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Trace Minerals Concentrations Calculations

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Introduction:

Recently I received a phone call from a sheep producer who had lost three ewes to copper toxicity. The first question asked was, "what is the upper safe limit of copper to feed to sheep?" When I explained that many factors affected the upper safety limit, but I would not recommend over 10 parts per million (ppm) in the diet, the caller became quite irritated. This person had hired a lawyer and had submitted samples to a lab for copper analysis. When they found the salt-trace mineral mix contained 200 ppm of copper, they were convinced this was a case of gross negligence. I then explained that I did not think the salt-trace mineral mix was the source of their problem. The caller then exclaimed, "how can you say that when you recommend less than 10 ppm of copper and the product they sell for sheep contains 200 ppm of copper, 20-fold greater than the upper recommended level?" I then tried to explain that the salt-trace mineral mix is only a small part of the diet, usually 1% or less and at 1% of the diet it would only contribute 2 ppm of copper in the total diet. Over the phone the caller was unconvinced and wanted to see the calculations in writing.

The purpose of this paper is to review the calculations involved in determining trace mineral concentrations and to give some general guidelines in estimating the contribution from each source in the diet.

Sampling the Diet

The first step in determining nutrient concentrations is to get representative samples of all ingredients in the diet. If a totally mixed diet is being fed, then taking 5-10 hand-fulls from a batch, thoroughly mixing them and sub-sampling is all that is required to get a representative sample. However, if as in the scenario above, the ewes were grazing pasture, receiving a grain mix and were fed the salt-trace mineral mix free choice, getting a representative sample of the complete diet is much more complicated. Although it is challenging because sheep and other animals are selective grazers, trying to cut the forage being eaten with a scissors is the best approach. Taking 8-10 clippings from several locations in the pasture and mixing them prior to sub-sampling is recommended. Usually fresh forage samples should be frozen before being shipped by overnight delivery.

Most labs will express nutrient concentrations on both an "as-is" and dry matter basis. An "as-is" analysis is with the water present. A dry matter analysis is with the water removed. Under practical conditions, an "as-is" analysis will always contain a lower nutrient concentration because the water acts as a diluent. Nutrient requirements and maximum tolerable levels are usually expressed on a dry matter basis. Unless the producer knows how much of each ingredient is being consumed each day on an as-fed basis, the information is of limited value.

Feed Tag Concentrations

Another confusing issue for many producers is that feed tags on salt-trace mineral mixes express nutrient concentrations as a percent, while feed analyses express trace mineral concentrations on a ppm basis. In the example described above the feed tag indicated the trace mineral mix contained 0.02% copper. The rule for converting percent to ppm is to move the decimal point four places to the right. The 0.02% is equal to 200 ppm of copper. The opposite is also true in that ppm is converted to percent by moving the decimal point four places to the left. Thus 200 ppm is equal to 0.02%. Feed tags are required to use percents because dealing with numbers with lots of zeros can be confusing. For example, most producers relate better to a supplement containing 1.0% zinc than one containing 10,000 ppm zinc, even though they are equal.

Converting English to Metric

Converting English to metric units can also be confusing for some producers. For example, many expected consumption rates for salt-trace mineral mixes are expressed in ounces per day. Grazing cattle will often consume 3-4 ounces of salt per day while sheep will often consume between 0.25 and 0.5 ounces per day. So in the above scenario, if the ewes consumed 0.5 ounces of the trace mineral salt containing 200 ppm (0.02%) copper, how much copper was being contributed to the 10 ppm maximum recommended intake? To make this conversion we must estimate how much dry matter the ewes were consuming per day. The ewes averaged around 100 lbs and were being fed 0.5 lb of grain mix per head per day. On medium quality forage, I would expect these ewes to consume 1.5 to 2.0 lbs of forage dry matter by grazing, so that their total intake would be approximately 2.5 lbs of dry matter.

Next we need to convert ounces (trace mineral salt) per pound dry matter intake to ppm. The easiest conversion process is to remember that milligram/kilogram is equal to ppm. Unit conversions to remember are that there are 1000 milligrams per gram, 454 grams per pound and 16 ounces per pound. So if the ewes ate 0.5 ounces of the trace mineral salt that is 0.03125 pounds (0.5/16 = 0.03125). To convert to grams, we multiply 0.03125 lb x 454 grams/lb, so 0.03125 lb X 454 g/lb = 14.19 grams of trace mineral salt per day. Next we can convert grams to milligrams by multiplying times 1000 to get 14,190 mg of trace mineral salt per day. Since the feed tag and feed analysis showed the trace mineral salt was 0.02% copper, we can calculate the mg of copper being consumed by multiplying 14,190 mg trace mineral salt times 0.02%, (14,190mg x 0.0002 = 2.84mg) which equals 2.84 mg copper.

Since ppm is equal to milligram per kilogram, we need to estimate the intake on a kg basis. Since there are 454 grams per pound and an estimated dry matter intake of 2.5 lbs this is equal to 1,135 grams per day (454 g/lb x 2.5 lb =1,135 g). So we have 2.84 mg of copper in 1.135 kilograms of intake, which is equal to 2.50 ppm of the diet (2.84 mg/1.135 kg = 2.50 ppm). Consequently, what seemed like a toxic amount of copper in the trace mineral mix (200 ppm) to the producer, only contributed approximately 2.5 ppm of copper to the total diet.

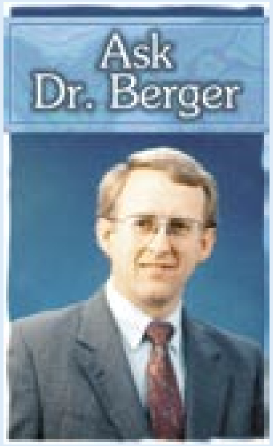
So where did the toxic copper concentration come from? It could come from the remainder of the diet or from the water. A water sample was analyzed and found to be very low in copper. Samples of the grain mix and pasture forage were analyzed and found to contain 56 and 8.0 ppm of copper, respectively. If the ewes consumed 0.5pound per day of the grain mix that is equal to 12.71 mg copper (0.5 lb X 454 g/lb = 227 grams, 227 grams x 1000 mg/gram = 227,000 mg of grain mix, 56 ppm = 0.0056 percent copper, 227,000 mg of grain mix X 0.000056 = 12.71 mg copper intake per day). The 12.71 mg of copper divided by the 1.135 kg estimate intake equals 11.20 ppm in the diet.

The estimated copper contribution from the grazed forage is 7.26 mg (2.0 lbs X 454 g/lb = 908 grams, 908 grams X 1000 mg/gram = 908,000 mg of forage, 8 ppm = 0.0008 percent copper, 908,000 mg of forage X 0.000008 = 7.26 mg copper intake per day). The 7.26 mg copper divided by the 1.135 kg estimated intake equals 6.4 ppm in the diet. The total estimated copper concentration in the diet is calculated by adding the 2.5 (trace mineral salt) + 11.20 (grain mix) + 6.40 (forage) to equal 20.10 ppm. Even though the trace mineral salt had the highest copper concentration, because of its low level in the total diet it only contributed approximately 11.9 percent of the total copper intake (2.5/20.95 ppm = 11.9%). In this case the grain mix was not formulated specifically for sheep and had much higher copper concentrations than would be recommended for sheep.

Summary

In summary, concentrations of a nutrient like copper in a trace mineralized salt mix can be quite high relative to the concentration in the normal diet. However, because the salt mix is typically included at less than one percent of the total diet, it will not cause a toxicity problem. Because of the different units and calculations involved, many producers often assume that the ingredient with the highest concentrations is the cause of their problem. However, knowing the intake and nutrient concentration for each ingredient of the diet is essential to determine the true source of the toxicity.

Question and Answers



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Q I was trying to formulate a low iron diet because of the amount of iron in the water and basal ingredients. When I analyzed the diet it contained more iron than what I predicted from the trace mineralized salt and basal ingredients. Do you know where this iron could be coming from?

A It is difficult to predict without knowing all the individual ingredients. However, many sources of deflournated rock phosphate can contain over 10,000 ppm of iron. I would check that first.

Q Is selenium-containing yeast a better selenium source than sodium selenite?

A Selenium-containing yeast have a higher bioavailability than sodium selenite, but they also cost more per unit of selenium. If you are confident that you have a selenium deficiency, I would first try one-third selenium-yeast and two-thirds inorganic selenium.

Q What are the main trace mineral antagonist I need to be concerned about?

A Iron, molybdenum and sulfur are the most common antagonist under practical feeding conditions.

Q If I feed my horses free choice trace mineralized salt do I need to be concerned about trace mineral accumulations in the soil?

A No, even in confinement situations the trace minerals accumulating in the soil will not create any problem for the animal or future uses of that soil.

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Salt and Rotational Grazing

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With rapidly increasing grain prices there is renewed interest in optimizing beef production from grazing systems. Rotational grazing, sometimes referred to as management intensive grazing, can increase beef production per acre by 30% compared to traditional grazing methods. The most common form of rotational grazing requires large pastures to be subdivided into smaller paddocks. These paddocks are grazed for 2-4 days and then the cattle are rotated to a new paddock. Often 10 or more paddocks are involved so that grazing occurs at roughly 30-day intervals. The purpose of this article is to review how salt can be used as a management tool to enhance rotational grazing.

Benefits of Rotational Grazing:

Besides the increased beef production per acre there are several ecological benefits from properly managed rotational grazing systems. First, more uniform grazing prevents bare spots that often result from localized grazing. When more than adequate forage is available cattle will often graze some areas very close because the regrowth is more succulent and less fibrous compared to plants that have been allowed

to mature because they were not grazed. In most rotational grazing systems, the cattle will be moved when the forages has been grazed to a height of 2-3 inches. This reduces wind and water erosion by maintaining a uniform forage cover. With rotational grazing the feces and urine are more evenly distributed across the paddock rather then being concentrated in resting areas as often occurs with traditional grazing methods. This improves nutrient recycling and increases forage production.

Salt and Ionophores:

Cattle grazing lush forages have an increased appetite for salt. Grazing cattle will usually consume twice as much salt as those fed high concentrate diets. Part of the explanation may be that lush forages are generally high in potassium and low in sodium. The body has to maintain a sodium: potassium balance, which may stimulate salt intake. Salt is an excellent means of delivering ionophores to grazing cattle.

The inophore Monensin, marketed as Rumensin, is cleared as a feed additive to increase daily gain of grazing cattle. In the studies reported by Muller, (1986) self-feeding a salt-monensin-supplement gave the same improvement in daily gain (0.2 pounds per day) as hand feeding the monensin supplement without salt. These data show that salt, an already proven intake regulator, can be made even better when combined with monensin. Although less data are available with lasalocid, a Georgia study showed that lasalocid fed in a free-choice salt and mineral mix increased the gains of replacement heifers, cows and calves (Kiser et al. 1986).

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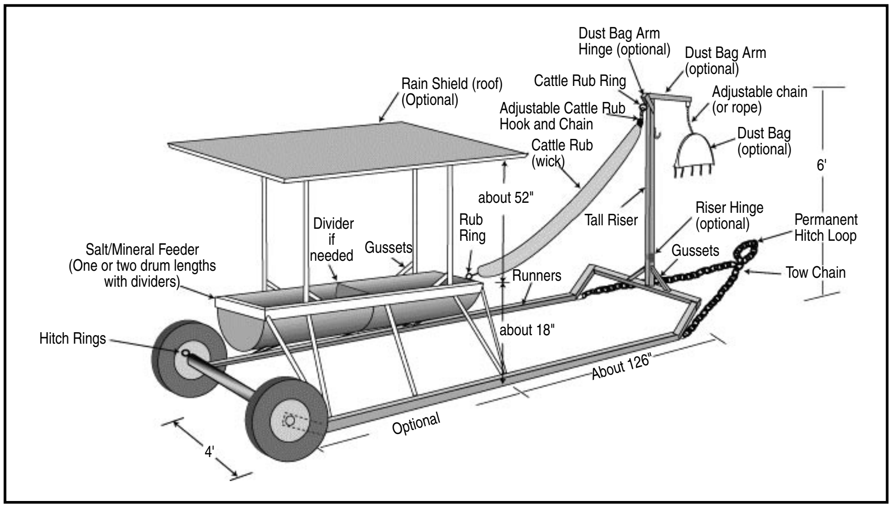

SALT FEEDERS AS A MANAGEMENT TOOL:

Trace mineralized salt-mineral mixtures should be formulated to supplement the existing forages and to meet the nutrient needs of the cattle. Working with a nutritionist who understands the complexities of the soil-forage-animal complex is the best way to ensure that optimum nutrition is available to the animals.

Because grazing animals have a keen appetite for salt, the salt feeder can be used as a management tool to accomplish several objectives besides meeting the animals nutritional needs. The Nobel Foundation of Ardmore, OK has done considerable research in using the salt feeder as a management tool to accomplish more than simply meeting the salt needs of cattle. Over time, they found that for it to be an effective management tool, it must possess four characteristics. First, it must be user friendly in that it can be easily constructed and rarely needs repairs. Commercial units are available today if the rancher does not want to build his own. Secondly, the unit must be transportable. This is essential if the unit is going to be moved every 2-4 days during the grazing season. Cattle learn to follow the unit to the new paddock. Thirdly, the unit must be properly sized and positioned according to the number of animals in the herd. The salt-mineral feeder must be durable and easily maintained. The salt feeder should be positioned such that it baits cattle to use the cattle rub portion of the tool. The cattle rub portion of the tool will be effective at controlling external parasites only if the cattle use it regularly. A diagram of the recommended design is shown in the illustration above.

Controlling fly populations can be a major challenge when there is a large number of grazing animals in a relatively small area. Recent research (Cocke et al. 1989); DeRouen et al, 1995 and Foil, et al 1996) reported that weight gains were increased 27 lbs per head for weaned calves and by an average of 17% in yearling grazing cattle when flies were effectively controlled. The Nobel Foundation has found that by combining the salt feeder and cattle rub in the same tool, the cattle rub becomes a much more effective method of controlling flies. Roberts and Saluta, 1982, reported that over 75% of the time cattle rubs impregnated with the appropriate insecticides were over 90% effective at controlling the fly population on grazing cattle. The main problem was training the cattle to use the rub often enough to control the flies. This problem appears to be overcome by combining the salt feeder and cattle rub into one tool. Putting the cattle rub immediately adjacent to the salt feeder seems to be the key that encourages consistent use of the rub.

Although hard block, pelleted and small granulated salt-mineral mixes have been used successfully in the feeding tool, the loose mineral appears most desirable for the following reasons. First, the cattle consume the loose salt-mineral mix more rapidly giving them time to also use the cattle rub. The large models with a 10-foot cattle rub have been used successfully for herds as large as 150 head. If only block salt is provided the amount of salt feeder space has to be increased to allow adequate consumption. Animals at the bottom of the pecking order may not get access to the salt or cattle rub when the feeder is constantly occupied. Secondly, feeding a mineral mix and or ionophores requires that the loose salt be mixed with the other ingredients to get the desired intake. The ratio of the salt to other ingredients may change with season of the year, pasture composition, and changing cattle requirements. Finally, most grazing cattle will consume 2 to 4 ounces of salt per day. This gives a starting point to estimate the ionophore concentration needed to get the desire intake. Practical experience has shown that 20-30% salt is the minimum concentration needed to encourage regular salt consumption and use of the cattle rub.

