is somewhat controlled. Grazing Merino wethers were given access to a self-feeder containing lupin seeds with a supplement allowance of 600 $g.hd^{-1}.d^{-1}$ (Curtis et al., 1994). Over half of the wethers failed to consume target intake of supplement. Thirty-three percent of sheep consumed less than 150 g/d, while 8% of sheep consumed more than 1200 g/d. Dove et al. (1984) measured supplement intake by grazing ewes suckling single lambs. Pelleted sunflower meal was fed from a trough at a rate of 460 $g.hd^{-1}.d^{-1}$. Mean daily supplement intake was 359 g/hd, and intakes ranged from 20-1030 g/hd.

Kahn (1994) fed cottonseed meal at two levels (55 or 110 $g.hd^{-1}.d^{-1}$) to determine variation in supplement intake in grazing sheep. The proportion of animals consuming from 0-10 g/d in the group fed a lower supplement allowance remained constant at 30% across three intake estimates. For animals receiving the higher supplement allowance, the proportion of non-feeders ranged from 25% to 17% throughout the experiment. These results agree with Bowman and Sowell (1997), who stated that larger quantities of supplement provided per animal reduce the number of non-feeders.

<u>Trough Space</u> Ewes were given three levels of concentrate (84, 252, or 504 $g.hd^{-1}.d^{-1}$) and trough-space of 300 (restricted), 400 (adequate), or 530 (generous) mm/hd (Kendall et al., 1980). The highest CV for individual supplement intake was 73.6%,

which occurred when ewes were given the lowest amount of supplement at the restricted level of trough-space. The lowest reported CV was 26.8% for ewes fed the highest supplement allowance and given a generous level of trough space.

Competition for oat grain was studied in three flocks of sheep, using a supplement allowance of 450 g per head fed with the amount of trough space ranging from 4 to 50 cm per sheep (Arnold and Maller, 1974). The experiments were designed to determine the effects of age, sex, breed, and weight on competitiveness. Results showed that in a flock of ewes of similar weight and breed, the proportion of non-feeders increased linearly as trough space decreased. At 24 cm per head, all sheep consumed supplement, while only 69% of sheep consumed supplement at 4 cm per head. In a mixed-age flock of rams, the youngest and oldest sheep had the highest proportion of non-feeders with low trough space, with 50% of 1-year-old sheep were non-feeders with a trough space of 4 cm per head. Conclusions made by these studies indicate that the rate of disturbance of sheep began to increase at trough space of less than 16 cm/sheep, and did not differ between age groups or breeds. However, there were significant differences in the proportion of non-feeders between age groups and breeds of sheep (Arnold and Maller, 1974).

SUPPLEMENT INTAKE, FORAGE INTAKE, AND PERFORMANCE BY GRAZING BEEF COWS

Summary

One hundred twenty-one pregnant Angus cross cows (3 to 9 years of age; avg. wt 636 kg ± 50 kg) grazing native range pastures (*Agropyron spicatum, Festuca idahoensis)* were used to determine effect of herd size and cow age on individual supplement intake of a hand-fed pelleted protein supplement, variation in supplement intake, individual forage intake, and performance. The study was conducted at the Montana State University Red Bluff Research Ranch near Norris, MT from October 14, 2002 to December 13, 2002. Treatment was herd size, with seventy-six cows assigned to a large herd and forty-five cows assigned to a small herd. Each herd was assigned to one of two native range pastures to achieve equal stocking rates (0.4 AU/ha). Titanium dioxide was added to the supplement at 1% as an external marker to estimate individual supplement intake. All supplemented animals were dosed with sustained release chromium boluses to estimate fecal output (FO). Five individual fecal samples were collected from each animal to yield 5 estimations of supplement intake per cow. Pasture production and forage quality were estimated by estimating 30 frames (0.25 m^2) per pasture and estimating and clipping 10 frames per pasture. Clip samples were incubated in the rumens of two cannulated cows per pasture for 48 h to determine DM digestibility. Forage intake was estimated using calculations of FO and 48 h DM digestibility. Individual forage and supplement intakes were estimated and analyzed using individual

animal as the experimental unit. Forage intake was higher (*P* = 0.05) for cows in the large herd vs. cows in the small herd (19.8 vs. 18.3 $kg.cow^{-1}.d^{-1}$). Three-year-olds consumed the least amount of forage (17.6 $kg.cow^{-1}.d^{-1}$) compared to all other age groups (avg. 19.3 $kg.cow^{-1}.d^{-1}$). Herd size did not affect ADG (*P* = 0.11; avg. 1.06 kg/d gain); however, ADG was lowest ($P < 0.001$) for 3-year-old cows (0.72 kg/d) and highest for 7-year-olds (1.33 kg/d). Average DM supplement intake was higher (*P* = 0.03) for the large herd vs. the small herd (0.99 vs. 0.82 $kg.cow^{-1}.d^{-1}$, respectively). Average DM supplement intake was 33% lower ($P < 0.001$) for 3- and 4-yr-old cows compared to 8- and 9-yr-olds (0.72 vs. 1.07 kg/d, respectively). Supplement DMI CV was similar (*P* = 0.35) between herds (avg. 21%). Herd size only affected individual animal consumption of supplement on only one of 5 sampling dates; however, 3-year-olds consumed the least amount of supplement on all sampling dates.

