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Introduction

Concern among some dairy nutritionists has recently been expressed that "high potassium" content of hay and silage is reducing milk production in some high-producing dairy herds. Alfalfa and grass hay and corn and grass silage, which have been heavily fertilized, are the objects of this concern. The nutritional question being considered in this article is whether an animal diet excessively high in potassium (K) is likely to bring on sodium (Na) deficiency in the animal due to ion antagonism. If, in fact, this is the case, a knowledge of Na accumulation by forages and the need to offset such an imbalance by feeding supplemental Na becomes important.

Salt (sodium chloride:NaCl) fertilization of pastures has been recently proposed in a popular dairy publication as a means of promoting production of grazing dairy cows. That article was based on British research on dairy cows grazing perennial ryegrass pastures and has spurred considerable interest among dairy farmers. Salt fertilization may appear to be an attractive option to salt supplementation because of its low cost, or as a partial substitute for more expensive K fertilizers, and because it may reduce some of the problems of dairy cows reportedly associated with forages with a high K content (>4% K in DM). A review of sodium in plants and animals seems appropriate at this time.

Role of Na in Animals and Plants

The ionic nature of Na and K results in their being mutually competitive in biological systems. In fact, there is substantial evidence that each can substitute for the other to some degree in cellular functions. The following discussion highlights the current knowledge about the role of Na in plants and animals.

Sodium in plants

Sodium is not essential for plant growth, but it is considered beneficial. Plants can be classified according to their Na uptake. Halophytes are plants that have evolved a tolerance to Na and are adapted to saline soils. Another class, natrophiles (salt-loving plants), also known as Na accumulators, have variable Na concentrations in their tissues, depending on the Na content of the soil. Sodium accumulators increase their Na content in response to fertilization with salt. Natrophobes (salt-hating plants), also known as non-accumulators of Na, typically have low Na concentrations in their herbage (<2 g/kg). Even if non-accumulators are fertilized with salt their herbage remains low in Na. There are two subclasses of non-accumulators. One class absorbs Na into roots but does not translocate Na to its aerial parts. Another class absorbs very little Na by selectively excluding it. A classification of most pasture species used in Kentucky according to Na type is shown in Table 1.

Sodium content of herbage

Some of the herbage species used in Kentucky grassland agriculture do not have enough Na to meet the needs of livestock, if they are the sole source of feed. Content of Na in forage DM ranges from 0.005% to 2.13 %, with an average of 0.22% (Table 2). The lower levels may be those of herbage of non-accumulators or of Na accumulators grown on soils of low Na content. Herbage grown on soils heavily fertilized with K may be of low Na content because uptake of K by plants invariably depresses Na uptake. Red clover and alfalfa are known to have low Na content. Sur-

prisingly, white clover supplies enough Na for livestock. Sodium content of alfalfa herbage DM grown at the University of Kentucky's Spindletop research farm in Fayette County in 1994 ranged from 0.02 to 0.09 % with an average of 0.04 %. Sub-tropical species, such as sudangrass, sorghum, crabgrass, pearl millet, and bermudagrass are low Na plants and may be exceptions for they may actually require some Na, albeit in very small amounts. Sudangrass appears to be very low in herbage Na (Table 2). Temperate grass species, such as annual and perennial ryegrass, and orchardgrass contain sufficient Na for livestock, but Na may be limiting in timothy. Classification of tall fescue with regard to Na accumulation is not clear. The Na content of tall fescue (Table 2) and its close genetic relationship to the ryegrasses would suggest that it is a Na accumulator.