Feeding a loose salt-mineral mix requires a roof over the salt feeder in most climates. In low rainfall areas, a roof may not be necessary. However, if a mixture of salt and ionophore are fed, a roof is recommended to prevent rain damage and reduce wind losses.

The salt feeder should be located away from the watering source and trees. These tend to attract cattle normally and often results in heavy grazing pressure around them. Positioning the salt feeder in a low traffic area will encourage more uniform grazing and manure and urine distribution.

In summary, grazing cattle have a keen appetite for salt which makes it an excellent management tool. Salt can be used to regulate the intake of minerals and ionophores without the labor of daily feeding. The salt feeder described above acts as an attractant to help animals learn to use the cattle rub. The salt-feeder-cattle rub tool is an effective means of controlling flies and other external parasites. Moving the salt feeder to low traffic areas improves grazing distribution. The salt feeder-cattle rub tool is user friendly, low cost device that can increase beef production in a rotational grazing system.

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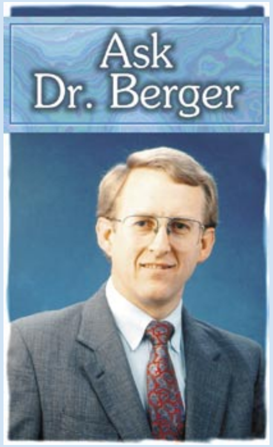
Question and Answers



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Q Are there trace minerals I need to monitor to reduce the risk of Developmental Orthopedic Disease in my young horses?

A Recent research suggests that copper and zinc play key roles in preventing Developmental Orthopedic Disease. Some experts are recommending a 4:1 zinc:copper ratio with at least 100 ppm of zinc in the diet.

Q I raise organic beef and want to fortify my diets with trace minerals to minimize the risk of disease. Is there any risk of increasing the trace mineral concentrations in the beef?

A No, A recent Irish study showed that the supplementation of Iodine, Copper and Selenium to cattle did not pose any risk to significantly increasing these elements in the human food chain.

Q I recently had a lamb born with white muscle disease without having a problem for years. Should I change my trace mineral program?

A Make sure your trace mineral product contains selenium. White muscle disease is commonly associated with low selenium diets.

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Preventing Salt Toxicity

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Recently I was involved in a case of salt poisoning. Although these cases are rare, there are certain management scenarios that are common to most incidents of salt poisoning. In this case supposedly the cattle had been without salt for only a couple days. Loose trace mineralized salt was then provided in large enough quantities to last the herd several weeks. They were grazing droughty pastures, were losing weight and had less than optimum nutrition. Within 48 hours of providing the salt several cows died. The necropsy exam showed symptoms consistent with salt toxicity. The purpose of this review is to identify those management scenarios that increase the risk of salt poisoning in all farm animal species and to discuss prevention strategies that can be successful.

Salt as a Nutrient Source:

Animals require sodium and chloride to survive. Salt is routinely provided as a source of supplemental sodium and/or chloride when the diet is deficient in these nutrients. So how does a common nutrient source become poisonous? The main difference between a nutrient source and a poison is the amount consumed. Most animal diets have 0.3-0.5% added salt. If animals generally eat 2- 4% of their body weight, they would be consuming approximately 200 mg salt/1000 grams live weight at the upper intake. Thus when salt is being added to diets as a nutrient source the risk of salt toxicity is essentially zero.

Nutrient or Toxic Element:

A pharmacology professor I had opened his class by saying he would give any student an automatic A if they could come up with something that he could not make toxic in some form or at some level of

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intake. Despite our best efforts, no one could come up with anything. So the critical difference between a nutrient and a poison is quantity and circumstances under which it is consumed. When measuring acute toxicity, the amount needed to cause sudden death, is termed the Lethal Dose. The Lethal Dose standard is based on a statistical benchmark call the LD50. The LD50 is the amount of a chemical required to kill 50% of the animals in a test group. Because toxicity is usually proportional to animal weight, the LD50 is measured as the weight of the chemical in milligrams per kilogram of animal weight to cause death. Mice or rats are the most common experimental animals in these studies. For example, the LD 50 of a common poison, arsenic trioxide is 15 mg/kg in rats. Everything consumed by man or animals has an LD50. For example, the LD50 of aspirin is 1,500 mg/kg in rats. In contrast, the LD50 of table salt is 3,750 mg/kg. So aspirin is 100 times less toxic than arsenic, and table salt is 2.5 times less toxic than aspirin (http://www.seventhgeneration.com/household_hazards/something_toxic.php).

The circumstances under which something is consumed can have a dramatic effect on how toxic it is. That is why salt toxicity is sometimes called "water deprivation sodium ion toxicosis" because if water intake is limited, salt becomes much more toxic (http://www.merckvetmanual.com/mvm/index.jsp?cfile=htm/bc/213200.htm). Water intakes can be reduced due to mechanical failure of the automatic waterers, too many animals per waterer, unpalatable water, or a frozen water source. Whenever salt toxicity occurs, water availability should always be questioned (NRC, Mineral Tolerance of Domestic Animals, 1980). For example, young pigs have developed salt toxicity with as little as 0.25% salt in the diet when accompanied by water deprivation. When free-choice fresh water was provided, diets containing as much as 13% salt have not caused toxicity in pigs. Pigs are generally considered to be the farm animal most susceptible to salt toxicity.

Water is key:

Water intake is critical because the kidney is the major organ which responds to excess sodium intake. Plasma concentrations of sodium are controlled by the hormone aldosterone, which controls the amount of sodium reabsorbed from the kidney tubule. The antidiuretic hormone from the posterior pituitary gland also helps regulate sodium in the blood by responding to changes in the osmotic pressure of extracellular fluids. The two hormones seek to maintain constant sodium to potassium ratio in extracellular fluids. Thirst is the most common rapid response to high levels of circulating sodium. The rule of thumb is that it takes about 40 grams of urine to eliminate each gram of salt consumed. A University of Arizona study showed that the maximum salt concentration in urine is approximately 2.3% (Cardon et al., 1951). This assumes the water consumed is free of salt. If the water contains salt also, this makes it much more difficult for animals to get rid of excess sodium.

Maximum tolerable levels:

Many times it is helpful to know what the upper safe inclusion levels would be for different species. The maximum tolerable levels (NRC Mineral Tolerance of Domestic Animals, 1980) are expressed as a percent of the total diet and assume that adequate water is available and that the animals have not been without salt prior to offering the diet. Based on the work of Demott et al. (1968) the maximum tolerable level in lactating dairy cattle was set at 4% of the diet dry matter. In other cattle and sheep, a 9% inclusion level was chosen based on the research of Meyer et al. (1955) and Meyer and Weir (1954). Swine can tolerate up to 8% salt in the diet when ad libitum fresh water is available. Based on the research of Barlow et al. (1948) with chickens and Matterson et al (1946) in turkeys, it appears poultry can tolerate 2% salt in their diets. Without definitive data, the NRC committee estimated that 3% salt would be the upper limit for horses and rabbits.

Clinical Signs:

The first sign in all farm animals is increased thirst. Pigs may also develop itching and constipation. Eventually the pigs may go blind, deaf and be oblivious to their surroundings. They will stop eating and drinking and may wander aimlessly. As soon as 48 hours after the excess salt consumption, they may go into a coma and die.

Cattle will often show excessive salivation, vomiting, abdominal pain

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Preventing Salt Toxicity (continued from page 2)

and diarrhea. Central nervous system signs include lack of coordination, walking in circles, blindness, seizures and partial paralysis. It is common for cattle to exhibit aggressive behavior as a side effect. Sheep will show similar signs, but are less susceptible to salt toxicity than cattle.

Poultry will exhibit labored breathing, fluid discharge from their beak, weakness, diarrhea, and leg paralysis (http://www.merckvetmanual.com/mvm/index.jsp?cfile=htm/bc/213200.htm).

Diagnosis:

Retaining samples of feed and water for sodium analysis is recommended in all cases of expected salt toxicity. Serum and cerebral spinal fluid with sodium concentrations greater than 160 mEq/liter are indications of salt toxicity. Brain (cerebrum) sodium concentrations greater than 1,800 ppm wet weight are indicative of salt toxicity. A scenario where the animals have been out of salt for several days and are then given unlimited access to loose salt is often associated with salt toxicity. Cattle can develop an intense craving within 8-10 days of being deprived of salt. If this happens salt intake should be controlled for several days to reduce the risk of over consumption.

Treatment:

In most situations a small portion of the herd or flock will show the signs described previously. The remaining animals should then be put on a low-salt diet or drinking water until the exact cause is determined. It is essential to verify that adequate clean fresh drinking water is available to all animals. In animals beginning to exhibit signs, it is better to give small amounts of water at frequent intervals than to allow the consumption of large quantities of water. Over consumption of water may exacerbate central nervous system symptoms by causing brain edema. If the animal will not drink, water should be given via a stomach tube.

In summary, sodium and chloride are essential for life and salt is an excellent source of these nutrients. Almost anything can become toxic at some level or under unique conditions, and salt is no exception. Water and/or salt deprivation are commonly associated with salt toxicity. An adequate supply of clean fresh water will almost guarantee that salt toxicity will not be a problem under normal management conditions. The benefits of feeding a well-fortified trace mineralized salt far out weigh the risk of a salt toxicity. ■

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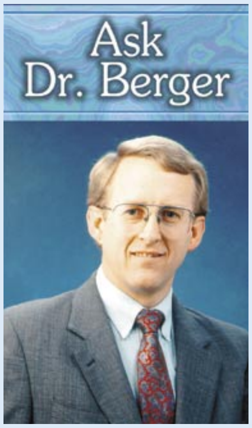
Question and Answers



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Q **Can a copper deficiency cause anemia?**

A Yes, normally anemia is associated with an iron deficiency, but because copper is required to get iron incorporated into hemoglobin, a copper deficiency can cause anemia.

Q **A recent manure analysis indicated it contained 3.6% salt. Where did all the salt come from?**

A The percent "salt" in manure is estimated by adding the percents calcium, potassium, sodium, and magnesium and then multiplying by 2. The term salt does not refer to sodium chloride in this context.

Q **Is hair analysis a good method to determine trace mineral deficiencies in farm animals?**

A Trace mineral concentrations of the hair can vary with season of the year, environmental conditions in which the animal is raised and even color with in the same species. There are other more definitive methods that are more accurate.

Q **Trace mineral requirements are often expressed on a parts per million basis. How much is that?**

A Parts per million is used because we are dealing with small quantities. For example, one part million is equal to one penny in $10,000 dollars.

Q **Do I need to change my trace mineral supplementation if I add additional calcium to my calf diets because I am balancing the high phosphorus level from feeding distillers grains?**

A High levels of calcium can reduce zinc absorption. I would consider adding additional zinc if the diet was over 0.7% calcium.

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Salt-limited Supplementation of Grazing Animals

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University of Illinois

Introduction:

Because of high grain prices, many beef producers are extending the grazing period to attain heavier weights before the cattle enter the feedlot. Typically, forage quality and quantity will decrease rapidly in late summer. In most cases to obtain acceptable rates of gain, protein and energy supplementation will be required. Limit-feeding large herds by hand has numerous challenges. Using salt as an intake limiter in a self-feeder offers several advantages. The purpose of this article is to review recent research that demonstrates the effectiveness of using salt as an intake limiter for grazing cattle.

Salt and Byproduct Feeds:

The rapid expansion of the ethanol industry has lead to a plentiful supply of the byproduct feeds, distillers grains and corn gluten feed. The supply of these feeds is fairly constant, but the demand is usually lowest in the summer months, which makes them an excellent buy. Other byproducts such as wheat midds, soy hulls, and brewers grains are also readily available in the summer. These feeds are excellent sources of protein and digestible fiber, which compliments the mature forage available in the late summer and fall. Because most of these byproducts are high in fiber and medium to low in protein, they are best suited to supplement high forage diets for ruminants. Recent Nebraska research showed that distillers grains had 125% the energy value of corn when supplementing high-forage diets (Loy et al. 2004). The reason these byproducts can have this much energy relative to corn is that they avoid what is termed negative associative effects. When corn or other readily fermentable carbohydrates are added to the diet of ruminants, the rapid acid production in the rumen can lower the pH. When rumen pH drops below 6.3, fiber-digesting bacteria are inhibited and fiber digestion drops. Thus supplementing high forage diets with corn or other grains can decrease the digestibility of the basal diet.

Schauer et al. (2004) reported the results of a two-year study conducted by North Dakota researchers to evaluate different self-limiting supplements with hand feeding for yearling steers grazing native range. The three self-limiting treatments were 16% salt, a mixture of 3% ammonium chloride and 2.25% ammonium sulfate, or 7% calcium hydroxide.

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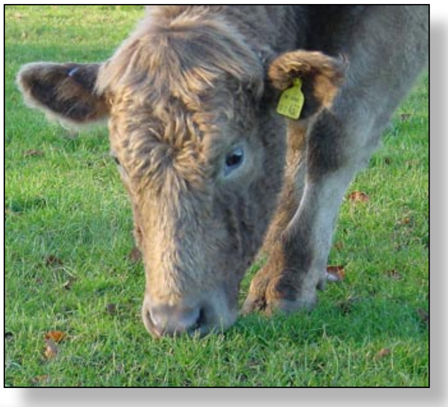
These were added to a byproduct supplement based on wheat midds, soy hulls and malt sprouts. The trial started in late June and ended in mid October. Supplements were offered in self-feeders that provided 17 inches of eating space per steer. Supplement remaining in the feeders were measured on a weekly basis. As the forage quality decreased and the steers adjusted to the intake-limiters, supplement intake as a percent of body weight, roughly doubled for all limiters from the beginning to the end of the study. As an average across the two years, steers fed the salt-limited supplement had gains that were equal to the hand-fed steers. In contrast, steers limited with the ammonium chloride-ammonium sulfate mixture or calcium hydroxide gained approximately 20 lbs less per steer.

In this trial, salt was included at 16% of the supplement throughout the study. Previous research has shown that cattle will gradually increase the salt intake over time, especially if forage quality and availability decreases (Kunkle et al., 1999). To maintain a constant supplement intake, salt concentrations needs to be adjusted. For example, Chicco et .al. (1971) reported that salt concentrations as high as 30% of the supplement were required to restrict supplement intake to 1.9 lbs per day. In this study steers were grazing poor quality Pangola grass containing 5.5% crude protein.



Salt Concentration:

Oklahoma State Researchers have excellent guidelines to use in estimating the amount of salt required to achieve the desire level of intake (Rich et al. 2006). Generally, cattle will consume about 0.1 lbs of salt per 100 lbs of body weight. The proportion of salt in the self-fed mixture may vary anywhere from 5% to 40%. To determine how much salt is needed, you first need to know the desired amount of supplement intake. If you want to restrict intake to 1 to 2 pounds per day, as high as 30% to 40% salt may be required with mature range cows. Yearling cattle grazing high quality forage may require only 5% salt initially to limit intake to a pound per day. However, as cattle grow and the grass gets more mature and less plentiful, 20% to 30% salt may be required to maintain desired levels of intake (Harvey et al. 1986). California researchers found that 8% to 10% salt was required to limit concentrate intake to 1% of body weight for yearling steers grazing lush, irrigated pastures.