Introduction

Protein is often the first-limiting nutrient on low quality native range pastures (Lusby, 1990), and providing protein supplements to range cattle during times of low forage quality can improve animal performance and increase reproductive efficiency (DelCurto et al., 2000). However, the success of supplementation programs is often limited by the inability to ensure that each animal is consuming recommended supplement intake levels. Using a hand-fed supplement delivery method allows for increased control of the amount of supplement given to each animal; however, variation from the target amount may occur due to competition between animals (Bowman and Sowell, 1997).

It is difficult to interpret the results of supplementation without information on individual supplement consumption by animals in a grazing situation (Nolan et al., 1974). Much of the research on hand-fed supplementation of beef cows has focused on factors such as the amount (Foot et al., 1973; Kahn, 1994) and source (Lobato et al., 1980b; Taylor et al., 2002), of supplement. Numerous studies have shown that age of the animal and social interactions influence supplement intake (Wagnon et al., 1966; Arnold and Maller, 1974; Bowman et al., 1995); however, research has not focused specifically on the relationship between the number of animals in a group feeding situation and supplement intake. Therefore, the objectives of our study were to determine the effects of herd size and cow age on individual supplement intake, variation in supplement intake, individual forage intake, and performance of cows grazing native range.

Materials and Methods

The study was conducted at the Montana State University Red Bluff Research Ranch near Norris, MT from October 14, 2002 to December 13, 2002. One hundred twenty-one pregnant, mixed-age, Angus cross cows (3 to 9 years old; avg. wt 636 kg ± 50 kg) were assigned by weight and age to either a large (n = 76) or small (n = 45) herd. Both herds were supplemented every other day with a commercially available protein supplement.

Animals and Feeding Management

Cow weight ranged from 506 kg to 758 kg. Between the two treatments, age distribution of the cows was as follows: twenty-eight 3-year-olds, nineteen 4-year-olds, twenty-six 5-year-olds, seventeen 6-year-olds, sixteen 7-year-olds, seven 8-year-olds, and eight 9-year-olds. All cows except the 3-year-olds had previous experience with hand-fed supplements. Cows were scheduled to begin calving March 1; therefore, cows used in the study were in the last month of their second trimester and the beginning of their third trimester of gestation.

Herd size was determined by setting equal and moderate stocking rates for each of two native range pastures. Cows were considered 1.4 AU, and stocking rates were set at 0.4 AU/ha. Seventy-six cows were assigned to the First Feeder pasture (257 ha), and forty-five cows were assigned to the Second Feeder pasture (158 ha). Since 63% of total cows were assigned to the First Feeder and 37% were assigned to the Second Feeder, age classes were distributed between herds so that approximately 63% of the total cows in each age group were in the First Feeder and 37% were in the Second Feeder. Cows remained on their assigned pasture for the duration of the study.

Supplement used in the study was a hand-fed, pelleted commercial protein supplement (Table 1; 20% CP, United Agri-Products, Billings, MT) with a target intake of 0.91 kg/cow-d (as-fed basis). Table 1 contains supplement composition. Titanium dioxide was mechanically mixed into the supplement at 1% of the total product at the time of manufacturing by United Agri-Products, and used as an external marker to estimate supplement intake. Titanium dioxide is recognized by the Food and Drug

Administration as GRAS (Generally Recognized As Safe), and can be added legally to feeds in amounts that do not exceed 1% of the finished product (Titgemeyer et al., 2001). Supplement was fed using a pickup and cake feeder at approximately 1300 h on alternate days beginning on d 2 and continuing throughout the study (d 4, d 6, d 8, etc.)

Table 1. Composition of hand-fed pelleted supplement provided at 0.91 kg/cow-d to two herds (large and small; n = 76 and 45, respectively) to determine effect of herd size on supplement intake

Item	Amount
Composition, %	
DM	92.55
OM	83.87
CP	22.15
ADF	16.07
Starch	18.54

Approximate time for consumption of supplement averaged 15-20 min. for both herds. Supplement refusals were measured once weekly by careful inspection of the feeding grounds after all animals were finished consuming supplement. Individual refused pellets were counted and noted for each herd. An average pellet weight was estimated by weighing each pellet in a representative target amount of supplement (0.91 kg). Total amount of supplement refused was estimated by multiplying average pellet weight by the number of pellets refused by both herds over the study period. Estimated supplement waste was 2.3 kg over the study period for both herds, and usually resulted from pellets accumulating in deep snow or feces.

Both herds had ad-libitum access to water, loose mineral (Table 2; Bio-Range, United Agri-Products, Billings, MT), and white salt. Target intake of mineral supplement was 3 oz/hd/d. Water sources in the First Feeder included one spring-fed tank waterer and access to Cottonwood Creek. Two spring-fed tank waterers were located in the Second Feeder. Water sources were checked every other day at the time of supplementation.

