Applied Nutritional Strategies for the Northwest

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Introduction

The two most important factors that affect the profitability of cow-calf operations are reproduction and nutrition (Hess et al., 2005). Reproductive efficiency of the herd is optimal when replacement heifers attain puberty as yearlings and calve at 2 years of age (Bagley, 1993) and mature cows are able to become pregnant early during the annual breeding season (Rae, 2006). Nutrition is the factor that most influences reproductive efficiency of cattle (Bagley, 1993). Studies from our research group have clearly demonstrated the importance of adequate nutrition on reproductive performance of mature cows as well as reproductive development of replacement heifers (Figure 1). Moreover, the nutritional status of mature cows during gestation has been shown to impact the future productivity of the calf. Therefore, it is imperative that the cowherd is maintained at adequate planes of nutrition throughout the year to maintain profitable levels of production.

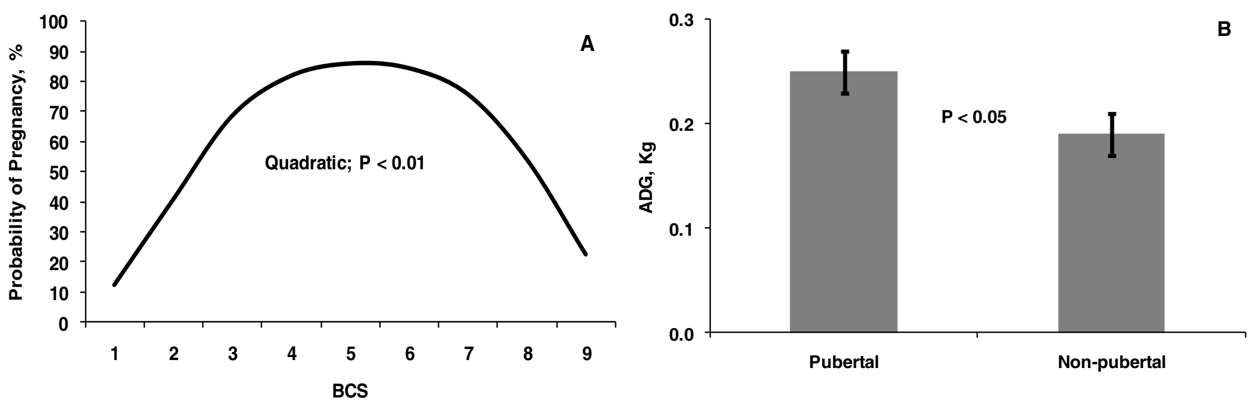


Figure 1. Probability of pregnancy in beef cows according to body condition score (BCS) at the beginning of the breeding season (Panel A). Average daily gain of heifers pubertal or not by 12 months of age (Panel B). Adapted from Cooke et al. (2009a,b).

Forage Quality in the Northwest

Most beef cows in the Northwest U.S. consume forages that, during at least a significant portion of the year, do not have adequate nutrient density (Figure 2; Ganskopp and Bohnert, 2001; Ganskopp and Bohnert, 2003) to meet their requirements (NRC, 1996). Consequently, management strategies that help offset the nutritional challenges encountered by many Northwest cow-calf operations are required to optimize reproductive efficiency.

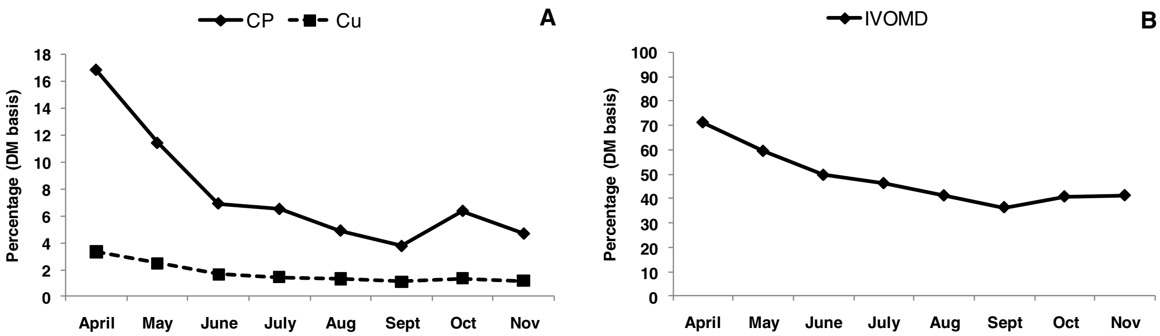


Figure 2. Average crude protein (CP) and copper (Cu) concentration (Panel A) and in vitro organic matter digestibility (IVOMD; Panel B) of grasses common to the Great Basin. Adapted from Ganskopp and Bohnert (2001) and Ganskopp and Bohnert (2003).

