The Relationship Between Mineral Nutrition of the Beef Cow and Reproductive Performance

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Introduction

Providing nutrients in adequate amounts is important for maintaining beef cow fertility. A nutrient is considered essential if upon removal from the diet there is an interference with an animal's ability to grow and (or) reproduce. Adequate mineral intake is required for proper functioning of many metabolic processes including reproduction. In general, deficiencies of copper, cobalt, iodine, selenium, zinc, manganese and phosphorus may occur in cattle maintained on forage-based diets. The effects of copper, zinc, manganese and phosphorus on beef cattle reproduction is the focus of this paper.

Trace Minerals

A mineral becomes limiting or deficient when the amounts consumed are not adequate to meet desired performance requirements. In addition, stage of production (pregnancy or lactation) dictates the dietary mineral requirements. Table 1 indicates how copper and zinc requirements vary for beef cattle growth, pregnancy and lactation.

Table 1. Copper and zinc requirements for cattle at different stages of production.[a]

Performance Level	Copper	Zinc
	---mg/kg DM intake---	
Growth	8-15	26-35
Pregnancy	13-20	13-21
Lactation	8-14	18-31

[a]Adapted from Graham (1991).

Mineral deficiencies may be classified either as primary or secondary (Graham, 1991) with a primary mineral deficiency caused by inadequate dietary intake of one or more essential minerals. A secondary deficiency (also referred to as a conditional deficiency) is due to impaired absorption, distribution or retention of minerals. A secondary deficiency can be caused by a preexisting disease condition or interaction between minerals which negatively affect metabolism. Both primary and secondary deficiencies can occur at the same time and evaluating the mineral status of cattle can become complex. Supplementing trace minerals has been shown to have an impact on reproduction. Doyle *et al.* (1988) conducted a study in which zinc, copper and manganese were added to a supplemental grain mix containing phosphorus and compared to either no supplement, a grain-urea mix or a grain mix with phosphorus. The average length of time from the beginning of the breeding season to conception was 22 days for the trace mineral supplement, 29 days for the grain mix with phosphorus, 35 days for the grain-urea mix and 42 days for nonsupplemented cows. Another study evaluated the effects of an organic-inorganic trace mineral combination versus inorganic trace minerals only on reproduction. Conception rates were not statistically influenced by type of trace mineral supplement, but cows which received the trace mineral supplements tended to have higher conception rates compared to a control with no added trace elements.

The reasons that intake of bioavailable minerals is crucial in postpartum animals include proper involution of the uterus, display of estrus, ovulation, conception and maintenance of a new fetus. Immediately following parturition, the blood supply is shunted from the reproductive organs to mammary glands to enhance milk production. Repair of the endometrium competes with milk production for minerals needed for enzyme systems. The nutritional and mineral status at the cellular level is vital to endometrial pathology, embryonic viability and fertility. In a study conducted by Manspeaker (1987) copper, zinc, manganese, iron and magnesium chelates were added to the basal diet fed to dairy heifers. Following parturition, endometrial tissue involution and regeneration was more effective, fewer infections were observed, and increased ovarian activity and decreased embryonic mortality were measured in supplemented heifers conceived 45 days earlier than controls.

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Table 2. Influence of Chelated Mineral Supplementation on Heifer Postpartum Fertility.

Item	Supplemented	No Supplement
Infections: Bacteria isolated from cervis & uterus, %	5	25
Ovarian Activity: Mature follicles 30-80 days postpartum (biopsy), %	35	20
Embryonic Mortality: Palpated embryonic depression 35-55 days postinsemination, %	0	20
Incidence of endrometrial scarring, %	10	58
Postpartum involution and tone of pregnant horn comparêd to nonpregnant horn	Indistinguishable @ 30-35 days	Distinguishable @ 50-55 days

Iodine is also essential for reproductive performance. Silent heat, early embryonic death, weak calves, retained placenta and decreased conception rates have been observed in iodine deficient cows (Corah and Ives, 1991). Bull fertility (decreased libido and sperm quality) can also be reduced with inadequate iodine levels. Iodine is easily provided in salt mixtures, and a deficiency is rare because of the common use of iodized salt.