Sewell (1993) developed a formula for estimating the salt concentration required based on the fact that most cattle will eat 0.1 lbs of salt per 100 lbs live weight. A 500 lb calf would eat 0.5 lbs per day while a 1200 lb cow would consume 1.2 lbs per day. To calculate the salt concentration required to restrict the 500 lb calf to 2.0 lbs of supplement, you would divide the .5 lbs of salt by the salt plus supplement intake and multiply by 100 (.5/(2.0 + .5) x 100) = 20%. If you wanted to restrict the cow to 2.0 lbs of supplement, it would require 37.5% salt (1.2/(2.0 + 1.2) x 100). As the cattle grow over a grazing period the amount of salt they will consume increases and needs to be adjusted accordingly.

The sodium concentration in the supplemental ingredients should

also be considered in determining how much salt to add. University of Illinois data suggest that the sodium concentration in distillers grains is often higher than what is quoted in feed composition tables. For example, the 2001 Dairy NRC gives the sodium concentrations in distillers grains plus solubles as 0.30%. In contrast, in a recent study the average sodium concentration for numerous samples was 0.73%. Since corn only contains 0.02% sodium, it appears a sodium source is being added in the fermentation process. It is best to get the byproduct feed analyzed before the salt is added. It is important to remember that salt contains 39.4% sodium, and sodium is what controls intake. The high-sodium distillers grains described above contains the sodium equivalent to 1.87% salt. Thus salt in the supplement should be adjusted accordingly.

It is not uncommon to adjust salt concentrations 4 to 7 times to maintain desired intake over a normal grazing season. Muller et al. (1986) showed that the number of adjustments in salt concentration required to maintain the desired intake can be cut in half when monensin is included in the salt mixture. Monensin, marketed as Rumensin, is cleared as a feed additive to increase daily gain of grazing cattle. Another advantage of including monensin is that it allows the use of a salt concentration

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that reduces the animal to animal variation in intake. In the studies reported by Muller, (1986) self-feeding a salt-monensin-supplement gave the same improvement in daily gain (0.2 pounds per day) as hand feeding the monensin supplement without salt. These data show that salt, an already proven intake regulator, can be made even better when combined with monensin. Although less data are available with lasalocid, a Georgia study showed that lasalocid fed in a free-choice salt and mineral mix increased the gains of replacement heifers, cows and calves (Kiser et al. 1986). Rumensin or Bovatec fed at 150 to 200 milligrams per head daily in grain or protein supplements has increased the gain of steers and heifers on pasture by approximately 0.15 to 0.20 pounds per head daily.

Hand feeding the salt-supplement mixture for a few days is recommended if grass is short and the cattle are extremely hungry. Approximately 3 oz of the daily salt intake should contain trace minerals with the remainder being plain white salt. Also, it is essential to have plenty of clean fresh water available at all times. The maximum salt concentration in cattle urine is 2.3% (Sewell, 1993). Consequently approximately 5 gallons of urine are needed to excrete each pound of salt consumed.

In summary, providing a salt-limited byproduct based supplement is an effective way to increase performance of grazing cattle. Cattle fed salt-limited supplements performed better than using an ammonium chloride-ammonium sulfate mixture or calcium hydroxide to control intake. The required salt concentration is determined by the weight of the cattle and the amount of supplement intake desired. Adding an ionophore, such as Rumensin or Bovatec will increase the performance of the grazing cattle and reduce the adjustments in salt concentration to achieve the desired supplement intake.

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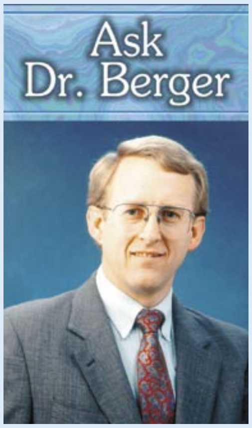
Question and Answers



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Q **Are there any data to suggest that chromium supplementation is required in animals?**

A Canadian research suggests that chromium supplementation may be helpful in stressed animals. Chromium decreased serum cortisol and improved immune response in stressed calves.

Q **What are the common signs of a selenium deficiency in poultry?**

A A condition call exudative diathesis often results from a selenium deficiency. With this condition, fluids accumulate between the breast muscle and skin and the affected area usually has a light blue color.

Q **I am feeding a high calcium supplement to balance the phosphorus in my swine diet that contains high levels of distillers grains. Do I need to be concerned about the effect of the extra calcium on trace mineral availability?**

A Yes, make sure that zinc concentrations are adequate in the diet. Excess calcium can reduce zinc absorption.

Q **What salt levels should be present in the diets of pheasants and quail?**

A Generally, 0.15% salt should be adequate for both pheasants and quail.

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Iodine Deficiency in Sheep

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Introduction:

In March, I received a phone call from a sheep producer in Northeast Iowa. She was very frustrated and ready to try any reasonable solution to solve her problem. She had lambed about a third of her 150 ewes. To that point, nearly all the lambs were dead at birth or were too weak to nurse if they were born alive. Ewes that had live lambs had little or no milk. Several ewes had died during lambing. Up to that point the ewes appeared fairly normal. Most of the lambs that were born had enlarged thyroid glands (goiter) and very little wool. The veterinary diagnostic lab in Ames had confirmed iodine deficiency both from outward symptoms and by autopsy. A new source of trace mineralized salt had been purchased from a supplier that catered to sheep producers and emphasized the low-copper content. However, based on the iodine concentrations, it appears that non-iodized salt was being used in the formulation. Although iodine deficiencies are rare due to the feeding of iodized salt, the purpose of this review is to emphasize its critical role as a nutrient and why it is essential to prevent significant losses in any ewe flock.

History:

Every continent has areas where goiter in humans and livestock has been associated with iodine deficiency. In the U.S., the Great Lakes region has had a history of goiter. In 1923-1924, the Michigan State Department of Health surveyed four regions of the state for goiter. Of the 66,000 school children examined, 39% had a visible enlargement of the thyroid gland. The Ohio Department of Health conducted a similar study between 1924 and 1936. In the early years of their study, 31% of the school children had goiter. However, by 1936 the incidence of goiter was reduced down to 7% in households that used iodized salt regularly.

In 1918, Hart and Steenbock showed that the addition of 10 grams of potassium iodide per 100 lbs of feed would prevent the birth of hairless pigs with goiter. Kalkus (1920) published another paper showing that iodine deficiency was the cause of goiter in domestic animals. Welch in 1928 reported that feeding salt containing 0.02% potassium iodide would prevent goiter in farm animals. After that, iodized salt was widely utilized as a means of preventing goiter in livestock.

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Iodine Requirements in Sheep:

Under normal feeding conditions, sheep require 0.1 to 0.8 ppm of iodine in their diets. Sheep appear to be more susceptible to an iodine deficiency than the other farm animal species. Underwood and Suttle (1999) described four factors that can affect the supplemental iodine requirements. First is the amount of iodine being consumed from feed, water, soil, etc. Second, there is the intake of dietary constituents, called goitrogens, which interfere with the thyroid gland' s ability to trap iodine and to convert it into thyroacitve substances. Third, an adequacy of selenium is required for proper iodine metabolism. Fourth, environmental factors, such as cold stress, can increase the iodine requirement, since the rate of basal metabolism must increase to maintain core body temperature.

Iodine Intake:

The amount of iodine supplied in the basal diet is depends on several factors. Location has a major impact on the amount of iodine in feedstuffs. For example, Hercus et al. (1925) estimated that 22-50 mg of iodine per acre fell annually in the rainfall on the Atlantic coastal plains, but only 0.7 mg per acre would fall in the Great Lakes region. The iodine in sea water is volatized into the air so that prevailing wind can have a major impact on the iodine being deposited through rain. For example, if the prevailing wind is away from the coastline, being near the sea does not ensure high iodine concentrations from feedstuffs grown in that region.

Plant and soil interactions have a major impact on the supplemental iodine required by grazing animals. Grasses tend to be lower in iodine than legumes. Statham and Bray (1975) reported that the risk of

iodine deficiency was greater during periods of high rain fall compared to the dry season. Increased herbage production during the rainy season provided less opportunity for soil contamination. Since many topsoils are higher in iodine concentration than the plants growing on them, soil ingestion can be a major source of iodine. Iodine status of grazing animals often decreases as the grazing season progresses. Alderman and Jones, (1967) reported as much as a five-fold reduction in iodine concentration in plants with increasing maturity.

Goitrogen Intake:

The presence of goitrogens in the diet can have a great impact on iodine status and it occurs more widely than is often recognized. Specific feedstuffs that are known to contain goitrogens include soybeans, cottonseed, peanuts, linseed, rape, millet, white clover, cassava, and brassica plants such as cabbage, turnips, kale, etc. Plant breeders have sought to lower the goitrogen content of important agricultural crops such as rape. The low-glucosinate rape-seed meals are now marketed as canola meal and have much less impact on iodine status. However, if animals are on low-iodine diets, the presence of one or more of these goitrogens can result in an iodine deficiency. For example, unheated soybeans contain a compound that can cause goiter by preventing the intestinal recycling of iodine (Hemken, 1960). Inorganic goitrogens have also been identified. For example, excess cobalt, rubidium and perchlorate have been shown to interfere with iodine absorption or to cause increased iodine excretion (Underwood and Suttle, 1999).

Selenium Status:

The impact of selenium deficiency on iodine metabolism has been confirmed in sheep (Donald et al., 1994) and cattle (Arthur et al., 1988). Selenium is required for the synthesis of a protein that is required to convert thyroxin to the more metabolically active triiodothyronine. This protein is not present in the thyroid gland, but is synthesized in the liver and kidney. Thus a marginal selenium status can increase the iodine requirement because the thyroid has to synthesize more thyroxine to get the same metabolic response.

Cold Stress:

Farm animals, especially cattle, sheep and horses are often raised in environments where cold stress occurs every winter. One mechanism animals use to adapt to cold stress is to increase their rate of basal metabolism, which results in increased heat production. The rate of basal metabolism is primarily controlled by thyroxin levels in the blood. Thyroxin requires four atoms of iodine per molecule. Consequently, cold stress indirectly increases the iodine requirement.

Clinical Symptoms of an Iodine Deficiency in Lambs:

Goiter, or enlargement of the thyroid gland, is an attempt by the body to compensate for the insufficient production of thyroid hormones. Goiter is most common in the newborn from a dam without any obvious signs of an iodine deficiency.

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Potter et al. (1982) reported iodine deficiency in ewes causes impaired brain maturation in the fetus, and lambs being stillborn and without wool. Lambs born alive often have high mortality rates shortly after birth, due to the role of thyroid hormones in producing lung surfactants required for oxygen uptake. Lambs born in the winter or early spring are often subjected to mild cold stress. If thyroid hormones are limiting, the lambs may not be able to increase their rate of basal metabolism to maintain body temperature. Thyroid deficiency in young lambs will result in reduced wool growth because the wool-producing secondary follicles require thyroid activity beyond that needed for the growth of other tissues (Ferguson et al., 1956).

It is questionable whether the abnormalities occurring during fetal development are reversible with iodine supplementation of the ewe or the lambs after birth. Iodine injections have been tried, but have generally been unsuccessful. Therefore, it is critical to ensure sufficient iodine nutrition in dams prior to fetal development.

Summary:

Sheep appear to be one of the most sensitive species for an iodine deficiency. Unfortunately, ewes will usually not show signs prior to lambing. Once lambs are born with goiter, it is too late to avoid losing a majority of the lamb crop. Feeding a properly fortified trace mineralized salt based on iodized salt is a key to a successful sheep enterprise.

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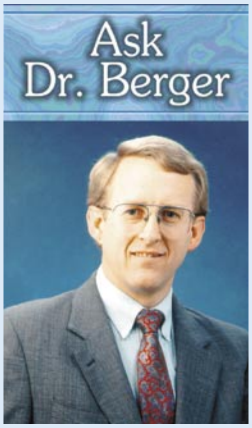
Question and Answers



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Q **Is a vitamin B_{12} deficiency different from a cobalt deficiency in livestock?**

A Cobalt is required to synthesize vitamin B_{12} in ruminants. Other animals have a vitamin B_{12} requirement, but not a cobalt requirement.

Q **Does heat increase the salt requirements for my horse?**

A Yes, it can if the horse is exercised regularly in the heat. Horses get rid of excess heat by sweating which contains a significant amount of sodium. If the horse is not exercised when it is hot, the heat will have little effect on the salt requirement. Free choice salt is the best way to ensure your horse has an adequate amount.

Q **Should molybdenum be included in the trace mineral mix for livestock?**

A Molybdenum has been shown to be essential for lambs, chicks and turkey fed purified diets. However, natural ingredients contain adequate molybdenum so that is not normally added to trace mineral mixes.

Q **Can I use the same trace mineral supplement for my sheep and goats that are being fed together?**

A Many people do feed the same supplement with no detectable problem. However, most sheep supplements are very low in copper. Goats have a much greater copper requirement than sheep. It would be better to feed them separately and to use a trace mineral mix designed for goats, or if that is not available, then use a cattle mineral mix in the goat diet.

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Role of Sodium Deficiency and Excess Nitrates in Grass Tetany

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I recently received an email from Dr. Thomas W. Swerczek concerning his research defining the role of sodium deficiency and excess nitrates in grass tetany. Dr. Swerczek is a veterinary pathologist in the Department of Veterinary Science, University of Kentucky. He researched and discovered the etiology and pathogenesis of several diseases of animals including wildlife, small animals, livestock and horses. His studies include the relationship between nutrition and infectious and metabolic diseases of livestock. Traditionally grass tetany has been described as a magnesium deficiency or hypomagnesemia. In the 1980s, it was discovered that a deficiency of sodium and excess potassium impaired magnesium absorption. Dr. Swerczek's research now suggests that excess nitrates in the diet further deplete the sodium and cation reserves resulting in electrolyte imbalances. The purpose of this paper is to summarize our current understanding of the role of sodium and nitrates in grass tetany.

Background:

Grass tetany most often occurs in lactating beef cows grazing lush cool seasonal grasses that have received nitrogen fertilization. The disease often occurs during or shortly after a period of cold, cloudy, wet weather. Under these conditions the forage is low in magnesium, sodium and soluble carbohydrates, but high in nitrates and potassium. Plants take up nitrates from the soil, but due to a lack of photosynthesis are unable to convert the nitrates to true protein.

Several researchers (Fontenot, 1979, Newtons et al., 1972, Grace, 1983) have shown that high potassium intakes reduce blood magnesium levels due to impaired absorption in the rumen. Potassium levels in the lush forages can be over 2% of the dry matter. At the same time sodium concentrations are often 0.1% or less. This would give a sodium to potassium ratio in the forage of 0.05. Marten and Rayssiguier (1980) reported that magnesium absorption increased four-fold in sheep when the rumen sodium to potassium ratio increased from 0.05 to 5.0. Magnesium absorption in sheep was increased over 50% (from 22.3% to 34.5%) when 2.3 grams of sodium was added to a low-sodium grass diet (Marten et al. 1987).

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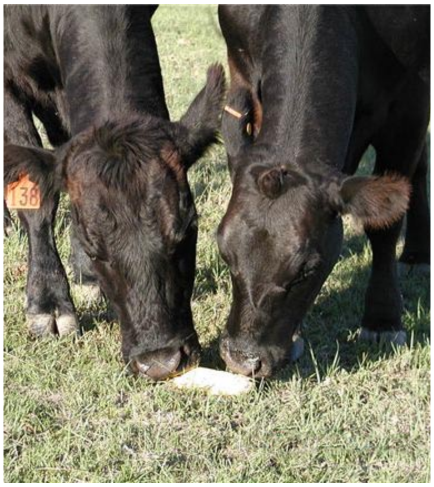
Smith and Aines (1959) fed sodium deficient diets to lactating dairy cows and induced clinical signs of grass tetany. Butler (1963) reported that cows grazing low-sodium grass had an increased incidence of grass tetany. However, when the sodium concentration of the grass was above 0.2%, the grass tetany problems disappeared.