Ganskopp and Bohnert (2001; 2003) compiled nutritional analyses for 7 of the most common grasses in the Great Basin (Sandberg's bluegrass, Bottlebrush squirreltail, Bluebunch wheatgrass, Idaho fescue, Thurber's needlegrass, Giant wildrye, and Cheatgrass) for April through November. The average crude protein (CP) percentage for all grasses ranged from 16.8 in April to a low of 3.7 in September; however, it should be noted that the only months with a forage CP concentration above 7.0 were April and May. Also, average invitro organic matter digestibility (IVOMD), which can be assumed comparable to total digestible nutrients (TDN), ranged from 71% (April) to 36% (September) and was below 50% for all months except April and May (Figure 2). To put these numbers in context, developing heifers require at least 55% TDN and 8.5% CP of diet dry matter to sustain adequate growth rates ($\geq$ 0.5 kg/d), whereas mature lactating cows, prior to the breeding season, require approximately 60% TDN and 11% CP of diet dry matter (NRC, 1996). Likewise, the concentration of most minerals was below levels required to meet animal requirements (Ganskopp and Bohnert, 2003). For example, copper ranged from a high of 3.3 ppm in May to a low of 1.1 ppm in September (Figure 2) while the suggested level needed to meet requirements for beef cattle, assuming no major antagonism, is 10 ppm (NRC, 1996). Similar results related to the mineral concentration of forages have been reported for western rangelands in Arizona (Sprinkle et al., 2000), Colorado (Ahola et al., 2007), and New Mexico (Mathis & Sawyer, 2004).

Supplementation Strategies in the Northwest

Deficiencies in forage quality and/or quantity must be corrected by nutrient supplementation to maintain cattle at adequate levels of performance. Consequently, nutritional programs for Northwest cow-calf operations often require some form of supplementation, protein, energy, and/or minerals, during the production cycle. A supplementation program needs to be designed according to the nutritional requirements of the animal to be supplemented, inadequacies of the consumed forage, and economic viability (DelCurto et al., 2000; Kunkle et al., 2000).

Protein Supplementation for Optimal Reproduction

The primary factor limiting reproductive and overall performance of cattle consuming diets based on low-quality forages is energy intake (Caton and Dhuyvetter, 1997). However, intake of low-quality forages is often limited because these forages have an inadequate amount of protein. As a general rule of thumb, forage intake declines as forage CP falls below about 7%, a relationship attributed to a deficiency of nitrogen (protein) in the rumen that limits microbial activity (Moore et al., 1991). Consequently, protein supplements can stimulate forage intake and may enhance the microbial digestion of forage. When the benefits of improved forage intake and improved digestion are combined, overall nutritional status of the animal is greatly enhanced.

Forage types can be grouped into cool-season (C3) and warm-season (C4). Physiological and biochemical differences distinguish C3 (first organic product during carbon fixation is 3-carbon 3-phosphoglycerate) from C4 (first organic product is the 4-carbon oxaloacetate) (Lambers et al., 1998) forages. In the Northwest, most forages used by beef cattle are C3.

Despite agronomic research evaluating physiological differences between C4 and C3 forages, and nutritional research demonstrating the advantages of CP supplementation of ruminants consuming low-quality forage, data comparing utilization of low-quality C3 vs. C4 forages by ruminants is limited. Past research with low-quality C3 forages has resulted in forage intakes that do not allow for much, if any, increase due to protein supplementation (Horney et al., 1996; Mathis et al., 2000; Bohnert et al., 2002a). This contrasts research with low-quality C4 forages which consistently show increases in forage intake of 40% or more with protein supplementation (Paterson et al., 1994; Moore and Kunkle, 1995; Mathis, 2003).