Table 2. Composition of mineral supplement provided ad libitum with a target intake of 3 oz/cow-d to two herds (Large and Small; n = 76 and 45, respectively) to determine effect of herd size on supplement intake (values provided by manufacturer)

Item	Amount
Calcium, min.	6.5%
Calcium, max.	7.5%
Phosphorus, min.	8.0%
Magnesium, min.	4.6%
Potassium, min.	4.6%
Copper, min.	2300 ppm
Selenium, min.	35.2 ppm
Zinc, min.	8600 ppm
Vit. A, min.	200, 000 IU/lb
Vit. D, min.	50,000 IU/lb
Vit. E, min.	200 IU/lb

Study Site Description

The Red Bluff Research Ranch is located near Norris in Madison County, MT. Elevation ranges from approximately 1432 to 1859 m, and annual precipitation ranges from 38.1 to 48.3 cm. During the study period, hourly weather data was collected from an observation site located at the ranch. Average temperature over the study period was 1°C, with a low of –25°C and a high of 20°C (Table 3). Cumulative precipitation was 0.69 cm, which did not include snowfall.

Upland vegetation was typical of a foothill bunchgrass type. Pastures were dominated by Idaho fescue (*Festuca idahoensis*) and bluebunch wheatgrass (*Agropyron spicatum),* and other commonly occurring grasses included blue grama (*Bouteloua gracilis*), prairie junegrass (*Koeleria macrantha*), and sandberg bluegrass (*Poa secunda*). Forbs and woody species included whitestem rubber rabbitbrush (*Chrysothamnus nauseosus hololeucus*), fringed sagewort (*Artemisia frigida*), western yarrow (*Achillea millefolium*), and threadleaf sedge (*Carex filifolia*).

Sample Collection and Laboratory Analysis

Cows were weighed at the beginning and end of the study, and fecal grab samples were collected on d 23, 36, 38, 40, and 61. Cows were gathered at approximately 0800 h on collection days, and were penned in working facilities located in their respective pastures. On collection days that were also supplement days, supplement was delivered after collections were complete (approximately 1400 h). All cows were dosed with sustained release Cr_2O_3 boluses (Captec LTD, Manurewa, Auckland, New Zealand) on d 23 of the trial to administer chromium oxide as an external marker to estimate fecal output. The bolus release rate as stated by the manufacturer was 1.03 g Cr per day, which was calculated using ruminally cannulated cattle free grazing rye grass and clover pastures in Armidale, NSW, Australia. Because release rate may differ due to feed type,

Table 3. Daily weather data collected from October 14, 2002 to December 13, 2002 at an observation site located at the Red Bluff Research Ranch near Norris, MT.

	Temperature (C°)			Temperature (C°)	
Date	Low	High	Date	Low	High
Oct. 14	4	20	Nov. 14	6	15
15	-5	17	15	6	12
16	-5	18	16	6	17
17	-6	14	17	9	17
18	1	20	18	5	15
19	-3	17	19	-6	5
20	-2	19	20	-5	9
21	1	16	21	5	12
22	2	15	22	3	9
23	-6	2	23	2	8
24	-6	2	24	-2	5
25	-12	8	25	-4	3
26	-10	9	26	-5	-2
27	-8	9	27	-7	-3
28	-11	13	28	-11	-1
29	-3	7	29	-10	-3
30	-13	-4	30	-3	2
31	-14	-12	Dec. 1	-5	0
Nov. 1	-22	-7	2	-4	2
2	-25	-4	3	-3	4
3	-20	-2	4	-1	5
4	-9	2	5	-4	-1
5	-3	5	6	-8	-1
6	-4	5	7	-4	4
7	2	12	8	-3	4
8	-5	7	9	-4	2
9	-3	16	10	-3	4
10	8	18	11	-14	0
11	-2	14	12	-16	-4
12	-4	15	13	-7	-1
13	5	16	-	-	-

four ruminally cannulated cows were used to determine the actual release rate by assessing the disappearance of the matrix over time. The average release rate for our study site and feeding conditions was 1.35 g Cr/d. Amount of titanium consumed per animal would have been approximately 9 g/d, assuming that each animal consumed the target intake of 0.91 kg/d.

Individual fecal samples from the five collection dates were analyzed separately for DM and Ti (Meyers et al., 2004). The titanium recovery procedure by Meyers et al. (2004), with minor modifications, can be found in Appendix A. Fecal grab samples collected on d 36, 38, and 40 were oven-dried, ground through a 1 mm screen in a Wiley mill, and composited on an equal-weight basis by cow. Composite fecal samples were analyzed for DM, OM, CP (AOAC, 2000), NDF, ADF (Van Soest et al., 1991), and Cr by inductively coupled plasma emission spectroscopy (Fassel, 1978). An estimate of fecal output was obtained by the following equation:

FO = Cr intake (g) / fecal Cr concentration (g)

Supplement samples were collected every week, composited, and analyzed for DM, OM, CP, starch (AOAC, 2000), ADF (Van Soest et al., 1991), and Ti (Meyers et al., 2004). Two ruminally cannulated cows per pasture were used to collect extrusa samples on d 23 via total rumen evacuation (Lesperance et al., 1960). Rumen contents were removed and stored in 50-gallon garbage cans. After removing contents of the rumen and reticulum, the rumen walls were washed with water, and animals were released to graze in their respective pastures for approximately 1 h. Grazed forage was removed from the rumen and replaced with original ingesta. One of the cannulated cows in the

First Feeder failed to graze during the allotted time period, and the other cow in that pasture had extrusa sample consisting almost entirely of shrubs. Therefore, extrusa samples were determined to be misrepresentative of available forage, and clipped samples were used to determine forage quality characteristics.