ROLE OF NITRATES:

It has been common knowledge that excessive nitrogen fertilization was often associated with an increased incidence of grass tetany (Swerczek, 2008). Martens and Schweigel (2000) reviewed the literature dealing with nitrogen fertilization of grasses and concluded that high levels of NH+ in the GI tract could interfere with magnesium absorption. Newton et al. (1972) also reported that excess potassium and a sodium deficiency could reduce magnesium absorption. Swerczek (2008) summarized several reports which found that low blood magnesium levels could occur even when the forages contained what would normally be considered adequate magnesium. Swerczek hypothesized that something was drastically reducing magnesium absorption, or that the body was excreting the magnesium in the urine, feces and/or milk at such a rate that the animals became depleted even when the diet appeared adequate. When the soil is low in calcium and sodium, but high in potassium and nitrogen, plant stress like frost can cause a sharp increase in forage potassium and nitrate levels. Once absorbed, positively charged minerals are required to remove the excess nitrates from the body. Swerczek (2008) hypothesizes that magnesium, calcium and sodium are more reactive with nitrates in the body then is potassium. If nitrates are high, magnesium and calcium will bind to the nitrates and be excreted as a complex. However, if adequate sodium in consumed, then the excess nitrate is removed from the body attached to sodium, and physiological levels of magnesium and calcium are maintained.



It appears that having an adequate supply of loose salt readily available is critical to ensure that sodium concentrations are adequate in the body. Dr. Swerczek believes that salt blocks may not be adequate during times of high nitrate intakes. If a nitrate spike in the forage occurs due to a frost or freeze, salt may not be consumed in adequate amounts to provide the sodium ions needed to allow nitrate excretion. Dr. Swerczek recommends that when environmental conditions are such that a nitrate spike is likely, hand feeding a grain mix-salt combination maybe the surest way to achieve adequate sodium intakes.

Cattle with apparent nitrate toxicity or clinical signs of grass tetany will often have elevated aldosterone levels, even when blood sodium concentrations are within the normal range (Swerczek 2008). Aldosterone is a hormone produced by the adrenal gland which normally reduces sodium excretion and increases potassium excretion in order to maintain a normal sodium to potassium balance in the body. Animals with grass tetany often have depleted blood sodium concentrations shortly before death. This severe sodium deficiency may not be recognized unless a blood sample is taken shortly before the animal dies (Swerczek 2008). While the body is trying to spare sodium, calcium and magnesium are being used to remove the excess nitrates resulting in hypomagnesemia and hypocalcemia. Dr. Swerczek believes that aldosterone levels may be the best indicator of ionic imbalances induced by excessive nitrate anions.

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PREVENTION:

Hand-feeding a grain mix containing 5-10% salt may be the best way to increase sodium intake under these high-risk situations. Lactating beef cows will normally consume 3-4 ounces of salt per day. However, if the forage is high in potassium this may reduce their appetite for salt, thus reducing their sodium intakes at the very time they should be increasing. If the forage is lush and palatable, adding 5-10% dried molasses to the grain-salt mixture will also encourage intake. If grass tetany has been a problem in the past, adding 5% magnesium oxide to the grain mixture is also recommended. In general, treatment of cattle showing clinical signs of grass tetany has not been very successful. Prevention then becomes the best way to prevent losses.

How much of the grain-salt mixture to feed per day becomes a risk to benefit assessment. For example, if there is a history of grass tetany, the cows are in early lactation, and the weather is cool and cloudy, then targeting 0.5 to 1.0% of body weight is a reasonable goal. In this situation a 1,000 lb cow will be fed between 5 and 10 lbs of the grain-salt mixture daily. This level of intake will also reduce forage consumption resulting in lower nitrate and potassium intakes. If the risk is determined to be less severe, then 2 to 4 lbs of the grain mix may be adequate. Free-choice loose salt should continue to be provided even when the grain mix is fed.

Feeding the grain-salt mixture in a pellet or cube on grass may be critical to achieving uniform consumption. If the grain-mix is fed in a bunk with less than two feet of linear space per cow, those at the top of the pecking order may over-consume and those at the bottom of the pecking order will get cheated. By feeding the mixture on grass so that the distribution prevents the dominant animals from getting more than their fair share is a critical management practice. If the producer has had a history of losing cattle due to grass tetany, then feeding 2 to 4 lbs per head of the grains mix daily prior to turning the cattle onto the tetany-prone pastures is also recommended.

SUMMARY

Grass tetany is a complex disease that causes significant economic losses for livestock producers every year. Like putting together a puzzle, more and more of the pieces are coming together so that we can understand the true causes of this disease. What we once thought was primarily a magnesium deficiency, is now recognized to be a combination of excess nitrates and potassium in combination with inadequate salt consumption. Increasing sodium consumption improves magnesium absorption and nitrate excretion, both keys to preventing grass tetany.

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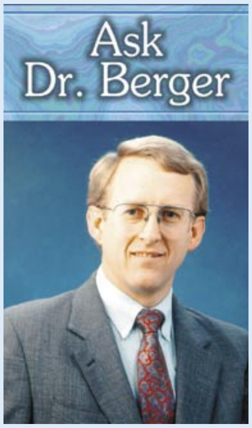
Question and Answers



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Q **Are the copper requirements of goats similar to sheep?**

A No, the copper requirement on a ppm basis for goats is much closer to cattle than sheep. If you cannot find a product specifically for goats, a mineral mix designed for cattle is better to feed your goats than one designed for sheep.

Q **Are cafeteria-style minerals better for my horse than feeding trace mineralized salt?**

A No, the assumption with cafeteria-style minerals for horses is that they can determine which minerals are needed and will consume the appropriate amounts. Unlike the situation with salt, there is no scientific research which proves that horses and most other animals, can determine which minerals they need and how much of each to consume.

Q **What salt concentration should I use if I wanted to limit-feed distillers grains to my replacement heifers through a self-feeder while grazing cornstalks?**

A It depends on what level of distillers grains intake you are targeting. I would suggest starting with 5 to 10% salt, and then adjust it up or down to get the desired intake. Remember that unlimited access to fresh water is essential when using salt as an intake limiter.

Q **What signs should I be watching for since I live in an area known to have high-molybdenum soils.**

A In ruminants, excess molybdenum can cause copper deficiency. It can also cause diarrhea, weight loss, graying of the hair, bone and joint disorders impaired reproduction, loss of crimp in wool, and anemia. Horses and monogastric animals are less susceptible than ruminants.

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Dietary Antagonist and Copper Nutrition

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Introduction

Copper nutrition of livestock and poultry is complex. Cattle are susceptible to copper deficiency, sheep are prone to copper toxicity and pigs benefit from high levels of copper supplementation. The copper requirements of goats are more like that for cattle than sheep, and poultry do not show the same health benefits of high copper intakes observed in pigs. In addition antagonists, primarily sulfur, molybdenum and iron greatly affect the bioavailability of copper in ruminants. Increasing amounts of distillers grains are being included in livestock and poultry diets. Distillers grains are high in sulfur and low in copper. High grain prices are encouraging the feeding of high-forage diets in combination with distillers grains. Forages can be high in molybdenum and iron. Thus, economics are encouraging the feeding of diets that increase the risk of copper deficiencies. The purpose of this review is to explore the interactions of changes in dietary formulations, mineral antagonists, and species differences on the copper nutrition of livestock and poultry.

Dietary Changes

Last year over 30% of the corn crop was fermented into ethanol for fuel use. For every bushel of corn fermented, approximately 18 pounds of distillers grains are produced. Distillers grains are an excellent source of energy, protein and phosphorus in livestock diets. Because distillers grains have been relatively cheap compared to other feedstuffs, economics have encouraged the feeding of higher levels than most nutritionists would have considered feasible a few years ago. Distillers grains are high in sulfur due to the addition of sulfuric acid during the fermentation process. The Dairy One forage lab (accessed 11/26/2008) reported that 2088 samples of distillers grains average 0.65% sulfur with a normal range of 0.47 to 0.82%. In the same data set, copper concentrations average 4.8 ppm with a normal range of 0.0 to 22.8 ppm. Suttle et al. (1996) reported that distillers grains byproducts have poor copper availability in ruminants. Many

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livestock and poultry diets now contain 15 to 40% distillers grains. This change will dramatically increase the sulfur concentrations, while in most cases reducing the amount of bioavailable copper.

Due to increased grain prices, ruminants are being fed higher levels of forage, often in combination with distillers grains. In beef cattle, poor quality forages and crop residues are being used because of the complementary energy and protein profile of distillers grains. In the Dairy One data, 16,152 grass hay samples averaged 174 ppm of iron with a standard deviation of 264 ppm. This large standard deviation shows that some hays can have very high iron concentrations. Similarly, molybdenum averaged 0.80 ppm, but had a high standard deviation of 0.99 ppm. Thus, the combination of distillers grains and high-iron and/ or -molybdenum forages, could set up dietary conditions that could greatly reduce copper absorption in ruminants.

Copper Antagonists

The antagonistic effects of sulfur, molybdenum, and iron on copper

absorption in ruminants are extensively reviewed by Underwood and Suttle (1999). Sulfur and molybdenum interact in the rumen to form thiomolybdates. The thiomolybdates then bind with copper to form an insoluble complex which are excreted in the feces. Some thiomolybdates are absorbed and interfere with copper metabolism in the body. Price et al. (1987) reported that tri- and tetrathiamolybdates were the sulfur-molybdenum complexes reducing copper absorption, while di- and trithiomolybdates had the greatest impact on copper metabolism. Underwood and Suttle (1999) reported that copper absorption decreased from 11% to less than 1% when sulfur concentrations

in a silage diet increased from 0.1% to 0.5%. When molybdenum concentrations in grass diets increased from 1.0 ppm to 5.0ppm, copper absorption decrease from 6% to 1%. When sulfur and molybdenum concentrations increased together, the reduction in copper absorption was more rapid then when either was increased by itself.

High iron concentrations can reduce copper absorption, and appears to be independent of the interaction with thiomolybdates. Suttle et al. (1984) reported that feeding 800 ppm iron from ferric oxide (similar to soil iron) or ferrous sulfate reduce copper absorption from 6% to 4% in sheep. Chase et al. (2000) reported that lactating dairy cows had reduced liver copper stores when fed 500 ppm of iron from iron sulfate in a basal diet containing 8.0 ppm of copper. When 15 or 30 ppm of copper from copper sulfate was added, liver copper stores were increased in spite of the iron addition. Soil contamination of forages is common and should be considered as a potential cause of reduced copper absorption.

High grain prices can encourage the use of molasses-based supplements for grazing cattle or cattle fed high forage diets. Molasses is usually 0.4 to 0.6% sulfur and can be fairly high in molybdenum. Arthington and Pate (2002) reported that molasses-based supplements decreased liver copper accumulation compared to a corn-based supplement containing a similar copper concentration. Arthington and Spears (2007) reported that hay consumption was reduced in growing beef heifers fed a molasses-based supplement without copper, compared to when copper was added in the form of tribasic copper chloride or copper sulfate. Ward et al. (1993) reported that growing steers having prolonged exposure to high levels of sulfur and

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molybdenum, had decreased in vivo cell-mediated immune function. Copper deficiency can compromise the immune status of several species.

SPECIES DIFFERENCES:

A logical question would be, does the same level of distillers grains or molasses supplementation have the same impact on copper nutrition across all farm animals. The answer is no, due to a variety of factors. First, thiomolybdates are only formed in the rumen. Consequently, monogastric animals like pigs and poultry should be less affected. Secondly, swine diets often use copper sulfate as a growth promoter with levels as high as 250 ppm of copper in the diet. Even if there was a reduction in copper absorption, it would certainly not cause a copper deficiency in pigs. On the same copper intake, sheep will usually have greater liver copper stores than cattle or goats, consequently sheep are less likely to become depleted as rapidly with high sulfur or molybdenum intakes.

Once sheep and cattle are copper depleted, then the inhibitory effects of the antagonist may be similar across the two ruminant species. Suttle (1978) reported that sheep and cattle being repleted from a copper deficient state, were affected similarly by sulfur and molybdenum due to reduced copper absorption. Since cattle excrete more copper in bile than sheep, molybdenum may impair copper recycling more in cattle than sheep (Underwood and Suttle, 1999).

Copper deficiency symptoms in cattle include depraved appetite, stunted growth, suppressed immune system, rough hair coat, diarrhea, straight pasterns, depigmentation of the hair and sudden death. Sometimes black hair around the eye will lose pigment and develop gray-spectacled appearance. Red hair in the ears or around the edge of the ears will turn more yellow. These conditions have often been associated with poor fertility and reproduction.

SUMMARY:

Agriculture is going through changes that encourage the feeding of high-distillers grains diets, resulting in conditions that could reduce copper absorption. Sulfur, molybdenum and iron are antagonists to copper. Ruminants are more susceptible to deleterious effects than swine or poultry due to the formation of thiomolybdates in the rumen. Cattle and goats are more susceptible to a copper deficiency than sheep due to the differences in copper metabolism. Using a properly fortified trace mineral supplement is critical to ensure proper copper status when feeding diets containing high levels of one or more of the antagonist.

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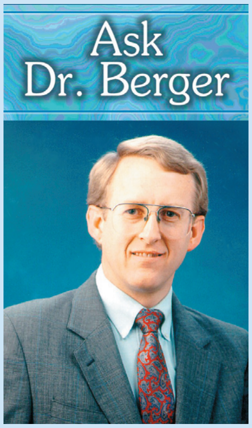
Question and Answers



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Q **How does increasing the salt concentration in the diet help to prevent urinary calculi in feedlot cattle or lambs?**

A Increasing the salt will increase the water consumption, increase the urine volume and dilute the phosphorus concentration in the urine. The reduced phosphorus concentration will prevent stone formation.

Q **Do free-range hens require zinc supplementation.**

A I am not aware of studies addressing this issue, but zinc supplementation is recommended because it is associated with immunocompetence. Free-range chickens are likely to be exposed to a greater variety of pathogens than those in confinement. Maximizing the immune response requires adequate zinc.

Q **Does plant maturity affect the bioavailability of trace minerals in forages.**

A Yes, in one trial 93, 45, and 41% of the manganese, zinc and copper were bound to the fiber in white clover. As the plant matures fiber digestibility usually decreases which would decrease the availability of these trace minerals.

Q **Can a hair samples be used to estimate the trace mineral status of my horse?**

A Generally hair samples are not a good indicator of trace mineral status. Hair may reflect the previous nutrition, but not current status. Hair samples are easily contaminated with trace elements in the environment. Work with your veterinarian to determine what other methods of accessing the individual trace element status are available.