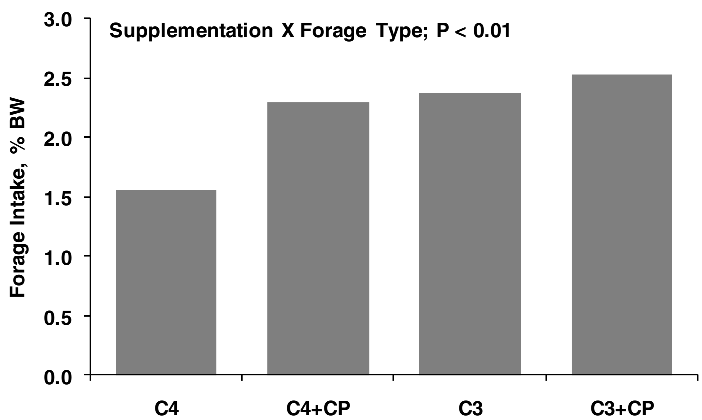


Figure 3. Forage dry matter intake by steers consuming low-quality cool-season (C3) and warm-season (C4) grass hay with or without supplemental protein (+CP). Adapted from Bohnert et al. (2011).

Recent work in our laboratory has suggested that the forage intake response to supplemental protein is dependent on the type of low-quality (< 7% CP) forage. The results of these experiments indicate that intake and digestibility of low-quality C3 and C4 forages are not similar and, more importantly, that the physiological response of ruminants to supplemental protein may depend, in part, on the cell wall structure of the basal diet, with intake and digestibility of C4 forages increasing to a greater extent with supplementation compared with C3 forages of similar nutritional quality (Figure 3; Bohnert et al., 2011). Based on our work and other published data, it appears that this is a consequence of greater voluntary intake and digestibility of unsupplemented C3 forages compared to unsupplemented C4 forages with comparable nutritional indices (CP, ADF, NDF, etc.).

There are numerous types of supplemental protein for cattle. In this article, however, we will focus on comparing natural sources of protein, such as feather meal and cottonseed meal, with non-protein nitrogen (NPN) sources, mainly urea. Due to the high cost of supplemental protein, particularly sources of natural protein, feeding NPN to cattle has become an attractive way to reduce costs of production while benefiting profitability of cow-calf operations. Nevertheless, many producers and nutritionists still have concerns regarding performance, including reproduction, in forage-fed cattle receiving protein supplements containing NPN. To address these concerns, we compared the reproductive performance of beef cows grazing low-quality pastures while receiving iso-caloric and iso-nitrogenous supplements containing urea or a mix of cottonseed meal and feather meal during a 60-d breeding season. No differences were detected on cow pregnancy rates or overall body condition score change (Figure 4).

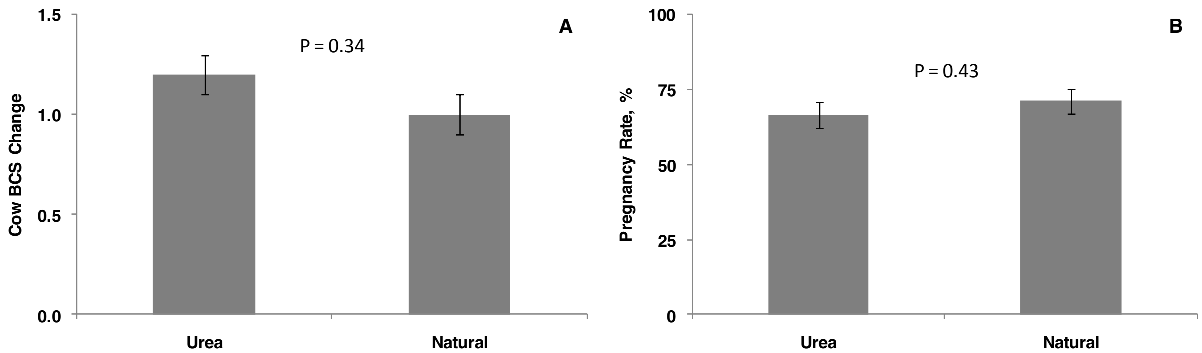


Figure 4. Changes in body condition score (BCS; Panel A) and final pregnancy rates (Panel B) of mature beef cows receiving supplements containing urea or natural protein (cottonseed meal + feather meal) during a 60-d breeding season. Adapted from Cooke and Arthington (2008).

In contrast, growing animals, including replacement heifers, usually have enhanced performance when supplemented with natural protein compared to NPN. This effect is attributed to their greater requirements for metabolizable protein and specific pre-formed amino acids for growth (NRC, 1996). Previous research (Pate et al., 1995; Figure 5) demonstrated that replacement heifers receiving supplements containing urea as protein source had reduced growth rates and pregnancy rates during the first breeding season compared to cohorts receiving supplements containing feather meal as protein source.