Sodium requirements of animals

Animals need Na because it is their most important extracellular cation. Sodium has many functions in animal metabolism, including electrolyte balance, nutrient absorption and transport, water balance and in the central nervous system. Bodies of adult cattle contain an average of 0.2% Na of body mass. Normally, only small regular inputs of Na are needed, because large Na reserves are maintained in their extracellular fluid volume (0.32 to 0.35% Na), particularly in the fluid of the reticulo-rumen. About 0.15 % Na (1.5g Na/kg) in herbage dry matter (DM) maintains satisfactory Na dietary levels in most classes of livestock, however, non-lactating beef cattle perform well at 0.06 to 0.08% Na (6-8 g/kg) in herbage DM. Lactating beef and dairy cows need more Na (0.18 % Na or 18g/kg) in diet DM because large amounts of Na are excreted in milk, which is relatively rich in Na (0.4% or 4g/kg).

Sodium deficiency of livestock has been recognized for decades. A recent survey revealed that most Kentucky beef cattle producers fed salt, trace-mineralized salt or a complete mineral mix to their herds. Recently, grazing systems researchers at the Forage Systems Research Center of University of Missouri in Linneus found that diets of beef cattle grazing pastures, which are very similar to those of Kentucky, were deficient in Na all year around. Salt-based mineral mixtures are also routinely used to deliver other macronutrients, micronutrients, larvacides, rumen modifers (e.g., monensin, lasalocid etc.) and bloat-preventing agents.

Cattle, like humans, can discriminate between salt, sweet, sour and bitter tastes. They also have a specific appetite for salt and will, given the opportunity, consume much more salt than they need for their physiological processes. If given the opportunity, livestock selectively graze plants that have higher Na content and this may compensate for ingestion of herbage that is low in Na.

Potential for Na Deficiency in Livestock

Salt deficiency in livestock is expressed in behavior such as languor, debility and pica (licking or eating soil), licking sweat off other animals or drinking urine and usually is reflected in low productivity. Many responses of livestock to Na deficiency are complex. The British research mentioned previously showed that salt fertilization of perennial ryegrass (a Na accumulator) increased milkfat production from grazing dairy cows even when dietary Na levels were adequate. It appears that Na substituted for K and delayed senescence of plant tissues and this led to greater herbage intake.

We might anticipate Na deficiencies of grazing livestock in Kentucky in the absence of Na supplementation when the species being grazed is a non-accumulator of Na, is under heavy K fertilization, is in monoculture, or is associated with herbage or weed species that are also Na non-accumulators. This scenario may seem unlikely but it describes a weed-free stand of alfalfa, or an alfalfa stand with a complement of crabgrass or foxtail that is intensively grazed by beef cattle, or one grown on high K soils. Sodium deficiencies are less likely to occur in weedy stands or in alfalfa-grass mixtures where the sown grass is a Na accumulator (e.g., orchardgrass). Their penchant for salt also explains why cattle may selectively graze weeds before they graze alfalfa. Animal behavior experts do not regard such responses as examples of "nutritional wisdom."

At the University of Kentucky Spindletop research farm, we found that salt applied to alfalfa canopies increased herbage DM intake of dry beef cows by 8%, a response apparently not related to taste and measured within days of removal of free-choice salt supplements. We thought that this response may be caused by "cecal dilatation and torsion."

In a series of lamb and beef stocker grazing trials on alfalfa in New Zealand, poor animal growth rates were attributed to low Na content of alfalfa herbage DM (0.03 to 0.04% Na). Death rates of lambs on weed-free alfalfa reached over 20%, soon after lambs were exposed to alfalfa. Mortality of lambs receiving salt

supplements or grazing weedy alfalfa was near zero. The weed herbage that was preferentially grazed had over 10 times more Na than the alfalfa herbage. Postmortems revealed the death was not due to legume bloat but to "intestinal torsion." Essentially, the hindgut rotated more than 270°, cutting off the blood flow of the anterior mesenteric artery and causing massive hemorrhaging of the intestines ("red gut" syndrome). Hindgut of lambs that survived rotated less than 90°. Intestinal torsion of sheep appears similar to cecal dilatation and torsion, supposedly a rare problem of cattle and, possibly, to abomasal displacement frequently reported in dairy cattle. Intestinal torsions may further intensify Na deficiency by reducing the volume of the Na reservoir. Some US scientists implicate Na and K in the etiology of abomasal displacement. Thus, it is possible that "red gut syndrome" of sheep, cecal dilatation and torsion and abomasal displacement of cattle are expressions of Na status of animal diet, moderated by different morphology of the ovine and bovine gastrointestinal tract.