Copper

Copper is stored in the liver and is necessary for a variety of enzyme systems. When a copper deficiency occurs, productivity may be reduced due to metabolic alterations of enzyme systems. Delayed or suppressed estrus and embryo copper deficiency in beef cattle (Herd, 1994). Copper deficiency in cows can result in decreased conception, infertility, anestrus and fetal reabsorption. Dairy cows with higher serum copper levels had significantly less days to first service, fewer services per conception and fewer days from calving to conception than cows with lower copper serum levels (Kappel *et al.,* 1984). In another study, dairy cows with low serum copper levels responded to supplemental copper and magnesium with increased percentage of cows that conceived at 75, 100, 125 and 150 d after calving compared to control, copper supplemented, or magnesium supplemented only (Ingraham *et al.,* 1987).

Infertility associated with copper deficiency may also be caused by an excess of molybdenum in the diet. In a study by Phillippo *et al.,* (1987) heifers were fed experimental diets containing marginal copper levels and excess molybdenum or excess iron. Heifers receiving the diet with marginal copper levels and excess molybdenum exhibited delayed puberty, lower ovulation rates and lower conception rates compared to heifers consuming the diet containing excessive iron. Depressed libido and reduced spermatogenesis which caused impaired fertility in bulls has been attributed to excess dietary molybdenum (Thomas and Moss, 1951).

Zinc

Zinc is involved in virtually every phase of cell growth, and a zinc deficiency can have a negative impact on productivity. Zinc appears to have more of an impact on male rather than female fertility. Zinc serves as an activator of enzymes necessary in steroidogenesis which regulates secretion of testosterone and related hormones. Inadequate zinc levels can cause impaired spermatozoan maturation, and a decrease in circulating testosterone (Apgar, 1985; Puls, 1990). The importance of zinc in growing bull calves was demonstrated when animals were fed a zinc deficient diet from 8 to 21 weeks of age. Reduced testicular size for unsupplemented calves was measured compared to calves receiving zinc (Pitts, 1966). When zinc was then added to the diet of the deficient calves, testicular size equalled that of the controls by 64 weeks of age. These results suggest that effects of a deficiency can be overcome by supplementing the deficient mineral. Similarly, Maas (1987) reported impaired growth, delayed puberty and decreased appetite in zinc deficient bull calves. A loss of appetite results in lowered mineral ingestion which can further decrease feed utilization through hindered nutrient metabolism.

Zinc deficiency in gestating cows may result in abortion, fetal mummification, lower birth weight, or altered myometrial contractibility with prolonged labor. When cows with low zinc serum levels were supplemented with zinc prior to calving, there was a lower incidence of dystocia (Duffy *et al.,* 1977). Inadequate zinc levels have also been associated with decreased fertility and abnormal estrus.

Manganese

Manganese is stored in the liver, kidneys and bones. Manganese is among the least toxic of all minerals for ruminants because mature beef animals only absorb 10-18% of dietary inorganic manganese. Manganese absorption drops rapidly with high levels of dietary calcium, phosphorous or iron in the diet which can greatly influence the dietary requirement. Normal fertility was maintained in cattle fed low levels of dietary manganese and a good balance between calcium and phosphorus. However, fertility was depressed if either calcium or phosphorus levels became too high, and were no longer balanced in relation to each other (King, 1971).

Manganese deficiency in cows results in silent estrus, anestrus, infertility, abortion, immature ovaries and dystocia (Pugh *et al.,* 1985). Corah and Ives (1991) suggested that typical responses of females supplemented with manganese includes increased ovarian activity and conception rate. The primary mechanism by which manganese has a role in reproduction is through cholesterol synthesis. Manganese is necessary for synthesis of cholesterol which in turn is required for ruminant steroidogenesis. Inadequate levels of manganese disrupts steroidogenesis resulting in decreased levels of circulating hormones, abnormal sperm in males and irregular estrous cycles in females (Brown and Casillas, 1986).

In addition to signs of reduced reproduction in mature cattle, calves born to deficient dams have general weakness, poor growth and "knuckle over" at the fetlocks (Dyer and Rojas, 1965; Wilson, 1966). Manganese supplementation is effective in reversing reproductive problems and calf skeletal changes that are due to a deficiency.

Phosphorus

Of the macro-minerals, phosphorus has often been considered as one of the most important minerals needed to maintain normal reproductive performance. Forage (the major dietary ingredient for producing beef cows) has a high level of calcium and a low level of phosphorus which might lead to the assumption that supplemental phosphorus is necessary especially when cattle are grazing mature forage during late fall and through the winter months. Numerous studies which have shown a positive impact on reproduction with phosphorus supplementation (Underwood, 1966; McDowell, 1985) were conducted in areas of the world with extreme phosphorus deficiencies and low fertility in cattle. Results may not be as applicable to the production settings in the United States.