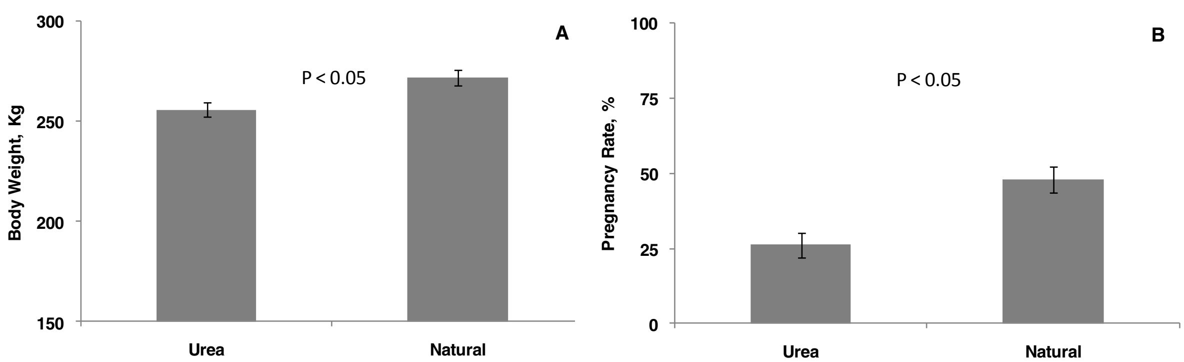


Figure 5. Body weight at the beginning of the breeding season (Panel A) and final pregnancy rates (Panel B) of replacement heifers receiving supplements containing urea or feather meal beginning at weaning until the end of their first breeding season. Adapted from Pate et al. (1995).

Research from Kansas State University has shown that when NPN constitutes approximately 30% or less of the ruminally degradable protein in a supplement, replacing ruminally degradable true protein (soybean meal) has little effect on cow body condition change (Figure 6; Farmer et al., 2004). However, when the proportion of ruminally degradable protein from urea exceeded 30%, cow performance decreased. The authors attributed this to decreased supplement intake rather than decreased efficiency of urea. This work demonstrated that more costly protein sources can be replaced with NPN without affecting body condition as long as NPN supplies less than 30% of the ruminally degradable protein in the supplement.

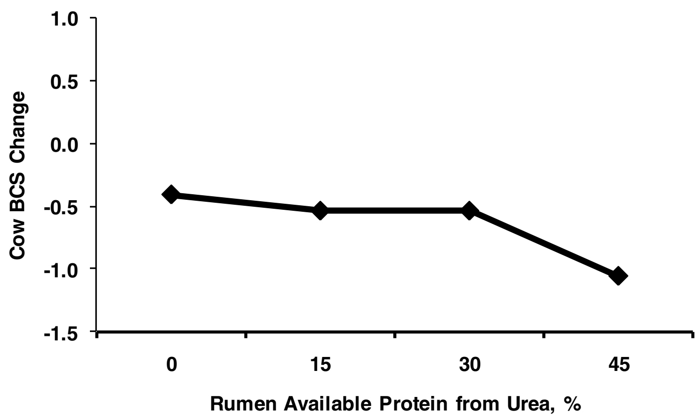


Figure 6. Prepartum cow body condition score (BCS) change in response to urea replacing rumen available protein from soybean meal. Supplements were isonitrogenous. Adapted from Farmer et al. (2004).

Therefore, NPN can be used effectively as a supplemental CP source for mature cows to maintain/improve BCS without any detriment to overall reproductive performance. The same strategy, however, cannot be applied to replacement heifers; they should receive sources of natural protein to ensure adequate growth rates and consequent reproductive development and performance during their first breeding season. Caution is always warranted when feeding urea to cattle, particularly when large amounts of supplemental CP are required and urea toxicity is a possibility.