Implications

One implication of the salt economy of pasture species is obvious. In Kentucky, grazing beef cattle need access to salt supplements all year around. This is also the recommendation of the Forage Systems Research Center of the University of Missouri. Fertilization of pastures with salt cannot elevate the Na content of herbage of pasture species that do not accumulate Na sufficiently to meet animal Na needs. As an example of Na required by grazing cattle, consider the needs of a 1000 lb beef cow grazing alfalfa. In this case, she may eat 30 lb of herbage DM per day. If the Na content of alfalfa herbage DM was 0.04% (0.4 g Na/kg), she would ingest 0.012 lb of Na (5.44 g) from alfalfa herbage each day. Because livestock require 0.15 % Na in their diet DM (1.5 g/kg), this 1000 lb cow needs 0.045 lb Na (20.4 g). To provide her Na requirements, her diet should be supplemented with 0.033 lb Na each day. This is the equivalent of 0.084 lb of common salt per day (about 1.33 ounces).

Fertilization of both Na accumulating and non-accumulating pasture species with K is likely to depress herbage Na content and, possibly, induce or intensify Na deficiency in livestock. Potassium fertilization of grazed alfalfa may further increase the potential for K-induced Na deficiency in animals because most of the ingested herbage K is recycled back onto the field in urine. Grazed alfalfa fields should be soil-tested each year to determine the amount of K fertilizer needed.

Sodium-accumulating grasses (orchardgrass or ryegrass) are preferable to Na non-accumulating grasses (timothy) as companion grasses in alfalfa-grass mixtures.

Summary

Some concern has been raised in Kentucky that feeding "high K" hay or silage may cause a Na deficient diet in dairy herds. At the current time, no such questions have been raised concerning Na deficiency in beef herds. This probably is due to alfalfa being much less used in diets of beef herds, and the fact that beef herds are grazed on pasture while dairy herds are kept in drylots for confined feeding.

Producers of alfalfa hay and silage should not "over-fertilize" alfalfa fields either with commercial fertilizers or with animal manures. Annual soil testing is the best way to determine whether K fertilization is needed. The best way to reduce the potential for Na deficiency in animal diets is to provide supplemental Na in mineral mixes or as common salt to dairy and beef herds. This is of particular importance where alfalfa is a major component of the animal diet.

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Table 1. Common Grassland Species Used in Kentucky Agriculture Classified According to their Na Uptake.

Species that accumulate sodium	*Species that do not accumulate sodium*
Perennial ryegrass	Sorghum
Annual ryegrass	Timothy
Prairie (rescue) grass	Alsike clover
Birdsfoot trefoil	Red clover
Turnips, kale	Alfalfa
White clover	Soybean
Orchardgrass	Maize
Bermudagrass	Crabgrass

Table 2. Typical Ranges of Sodium Found in Herbage Dry Matter.

Plant Species	*Average Na % DM*	*Range Na % DM*
Annual ryegrass	0.11	0.02 to 0.35
Perennial ryegrass	0.42	0.11 to 0.87
Orchardgrass	0.51	0.04 to 1.01
Timothy	0.05	0.01 to 0.19
Prairie grass (Matua)	0.14	0.08 to 0.19
Tall fescue	0.29	0.06 to 0.69
Bermudagrass	0.03	0.01 to 0.09
Sudangrass	0.01	Trace to 0.01
Maize	0.03	0.02 to 0.03
Alfalfa	0.04	0.02 to 0.08
Red clover	0.09	0.02 to 0.16
White clover	0.11	0.01 to 0.35