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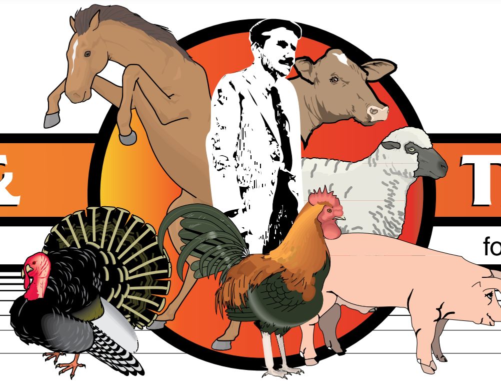

Trace Minerals and Stress in Dairy Cows

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The lactating dairy cow is the most productive of all farm animals with many cows giving over 100 lbs of milk per day during peak lactation. In order for cows to achieve their genetic potential for milk production they must be fed well balanced diets before they calve. The transition period, beginning about three weeks prior to calving and continuing for three weeks post-calving, is one of the most stressful periods in the life of a dairy cow. Recent research has shown that adequate trace mineral and vitamin nutrition during this transition period is critical to avoiding many of the most common diseases occurring at or shortly after calving. The purpose of this paper is to review the relevant research showing that proper nutrition is essential in helping the dairy cow cope with the stress of early lactation.

Transition Period:

During the transition period, the dairy cows go through dramatic physiological changes to prepare them for the onset of lactation and the climb to peak milk production. Because of these endocrine changes immunosuppression is common resulting in increased susceptibility to disease. Immunosuppression is most often expressed as reduced neutrophil function, lymphocyte responsiveness to mitogen stimulation, antibody response and cytokine production (Mallard et al., 1998; Kehrli et al., 2006). Mastitis, metritis and retained placentas are three common diseases linked to a compromised immune system.

Oxidative stress during this period is also believed to contribute to the increased disease risk. Changes in the metabolic profiles associated with moving from the dry period to calving to early lactation may increase the production of reactive oxygen radicals causing oxidative stress. Oxidative stress occurs when the reactive oxygen radicals overwhelm the antioxidant defense mechanisms. Immune cells are extremely sensitive to oxidative stress because their cell membranes contain polyunsaturated fatty acids which are oxidized by the reactive oxygen radicals resulting in more reactive oxygen radicals. Several trace minerals and vitamins are essential for an effective antioxidant defense system (Spears and Weiss, 2007).

Selenium and Vitamin E:

Selenium and vitamin E are complementary in allowing the cow to handle immune system-challenges. Both selenium and vitamin E are required to optimize the effectiveness of neutrophils when attacking and destroying invading bacteria (Spears and Weiss, 2007). Chemotatic migration of neutrophils towards invading organisms was reduced by a selenium deficiency in goats (Aziz et al., 1984). Likewise, peripheral blood lymphocytes isolated from selenium deficient cows exhibited a reduce response to mitogen stimulation (Cao et al., 1992). Whole blood selenium concentrations were negatively correlated with

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mammary infections in a study involving 32 Pennsylvania dairy herds.

The complementary nature of selenium and vitamin E in reducing the incidence and severity of mastitis was clearly shown by Smith et al., (1984). Giving 0.1 mg selenium/kg body weight 21 days before calving reduced the duration of clinical mastitis by 46%, but did not reduce the incidence. Oral administration of 740 IU vitamin E/day in combination with selenium reduced the incidence of mastitis by 37% and the duration by 62%.

Several trials have shown that selenium supplementation of selenium deficient diets reduced the incidence of retained placentas in dairy cows (Allison and Laven, 2000). Often, if dairymen suspect a deficiency, they wonder whether selenium should be given by injection rather than feeding due to variation in feed intake by individual cows. Julien et al (1976) showed that oral supplementation was as effective as intramuscular injection of selenium and vitamin E in preventing retain placenta in cows fed selenium deficient diets.

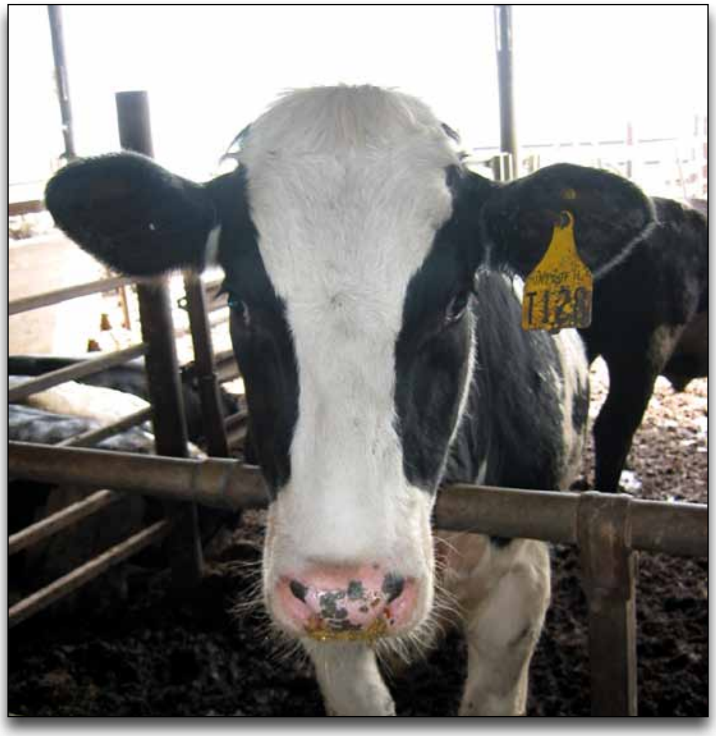
Copper:

Copper is important to the antioxidant system because it is part of the copper-zinc superoxide dismutase enzyme. This enzyme helps convert superoxide radicals to hydrogen peroxide in the cell. Copper deficiency can occur in diets normally considered adequate because of high levels of antagonists such as sulfur, iron, and molybdenum which reduce bioavailability.

Harmon (1998) reported that fed heifers diets that were marginally copper deficient (6-7 mg Cu/kg diet) had 60% infected mammary glands at calving compared to 36% in heifers fed copper adequate diets (20 mg Cu/kg diet). In a similar study, heifers fed 20 mg Cu/kg diet and challenged with E. Coli had lower clinical mastitis scores, lower somatic cell counts, and lower peak rectal temperatures then heifers fed 6.5 mg Cu/kg diet (Scaletti et al., 2003).

Zinc:

Zinc is essential as a cofactor for over 80 enzymes, many of which are needed for the synthesis of DNA or RNA. Thus zinc may impact immune function because of its essential role in cell replication and proliferation. Zinc is also required for the synthesis of metallothionein, a metal binding protein that may scavenge hydroxide radicals (Prasad et al., 2004). Severe zinc deficiency in calves has been shown to impair immunity (Droke and Spears, 1993). Plasma zinc concentrations normally decrease in dairy cows at calving, but usually return to normal within 3 days (Goff and Stable, 1990). The exact role this has in the increased incidence of disease post-calving has not been investigated.



Chromium:

The most recent Dairy NRC (2001) does not give a requirement for chromium in the lactating cows. However, Spears (2000) reported that chromium supplementation may improve health and immune function in stressed calves. Chromium supplementation of cows' diets prior to calving has improved immune response. Lymphocytes from cow supplemented with 0.5 mg chromium-amino acid chelate/kg diet had an increased blastogenic response and an improved antibody response to ovalbumin administration over unsupplemented cows (Burton et al., 1993). Cows receiving 3.5 mg chromium from chromium picolinate the last 9 weeks of pregnancy reduced the incidence of retained placentas to 16% compared with 56% in unsupplemented cows (Villalobos et al. 1997).

Economics:

Long term cost-benefit ratio studies are very costly when evaluating the merits of trace mineral supplementation for lactating cows. Depending on the level of trace mineral fortification, 10 to 15 cents per cow per day is probably on the high side of expected cost. This would equal approximately $36 to $50 per year per cow. A dairy industry average is $100 to $150 of cost per case of clinical mastitis.

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For every incidence of mastitis that is prevented, you could feed that cow trace minerals for 2 to 4 years. When the benefits from reduced retained placenta and metritis are added on top of that, the return on investment is very positive.

Summary:

Trace minerals and vitamin E are essential to having a healthy immune system in lactating cows. Dairy cows undergo a period of immunosuppression just before and after calving. Proper supplementation of selenium, vitamin E, copper, zinc and chromium has shown benefits in maximizing the immune response. Proper trace mineral supplementation of dairy cow diets is essential to maintaining the health of cows and the economic competitiveness of the dairyman.

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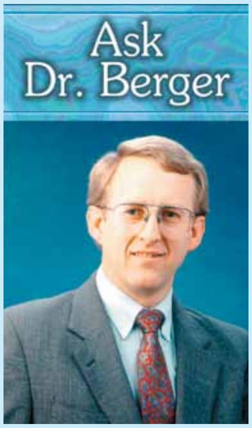
Question and Answers



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Q **Should I give my hunting dog additional salt to prevent fatigue before I take him hunting this fall?**

A Although fatigue and exhaustion are common symptoms of a sodium deficiency, most dog diets contain adequate sodium that salt supplementation is not needed.

Q **Is iodine supplementation necessary for sheep?**

A Yes, definitely; I am familiar with a sheep producer who lost most of this year's lamb crop due to feeding non-iodized salt. Most lambs were born with very little wool and had goiter.

Q **If my cows have been without salt for several days or weeks, should I be concerned about feeding loose salt ad libitum.**

A Cattle can develop a strong craving for salt after as little as 7 days without salt. I would recommend spreading a limited amount (1-2 ounces/head) of loose salt in many locations for a few days before giving them ad libitum access. Free-choice feeding of salt is very safe, but salt toxicity can occur if the cattle have been without salt for an extended period.

Q **Should I be concerned that the salt-trace mineral supplement being fed to my 4-H pig does not contain cobalt?**

A Pigs and poultry do not require supplemental cobalt. Vitamin B12 is added to monogastric animal diets, while ruminants can synthesize B12 in the rumen if adequate cobalt is present.

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CHROMIUM IN ANIMAL NUTRITION

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Introduction

In the late 1950's Schwartz and Mertz (1959) found that chromium was an essential component of a factor in brewers yeast that corrected impaired glucose metabolism in rats fed certain diets. Subsequent research demonstrated that chromium functioned by enhancing insulin action. Insulin is an important hormone that triggers glucose uptake by muscle, adipose tissue, and liver following a meal. A lack of chromium in the body results in tissues becoming less responsive or resistant to insulin. Chromium deficiency is believed to be one factor associated with the development of type 2 or adult onset diabetes in humans (Anderson, 1992).

Chromium absorption has not been studied in livestock but in humans only 0.5 to 2.0 % of chromium in foods is absorbed (Anderson and Kozlovsky, 1985). Inorganic sources of chromium, such as chromium chloride, are also considered to be poorly absorbed. Most research suggests that organic forms of chromium are more bioavailable than inorganic chromium sources.

Traditionally, it has been assumed that practical diets fed to livestock and poultry provide sufficient chromium to meet animal requirements. This assumption has changed in the past 10 to 15 years as a number of studies have indicated that chromium supplementation of animal diets can affect animal metabolism and production criteria. In swine (Amoikon et al., 1995) and cattle (Stahlhut et al., 2006a) chromium supplementation has enhanced insulin sensitivity. This paper will update regulations regarding chromium supplementation of animal diets, and discuss responses to chromium supplementation that have been observed in cattle and swine.

Chromium Forms and Levels Permitted in Animal Diets

Chromium supplements have been available across the counter for human use for a number of years. It has only been recently that certain forms of chromium have been permitted as supplemental sources of chromium in swine and cattle diets. In the United States research with chromium sources must be evaluated for safety by the Food and Drug Administration (FDA) prior to their use in animal diets. This evaluation includes not only animal safety but also human safety, as meat and milk from animal supplemented with chromium will enter the human food chain.

Two organic forms of chromium (chromium picolinate and chromium propionate) are currently permitted for addition to swine diets at levels not to exceed 0.2 mg of supplemental chromium per kg of diet. The FDA issued a regulatory discretion letter in July, 2009 which permitted the use of chromium propionate in cattle diets. Chromium propionate is the only chromium source currently permitted for supplementation to cattle diets in the United States. It can be added at levels up to 0.5 mg of supplemental chromium per kg of diet dry matter (DM). Currently, chromium supplementation is not permitted in poultry, equine, sheep, goat, and companion animal diets. In countries outside the United States, regulations regarding chromium supplementation to animal diets vary greatly from one country to another.

Swine

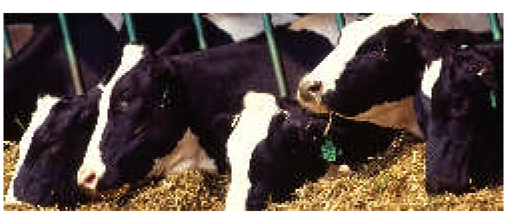
Growth and feed efficiency responses to chromium supplementation in swine have been highly variable. Page et al. (1993) found that supplementing 0.2 mg chromium/kg diet, as chromium picolinate, increased gain in one of three experiments with growing and finishing pigs. In a more recent study, chromium propionate supplementation did not affect weight gain of growing and finishing pigs (Jackson et al., 2009). Supplementation of chromium to pig diets has improved carcass quality in a number of studies. Reduced backfat and increased percentage of muscle has been reported in growing and finishing pigs supplemented with chromium picolinate (Page et al., 1993) and chromium propionate (Jackson et al., 2009).

Addition of chromium to sow diets has improved reproductive performance. Lindemann et al. (2004) reported that supplementing 0.2 mg chromium (chromium picolinate)/kg diet increased the number of pigs born alive by 0.33/litter. This study involved a total of 245 sows and was conducted at three different Universities. In a study conducted at a commercial swine operation in Kansas, chromium picolinate addition to sow diets increased first service farrowing rate from 82.9 to 95.5 % in the first parity (Real et al., 2008).

Dairy Cattle

A number of recent studies have indicated that chromium supplementation of dairy cows can increase feed intake and milk production. Most of the chromium studies with dairy cows have involved supplementation during the transition period. It is well documented that the transition period from 21 days prepartum to approximately 21 days postpartum is a critical period in regard to health and subsequent milk production in high producing dairy cows. In studies conducted in Wisconsin (Hayirli et al., 2001) and New York (Smith et al., 2005) supplementing chromium methionine from 21 days prepartum until 28 days postpartum increased feed intake and milk production during the first 28 days in milk. Maximizing feed intake is important in early lactation because high producing dairy cows secrete more energy in milk than they consume. This results in considerable mobilization of body fat and protein, that can result in ketosis or fatty liver due to the large amounts of fatty acids released from adipose tissue to support milk production.

Supplementing with chromium during the transition period may increase feed intake and milk production later in lactation even if chromium supplementation is discontinued. McNamara and Valdez (2005) supplemented dairy cows with chromium propionate from 21 days prepartum until 35 days postpartum. After chromium propionate was removed from the diet on day 35, feed intake and milk production continued to be monitored through 90 days in milk. Chromium supplementation increased feed (DM) intake 3.7 lbs/day and milk production 1.8 lbs/day the first 35 days of lactation. However, from days 36 to 90 of lactation, cows that had previously received chromium supplementation consumed 9.5 lbs more DM/day and produced 8.4 lbs more milk/day than control cows.



Beef Cattle

Considerable research indicates that chromium can affect immune response and disease resistance in cattle (Spears, 2000). Several studies at the University of Guelph in Canada have evaluated chromium supplementation of calves that had been exposed to stresses associated with shipping. In some of these studies chromium supplementation has reduced morbidity from respiratory diseases (Moonsie-Shageer and Mowat, 1993; Mowat et al., 1993). Stress is known to reduce the immune response causing cattle to be more susceptible to disease. Furthermore, studies in humans have indicated that stress increases urinary excretion of chromium, and may increase chromium requirements. Chromium supplementation of stressed calves during the receiving period also has improved or at least tended to improve gain and feed efficiency (Moonsie-Shageer and Mowat, 1993; Mowat et al., 1993).