Energy Supplementation for Optimal Reproduction

Supplemental energy is required when energy availability from grazed forages is limited (Caton and Dhuyvetter, 1997). Also energy-based supplements containing adequate amounts of protein have been shown to improve the performance and reproductive efficiency of mature cows and developing heifers (Mass, 1987; Schillo et al., 1992; Roberts et al., 1997). Similar to protein sources, there are numerous energy ingredients that can be supplemented to beef cattle. In this article, we will discuss energy–dense feedstuffs that yield different ruminal volatile fatty acid profiles, more specifically ingredients that favor propionate synthesis compared to those that favor either acetate of butyrate. This is of extreme importance given that propionate synthesis is directly associated with circulating levels of glucose, insulin, and IGF-I in beef cattle, each being imperative for optimal reproductive function of beef females (Wettemann et al., 2003). Indeed, a research group from Oklahoma State University (Ciccioli et al., 2005) reported that replacement beef heifers offered diets based on starch (favors propionate synthesis in the rumen) had hastened puberty attainment compared to cohorts fed diets based on digestible fiber (favors acetate synthesis in the rumen). Our research group evaluated growth rates and reproductive development of replacement heifers grazing low-quality pastures and offered iso-caloric and iso-nitrogenous supplements based on citrus pulp or molasses (Cooke et al., 2007a). Although both ingredients do not favor ruminal propionate synthesis, molasses contains an elevated sucrose content that favors butyrate synthesis, thereby impairing conversion of propionate to glucose (Aiello et al., 1989). Our results demonstrated that replacement heifers offered citrus-pulp had improved growth rates and elevated circulating concentrations of glucose, insulin, and IGF-I compared to cohorts receiving molasses-based supplements (Table 1). However, no treatment effects were detected on puberty attainment and pregnancy rates at the end of the breeding season. These results were unexpected based on treatment differences detected in observed growth rates and circulating metabolites and hormones.

Table 1. Average daily gain (ADG) and plasma concentrations of glucose, insulin, and IGF-I in replacment beef heifers grazing low-quality pastures, ans offered supplements based on citrus pulp or molasses from weaning until the end of their first breeding season. Adapted from Cooke et al. (2007a).

Item	**Citrus Pulp**	**Molasses**	***P* =**
ADG (kg/d)	0.4	0.3	< 0.01
Glucose (mg/dL)	83	75	< 0.05
Insulin (ng/mL)	0.89	0.75	< 0.05
IGF-I (ng/mL)	122	109	< 0.05

However, when heifers from Cooke et al. (2007a) were classified according to reproductive performance, those that became pubertal and pregnant during the study had greater mean plasma IGF-I concentrations compared to non-pubertal and non-pregnant heifers (Figure 7). Further, in regards to mature cows, circulating IGF-I concentrations at the beginning of the breeding season also influenced final pregnancy rates in a different study from our group (Cooke et al., 2009a). It is important to note that cows with extremely elevated plasma IGF-I concentrations also had impaired pregnancy rates (Figure 7), demonstrating the negative consequences of over-conditioning cows on reproductive function.

When supplemental energy is required, ingredients that promote rumen propionate synthesis should be supplemented to cattle to optimize reproductive performance. However, caution should be adopted to prevent ruminal disorders and potential decreases in forage intake/utilization when feeding supplemental energy to cattle, particularly feeds containing elevated starch and/or fat.

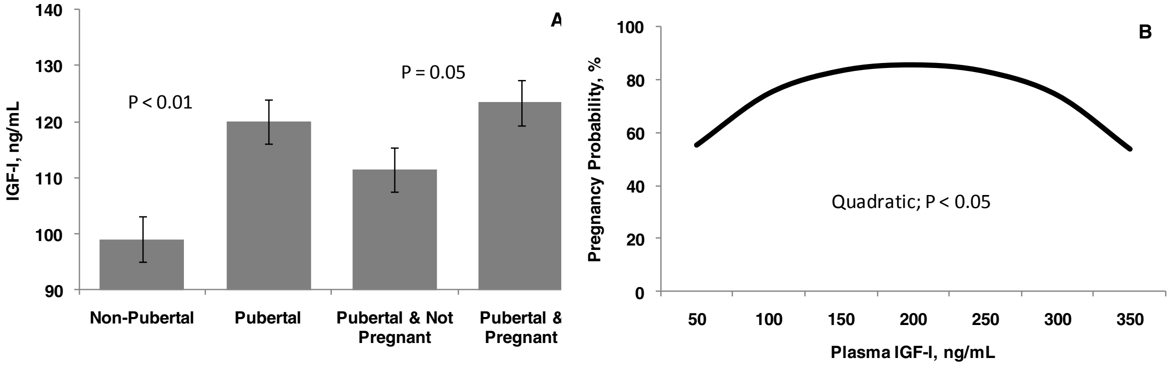


Figure 7. Plasma IGF-I concentrations in replacement beef heifers according to reproductive parameters during their first productive year (Panel A; Only pubertal heifers were exposed to bulls) and probability of pregnancy rates in beef cows according to plasma IGF-I concentration at the beginning of the breeding season (Panel B). Adapted from Cooke et al. (2007a; 2009a).