Forage samples for each pasture and estimates of standing crop biomass were made on October 18 and December 18. The double-sampling method (Wilm et al., 1944) was utilized whereby forage production was estimated using forty plots (0.25 m^2) per pasture, with every fourth plot both clipped and estimated. Estimated plots were adjusted using regression techniques to calculate total forage production. For both sampling dates, the ten clipped samples from each pasture were composited on an equal-weight basis by pasture and ground to pass a 5 mm screen. Nylon bags containing approximately 5 g of sample were incubated in the rumen of cannulated cows for 48 and 72 h. *In situ* 72 h DM digestibility was not calculated for the second sampling date due to limited sample. A total of 7 nylon bags were placed within each cow for each time point, consisting of three clipped samples, three bags containing straw samples with known digestibility, and one blank bag as a method to measure microbial contamination and entry of particulate material into bags. After removal from the rumen, bags were hand-washed in cold water until the rinse water ran clear. Bags were dried in a forced air oven at 60° C for 48 h, and *in situ* DM digestibility was calculated. The remaining clip sample from both sampling dates was ground through a 1 mm screen and analyzed for DM, OM, CP (AOAC, 2000), NDF, and ADF (Van Soest et al., 1991).

Estimates of individual forage and supplement intake were obtained using the following equations:

Forage intake = FO / (1 – 48 h DM digestibility)

$$\text{Supplement intake} = \frac{(\text{fecal Ti concentration}) * (\text{FO})}{\text{Supplement Ti concentration}}$$

Estimates of fecal output were not available for the beginning and end of the study; therefore, a regression equation was developed to predict supplement intake for d 23 and d 61 based on 110 observations of the relationship between avg. fecal Ti concentration and supplement intake for d 36, 38, and 40 (Figure 1).

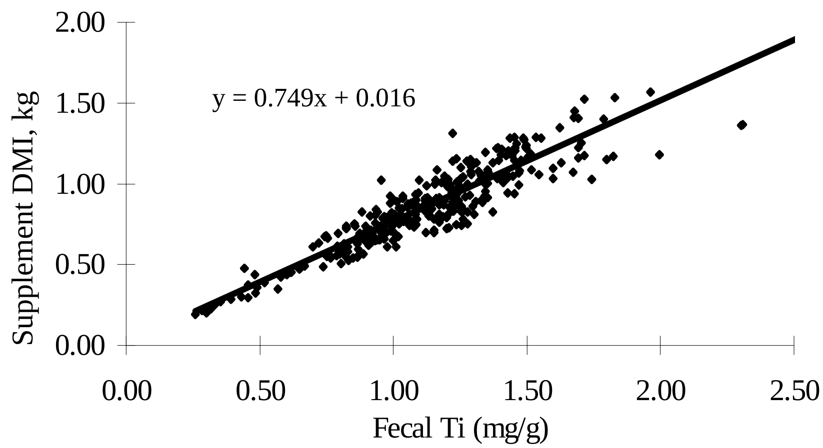

Figure 1. Relationship between fecal Ti and supplement DMI ($R^2 = 0.86$, $P < 0.001$)

Distribution of supplement intake was determined for the five sampling dates for each herd. Cows were classified into one of four consumption categories based on supplement intake as a % of mean DM supplement intake : 1) Low (< 75%); 2) Target (76-100%); 3) High (101-125%); and 4) Excessive (> 125%).

Statistical Analysis

Data were analyzed using the GLM procedure of SAS (SAS Inst. Inc., Cary, NC) for a completely randomized design with individual animal as the experimental unit. Significant treatment means ($P < 0.050$) were separated using the LSD test. Least square means and *P*-values are reported. Supplement intake distribution was analyzed as a 2 x 7 factorial, with herd size and cow age as the main factors. Each age group within pasture was used as the experimental unit for calculation of the CV for individual supplement intake and the proportion of cows consuming low, target, high, and excessive amounts of supplement. Data were also analyzed using the CORR procedures of SAS (SAS Inst. Inc., Cary, NC) to determine the relationships between age, supplement and forage intake, and ADG.

Results and Discussion

Forage Quality and Production

Estimated forage production at the beginning of the study was over 100 kg/ ha greater in the First Feeder compared to the Second Feeder; however, production was similar between pastures at the end of the study (Table 4). Forage samples collected from both pastures would be considered low quality (avg. 4.6% CP, 72.40% NDF, and 41.54% ADF). Forage in both pastures would be deficient in meeting the CP requirement of mature, gestating beef cows (6.59%; NRC, 1996).

Table 4. Pasture size, forage production, and composition and in situ dry matter disappearance of native range pastures grazed by beef cows in one of two herd sizes and supplemented with a 20% CP hand-fed supplement (based on clipped samples)

	First Feeder		Second Feeder	
Sampling Date	10/18/02	12/18/02	10/18/02	12/18/02
Size of pasture, ha	257	-	158	-
Production, kg/ha	464	229	349	256
Composition, %				
DM	96.17	92.42	96.21	93.42
OM	91.76	94.62	93.72	91.91
CP	4.88	4.64	4.50	4.22
NDF	69.20	77.21	70.65	72.53
ADF	39.12	42.93	45.33	38.87
DM disappearance, %				
48 h	58.88	40.64	55.06	61.37
72 h	69.94	-	65.87	-
DOM:CP	11.1	8.3	11.5	13.4