Call *et al.* (1977) conducted a study for two years using Hereford heifers fed diets containing either 66% or 172% of the NRC requirement for phosphorus. Reproduction parameters (age at puberty, pregnancy rate and percent live calves) were similar between treatment groups. In addition, bone sections and tissue phosphorus levels were not different. As might be expected, fecal and urine excretion were much higher for the heifers receiving the high level of phosphorus. A second study reported by Butcher *et al.* (1979) utilized Hereford heifers fed basal diets containing .14% or .36% phosphorus (66% or 174% of NRC requirement) for four years. During late gestation of the fourth year, half of the cows in each treatment group were reassigned to a very low level of phosphorus, 0.9%, while the other half of each group remained on their original diets. Supplemental phosphorus levels had no negative effects on the remaining gestation period, calving or lactation. A decrease in appetite and subsequent weight loss were observed in the low level phosphorus group, however, there were no differences in the percentage of cows bred by natural service during the breeding season. These data suggested that phosphorus levels below 50% of NRC recommendations were still adequate for maintaining fertility.

Forage Mineral Content

Beef producers are faced with the challenge of balancing mineral requirements according to the animal's level of production and mineral content available in feed sources. Forages may provide all the essential minerals required by cattle, but if the forage is deficient in one or more minerals, then a mineral supplement would be necessary to maintain normal metabolic functions. Severe mineral deficiencies are uncommon while marginal deficiencies are difficult to identify and are more likely to occur.

Bioavalibility of minerals is defined as the proportion of ingested element that is absorbed, transported to the action site and converted to an active form (O'Dell, 1984). Distribution of the mineral in the plant, chemical form and mineral interaction can influence bioavailability. Forage mineral content and bioavability vary (Spears, 1994) because of such factors as soil mineral level, soil pH, climatic conditions, plant species and stage of plant maturity. When comparing legumes and grasses grown in the same location, legumes have been shown to be higher in calcium, copper, zinc and cobalt than grasses. Grasses do, however, contain higher levels of manganese. Concentration of minerals in forages often decrease as plants mature and dry matter content increases more rapidly than mineral uptake.

Mineral analysis of native range grass collected from the same pasture over three years during the winter was similar for zinc, copper, manganese, iron, potassium, calcium and phosphorus (Clark *et al.*, 1994). These results suggest that forage mineral content does not vary tremendously from year to year, however, the method of mineral analysis does not indicate bioavability of the minerals which may be effected by year to year variation in growing conditions.

Deciphering the Feed Tag

Finding mineral requirements for a particular group of animals is the easy task. Knowing if you have a deficiency and then properly supplying adequate amounts becomes more difficult. Diagnosing the mineral status of the herd will require additional information such as animal symptoms, performance, liver blood and (or) hair analysis, and feed (possibly water) analysis. Once you have a number of values gathered, the bioavailability and interactions of minerals can be considered in formulating a desired mineral supplement.

However, after you have defined your deficiency, is it as simple as formulating a supplement for your cows? No? Why Not? The first problem is that all minerals are not created equal in regard to utilization. Secondly, feed tags do not always tell you everything you need to know and may often be confusing. Many times the levels added to trace mineral supplements are given only in order of incorporation and not the exact quantities added to the mix. For example, you may find a trace mineralized salt containing copper, but the amount of copper is not stated, only that copper oxide is the fourth most used compound in a supplement containing 98% salt. In reality, this supplement contains very little if any available supplemental copper because of the form copper is in.

Even when all the minerals are individually listed on a feed tag, determining if mineral requirements are met can be difficult and confusing. It would not be uncommon for you to have your forage tested at a lab and your mineral analysis reported back to you as a percent of the forage. When you looked up the animal requirements, you found it listed as parts per million (ppm) in the diet and upon reading the feed tag you find the amount of mineral given as milligrams per pound (mg/lb). You are now comparing apples, oranges and grapes. Although the conversions to a common denominator are relatively simple, care must be taken because being off by one decimal point may be the difference between a deficient and toxic mineral supplement. The following table (3) provides an example of a "miscalculation."

Table 3. Example of a common error in calculating daily intake of copper for cows.