Frequency of Supplementation

Up to 63% of annual production costs in beef cow/calf operations are associated with cattle feeding, including forage production and feed purchase (Miller et al., 2001). Additional expenses associated with feeding, such as fuel and labor, also contribute significantly to these production costs. Supplementing cattle infrequently, such as once or three times weekly instead of daily, is a typical strategy to decrease costs of supplementation because the expenses associated with labor, fuel, and equipment are reduced. This means that cattle supplemented daily or three times weekly receive the same amount of supplement on weekly basis, but different amounts per feeding. As an example, supplementing cattle at our research station once every 6 days decreased the costs associated with providing the supplement by 83% compared to daily supplementation (Table 2).

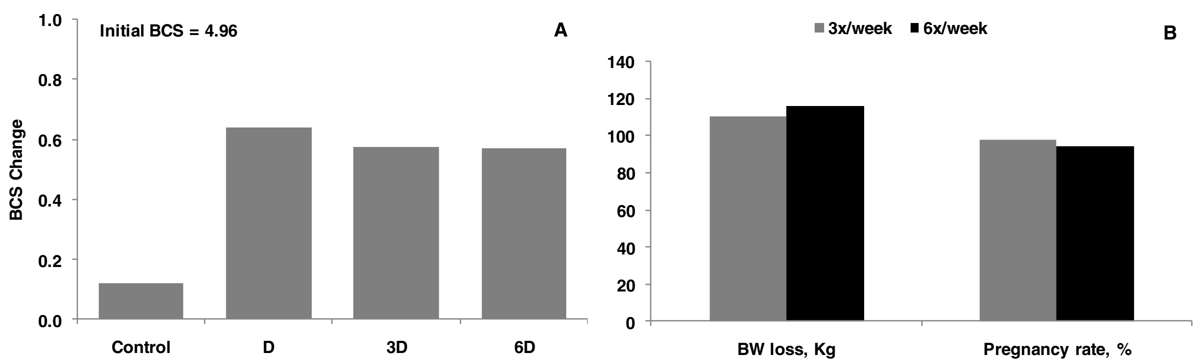
Table 2. Estimated fuel and labor costs associated with supplement feeding.

	Supplementation Interval			
Item	**Daily**	**2 days**	**3 days**	**6 days**
Fuel cost ($)[a]	360.00	180.00	120.00	72.00
Labor cost ($)[b]	630.00	315.00	210.00	105.00
Total Costs ($)	990.00	495.00	330.00	177.00
Cost Reduction	0	50%	67%	83%
Benefit ($)	0	495.00	660.00	813.00

[a] Fuel costs calculated as 3 gallons/supplementation day at $4.00/gallon
[b] Labor calculated as 2.5 hours/supplementation day at $8.40/hour

Kunkle et al. (2000) compiled results from several experiments comparing different supplementation frequencies of protein-based feeds for cattle grazing low-quality forages and reported that supplementing protein as infrequently as once a week instead of daily did not alter cattle performance. Research from our group at Oregon State University demonstrated that beef cows consuming low-quality forages and offered supplemental protein (based on soybean byproducts) daily, once every 3 days, or once every 6 days had similar performance (Figure 8; Bohnert et al., 2002b). Also, research from Oklahoma State University demonstrated that beef cows grazing low-quality forage and receiving supplemental protein during winter and the subsequent breeding season had similar body weight change and pregnancy rates if supplementation occurs 3 or 6 times weekly (Figure 8; Wettemann and Lusby, 1994). Therefore, protein supplements can be offered to beef heifers or mature cows consuming low-quality forages as infrequently as once a week without impairing performance traits. Caution should be adopted, however, when supplements contain urea as protein source to prevent excessive urea intake and potential toxicity.

Figure 8. Changes in body condition score (BCS) in non-lactating pregnant beef cows consuming low-quality forage and receiving no supplement (control), or protein supplement (based on soybean byproducts) daily, once every 3 days (3D), and once every 6 days (6D; Panel A). Pregnancy rates and body weight (BW) change in cows consuming low-quality forages and receiving protein supplementation 3 times or 6 times weekly (Panel B). Adapted from Bohnert et al. (2002b) and Wettemann and Lusby (1994), respectively.



