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## IMPORTANCE OF SALT IN DIGESTION AND ABSORPTION OF NUTRIENTS

by

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### INTRODUCTION

Sodium and chloride are essential for numerous processes in the body including the regulation of osmotic pressure and acid-base balance. Both sodium and chloride also play important roles in the digestion and absorption of several nutrients from the gastrointestinal tract. Absorption of glucose and most amino acids from the small intestine requires an adequate supply of sodium. In cattle, magnesium absorption from the rumen is dependent on sodium. Chloride is necessary for the production of hydrochloric acid in the stomach of simple stomach animals and the abomasum of ruminants. Hydrochloric acid is required for the digestion and absorption of many nutrients.

Most feeds are deficient in sodium. Salt is the cheapest and most common source of sodium and chloride in animal diets. A low intake of salt can reduce nutrient absorption resulting in reduced growth and efficiency in animals.

### SODIUM AND MAGNESIUM ABSORPTION IN RUMINANTS

In cattle and other ruminants magnesium absorption occurs primarily from the rumen. Magnesium absorption from the rumen occurs by a process that is dependent on sodium. A low absorption of magnesium in ruminants can result in a disorder called grass tetany or grass staggers.



Grass tetany occurs primarily in lactating cows and is caused by low blood magnesium concentrations. Initial signs of grass tetany in cows include nervousness, reduced feed intake, and muscular twitching around the face and ears. Animals are uncoordinated and walk with a stiff gait. Within a matter of minutes to a few hours cows often collapse to the ground and

go into convulsions. This condition is of major economic importance because most animals

showing signs of grass tetany die within a short period of time, unless treated intravenously or subcutaneously with a magnesium solution. Grass tetany is most common in mature lactating cows grazing lush spring pastures or being fed harvested forages low in magnesium. With spring pastures grass tetany is usually more related to low availability (or absorption) of magnesium rather than low forage magnesium levels.

Early studies indicated that pastures low in magnesium and sodium and high in potassium were associated with the occurrence of grass tetany in cows (Butler, 1963). Lush green pastures in the spring generally contain 3 to 4% potassium but very low levels of sodium (often less than 0.05%). Potassium is a required nutrient for plants, and potassium fertilizer has been applied to pastures in many areas to increase forage yield. However, potassium fertilization of pastures not only increases potassium levels in forage but reduces forage sodium concentrations (Paterson and Crichton, 1960).

Paterson and Crichton reported in 1960 that providing salt-free choice greatly reduced the incidence of grass tetany in dairy cows grazing pasture. Since that time the connection between salt and grass tetany has become clearer. A number of studies have demonstrated that high forage potassium concentrations reduce magnesium absorption (Suttle, 2010). Salt, by providing sodium, can increase magnesium absorption and also overcome some of the adverse effects of potassium. A close relationship exists between potassium and sodium in the rumen. A high intake of potassium increases potassium concentrations in the rumen but reduces sodium concentrations by increasing the absorption of sodium from the rumen (Khorasani and Armstrong, 1990). A high ratio of potassium to sodium interferes with the ability of sodium to enhance magnesium absorption. Increasing the intake of sodium reduces the potassium to sodium ratio in the rumen and can increase magnesium absorption. For example, supplementing salt to increase dietary sodium from 0.025 to 0.21% increased magnesium absorption from 22 to 35% in sheep fed a high potassium (3.3%) grass (Martens et al., 1987). In this study increasing sodium reduced the ratio of potassium to sodium in rumen fluid from 5.5 to 1.0.

A salt containing mineral should always be provided free choice to ruminants grazing pasture. Not allowing salt feeders to get empty is especially critical during the grass tetany season. In addition to an adequate supply of salt, a source of supplemental magnesium in the mineral supplement is also generally recommended to prevent grass tetany.

### **SODIUM AND PHOSPHORUS ABSORPTION**

A large portion of dietary phosphorus is absorbed from the small intestine using a sodium dependent transport system. For this system to transport phosphorus into the intestine, sodium must be transported at the same time. A recent study indicates that a low level of salt reduces phosphorus absorption in young pigs (Yin et al., 2007). Pigs in this study were fed a corn-soybean meal based diet that was supplemented with 0.1, 0.2, 0.3, 0.4, 0.5, or 0.6% salt. Absorption of phosphorus was much lower in pigs supplemented with 0.1 or 0.2% salt compared with pigs fed 0.3% salt or higher. Phosphorus absorption was 35.7, 39.3, and 53.3% in pigs supplemented with 0.1, 0.2, and 0.3% salt, respectively (Yin et al., 2007). Increasing salt above 0.3% in the diet did not result in further improvements in phosphorus absorption.