Forage Intake and Cow Performance

Estimates of forage and supplement intake for nine cows in the large herd and two cows in the small herd were not included in statistical analysis due to extremely high fecal Cr content. No age x treatment interactions ($P > 0.050$) were seen for forage intake or animal performance variables; therefore, main effects of age and treatment are presented (Table 5 and Table 6). Forage DM intake and intake in g/kg BW were higher ($P < 0.050$) in the large herd than the small herd (19.8 vs. 18.3 kg and 29 vs. 27 g/kg BW, respectively; Table 5). Cow age also had an effect on forage DMI ($P = 0.003$), although forage intake in g/kg BW was not different between ages (avg. 28 g/kg; Table 6). Three-year-olds consumed the least amount of forage and 7-year-olds consumed the most (avg. 17.6 vs. 20.3 kg/d, respectively), with 4-, 5-, 6-, 8-, and 9-year-olds intermediate (avg. 19.1 kg/d).

Table 5. Performance and forage dry matter intake by beef cows grazing native range in one of two herd sizes and supplemented with a 20% CP hand-fed supplement

	Herd Size			*P*-value	
Item	Large	Small	SE	Trt	Age*Trt
No. of cows	76	45	-	-	-
Weight, kg					
Initial	644	649	6.3	0.634	0.313
Ending	712	710	6.0	0.740	0.185
Wt change	68	61	3.1	0.113	0.911
ADG, kg	1.12	1.00	0.051	0.113	0.911
Forage Intake					
DM, kg	19.8	18.3	0.30	<0.001	0.055
DM, g/kg BW	29	27	0.5	0.001	0.099

We were unable to determine if supplementation increased forage intake and digestibility due to lack of a control treatment. However, forage intake in this study is in agreement with previous reports in the literature for supplemented cows grazing native range. Bowman et al. (1999) found that forage DMI of 2- and 3- year old liquid supplemented cows grazing native range averaged 2.1% BW. Sowell et al. (2003) measured forage intake of supplemented vs. unsupplemented cows grazing native winter range. They found that unsupplemented cows consumed 12.6 kg forage, while cows with restricted access to liquid supplements consumed 23.1 kg. In addition, supplementation increased 48-h in situ DMD by over 50% compared to the control treatment.

Initial and ending BW were similar ($P > 0.050$; Table 5) between treatments; however, weights were affected by cow age ($P < 0.001$; Table 6), with 3-year-olds the lightest and 8-year-olds the heaviest at the beginning and end of the study (avg. 585 vs. 681 kg initial wt and 629 vs. 744 kg ending wt, respectively). Cows in the large herd tended ($P = 0.113$; Table 5) to gain more weight than cows in the small herd (avg. 1.12 vs. 1.00 kg/d). This could be due to greater forage availability in the pasture where the large herd was grazing. Heldt et al. (1998) examined supplement intake by beef cows grazing native winter range with differing forage availabilities, and found that cows grazing the high available forage pasture gained 24 kg more weight over the two month study period than cows grazing the low available forage pasture.

Three-year-olds gained the least amount of weight ($P < 0.001$) when compared to all other age groups (avg. 0.72 vs. 1.12 kg/d, respectively; Table 6). Wagnon (1965) reported that older, more dominant 6- through 10-year-old cows kept 4- and 5-year-olds from consuming self-fed supplement, resulting in lower weight gain by the younger cows. In our study, 3-year-olds consistently consumed less supplement than older cows (Table 5), indicating that a similar situation may have occurred.

The NRC (1996) estimates that pregnant beef cows will gain an average of 0.29 kg/d in calf weight at the end of the second trimester. Additional increases in weight gain in our study were probably due to favorable weather conditions combined with supplement and forage intake. Moore et al. (1995) found that when DOM:CP ratio was greater than 7, supplementation increased forage intake and animal weight gain. DOM:CP for forage in the current study averaged 11.1 [(OM / CP content) * (48-h digestibility)] across both pastures (Table 4), indicating that increases in weight gain would be possible due to supplementation and increased forage intake.

Supplement Intake

Fecal collections on d 23 and d 61 were conducted the day after cows were supplemented, while collections on d 36, 38, and 40 were conducted two days after cows had last received supplement. Although little information is available in the scientific literature about the passage rate of TiO_2, a study conducted using dairy cows reported diurnal variation in excretion patterns of TiO_2 (Hafez et al., 1998, as cited by Titgemeyer et al., 2001). This agrees with findings in our study, where fecal samples collected the day after supplementation had much higher TiO_2 concentrations than samples collected two days after supplementation. Fecal TiO_2 concentrations from samples collected on d 23 and 61 overestimated individual supplement intake so that total intake for each herd was more than what was actually fed. Therefore, individual supplement intakes for those

Table 6. Performance and forage dry matter intake by beef cows of different ages grazing native range in one of two herd sizes and supplemented with a 20% CP hand-fed supplement

	Cow Age								
Item	3	4	5	6	7	8	9	SE	*P*-value
Weight, kg									
Initial	585^{a}	644^{b}	636^{b}	658^{bc}	658^{bc}	681^{c}	662^{bc}	11.5	<0.001
Ending	629^{a}	709^{b}	707^{b}	717^{bc}	740^{c}	744^{c}	732^{bc}	10.9	<0.001
Wt change	44^{a}	65^{bc}	71^{cd}	59^{b}	82^{d}	64^{bc}	69^{bd}	5.7	<0.001
ADG, kg	0.72^{a}	1.06^{bc}	1.16^{cd}	0.97^{b}	1.33^{d}	1.04^{bc}	1.13^{bd}	0.094	<0.001
Forage Intake									
DM, kg	17.6^{a}	19.2^{bc}	18.5^{ab}	19.2^{bc}	20.3^{c}	19.3^{bc}	19.5^{bc}	0.55	0.003
DM, g/kg BW	29	29	28	28	29	27	28	0.9	0.506

sampling dates were adjusted for the actual amount of supplement fed. Future research needs to address diurnal variation in TiO_2 excretion in order to determine the accuracy and precision of TiO_2 as a marker for supplement intake.

