NUTRITIONAL INFLUENCES ON REPRODUCTION: MINERAL SUPPLEMENTATION

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Introduction

Reproductive success is fundamental to the economic viability of the beef cow-calf herd. Based on Standardized Performance Analysis (SPA) data, pounds weaned per cow exposed has been shown to impact the overall profitability of the operation. When modeling pounds weaned per cow exposed, this variable was found to be significantly impacted by four factors: investments in livestock (+), calving percentage (+), death losses (-) and extended breeding seasons (-)(Ramsey et al., 2002). Investing in genetics to increase production and managing to ensure cows conceived and had healthy, live calves positively affected pounds weaned per cow exposed while calf mortality and longer breeding seasons lowered the pounds weaned per cow exposed. The relationships between reproductive success and nutritional adequacy have been well established (Herd and Sprott, 1998). In most operations, balancing nutrient needs with nutrient availability requires some degree of supplementation. The need for additional energy, protein or mineral intake to optimize production is dependent upon a variety of factors. Though little attention is given to mineral supplementation programs by producers, recent price increases in mineral supplements have producers asking what is needed and what can be cut from the mineral. Minerals play an important role in both female and male fertility. Calcium for instance is well documented in its role in sperm capacitation. Interactions between minerals and gene function are also continuing to be unraveled and understood. Blindly removing mineral supplementation from beef herds is not advisable. The following will discuss some of the key macro- and micro-minerals supplemented to beef cattle in the southeastern United States and their involvement in reproduction.

Phosphorus

An element essential for cellular energy metabolism and skeletal development, phosphorus (P) is the most prevalent mineral deficiency of grazing livestock globally (McDowell, 2003). Phosphorus comprises approximately 29% of the total mineral content within the body (McDowell, 2003). It is central for cellular energy metabolism in forms of adenosine mono-, di- and tri-phosphate (AMP, ADP, and ATP, respectively). These compounds are the currency form for cells when we discuss cellular energy metabolism. A more top of mind function of P is skeletal formation. Bone is the primary reserve with 80-85% of P being associated with the skeleton (McDowell, 2003). Within bone, phosphorus is generally found to be associated closely with calcium (Ca) in the form of either Ca phosphate or hydroxyapatite and often in a ratio of 2:1 of Ca to P. A variety of studies conducted with rats has indicated that as the Ca:P ratio was reduced by increasing dietary P levels, bone strength was actually reduced. Phosphorus is also an integral component of soft tissue. It is found in cell membranes in the form of phospholipids providing the formation of a phospholipid bi-layer membrane. Phosphorus can be found associated with proteins and nucleic acids as well. It is involved in other activities including gene transcription, hormone signaling, and oxygen release from red blood cells. Further, phosphorus in the form of phosphates acts as a buffer.

Phosphorus deficiency will impact a variety of systems and be detrimental to overall performance. Deficiency is difficult to recognize and like many mineral deficiencies often will impact performance negatively for a period of time before clinical signs are observed. Reduced performance, both weight gain and milk production, is routinely observed with inadequate phosphorus intake. Lowered dry matter intake can be observed partially explaining the reduced performance. The most significant impact for the cow-calf producer is the lowered fertility observed under severe phosphorus deficiency. The fear of reduced reproductive success has resulted in phosphorus supplementation of grazing beef cows as a standard practice. Free-choice commercial mineral mixtures typically contain between 3-12% phosphorus. Often a standard 2:1 calcium to phosphorus ratio mineral is provided to beef cows by producers with a common analysis being 12% calcium and 6% phosphorus with a targeted intake of 3-4 ounces daily for this type of product. However, is this level of supplementation adequate? Too few producers routinely sample and analyze forages to develop their supplementation programs around the requirements of the animal.