Pigs used in this study had an average body weight of 21 kilograms. The Nutrient Requirements of Swine (NRC, 1998) indicates that pigs between 20 and 50 kilograms require 0.10% sodium (equivalent to 0.26% salt). Results of this recent study suggest that 0.26% salt may not support maximum absorption of phosphorus. Maximizing phosphorus absorption is important because: 1) phosphorus is the most expensive macromineral added to swine diets and 2) there is considerable environmental pressure to reduce the amount of phosphorus excreted in animal waste.

### **SODIUM AND ABSORPTION OF PROTEIN AND ENERGY**

Glucose is the major energy source for nonruminant animals. Absorption of glucose from

the small intestine requires sodium. In addition to glucose, galactose is also present in dairy products. Galactose is absorbed by the same sodium requiring transport system as glucose. Protein consumed by animals is broken down by enzymes in the gastrointestinal tract to its constituent amino acids prior to absorption. Absorption of most amino acids requires sodium. Absorption of glucose, galactose, and many amino acids involve transporters in the small intestine that require sodium to be transported along with the sugar or amino acid.

A recent study in rabbits clearly demonstrates the importance of sodium in energy and protein digestion and absorption (Chamorro et al., 2007). Rabbits were fed a diet supplemented with 0 or 0.5% salt. The control diet was deficient in sodium (0.06%) but was considered adequate in chloride (0.27%). The addition of 0.5% salt increased the sodium level to 0.27% and the chloride level to 0.57%. Digestion of protein from the small intestine was lower (52.7 vs. 63.5%) in rabbits fed the low sodium diet. Disappearance of individual amino acids from the small intestine was also measured. Disappearance would indicate that the amino acid was absorbed or used by the tissue. Of the 17 amino acids measured, absorption of all of them, with the exception of phenylalanine, was lower in rabbits fed the low sodium diet. Energy digestibility from the entire digestive tract also was improved by adding 0.5% salt to the diet.

### **ROLE OF CHLORIDE IN DIGESTION**

Chloride is also important in the digestion and subsequent absorption of nutrients from feeds. While sodium is required for absorption of nutrients from the small intestine, chloride performs its primary role in the stomach. Chloride and hydrogen are secreted from the stomach and form hydrochloric acid. The hydrochloric acid secreted, following consumption of feed, reduces the pH in the stomach causing the release of various nutrients from feedstuffs. Hydrochloric acid is critical for protein digestion. Most digestion of protein and absorption of amino acids occur in the small intestine. However, hydrochloric acid activates pepsin, the enzyme that initiates protein digestion in the stomach, and modifies the structure of proteins so they are more susceptible to enzyme digestion in the small intestine.



Young pigs that have been weaned from milk and placed on dry feed have a high requirement for chloride. Pigs are generally weaned at approximately 3 weeks of age and the ability of pigs to produce hydrochloric acid appears to be limited until 4 to 5 weeks of age (Cranwell et al., 1976). When pigs are weaned from milk to dry feed, dried whey is usually included in their nursery diet for the first few weeks. Dried whey is an excellent source of sodium and chloride, and inclusion of 20% whey in the diet will meet NRC (1998) recommendations for sodium and chloride without adding any salt to the diet.

Studies conducted at Ohio State University indicate that pigs weaned at 22 to 23 days of age benefit from additional salt in their diets the first two weeks following weaning (Mahan et al., 1996; Mahan et al., 1999). In an initial study, pigs (initial body weight of 6.6 kilograms) were supplemented with 0, 0.20, 0.40, or 0.60% salt. The diet not supplemented with salt analyzed 0.20% sodium and 0.35% chloride, while the current NRC recommendations for pigs 5 to 10 kilograms in body weight is 0.20% for

both sodium and chloride. Supplementing salt to the diet improved gain and feed efficiency by approximately 20% during the first 2 weeks after weaning. Increasing the level of salt in the diet from 0.20 to 0.40 resulted in small increases in gain and feed efficiency. Pig performance was not further improved by increasing salt level above 0.40%.

Additional studies showed that the growth response to added salt in weaning pigs was largely due to increasing chloride in the diet (Mahan et al., 1996; Mahan et al., 1999). Increasing chloride above the NRC recommended level of 0.20% was found to increase protein digestion in weanling pigs. During the first 2 weeks following weaning 0.38 to 0.42% chloride was required to maximize protein digestion.

## **Summary**

Providing animals with adequate salt is critical for maximizing utilization of energy, protein, and some minerals. Sodium is required for absorption of glucose and most amino acids from the small intestine. Phosphorus absorption from the small intestine and magnesium absorption from the rumen of ruminants are reduced by a lack of dietary sodium. Chloride forms hydrochloric acid in the stomach, which creates an acidic condition in the stomach that initiates protein digestion and causes release of other nutrients from feedstuffs. A deficiency of either sodium or chloride can reduce animal performance by reducing digestion and absorption of essential nutrients.

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