No age by treatment interactions were detected (*P* > 0.10) for supplement DM intake (Table 7). All individual fecal samples across all sampling dates contained TiO_2, indicating that all cows consumed some level of supplement. Size of herd did not have a significant effect (*P* > 0.050) on supplement intake on d 23, 38, 40, or 61; however, the large herd had higher (*P* = 0.025) supplement intake than the small herd on d 36 (avg. 0.99 vs. 0.82 kg/d, respectively). Average DM supplement intake was 0.08 kg higher (*P* = 0.028) for the large herd than the small herd (0.94 vs. 0.86 kg/d).

Table 7. Supplement dry matter intake by beef cows in one of two herd sizes grazing native range and supplemented with a 20% CP hand-fed supplement

	Herd Size			*P*-value	
Item	Large	Small	SE	Trt	Age*Trt
Supplement DMI, kg					
Nov. 11, 2002 (d 23)[x]	0.92	0.88	0.044	0.488	0.589
Nov. 18, 2002 (d 36)	0.99	0.82	0.054	0.025	0.190
Nov. 20, 2002 (d 38)	0.95	0.89	0.028	0.139	0.570
Nov. 22, 2002 (d 40)	0.90	0.86	0.025	0.279	0.262
Dec. 13, 2002 (d 61)[x]	0.87	0.89	0.031	0.659	0.315
Avg. supplement DMI	0.94	0.86	0.028	0.028	0.121

[x] Determined using regression equation
[y] Average of d 36, 38, and 40

Supplement intake between herds was statistically different for only one out of five sampling dates. Therefore, these results suggest that the size of the herd had little

Table 8. Supplement dry matter intake by beef cows of different ages in one of two herd sizes grazing native range and supplemented with a 20% CP hand-fed supplement

	Cow Age								
Item	3	4	5	6	7	8	9	SE	*P*-value
Supplement DMI, kg									
Nov. 11, 2002 (d 23)[x]	0.61^{a}	0.70^{a}	0.91^{b}	0.99^{b}	0.93^{b}	1.08^{b}	1.09^{b}	0.080	< 0.001
Nov. 18, 2002 (d 36)	0.68^{a}	0.70^{a}	0.94^{b}	0.87^{b}	0.94^{b}	0.99^{bc}	1.19^{c}	0.098	0.007
Nov. 20, 2002 (d 38)	0.72^{a}	0.78^{ab}	0.84^{b}	0.95^{c}	0.96^{c}	1.12^{d}	1.04^{cd}	0.052	<0.001
Nov. 22, 2002 (d 40)	0.65^{a}	0.76^{b}	0.85^{c}	0.91^{cd}	0.94^{d}	1.10^{e}	0.94^{cd}	0.045	<0.001
Dec. 13, 2002 (d 61)[x]	0.72^{a}	0.77^{a}	0.89^{b}	1.00^{c}	0.88^{b}	0.94^{bc}	0.97^{bc}	0.180	<0.001
Avg. supplement DMI[y]	0.68^{a}	0.75^{a}	0.88^{b}	0.91^{b}	0.95^{bc}	1.07^{c}	1.06^{c}	0.050	<0.001

[x] Determined using regression equation
[y] Average of d 36, 38, and 40

influence on supplement intake in mixed-age groups of cows. Differences may be more pronounced in larger herds, where increased social interactions may occur as more animals compete for supplement.

Individual supplement intake was significantly affected by cow age throughout the study. Three-year-olds had the lowest supplement intake for all sampling dates compared to all other age categories (P < 0.050; Table 8). Average supplement intake was 49% lower for 3- and 4-yr-old cows compared to 8- and 9-yr-olds (avg. 0.72 vs. 1.07 kg/d, respectively). Low supplement intake by the 3-year-olds could explain lower ADG in that age group. Bowman et al. (1999) found that 3-year-old cows consumed 219% more self-fed liquid supplement than 2-year-olds (1.02 vs. 0.32 kg/d, respectively). Sowell et al. (2003) reported that intake of liquid supplement was lowest for 2-year-old cows (0.5 kg) and highest for 4- and 6-year-olds (0.9 kg).

Distribution of Supplement Intake

Supplement intake distribution by individual cows for the first sampling date (d 23) is presented in Table 9 (by treatment) and 10 (by cow age). The CV for individual cow supplement DMI was higher for cows in the large herd, with a greater proportion of cows in the large herd classified as low consumers (< 75% of mean supplement DMI) and extremely high consumers (> 125% of mean supplement DMI; 30.3 vs. 22.7% and 26.3 vs. 18.2%, respectively; Table 9). Approximately 60% of three-year-olds were classified as low consumers, compared to less than 30% low consumers for all other age categories (Table 10). The CV was highest for 3-year-olds and lowest for 8- and 9-year-olds.