Maintenance requirements of phosphorus include endogenous fecal and urinary losses. In the 1996 Beef NRC, the maintenance requirement for P was listed as 16 mg per kg of body weight. Thus, a 1,300 lb cow would have a maintenance P requirement of 14 gm per day after adjusting for a 68% availability from the feedstuff. Additional phosphorus needs are calculated based on partitioning these towards lactation, gain and/or fetal development. A cow with a peak milk production potential of 17 lbs would require an additional 11 gm of phosphorus daily at peak. Fetal growth and nutrient demands are greatest the last 90 days of gestation. The phosphorus needs during this time for a projected 85 lb calf at birth equals maintenance needs plus 5 gm additional P to support fetal growth. Assuming an intake of 26 lbs of dry matter, the forage would need to contain 0.21% phosphorus to meet maintenance and peak lactation phosphorus needs and only 0.16% for a dry cow in mid-gestation.

Recent forage testing by several states would suggest the phosphorus supplementation may require some reconsideration. West Virginia researchers investigated pasture forage nutrient concentrations across the state during the years of 1997 through 2001 (Rayburn et al., 2006). More than 600 forage samples were analyzed for various nutrients. It was reported that the mean P concentration of these pasture samples was 0.34% with the minimum concentration being 0.10% and the highest being 0.59%. In similar sampling conducted in Tennessee and Kentucky, samples collected in 2003 and 2004 had minimum, mean, and maximum P concentrations of 0.13%, 0.36%, and 0.55%, respectively. These numbers represent 292 samples that were identified as being primarily fescue or fescue mix forage samples (Lane, personal communication). Central Iowa forage samples were reported to contain between 0.12% and 0.25% P (Haan et al., 2007). In Florida research with annual forages (oats/rye/ryegrass), it was observed that forage P concentration were adequate to meet the requirement for grazing beef cattle with P levels varying by month and tended to decline as time progressed (Chelliah et al., 2008). During 2009, 98 hay samples from Kentucky beef farms were found to contain on average of 0.29% P with minimum concentration being 0.11% and the highest level being 0.57% agreeing with the previous literature. On average, these forages meet or exceed the P requirements for a beef cow during all stages of production. However, there are samples that fall short and would need to be supplemented to meet the NRC recommended levels.

With respect to reproduction, phosphorus levels required are not clearly defined. Wu and Satter (2000) found that feeding lactating dairy cows a diet containing 0.38% P did not differ in milk production or reproduction compared to diets containing 0.48% P. In a following trial, Lopez and co-workers (2004) did not observe any differences on a variety of reproductive variables studied when P was fed at the recommended level of 0.37% versus a diet containing 0.58%. Pennsylvania researchers also did not observe any reproductive impacts when dietary phosphorus was lowered from 0.47% to 0.35%. In a recent review of the older literature which established the relationships between dietary P intake and reproduction, Ferguson and Sklan (2005) concluded that diets containing 0.15% to 0.20% phosphorus and provided adequate energy and protein intake did not impair reproduction. The authors go on to state with respect to dairy cows:

"…dietary P does not seem to have a major impact on reproduction until dietary concentrations are below 0.10%. In fact, many pasture studies in beef cattle find no benefit with supplementation when pasture concentrations are 0.15% to 0.20%."

Selenium

Selenium is unique in its narrow range between the amount necessary to support biological functions and toxicity. It is the only mineral currently regulated by FDA for this reason with the maximum daily supplemental level being 3 mg daily. Most selenium supplementation to beef cows occurs via free-choice mineral supplements. These supplements are typically formulated to provide the maximum allowable supplementation level of 3 mg at a specified targeted intake for the product. However, due to mineral intake variability, low concentration and/or bioavailability of selenium in the main dietary components, and antagonisms with other minerals, it is possible that deficiencies may occur when using these supplemental products.