In beef cows, grazing pastures and being feed harvested forages in the winter, chromium supplementation has improved reproductive performance. In these studies chromium was provided in a free choice mineral where salt was used to regulate mineral consumption. Stahlhut et al. (2006b) reported that chromium picolinate supplementation increased pregnancy rate in beef cows 5 years of age or younger. Chromium did not affect pregnancy rate in cows 6 years of age or older. The improved pregnancy rate was associated with much lower plasma nonesterified fatty acid concentrations at approximately 21 and 79 days after calving in chromium-supplemented cows. Lower plasma nonesterified fatty acid concentrations would suggest that chromium-supplemented cows were mobilizing less body fat to support milk production. Consistent with the lower plasma nonesterified fatty acid levels, chromium supplementation reduced body weight loss in young cows (2 and 3-year olds) after calving. Improving pregnancy rate in young beef cows is important because pregnancy rate is lower in young cows compared to mature cows.

Supplementation of chromium, as chromium yeast, in a free choice mineral reduced the interval from calving to first estrus and tended to improve pregnancy rate in young Zebu cows in Brazil (Aragon et al., 2001). Body weight gain was also greater in cows supplemented with chromium from parturition until their calves were weaned. At the present time chromium is not permitted in free choice mineral supplements. In the future chromium may be cleared for use in trace mineral salt and other free choice mineral supplements.

Summary

Chromium functions to enhance the actions of insulin. Studies in cattle and swine have shown that chromium addition to certain practical diets can increase insulin sensitivity. Chromium supplementation is currently permitted only in swine and cattle diets. Chromium picolinate and chromium propionate can be added to swine diets at levels not to exceed 0.2 mg chromium/kg diet. Chromium propionate is permitted in cattle diets at levels up to 0.5 mg supplemental chromium/kg diet DM. In swine chromium supplementation has reduced backfat and increased percentage of muscle in growing and finishing pigs and improved reproduction in sows. Chromium has increased feed intake and milk production when supplemented during the transition period to high producing dairy cows. In beef cattle chromium supplementation has increased reproductive performance of cows and reduced the incidence of morbidity in stressed calves.

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Salt & Trace Minerals

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UNIQUENESS OF SALT AS A CARRIER OF OTHER MINERALS

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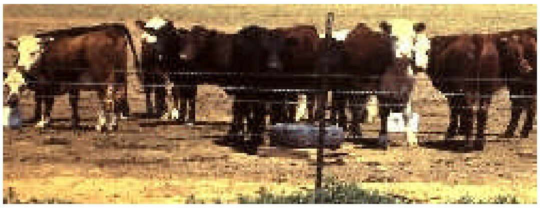
INTRODUCTION

It has long been known that animals have a specific appetite for sodium chloride (salt). Actually the appetite is more for sodium than chloride but salt is the cheapest source of sodium. If salt is provided free choice, ruminants grazing forages will consume adequate amounts to meet their sodium and chloride requirements. Equally important animals will not over consume salt to the point that toxicity occurs if adequate drinking water is available. In his textbook published in 1912, Kellner stated that “salt possesses, in a very high degree, the properties of a spice; it improves the appetite and makes many feedstuffs palatable which without salt, would not be readily eaten”.Animals such as cattle, sheep, goats, and deer, grazing pastures are usually dependent on a free choice mineral supplement to provide any minerals that are not supplied in adequate amounts in their forages. The palatability characteristic of salt is important because most trace minerals and major minerals are not very palatable, and salt is the driving force that not only promotes but also regulates intake of free choice mineral supplements.



The term “nutritional wisdom” has been used to describe an animal’s ability to recognize that a particular mineral is deficient in their diet, and consequently to select and consume (if a source of the mineral is available) a source of the mineral in adequate amounts to meet their requirement. The ability of animals to consume different minerals based on their need or requirement has been studied using cafeteria style mineral feeders. With cafeteria style mineral feeders animals are offered a choice of up to 11 different minerals in separate compartments. This paper will discuss the ability or in most instances the inability of animals to select and consume minerals based on their nutritional need.

SODIUM DEFICIENCY AND APPETITE FOR SALT

Animals exhibit an appetite for sodium that can easily be satisfied by providing salt free choice or adding salt to the complete diet of animals raised in confinement. There is little question that animals exhibit a high degree of nutritional wisdom in regard to their need for sodium. A strong appetite for salt is apparent long before signs of deficiency occur, indicating the ability of animals to recognize that they are not receiving adequate salt. Dairy cows receiving no salt in their diet show an increased appetite for salt after two or three weeks (Maynard and Loosli, 1969). Interestingly, cows receiving no salt did not express clinical signs of deficiency for approximately one year. Overtime the dairy cows exhibited unthriftness, loss of appetite, and a drastic decline in body weight and milk production.

The desire of sodium-deficient cattle and sheep to increase their consumption of salt has been studied experimentally by surgically cannulating a major salivary gland (parotid) and removing saliva. Ruminants secrete large volumes of saliva during feed ingestion and rumination, and saliva is very high in sodium. When saliva is removed and not replaced, sheep and cattle rapidly become sodium deficient. Following removal of saliva from the parotid gland, sheep offered rock salt free choice consumed 5 to 15 grams per day (Denton, 1982). This was much higher than the normal intake of 0.5 to 2 grams of rock salt per day. When saliva was removed from calves, they rapidly develop the ability to select solutions containing either sodium chloride or sodium bicarbonate (Bell and Williams, 1960). These studies clearly demonstrate the ability of cattle and sheep to recognize that they are deficient in sodium and to increase their free choice consumption of salt.

The ability of animals to sense the need, and select for sodium is not unique to cattle and sheep. Horses deficient in sodium show a specific appetite for salt (Ralston, 1984). Stockstad and coworkers (cited by Denton, 1982) studied intake of various mineral compounds by big game animals in western Montana, over a two-year period, when the minerals were provided individually in separate compartments. Sodium compounds evaluated included salt, sodium bicarbonate, sodium phosphate, and sodium iodide. All sodium compounds were consumed in large quantities during the study. Chloride and phosphate compounds other than sodium chloride and sodium phosphate were consumed in only small amounts or not at all. Of the trace minerals evaluated in this study only cobalt (cobalt chloride) was consumed by the wild animals. Copper, iron, and iodine forms other than sodium iodide were not consumed. Deer that were consuming a diet that contained approximately 27% of their sodium requirement, also selected and readily consumed salt when it was offered free choice in cafeteria style feeders (Ceacero et al., 2009).

OTHER MACROMINERALS AND NUTRITIONAL WISDOM

When macrominerals (other than sodium) are deficient in the diet, there is little evidence that animals recognize the need for the mineral and consume it in adequate quantities to satisfy their requirement. Early studies indicated that cattle consuming phosphorus-deficient diets exhibited a deprived appetite resulting in animals chewing on bones. Because of the high phosphorus content of bones, it was assumed that cattle were chewing on bones to derive phosphorus. Gordon et al. (1954) studied the ability of cattle and sheep grazing phosphorus-deficient pastures to correct their deficiency by selecting and consuming adequate quantities of a phosphorus containing supplement. Over a two-year period animals were exposed to two troughs containing calcium carbonate and one trough containing a mixture of 50% calcium carbonate and 50% dicalcium phosphate. Animals failed to show a preference for the phosphorus-calcium mixture over calcium carbonate alone, and did not consume sufficient amounts of phosphorus over the two-year period to correct their phosphorus deficiency. Studies in lactating dairy cows also have indicated little relationship between diet phosphorus contain and free choice intake of dicalcium phosphorus (Coppock et al., 1976; Muller et al., 1977).

In chicks there is some evidence to support a specific appetite for calcium during calcium deficiency. Hughes and Wood-Gush (1971) gave calcium-deficient chicks a choice of a diet low in calcium or the diet supplemented with 2% calcium carbonate. Approximately 80% of the chicks showed a preference for the calcium-supplemented diet. However, ponies (Ralston, 1984) and lambs (Pamp et al., 1977) do not show a preference for calcium supplements when fed calcium-deficient diets. Pamp et al. (1977) conducted a study to determine whether lambs fed a diet deficient in calcium would select and consume adequate amounts of calcium when several different minerals were offered free choice. Ten minerals were offered in separate containers to one-half of lambs fed a diet either adequate or deficient in calcium. Growth rate of lambs fed the calcium-deficient diet was greatly reduced during the 60-day study compared to lambs fed the same diet but supplemented with sufficient calcium. Lambs fed the calcium-deficient diet and offered the different minerals free choice did not consume adequate amounts of calcium carbonate to prevent the growth depression caused by calcium deficiency. For the entire study intake of salt was similar for lambs fed calcium-adequate and calcium-deficient diets, supporting the specific appetite of animals for salt regardless of their nutritional status.

Animals do not appear to have a specific appetite for either potassium or magnesium, even when receiving diets deficient in these minerals (Denton, 1982). Most forms of magnesium are known to be unpalatable to cattle. A supplement consisting of a mixture of magnesium oxide and magnesium sulfate was consumed in very small amounts when offered free choice to lactating dairy cows in cafeteria style feeders (Muller et al., 1977). Similarly, consumption of magnesium oxide by deer was very low when different minerals were offered cafeteria style (Ceacero et al., 2009). Because of the poor palatability of magnesium it is necessary to combine magnesium sources with palatable ingredients, such as salt, molasses, and grain byproducts, to achieve sufficient magnesium intake to prevent grass tetany in cattle. Tags on most high magnesium mineral supplements indicate that the magnesium supplement should be fed as the sole source of salt. If an alternate source of salt is available cattle will likely consume it instead of the magnesium supplement.

TRACE MINERALS AND NUTRITIONAL WISDOM

Limited research suggest that large wild game animals (Denton, 1982) and deer (Ceacero et al., 2009) may have an appetite for cobalt, especially when fed diets deficient in cobalt. For other trace minerals there is no evidence that animals are capable of regulating their intake based on nutritional wisdom.

Ensuring adequate consumption of trace minerals from free choice mineral supplements is important in animals grazing pastures. However, it is equally important that intake of trace minerals from free choice supplements be controlled to prevent toxicity. Zervas et al. (2001) found that lambs receiving high levels of trace minerals in their diet were unable to distinguish between a mineral supplement containing normal levels of trace minerals and one high in trace minerals. In this study lambs were fed alfalfa hay and a concentrate mix that differed in the amount of trace minerals added. The concentrate mix contained no supplemental trace minerals, a trace mineral premix, or the trace mineral premix added at three times (3X) the normal level. After receiving the diets for 31 days, lambs in each group were offered two different mineral lick blocks. Both mineral blocks contained 50% salt, but one contained 3X greater trace mineral content than the other. Lambs receiving the concentrate mix with no added trace minerals consumed more total mineral lick than the other two groups. However, they consumed a greater percentage of the 1X mineral lick (55%) than the 3X mineral lick block (45%). In contrasts lambs receiving the concentrate mix that contained the trace mineral premix at 3X the normal level consumed more (67 vs. 33%) of the high trace mineral lick than the 1X trace mineral block. Liver and plasma zinc and copper concentrations were higher in lambs receiving the high trace mineral concentrate mix than in those receiving the normal level of supplemental trace minerals in their concentrate mix. Interestingly, despite their high zinc and copper status, lambs receiving high concentrations of trace minerals in their diet selected more of the high mineral block than the normal trace mineral block.

SUMMARY

Sodium is the only mineral that animals clearly exhibit nutritional wisdom. Animals receiving inadequate sodium in their diet will seek a source of sodium, and if salt or some other source of sodium is available, they will consume it in amounts sufficient to meet their nutritional sodium requirement. Salt is an excellent carrier for other minerals included in free choice mineral supplements because of the specific appetite that animals have for salt. The palatability of salt promotes consumption of minerals in free choice minerals that would otherwise not be consumed in adequate amounts. Salt also is important in controlling the consumption of free choice mineral supplements, thus helping to prevent overconsumption of trace minerals, such as copper and selenium, that can cause toxicity.

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Salt & Trace Minerals

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HEAT STRESS AND EXERCISE INCREASE SALT REQUIREMENTS

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INTRODUCTION

We are in the middle of summer and many parts of the United States are experiencing record high temperatures. It is important to recognize that humans are not the only creatures that suffer from heat. Animals are also affected by heat stress. Heat stress in animals results in depressed feed intake and production (growth, milk production, egg production, etc.) and may even cause death in some instances.

Regulation of body temperature within a fairly narrow range is critical for survival of humans and most animals. Normal metabolism in the body results in the generation of heat. The temperature of the body is controlled by processes that cause heat to be retained or dissipated from the body. When the environmental temperature is high, heat must be lost or dissipated from the body for body temperature to be maintained in the normal range. Most animals rely on sweating (humans, cattle, horses) or panting (poultry, dogs, swine, sheep) to dissipate heat and cool the body when environmental temperatures are high. Panting refers to a rapid shallow breathing which increases the amount of water vaporized in the mouth and respiratory passages. High environmental temperatures increase losses of electrolytes, such as sodium, chloride, and potassium in sweat, and therefore can increase requirements for these minerals. Increasing the level of salt in the diet of some animals may also alleviate some of the adverse effects of heat stress.

Exercise will also increase sweating and the effect of exercise on mineral requirements is often ignored. Exercise in horses greatly increases sweat losses of sodium, chloride, and potassium. Exercising horses in the summer when environmental temperatures are high will further increase sweat losses. This newsletter will discuss the effect of heat stress in various animals and exercise in horses on salt requirements.

HEAT STRESS IN CATTLE

Cattle increase sweating and respiration rates during heat stress in an attempt to maintain their body temperature. In lactating dairy cows heat stress is associated with reduced feed intake and milk production. Slight decreases in feed intake of dairy cows usually occur at ambient temperatures of 77 to 81° F, and more dramatic depressions in intake are apparent when environmental temperatures exceed 86° F (Sanchez et al., 1994). Lactating dairy cows require approximately 0.22% sodium and 0.20% chloride under non- heat stress conditions (NRC, 2001). Most of the sodium and chloride required by cows under normal conditions is secreted in milk. However, the NRC

(2001) estimates that when environmental temperatures are 86° F or greater an average size dairy cow will lose an additional 3.5 grams of sodium (9 grams of salt) per day in sweat. In a study conducted during the summer at the University of Florida, increasing the sodium (from either salt or sodium bicarbonate) level in the diet from 0.18 to 0.55% increased feed intake and milk yield (Schneider et al., 1986).

Heat stress in beef cattle can reduce feed intake, weight gain, milk production, and in extreme cases cause death. For example this year in Kansas a number of feedlot cattle have died as a result of heat stress. Salt requirements of beef cattle are higher under tropical or hot, semi-arid conditions due to large losses of water and salt occurring via sweat (McDowell, 2003). Cattle grazing forages often consume forages that are high in potassium, and high intakes of potassium can also increase salt requirements. Forages grown in most areas are deficient in sodium. Therefore, it is especially important not to let cattle run out of salt or a salt containing mineral supplement during the summer.