In contrast to protein-based supplements, decreasing the supplementation frequency of energy-based feeds to cattle consuming low-quality forages has been shown to be detrimental to animal performance (Kunkle et al., 2000). With high-starch energy supplements, forage-fed cattle supplemented daily experience improved performance compared to cohorts supplemented infrequently, mainly due to improved ruminal function and consequent forage intake by daily-fed cattle. The same rationale can be applied to energy supplements based on high-lipid ingredients (Cooke et al., 2010). High-starch supplements can have negative effects on rumen health and forage intake and digestibility in cattle consuming low-quality forages even if offered daily (Sanson et al., 1990). This negative impact is associated with decreased ruminal pH and activity of cellulotic enzymes (Martin et al., 2001), impaired bacterial attachment to fibrous material (Hiltner and Dehority, 1983), and an increase in lag time for digestion (Mertens and Loften, 1980). Conversely, energy supplements based on low-starch ingredients, such as fibrous by-products, have been shown to maintain forage intake (Bowman and Sanson, 2000) while animal performance is comparable to when high-starch supplements are fed (Sunvold et al., 1991; Horn et al., 1995).

A recent study from University of Nebraska demonstrated that forage-fed heifers offered supplements based on distillers grains daily or on alternate days had similar forage intake, rumen pH, and in situ NDF disappearance (Loy et al., 2007).These authors concluded that low-starch energy supplements can be offered infrequently to cattle without impairing forage intake and digestibility. Following the same rationale, our research group initially evaluated growth rates and forage intake of yearling steers consuming low-quality forage and offered a citrus-pulp based supplement daily or three times per week (weekly rate of 16.1 kg of dry matter per steer; Cooke et al., 2007b). Steers supplemented daily had similar forage intake, but greater growth rates compared to steers supplemented three times weekly (Figure 9). We attributed differences in growth rates to beneficial effects of frequent supplementation on circulating concentrations of glucose, insulin, and IGF-I. Therefore, we speculated that frequent supplementation of low-starch energy feeds is also expected to benefit cattle reproduction.

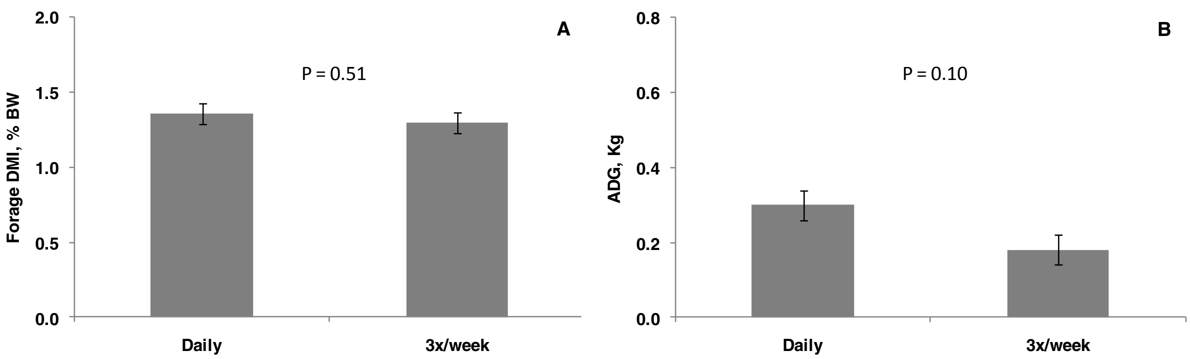


Figure 9. Daily forage dry matter intake (as % of body weight; Panel A) and average daily gain (ADG in kg/d; Panel B) of steers consuming low-quality forage, and offered energy supplements based on citrus-pulp daily or three times weekly. Adapted from Cooke et al. (2007b).

As we expected, replacement heifers consuming low-quality forages and receiving an energy supplement (based on soybean hulls, from weaning until the end of the first breeding season) daily had improved growth rates, hastened puberty attainment, and greater pregnancy rates compared to cohorts supplemented three times weekly (Figure 10; Cooke et al., 2008). Heifers from both treatments had similar mean circulating concentrations of glucose and insulin during the study, suggesting similar nutrient intake. However, mean circulating concentrations of IGF-I were greater in heifers supplemented daily, which suggests that overall nutrient utilization was improved in these heifers compared to cohorts supplemented three times weekly. Therefore, energy supplements, independent of the ingredients used (starch, digestible fiber, of fat sources), should be offered daily in order to optimize performance and reproductive efficiency of beef females consuming low-quality forages.