Selenium is important for normal spermatogenesis and largely as a component of selenoproteins phospholipid hydroperoxide glutathione peroxidase (PHGPx/GPX4) and Selenoprotein V (Boitani and Puglisi, 2009). Most of the selenium found in the testis is associated with PHGPx/GPX4. It serves as a powerful antioxidant protecting cells from oxidative stress. According to the review by Boitani and Puglisi (2009), PHGPx also appears to be involved as a structural protein to provide normal sperm motility. It has also been shown that a variant to this protein is necessary for normal chromatin condensation and subsequent normal spermatozoa head formation. Both deficiency and excessive selenium have been demonstrated to be detrimental to normal spermatogenesis. Recent research with goats has illustrated that the dietary selenium level of the dam can influence spermatogenesis male offspring through elevated milk concentrations. This work supports the need for adequate selenium intake and the avoidance of excessive intake with respect to apoptosis control of germ cells (Shi et al., 2010). The impact of dam intake on fetal development has been shown in the female offspring as well. Feeding high levels of selenium to pregnant ewes resulted in suppression of fetal ovarian cell proliferation compared to those fed a diet adequate in selenium (Grazul-Bilska et al., 2009).

Zinc

Limited recent research has been conducted on the impacts of zinc supplementation and reproduction. A recent study investigating level and source of zinc on a limited number of crossbred bulls (n=16) demonstrated that zinc supplementation increased mean ejaculate volume, sperm concentration, percent live and percent motility (Kumar et al., 2009). Studying fertile and infertile men, it was observed that seminal zinc levels were lower for infertile men than fertile men and researchers suggested that poor zinc nutrition may be a risk factor for infertility in men (Colagar et al., 2009). Zinc supplementation was shown to reduce asthenozoospermia in men by reducing oxidative stress, DNA fragmentation and apoptosis (Omu et al., 2009). However, there is conflicting evidence as to the importance of zinc concentrations in the semen and infertility of men. This said there appears to be sufficient evidence in the literature to suggest that zinc plays a role in male fertility.

Copper

Drosophila have three homologs of Ctr1 a cellular copper importing protein. It has recently been shown that one homolog in the Drosophila, Ctr1c, is an important copper importer unique to the male germ line. This homolog was shown to be specifically important to male Drosophila fertility and likely demonstrating the importance of copper in male fertility and a possible mechanism (Steiger et al., 2010). Copper deficiency has been shown to reduce fertility in cows by delaying or depressing estrus, and abortions (McDowell, 2003). Bull fertility was also observed to be negatively affected when a copper deficiency was present (Larson et al., 1995). The interaction of copper with molybdenum and sulfur reducing its availability is a concern and deficiencies can be induced when these antagonistic minerals are present at high concentrations it the diet. Concerns over possible induced copper deficiencies when feeding coproducts feeds high in sulfur are currently being investigated.

Manganese

Manganese deficiency has been reported to reduce first service conception rates and reduce fertility in ruminants (McDowell, 2003). However, deficiencies in manganese are suggested to be less likely than other trace elements such as cobalt, copper, selenium and zinc (McDowell, 2003). Recent research with beef heifers fed a control diet containing 15.8 mg/kg of dietary Mn was sufficient for growth and reproduction and supplemental Mn had no effect (Hansen et al., 2006). Bull semen quality may be enhanced during cryopreservation with Mn addition to the extender (Cheema et al., 2009). Manganese role in improving cryopreservation is thought to be through antioxidant properties and reducing reactive oxygen species generated by sperm.

Conclusion

Beef producers considering strategies to lower mineral input costs may first wish to focus on forage mineral concentrations. This requires an investment in forage sampling and testing. Accessibility to forage testing laboratories that provide mineral analyses has increased in the last few decades and many minerals can be determined for minimal expense. This information can be utilized in developing mineral supplementation programs and/or selecting the most appropriate commercial mineral supplement. This information combined with knowledge regarding bioavailability allows for strategic supplementation programs specific to regions and individual operations. It is critical that mineral supplementation be offered at appropriate levels to optimize reproductive success and fertility of both the male and female. Advances in technologies for sexing semen and extending semen for cattle and other species are expected to be enhanced through new knowledge of minerals' role in storage and sperm quality.