HEAT STRESS IN POULTRY

Birds are particularly susceptible to heat stress because they are not able to sweat because of the absence of sweat glands. When the temperature and relative humidity exceeds the comfort level of birds they loss their ability to effectively dissipate heat. This causes birds to decrease their feed intake in order to reduce their heat production. Heat stress in poultry also reduces growth rate, hatchability of eggs, and increases death loss.

Because birds are unable to sweat at high ambient temperatures they are more dependent on panting to dissipate body heat. Respiration rate can increase from 25 breaths per minute under normal conditions to over 250 breaths per minute when birds are exposed to acute heat stress (Teeter and Belay, 1996). The increased respiration rate results in a respiratory alkalosis (higher than normal blood pH) that results in losses of sodium and potassium from the body. Deyhim and Teeter (1991) showed that adding 0.39% sodium chloride to drinking water of heat stressed broilers reduced death losses from 12% in controls to 7%. Water consumption was 35% greater in broilers receiving sodium chloride-treated water than in birds receiving normal water. The greater water consumption may explain the higher survivability of broilers consuming sodium chloride-treated water during heat stress. Adding 0.5% potassium chloride to drinking water in this study appeared to be more effective than adding 0.39% sodium chloride in alleviating heat stress (Deyhim and Teeter, 1991). However, potassium chloride is considerably more expensive than sodium chloride.

Recent research suggests that sodium and chloride requirements of broilers are higher than NRC (1994) recommendations. According to the NRC, broilers from 1 to 21 days of age require 0.20% sodium and 0.20% chloride. Murakami et al. (1997) found that young male broilers required 0.25% sodium and 0.20% chloride for maximum 21-day body weights. More recently, Oviedo-Rondon et al. (2001) reported that broilers from 1 to 21 days of age required 0.28% sodium and 0.25% chloride for optimal performance. Under subtropical summer conditions in Pakistan, broilers required 0.25% sodium and 0.30% chloride for maximum performance (Mushtaq et al., 2005).

SODIUM NEEDS OF EXERCISING HORSES

Horses are used by humans for a number of activities such as recreational riding, racing, ranch work, and rodeos. All of these activities involve work or exercise of varying intensities. Horses sweat profusely during intense exercise, and high environmental temperatures will further increase sweating. Sweat from horses contains 4 to 5 times more sodium and chloride than sweat from humans (Lewis, 1995). Thus, the salt requirement of horses is greatly affected by their level of work and environmental temperature.

The Nutrient Requirements of Horses (NRC, 2007) for work are divided into four categories (light, moderate, heavy, and very heavy) based on exercise intensity. Horses used for recreational riding would fall into the light or moderate exercise category, while Quarter horses and Thoroughbreds used for racing would be in the very heavy exercise category. Sodium requirements are 40, 78, 155, and 310% greater for horses doing light, moderate, heavy, and very heavy exercise, respectively, compared to the adult horse with a sedentary lifestyle (NRC, 2007).

Salt deficiency in horses, caused by sweating, results in fatigue, dehydration, exhaustion, and muscle spasms and cramps (Cunha, 1991). One should not assume that the grain mix fed to exercising horses will meet their salt requirement. Salt should be available free choice to horses at all times. When salt is provided free choice horses consume sufficient quantities to meet their requirements for sodium and chloride. Salt can be provided in loose form or as a salt block. Consumption of salt is usually greater when offered as loose salt. The amount of salt consumed per day by horses will vary depending on activity level and ambient temperature as well as a number of other factors. A study conducted in the 1920s measured the salt intake of work horses during the hot summer months. Daily salt intake per horse was 0.64 ounces in May and increased each month to a high of 3.18 ounces per horse in August (Cunha, 1991).

SUMMARY

It is important to supply animals with adequate amounts of salt during hot weather. During heat stress conditions cattle sweat and increase their respiration rate resulting in considerable losses of sodium, chloride, and water. Poultry respond to heat stress by panting or increasing their respiration rate. The increased respiration rate in poultry results in a higher than normal blood pH that causes increased losses of electrolytes from the body. Adding salt at low levels to drinking water has reduced death losses in broilers exposed to acute heat stress. The salt requirement of horses is greatly affected by their level of activity (exercise) and the environmental temperature. Horses sweat profusely during intense exercise and this causes major losses of sodium and chloride. A source of salt should be available free choice to horses at all times.

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HEAT STRESS AND EXERCISE INCREASE SALT REQUIREMENTS

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INTRODUCTION

We are in the middle of summer and many parts of the United States are experiencing record high temperatures. It is important to recognize that humans are not the only creatures that suffer from heat. Animals are also affected by heat stress. Heat stress in animals results in depressed feed intake and production (growth, milk production, egg production, etc.) and may even cause death in some instances.

Regulation of body temperature within a fairly narrow range is critical for survival of humans and most animals. Normal metabolism in the body results in the generation of heat. The temperature of the body is controlled by processes that cause heat to be retained or dissipated from the body. When the environmental temperature is high, heat must be lost or dissipated from the body for body temperature to be maintained in the normal range. Most animals rely on sweating (humans, cattle, horses) or panting (poultry, dogs, swine, sheep) to dissipate heat and cool the body when environmental temperatures are high. Panting refers to a rapid shallow breathing which increases the amount of water vaporized in the mouth and respiratory passages. High environmental temperatures increase losses of electrolytes, such as sodium, chloride, and potassium in sweat, and therefore can increase requirements for these minerals. Increasing the level of salt in the diet of some animals may also alleviate some of the adverse effects of heat stress.

Exercise will also increase sweating and the effect of exercise on mineral requirements is often ignored. Exercise in horses greatly increases sweat losses of sodium, chloride, and potassium. Exercising horses in the summer when environmental temperatures are high will further increase sweat losses. This newsletter will discuss the effect of heat stress in various animals and exercise in horses on salt requirements.

HEAT STRESS IN CATTLE

Cattle increase sweating and respiration rates during heat stress in an attempt to maintain their body temperature. In lactating dairy cows heat stress is associated with reduced feed intake and milk production. Slight decreases in feed intake of dairy cows usually occur at ambient temperatures of 77 to 81° F, and more dramatic depressions in intake are apparent when environmental temperatures exceed 86° F (Sanchez et al., 1994). Lactating dairy cows require approximately 0.22% sodium and 0.20% chloride under non- heat stress conditions (NRC, 2001). Most of the sodium and chloride required by cows under normal conditions is secreted in milk. However, the NRC

(2001) estimates that when environmental temperatures are 86° F or greater an average size dairy cow will lose an additional 3.5 grams of sodium (9 grams of salt) per day in sweat. In a study conducted during the summer at the University of Florida, increasing the sodium (from either salt or sodium bicarbonate) level in the diet from 0.18 to 0.55% increased feed intake and milk yield (Schneider et al., 1986).

Heat stress in beef cattle can reduce feed intake, weight gain, milk production, and in extreme cases cause death. For example this year in Kansas a number of feedlot cattle have died as a result of heat stress. Salt requirements of beef cattle are higher under tropical or hot, semi-arid conditions due to large losses of water and salt occurring via sweat (McDowell, 2003). Cattle grazing forages often consume forages that are high in potassium, and high intakes of potassium can also increase salt requirements. Forages grown in most areas are deficient in sodium. Therefore, it is especially important not to let cattle run out of salt or a salt containing mineral supplement during the summer.

HEAT STRESS IN POULTRY

Birds are particularly susceptible to heat stress because they are not able to sweat because of the absence of sweat glands. When the temperature and relative humidity exceeds the comfort level of birds they loss their ability to effectively dissipate heat. This causes birds to decrease their feed intake in order to reduce their heat production. Heat stress in poultry also reduces growth rate, hatchability of eggs, and increases death loss.

Because birds are unable to sweat at high ambient temperatures they are more dependent on panting to dissipate body heat. Respiration rate can increase from 25 breaths per minute under normal conditions to over 250 breaths per minute when birds are exposed to acute heat stress (Teeter and Belay, 1996). The increased respiration rate results in a respiratory alkalosis (higher than normal blood pH) that results in losses of sodium and potassium from the body. Deyhim and Teeter (1991) showed that adding 0.39% sodium chloride to drinking water of heat stressed broilers reduced death losses from 12% in controls to 7%. Water consumption was 35% greater in broilers receiving sodium chloride-treated water than in birds receiving normal water. The greater water consumption may explain the higher survivability of broilers consuming sodium chloride-treated water during heat stress. Adding 0.5% potassium chloride to drinking water in this study appeared to be more effective than adding 0.39% sodium chloride in alleviating heat stress (Deyhim and Teeter, 1991). However, potassium chloride is considerably more expensive than sodium chloride.

Recent research suggests that sodium and chloride requirements of broilers are higher than NRC (1994) recommendations. According to the NRC, broilers from 1 to 21 days of age require 0.20% sodium and 0.20% chloride. Murakami et al. (1997) found that young male broilers required 0.25% sodium and 0.20% chloride for maximum 21-day body weights. More recently, Oviedo-Rondon et al. (2001) reported that broilers from 1 to 21 days of age required 0.28% sodium and 0.25% chloride for optimal performance. Under subtropical summer conditions in Pakistan, broilers required 0.25% sodium and 0.30% chloride for maximum performance (Mushtaq et al., 2005).

SODIUM NEEDS OF EXERCISING HORSES

Horses are used by humans for a number of activities such as recreational riding, racing, ranch work, and rodeos. All of these activities involve work or exercise of varying intensities. Horses sweat profusely during intense exercise, and high environmental temperatures will further increase sweating. Sweat from horses contains 4 to 5 times more sodium and chloride than sweat from humans (Lewis, 1995). Thus, the salt requirement of horses is greatly affected by their level of work and environmental temperature.

The Nutrient Requirements of Horses (NRC, 2007) for work are divided into four categories (light, moderate, heavy, and very heavy) based on exercise intensity. Horses used for recreational riding would fall into the light or moderate exercise category, while Quarter horses and Thoroughbreds used for racing would be in the very heavy exercise category. Sodium requirements are 40, 78, 155, and 310% greater for horses doing light, moderate, heavy, and very heavy exercise, respectively, compared to the adult horse with a sedentary lifestyle (NRC, 2007).

Salt deficiency in horses, caused by sweating, results in fatigue, dehydration, exhaustion, and muscle spasms and cramps (Cunha, 1991). One should not assume that the grain mix fed to exercising horses will meet their salt requirement. Salt should be available free choice to horses at all times. When salt is provided free choice horses consume sufficient quantities to meet their requirements for sodium and chloride. Salt can be provided in loose form or as a salt block. Consumption of salt is usually greater when offered as loose salt. The amount of salt consumed per day by horses will vary depending on activity level and ambient temperature as well as a number of other factors. A study conducted in the 1920s measured the salt intake of work horses during the hot summer months. Daily salt intake per horse was 0.64 ounces in May and increased each month to a high of 3.18 ounces per horse in August (Cunha, 1991).

SUMMARY

It is important to supply animals with adequate amounts of salt during hot weather. During heat stress conditions cattle sweat and increase their respiration rate resulting in considerable losses of sodium, chloride, and water. Poultry respond to heat stress by panting or increasing their respiration rate. The increased respiration rate in poultry results in a higher than normal blood pH that causes increased losses of electrolytes from the body. Adding salt at low levels to drinking water has reduced death losses in broilers exposed to acute heat stress. The salt requirement of horses is greatly affected by their level of activity (exercise) and the environmental temperature. Horses sweat profusely during intense exercise and this causes major losses of sodium and chloride. A source of salt should be available free choice to horses at all times.

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ESTIMATION OF THE SODIUM AND CHLORIDE REQUIREMENTS FOR THE YOUNG BROILER CHICK[1]

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Primary Audience: Nutritionists, Veterinarians, Production Managers

SUMMARY

An experiment was conducted to evaluate the requirements for Na and Cl in diets fed to male broilers to 21 days. Four test diets were prepared from a common corn-soybean meal basal which represented extremes in levels of Na and Cl, providing 1) low Na-low Cl, 2) low Na-high Cl, 3) high Na-low Cl, and 4) high Na-high Cl. These diets were then used to prepare blends that provided the final experimental feeds. The experiment consisted of a factorial arrangement of six levels of Na (0.10 to 0.35% of the diet) and six levels of Cl (0.10 to 0.35% of the diet). Day-old male chicks of a commercial strain (Ross 308) were grown in battery brooders with six chicks per pen and six pens per treatment. Test diets and tap water (5.3 ppm Na and 0.7 ppm Cl) were provided for *ad libitum* consumption. Body weight gains (BW), feed intake (FI), feed conversion ratios (FCR), and tibia ash content were determined.

No significant interaction of Na and Cl was observed for any parameter. Both Na and Cl levels significantly influenced 21 day BW. FI was significantly influenced by levels of Cl but not by Na; FCR were not significantly influenced by levels of either Na or Cl. Increasing Cl tended to improve bone ash while increasing Na appeared to decrease bone ash.

Key words: Broilers, chloride, requirements, sodium
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DESCRIPTION OF PROBLEM

Sodium and chloride are essential minerals for poultry [1, 2]. Satisfying the requirements for Na and Cl in poultry feeds is relatively inexpensive, so providing liberal quantities of these minerals adds little to the cost of production. However, due to the problems with wet litter often associated with increased bird densities or reduced ventilation rates, nutritionists are often pressured to limit the quantities of these minerals in the diet. The literature reports a wide range of requirements for both Na and Cl. The National Research Council recently increased the minimum recommended level of both minerals in diets for broilers 0 to 21 days from 0.15% [3] to 0.20% [4]. Because of these variations in

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reported requirements, a study was conducted to evaluate the requirements of Na and Cl in diets for broilers from 0 to 21 days.

Materials and Methods

FORMULATION AND DIET PREPARATION

Four basal diets were formulated using nutrient composition values suggested by NRC [4]. The amount of corn, soybean meal, poultry oil, methionine, and vitamin and trace mineral premixes was identical among diets (Table 1). Variable amounts of limestone, mono-dicalcium phosphate, monobasic sodium phosphate, sodium bicarbonate, calcium chloride, and washed builders sand were utilized to maintain constant calcium and nonphytate phosphorus levels from highly available sources while providing a range of

TABLE 1. Composition and calculated analysis of basal diets for sodium-chloride studies

INGREDIENT	A	B	C	D
	g/kg			
Yellow corn	539.83	539.83	539.83	539.83
Soybean meal, dehulled	366.89	366.89	366.89	366.89
Poultry oil	44.97	44.97	44.97	44.97
Vitamin premix[A]	5.00	5.00	5.00	5.00
DL-Methionine	2.07	2.07	2.07	2.07
Trace mineral mix[B]	1.00	1.00	1.00	1.00
Limestone	15.26	22.15	9.92	16.81
Mono-dicalcium phosphate	14.72	0.00	14.72	0.00
Sodium phosphate monobasic	0.00	13.22	0.00	11.98
Sodium bicarbonate	0.00	4.87	0.00	5.76
Washed sand	10.26	0.00	9.90	0.00
Calcium chloride	0.00	0.00	5.70	5.69
	1000.00	1000.00	1000.00	1000.00
CALCULATED ANALYSIS				
Sodium, %	0.02	0.40	0.02	0.40
Sodium, % (analyzed)	0.02	0.41	0.02	0.41
Chloride, %	0.04	0.04	0.40	0.40
Chloride, % (analyzed)	0.06	0.05	0.37	0.39
Potassium, % (analyzed)	0.94	0.93	0.97	0.97
ME kcal/kg	3080.00	3080.00	3080.00	3080.00
Crude protein, %	22.14	22.14	22.14	22.14
Calcium, %	0.96	0.96	0.96	0.96
Calcium, % (analyzed)	0.99	1.08	1.10	1.07
Phosphorus, %	0.69	0.72	0.69	0.69
Phosphorus, % (analyzed)	0.68	0.78	0.72	0.71
Phosphorus, nonphytate, %	0.43	0.43	0.43	0.43
Methionine, %	0.55	0.55	0.55	0.55
TSAA, %	0.91	0.91	0.91	0.91
Lysine, %	1.23	1.23	1.23	1.23

[A]Provides per kg of diet: 7714 IU vitamin A; 2204 IU vitamin D_3; 16.53 IU vitamin E; 0.013 mg vitamin B_{12}; 6.6 mg riboflavin; 39 mg niacin; 10 mg pantothenic acid; 465 mg choline; 1.5 mg vitamin K; 0.9 mg folic acid; 1.54 mg thiamin; 2.76 mg pyridoxine; 0.066 mg d-biotin; 125 mg ethoxyquin; 0.1 mg Se.