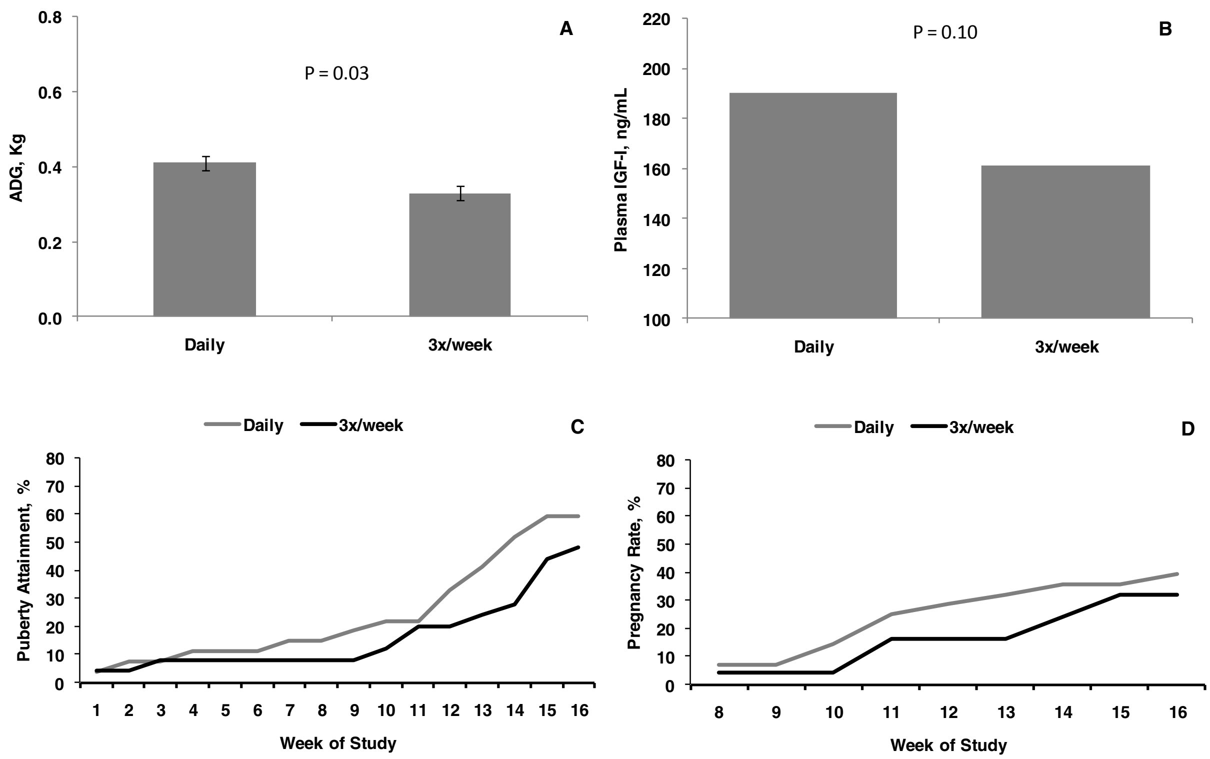


Figure 10. Average daily gain (Panel A), mean plasma IGF-I (Panel B), puberty (Panel C) and pregnancy attainment during the breeding season (Panel D) in heifers consuming low-quality forages as supplemented daily or three times weekly with an energy supplement based on soybean hulls. Adapted from Cooke et al. (2008).

Conclusions

Supplementation programs are essential for optimal productivity of cow-calf operations using low-quality forages in the Northwest. Beef females should be in adequate planes of nutrition to ensure optimal reproductive development and function, as well as future productivity of the offspring. When protein needs to be supplemented, growing females will benefit the most if natural sources of protein are being offered. On the other hand, mature cows will perform similarly if receiving supplemental protein in the form of natural or non-protein nitrogen. When energy needs to be supplemented, reproductive performance will be maximized when ingredients that favor propionate synthesis are offered. Given that supplementation programs are unattractive to many beef producers due to economical aspects, reducing the frequency at which supplements are offered to cattle is a potential alternative to reduce supplementation costs. Protein supplements can be offered as infrequently as once every 6 days without impairing performance and reproduction of beef females. On the other hand, energy supplements should be offered daily to minimize ruminal disorders, exploit nutrient utilization, and optimize performance and reproductive efficiency of beef heifers and cows.

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