Table 9. Supplement intake distribution by beef cows in one of two herd sizes grazing native range and supplemented with a 20% CP hand-fed supplement (d 23)

	Herd Size	
Item	Large	Small
No. of cows	76	44
Supplement DMI, kg		
Min.	0.15	0.31
Max.	1.77	1.45
Mean	0.86	0.83
Supplement DMI CV, %	42	32
Proportion of cows within consumption group:		
Low (< 75% of mean)	30.3	22.7
Target (76 – 100% of mean)	30.3	50.0
High (101 – 125% of mean)	13.2	9.1
Excessive (> 125% of mean)	26.3	18.2

Supplement intake distribution by individual cows for the middle sampling dates (d 36, 38, and 40) is presented in Table 11 (by treatment) and Table 12 (by cow age). The range in supplement intake was smaller for cows in the small herd compared to cows in the large herd (0.63 to 1.10 kg/d vs. 0.70 to 1.24 kg/d, respectively); however, the CV for supplement intake was not different ($P = 0.35$) between treatments (avg. 21%; Table 11). The proportion of cows classified as low, target, and high consumers was not different between treatments ($P > 0.050$), while there were nearly twice as many cows in the large herd classified as excessive consumers than cows in the small herd (31.2 vs. 16.7%). This could be explained by an increased opportunity for an individual animal to consume excess amounts of supplement due to a greater supplement allowance provided to the larger herd.

TableTable 10. Supplement intake distribution by beef cows of different ages in one of two herd sizes grazing native range and supplemented with a 20% CP hand-fed supplement (d 23)

	Cow Age						
Item	3	4	5	6	7	8	9
No. of cows	28	18	26	17	16	7	8
Supplement DMI, kg/d							
Min.	0.15	0.36	0.48	0.52	0.52	0.63	0.63
Max.	1.43	0.99	1.77	1.63	1.39	1.53	1.45
Mean	0.60	0.68	0.91	1.01	0.96	1.08	1.11
Supplement DMI CV, %	46	22	33	35	27	30	30
Proportion of cows within consumption group:							
Low (< 75% of mean)	60.7	27.8	15.4	23.5	6.3	14.3	12.5
Target (76-100% of mean)	28.6	66.7	46.2	23.5	31.3	28.6	25.0
High (101-125% of mean)	7.1	5.6	11.5	11.8	37.5	0.0	0.0
Excessive (> 125% of mean)	3.6	0	26.9	41.1	25.0	57.1	62.5

Table 11. Supplement intake distribution by beef cows in one of two herd sizes grazing native range and supplemented with a 20% CP hand-fed supplement (avg. of d 36, d 38, and 40)

	Herd Size			
Item	Large	Small	SE	*P*-value
No. of cows	67	43	-	-
Supplement DMI, kg				
Min.	0.70	0.63	0.031	0.16
Max.	1.24	1.10	0.058	0.13
Mean	0.95	0.86	0.029	0.07
Supplement DMI CV, %	19	23	2.8	0.35
Proportion of cows within consumption group:				
Low (< 75% of mean)	13.4	23.2	4.62	0.18
Target (76 – 100% of mean)	33.8	33.2	7.90	0.95
High (101 – 125% of mean)	21.6	27.0	4.54	0.43
Excessive (> 125% of mean)	31.2	16.7	3.97	0.04

Cow age had a significant effect on mean supplement intake ($P < 0.050$; Table 12), with 3-year-olds consuming the least (0.69 kg/d), 4- through 7-year-olds intermediate (avg. 0.88 kg/d), and 8- and 9-year-olds consuming the most (avg. 1.08 kg/d). Eight- and nine-year olds had the highest minimum supplement intake compared to all other age categories (avg. 0.84 vs. 0.60 kg/d). The coefficient of variation for supplement intake was similar across age categories, with an average of 21%. More than 50% of 3-year-olds were classified as low consumers, compared to 0% of 8- and 9-year-olds. In contrast, 65% of 8-year-olds and 47% of 9-year-olds were classified as excessive consumers, while there were no excessive consumers in the 3- and 4-year-old age categories.

Table 12. Supplement intake distribution by beef cows of different ages in one of two herd sizes grazing native range and supplemented with a 20% CP hand-fed supplement (avg. of d 36, 38, and 40)

	Cow Age								
Item	3	4	5	6	7	8	9	SE	*P*-value
No. of cows	25	16	22	16	16	7	8		
Supplement DMI, kg/d									
Min.	0.52^{a}	0.57^{a}	0.67^{a}	0.61^{a}	0.63^{a}	0.83^{b}	0.85^{b}	0.058	0.039
Max.	0.91	0.96	1.11	1.25	1.41	1.33	1.22	0.109	0.108
Mean	0.69^{a}	0.75^{ab}	0.88^{bc}	0.91^{c}	0.96^{cd}	1.09^{d}	1.06^{d}	0.055	0.014
Supplement DMI CV, %	20	18	14	25	26	26	17	5.3	0.579
Proportion of cows within consumption group:									
Low (< 75% of mean)	51.3^{c}	38.2^{cb}	5.0^{a}	16.6^{ab}	16.6^{ab}	0.0^{a}	0.0^{a}	8.63	0.032
Target (76-100% of mean)	40.6	47.3	48.4	31.6	15.0	25.0	26.7	14.77	0.658
High (101-125% of mean)	8.1^{a}	14.5^{a}	42.5^{bc}	18.4^{a}	50.0^{c}	10.0^{a}	26.7^{ab}	8.49	0.069
Excessive (> 125% of mean)	0.0^{a}	0.0^{a}	4.1^{a}	33.4^{bc}	18.4^{ab}	65.0^{d}	46.6^{cd}	7.44	0.004