Item	Grass Hay	Mineral Supplement	Total Intake
Amount fed / day	22 lbs	2 ounces	
Conversion to kg	22 lbs x .454 = 10 kg	2 ounces x 02835 = .0567 kg	10.0567 kg
Copper analysis	5 ppm	2 %	--
Conversion to mg/kg	5 x 1.0 = 5 mg/kg	**.02 / .0001 = 200 mg/kg[a]**	--
Daily intake of copper	10 kg x 5 mg/kg = 50 mg	.0567 kg x 200 mg/kg = 11.34 mg	61.34 mg[b]

[a]A common error occurs at this point; when converting from percent to ppm, use the whole number, not the decimal equivalent (2% = 2/.0001 **not** .02 / .0001).
[b]61.34 mg copper / 10.0567 kg feed = 6.1 mg/kg (ppm) copper. This example shows the copper requirement not being met when actually it would be toxic at 1134 ppm copper.

The calculations in the previous table are correct if the supplement contained 0.02% copper. In practice, you should never find a mineral supplement containing 2% copper. To help simplify conversions between units commonly used in reference to nutrients, Table 4 has been provided.

Summary

Maintaining fertility in beef cattle requires adequate dietary intake and absorption of essential minerals. The minerals are necessary for normal function of various enzyme systems. Feeding a diet deficient in a single mineral can negatively affect reproduction in beef cows and bulls. The influence of an iodine, copper, zinc or manganese deficiency on fertility is summarized in Table 5. When evaluating cattle diets for the different stages of production, levels and interactions of minerals should be considered. If a deficiency is evident, then supplementing to meet the animal's requirement could have a positive impact on reproduction and profitability for the beef cattle producer.

Table 4. Conversion factors for commonly used units in reference to nutrients.

Unit	Conversion Factor Multiply going right→ Divide going left ←	Unit
lb.	0.454	kg
lb.	454.0	g
oz.	0.02835	kg
oz.	28.35	g
g	0.001	kg
g	1000.o	mg
mg / kg	0.454	mg / lb
g / kg	0.454	g / lb
ppm	1.0	mg / kg
ppm	0.0001	%
ppm	0.454	mg / lb
ppm	0.91	g / ton
g/ton	0.00011	%

Table 5. Summarized influence of iodine, copper, zinc and manganese deficiency on fertility of beef cattle.

Deficiency	**Female Fertility**	Reference	**Male Fertility**	Reference
Iodine	⇑ Silent heat	6	⇓ Libido	6
	⇑ Embryonic death		⇓ Sperm quality	
	⇑ Weak calves			
	⇑ Retained placentas			
	⇓ Conception rates			
Copper	⇑ Delayed or suppressed estrus	11, 12, 13		
	⇑ Embryo death			
	⇓ Conception rates			
Copper[a]	Delayed pubery	19	⇓ Libido	24
	⇓ Ovulation rates		⇓ Spermatogenesis	
Zinc	⇑ Dystocia	8 , 15	Imparied growth	1, 15, 20,
	⇑ Abnormal estrus		Delayed puberty	22
			⇓ Testosterone	
			⇓ Testicular size	
			⇓ Libido	
Manganese	⇑ Anestrus	2, 6, 21	⇑ Abnormal sperm	2
	⇑ Abortion			
	⇑ Dystocia			
	⇓ Ovarian activity			
	⇓ Conception rates			

[a]Copper with excess molybdenum in the diet.

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Abstract

Sex preselection in cattle: a field trial

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Producing livestock progeny of a predetermined sex has been a long sought goal of producers worldwide. Benefits would be expected to follow in terms of genetic improvement and farm management and the tailoring of offspring to meet particular market demands. In spite of numerous approaches to the problem only one procedure has stood the test of laboratory validation and appropriate skewness of the sex ratio of the progeny. This procedure (Beltsville Sperm Sexing Technology) is based on the well established difference in total DNA content between mammalian X- and Y-chromosome bearing sperm (Johnson 1992). The separation is carried out by flow cytometric sorting of individual sperm (Johnson and others 1989, Johnson 1991, Cran and others 1993) and the separated sperm populations may be either inseminated surgically or used for in vitro fertilization (IVF). These reports have demonstrated skewness of the sex ratio in rabbits, pigs and cattle ranging from 70 to 90 percent. In an initial study to produce progeny in cattle, Cran and others (1993) reported the birth of six calves using this technology; all the calves were of the predicted sex. The present report is an extension of these studies carried out in a field trial in which Y sperm only were sorted, then used for IVF to produce embryos for transfer to recipient cows. They report the birth of 41 calves that had a sex ratio of 90 percent male.