[B]Provides per kg of diet: Mn ($MnSO_4.H_2O$), 100 mg; Zn ($ZnSO_4.7H_2O$), 50 mg; Cu (CuSo $.5H_20$), 10 mg; I ($Ca(IO_3)_2.H_20$), 1 mg.

Na and Cl levels. These diets represented extremes in levels of Na and Cl, providing 1) low Na-low Cl, 2) low Na-high Cl, 3) high Na-low Cl, and 4) high Na-high Cl. All other nutrients met or exceeded recommended nutrient standards [4].

A large batch of a mixture made up of the common dietary components was produced and aliquots used for mixing the four primary test diets with the variable components. Samples from the four primary diets were submitted to five different analytical laboratories to determine actual content of Na, Cl, K, Ca, and P. Using the resulting mean values, these four primary diets were blended to provide the final experimental diets. The experimental diets consisted of a factorial arrangement of six levels of Na (0.10, 0.15, 0.20, 0.25, 0.30, and 0.35%) and six levels of Cl (0.10, 0.15, 0.20, 0.25, 0.30, and 0.35%). After mixing the final experimental diets, samples were subjected to assay for Na and Cl to verify proper mixing prior to beginning the study. Analytical values for Na and Cl in the basal diets (Table 1) and the experimental diets (Tables 2 and 3) were in agreement with calculated values.

BIRDS AND HOUSING

Day-old male chicks of a commercial strain [5] were obtained from a local hatchery and randomly assigned to compartments in electrically heated battery brooders. The chicks were vaccinated in the hatchery for Marek's disease, Newcastle disease, and infectious bronchitis. Six chicks were placed in each of 216 compartments. Six replicate groups of birds were assigned to each of the 36 dietary treatments, stratified across tiers of the battery brooders. The brooders were maintained in an environmentally controlled room (72°F) with continuous fluorescent illumination. Experimental diets, fed in mash

TABLE 2. Analyzed sodium levels in experimental diets[A]

% CALCULATED CHLORIDE	% CALCULATED SODIUM					
	0.10	0.15	0.20	0.25	0.30	0.35
	% Analyzed Sodium					
0.10	0.096	0.161	0.207	0.249	0.291	0.356
0.15	0.089	0.149	0.185	0.247	0.287	0.353
0.20	0.104	0.169	0.216	0.254	0.304	0.342
0.25	0.122	0.167	0.218	0.260	0.306	0.341
0.30	0.113	0.152	0.219	0.253	0.318	0.359
0.35	0.120	0.160	0.208	0.268	0.323	0.364
Mean	0.107	0.159	0.209	0.255	0.305	0.352

[A]Analysis conducted by Agricultural Diagnostic Services Laboratory, University of Arkansas, Fayetteville, AR.

TABLE 3. Analyzed chloride levels in experimental diets[A]

% CALCULATED CHLORIDE	% CALCULATED SODIUM						MEAN
	0.10	0.15	0.20	0.25	0.30	0.35	
	% Analyzed Chloride						
0.10	0.122	0.108	0.106	0.108	0.105	0.108	0.109
0.15	0.141	0.155	0.138	0.149	0.156	0.137	0.146
0.20	0.194	0.192	0.198	0.182	0.219	0.187	0.195
0.25	0.261	0.232	0.260	0.250	0.247	0.263	0.252
0.30	0.297	0.316	0.323	0.312	0.328	0.275	0.308
0.35	0.335	0.366	0.348	0.347	0.354	0.362	0.352

[A]Analysis conducted by Agricultural Diagnostic Services Laboratory, University of Arkansas, Fayetteville, AR.

form, and tap water were provided for *ad libitum* consumption. Analysis of the tap water indicated that it contained 5.3 ppm Na and 0.7 ppm Cl. Birds were placed on their respective test diets for a 21-day feeding period.

MEASUREMENTS

Pen body weights were obtained at day-old and at 21 days of age, with feed consumption determined over the test period. Birds were checked for mortality twice daily; all birds that died were weighed and the weight was used for adjustment of feed conversion. At the conclusion of the study three birds were randomly selected from each pen, killed by CO_2 inhalation, and their left tibiae removed for ash determination of dry, fat-free bone [6].

STATISTICAL ANALYSIS

Pen means were the experimental unit for statistical analysis. The data were analyzed as a factorial arrangement of treatments using the general linear model of the SAS Institute [7]. The model included Na and Cl levels and their interaction.

Results and Discussion

Levels of both Na and Cl significantly affected 21-day body weight (Table 4). A Na level of 0.25% resulted in significantly greater body weight than did lower levels; this level is higher than the present NRC [4] recommendation of 0.20%. Body weight was not significantly increased by Cl levels in excess of 0.20%, in agreement with NRC [4] recommendations. There was no interaction of Na and Cl in relation to body weight.

Feed consumption (Table 5) was significantly influenced by levels of dietary Cl but not by levels of Na. Feed consumption reached a maximum at a Cl level of 0.20%. There was no interaction of Na and Cl on feed intake. Feed conversion (g feed/g gain) was influenced by both Na (P = .10) and Cl (P = .06). Feed conversion tended to improve as both Na and Cl levels increased, but there did not appear to be a clear breakpoint in response (Table 6). There was no interaction of Na and Cl on feed conversion.

Tibia ash content (Table 7) was significantly influenced by both Na and Cl. Increasing Cl levels up to 0.20% improved tibia ash content; birds fed diets with 0.20% Cl and higher appeared to plateau in ash content. Conversely, increasing Na levels resulted in a significant decline in tibia ash in diets with greater than 0.25% Na. There was no interaction of Na and Cl on tibia ash content.

A wide range of requirements for Na and Cl for the young broiler chick have been reported. In many of these studies, such wide increments were used between levels of the test mineral that a precise estimate of a requirement is difficult. Few studies have com-

TABLE 4. Influence of sodium and chloride levels on 21-day body weight of male broilers

% CHLORIDE	% SODIUM						MEAN
	0.10	0.15	0.20	0.25	0.30	0.35	
	g						
0.10	634	633	617	625	620	646	629^{d}
0.15	674	686	704	697	680	717	693^{c}
0.20	694	717	746	762	740	715	729^{ab}
0.25	712	730	716	748	756	727	732^{ab}
0.30	698	715	699	736	710	721	713^{b}
0.35	714	749	729	762	738	755	742^{a}
Mean	688^{c}	705^{bc}	702^{bc}	722^{a}	708^{ab}	714^{ab}	

FACTOR	SEM	PROBABILITY > F
Sodium	7	0.02
Chloride	7	0.0001
Sodium x Chloride	17	0.85

a–c Means in row or column with different superscripts indicate significant differences (P ≤ .05).

TABLE 5. Influence of sodium and chloride levels on 21-day feed consumption by male broilers

% CHLORIDE	% SODIUM						MEAN
	0.10	0.15	0.20	0.25	0.30	0.35	
	g Feed/Bird						
0.10	902	899	893	875	879	877	887[c]
0.15	938	958	975	958	942	990	960[b]
0.20	996	999	1024	1040	1043	996	1016[a]
0.25	969	1033	984	1038	1053	1012	1015[a]
0.30	1005	1003	1010	1015	990	999	1004[a]
0.35	877	990	996	1013	999	1042	1016[a]
Mean	968	987	980	989	989	989	

FACTOR	SEM	PROBABILITY > F	
Sodium	9	0.56	
Chloride	9	0.0001	
Sodium x Chloride	23	0.73	

[a–c]Means in column with different superscripts indicate significant differences ($P \leq .05$).

TABLE 6. Influence of sodium and chloride levels on 21-day feed conversion by male broilers

% CHLORIDE	% SODIUM						MEAN
	0.10	0.15	0.20	0.25	0.30	0.35	
	g Feed/g Gain						
0.10	1.425	1.423	1.447	1.399	1.420	1.357	1.412
0.15	1.392	1.398	1.385	1.375	1.387	1.380	1.386
0.20	1.437	1.395	1.374	1.365	1.412	1.396	1.396
0.25	1.363	1.419	1.378	1.390	1.389	1.393	1.389
0.30	1.441	1.402	1.444	1.378	1.396	1.388	1.408
0.35	1.396	1.375	1.362	1.329	1.394	1.380	1.373
Mean	1.409	1.402	1.398	1.373	1.400	1.382	

FACTOR	SEM	PROBABILITY > F	
Sodium	0.010	0.10	
Chloride	0.010	0.06	
Sodium x Chloride	0.024	0.75	

pared sufficient levels of both minerals simultaneously. Burns *et al.* [8], utilizing purified diets, reported that the Na requirement varied with rate of growth, ranging from 0.1 to 0.3%, and the requirement for Cl was no more than 0.06%. McWard and Scott [9] found the Na requirement of chicks fed a glucose-isolated soy diet to be 0.11%. Using a casein-gelatin diet, the need for Na was 0.20%. The higher requirement was thought to be due to problems with intake on this type of diet. Leach and Nesheim [10] found the Cl requirements of chicks fed glucose-isolated soy diets to be 0.15%. Nott and Combs [11] found the Na requirement for maximum growth of broiler chicks to 4 wk of age was between 0.11 and 0.13% in a corn-soybean diet; there was no effect on feed utilization at levels between 0.13 and 0.40%. Workers at Borden Chemical Co. [12] suggested that the Na requirement of broilers to 4 wk was 0.14% with Cl levels of 0.11% (females) and 0.12% (males). Dilworth *et al.* [13] suggested that the Na requirement of the chick was 0.084 to 0.104%, depending upon particle size of the salt supplement. Hurwitz *et al.* [14] observed an interdepend-

TABLE 7. Influence of sodium and chloride levels on 21-day tibia ash of male broilers

% CHLORIDE	% SODIUM						MEAN
	0.10	0.15	0.20	0.25	0.30	0.35	
	% Ash						
0.10	37.97	38.18	38.32	37.91	37.84	38.41	38.10[d]
0.15	38.99	39.66	38.14	38.37	39.04	37.91	38.69[c]
0.20	38.80	39.32	39.51	39.32	39.07	38.44	39.08[abc]
0.25	39.04	38.93	39.13	39.19	38.52	38.21	38.84[bc]
0.30	39.52	40.32	40.02	39.22	38.53	38.78	39.40[a]
0.35	40.28	39.36	39.34	39.78	38.26	38.42	39.24[ab]
Mean	39.10[a]	39.29[a]	39.07[ab]	38.96[ab]	38.55[bc]	38.36[c]	

FACTOR	SEM	PROBABILITY > F
Sodium	0.19	0.005
Chloride	0.19	0.0001
Sodium x Chloride	0.46	0.47

[a–c]Means in row or column with different superscripts indicate significant differences ($P \leq .05$).

ency between the two elements. Optimal growth was obtained on diets with 0.13% Na and 0.13% Cl. Dewar and Whitehead [15] reported that maximum growth and feed conversion to 4 wk of age on corn-soy-wheat diets was attained with a Na level of 0.20%. Gardiner and Dewar [16] reported a Cl requirement of 0.12%. Ross [17] suggested a Na requirement of 0.20 to 0.25%. Nam and McGinnis [18] reported that chicks required 0.13% Cl for maximum growth and feed efficiency. Based primarily on these recommendations, the NRC [4] established a requirement of 0.20% for both Na and Cl. Results of the present study agree with this recommendation.

More recent work would suggest considerably higher requirements for both Na and Cl. Edwards [19] reported that the Na requirement for maximum growth rate at 1, 2, and 3 wk of age was 0.41, 0.33, and 0.30%, respectively. Cl requirements for the same ages were 0.53, 0.37, and 0.36% of the diet. This study was characterized by relatively close increments of Na and Cl in the experimental design. Britton [20] concluded that the Na and Cl requirements for maximum growth are both at least 0.45% of the diet. This requirement is based primarily upon one study in which rather wide increments of both minerals were used. The results of other trials in this report make it difficult to suggest a Cl level greater than approximately 0.20%. Varying Na levels were utilized in only one study; a level of 0.30% Na supported higher body weights than did 0.15% Na but there were no intermediate levels evaluated.

The weak effect of Na and strong effect of Cl on feed intake and subsequent feed conversion in the present study are in agreement with several previous reports [12, 14, 15, 17, 18]. Edwards [19] reported that increasing the levels of Na and Cl caused a gradual increase in bone ash, but it is not clear from the data how much each mineral contributed to this increase in ash content.

Concerns about dietary acid-base balance and the role of Na and Cl in maintaining this balance have long been an issue among nutritionists [8, 10, 21, 22]. Hurwitz *et al.* [14] reported that optimal growth of chicks was obtained with a Na:Cl ratio of unity. Few studies in the literature evaluate both nutrients together at incremental levels sufficient to test this hypothesis. While the overall results of the present study in terms of Na and Cl requirements agree with this suggested ratio, the lack of Na:Cl interactions throughout the study questions the strength of this relationship and the need to implement such a ratio in practical diet formulation.

While levels of Na and Cl higher than those required for optimum growth did not appear to impair growth rate and feed conversion, concerns regarding excessive levels must be taken into consideration. Although no attempts were made in the present study to evaluate moisture content of the droppings, Hurwitz *et al.* [14] reported a positive dependence of the moisture content of droppings on the dietary sodium content and the Na:Cl ratio. Work by Dewar *et al.* [23] and Whitehead *et al.* [24] also showed a relationship between dietary sodium levels and incidence of testicular cysts. The mechanism of cyst formation is not completely understood and does not apparently interfere with normal growth of the bird; however, appearance of testicular cysts might lead to an increase in condemnation rates. Therefore, limitations of excess levels of sodium are suggested.

CONCLUSIONS AND APPLICATIONS

1. Levels of 0.25% Na and 0.20% Cl were required for maximum 21 day body weight by male broiler chicks fed a corn-soybean meal type diet.
2. Cl, but not Na, appeared to have a strong effect on feed intake. Feed conversion was only weakly affected by levels of Na and Cl, suggesting that the greatest effect of these minerals was upon appetite.
3. Increasing Cl tended to improve bone ash, while increasing Na appeared to decrease bone ash. Previous research has not extensively evaluated the effect of these minerals on bone development; this area requires further research.
4. Within the levels tested in this experiment, there were no interactions of Na and Cl on any of the parameters examined. This finding suggests that the application of specific Na:Cl ratios in the formulation of practical poultry diets may not be beneficial.

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