Supplement intake distribution by individual cows for the last sampling date (d 61) is presented in Table 13 (by treatment) and Table 14 (by cow age). Mean supplement intake was similar between herds, as were CV's for supplement intake (avg. 0.85 kg and 25%, respectively; Table 13). Zero percent of 9-year-olds were and 39% of 3-year-olds were classified as low consumers. There were no excessive consumers in the 3- and 4-year-olds compared to 33% of 9-year-olds.

Table 13. Supplement intake distribution by beef cows in one of two herd sizes grazing native range and supplemented with a 20% CP hand-fed supplement (d 61)

	Herd Size	
Item	Large	Small
No. of cows	75	44
Supplement DMI, kg		
Min.	0.43	0.34
Max.	1.34	1.21
Mean	0.86	0.84
Supplement DMI CV, %	26	23
Proportion of cows within consumption group:		
Low (< 75% of mean)	17.3	15.9
Target (76 – 100% of mean)	37.3	40.9
High (101 – 125% of mean)	25.3	36.4
Excessive (> 125% of mean)	20.0	6.8

Bowman and Sowell (1997) stated that coefficients of variation in supplement intake usually decrease the longer that animals are exposed to supplements. In our study, the average CV decreased by 12.5% from the first sampling date to the last sampling date (37% vs. 24.5%). In addition, we found that the proportion of 3-year-olds consuming low amounts of supplement decreased by 22% over the study period.

Table 14. Supplement intake distribution by beef cows of different ages in one of two herd sizes grazing native range and supplemented with a 20% CP hand-fed supplement (d 61)

	Cow Age						
Item	3	4	5	6	7	8	9
No. of cows	28	18	26	17	16	6	8
Supplement DMI, kg/d							
Min.	0.37	0.45	0.34	0.73	0.59	0.53	0.65
Max.	1.08	1.01	1.34	1.28	1.11	1.12	1.30
Mean	0.72	0.76	0.91	1.00	0.89	0.84	0.98
Supplement DMI CV, %	27	21	24	17	15	29	22
Proportion of cows within consumer group:							
Low (< 75% of mean)	39.3	22.2	7.7	0.0	6.3	33.3	0.0
Target (76-100% of mean)	32.1	50.0	50.0	29.4	37.5	16.7	37.5
High (101-125% mean)	28.6	27.8	15.4	35.3	50.0	16.7	37.5
Excessive (> 125% of mean)	0.0	0.0	26.9	35.3	6.3	33.3	25.0

Cow age, forage and supplement intake, and ADG

Age had the highest correlation with supplement DMI than other variables tested (*P* < 0.001; Table 15). Lobato and Beilharz (1979) found a positive relationship between liveweight and dominance ranking of sheep and intake of oats and hay, which agrees with results found in our study. We also found a positive correlation between ADG, age, forage DMI, and supplement DMI (*P* < 0.001). Mulholland and Coombe (1979) found that liveweight loss was reduced from 0.66 kg/week in unsupplemented sheep to 0.47 kg/week for sheep given a mineral block supplement and 0.37 kg/week for sheep given mineral/urea blocks or molasses-urea licks. Sowell et al. (2003) reported that although all cows lost weight during a winter supplementation trial due to harsh weather, supplemented cows lost less body condition than unsupplemented cows.

Table 15. Pearson correlation coefficients (r) for cow age, forage and supplement dry matter intake, and ADG for all beef cows (N = 121)

	Forage DMI	ADG	Supplement DMI
Age	0.32*	0.35**	0.59**
Forage DMI		0.32**	0.46**
ADG			0.44**

* *P* = 0.001
** *P* < 0.001

SUMMARY AND IMPLICATIONS

This is the first study to investigate the effects of herd size on supplement intake by a mixed-age group of cows. Although we did find statistical differences in supplement intake due to herd size, those differences may not be biologically significant, due to similar cow performance across treatments. Age of the cow consistently affected supplement intake throughout our study, with three-year-olds consuming the least amount of supplement compared to older cows. This indicates that younger cows should be managed separately in order to obtain maximum benefit from supplementation.

Both herds grazing low quality native range and receiving a protein supplement had an increase in weight gain. This shows the value of providing protein supplements during gestation as a way to maintain or increase body condition prior to calving. Cow age had a significant effect on performance, with three-year olds gaining the least amount of weight. This could be due to their inability to consume the target amount of supplement due to social interactions.

The coefficient of variation for supplement intake of hand-fed pelleted supplement in our study was lower than reports in the literature for self-fed supplements, and all cows consumed supplement. Minimizing variation in supplement intake and decreasing the proportion of non-feeders are important in improving animal response to supplementation.

Titanium dioxide is an economical alternative to Yb, and could be used for large-scale supplementation studies in commercial production situations. Further research is warranted to assess diurnal variation and marker recovery.

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