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Absorption and Macromineral Interactions in Broiler Production: An Overview

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Abstract: In recent years nutrition advances made various terminologies were used to aid understanding of physiological process in broiler. Absorption and related terms are such as progress. Furthermore, broiler fed complete diets (supplemented by mineral pre-mix) in reared systems and it seems that not experience metabolic problems from mineral interactions. However, there are at least fifty interactions among twenty-seven elements; certain of them are more crucial to producers, but, most of them had little practical importance in broiler production. The common problems results in mineral interaction are widely known; however, knowledge concerning a problem and the practical application thereof are not always mutual. Consumption of needed quantities of mineral supplements cannot be guaranteed by every individual and, consequently, problems arising from interactions are still observed under field conditions. The broiler morbidity, mortality and even death will occur from imbalances and mineral interactions. Therefore, in this overview to have comprehensive sight on the subject of absorption, related terms were explain considerably and known and possible interactions between the macrominerals [Calcium (Ca), phosphorus (P), sodium (Na), chlorine (Cl), potassium (K), magnesium (Mg) and Sulfur (S)] were considered in broiler production and some recommendations were done. It well known that interactions are affected by source, species of the element, concentrations and proportions of every mineral in the diet, bird physiological state and which element is in excess.

Key words: Macromineral Interaction · Broiler Production

INTRODUCTION

True definition of terminology in biology would help to have very good sight from live process. Some conflictions have existed in digestion process terms in broiler. This problem is very obvious in mineral procedure. On the other hand, interactions between dietary nutrients get much attention in recent years [1, 2]. Minerals are critical in life because of more roles as enzyme cofactors, stabilizers of proteins, second messengers, regulators of acid-base balance and maintenance of cellular electrical potential. Historically, minerals have been individually studied and requirements determined. However, research has reported numerous interactions between minerals [3-6]. In broiler production, minerals requirements are expressed as the mean requirements of flock [7] so that nutritionists include a margin of safety which could unintended provide minerals interaction conditions. Otherwise, minerals are much more likely to interact than other nutrients due to their ability and tendency to form chemical bonds [6, 8].

Animal nutritionists would probably agree that all dietary nutrients are interrelated to some degree [1, 2] and that there is an optimal concentration for each nutrient in relation to the levels of all others to obtain the most efficient desired animal responses. The requirement for optimal nutrient concentrations is important within diet, the intestinal tract and at the cellular level [6]. While traditional reductionist approaches have revealed many aspects of mineral metabolism, but significant gaps still exist regarding mineral interactions. For example, it is clear that mineral-mineral interactions exist but we don't fully understand how they influence the absorption, excretion, storage and utilization of other elements. One important reason might be due to the minerals interactions being able to occur anywhere from the feed, intestine and

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cellular levels as well as incorrect terminology of mineral absorption. Therefore, this overview will explain some definition for digestibility terminology and will explain known and possible interactions, up to now, between macrominerals (Ca, P, Na, Cl, K, Mg and S) in broiler production.

Digestibility and Absorption: Simply analysing foodstuffs or supplementations for total mineral contents does not show how efficiently they will be reach on the cell surface, so it seems to be logical that one must focuses on mineral efficiently as forward stepwise with more precision. Therefore, digestibility, absorbability, metabolazable, utilizable and bioavailability of mineral could help to predicate real mineral which reach on the cell surface to various cell targets. Digestibility is defined as the amount of one mineral that disappear in the intestine or not excrete [9]. However, it is not show that how amount of mineral pass through intestinal mucosa. Thus, the amount of mineral which is absorbed and available to the body is called bioavailability. But it seems that this term must be corrected as 'mineral bioavailability for digestion', 'mineral bioavailability for absorption', 'mineral bioavailability for metabolazable' and 'mineral bioavailability for utilization'. But, this is a hypothesis and it warranted more researches in the future.

Mechanisms of Interactions: O'Dell [5] is defined the term "interaction" as "interrelationships among mineral elements as revealed by physiological or biochemical consequences". There are two major classes of interactions, synergistic and antagonistic [6]. There may be a direct interaction between elements in structural processes, or the result of simultaneous participation of elements at the active center of enzymes, interact with others through functions of the endocrine organs, expressing their effect on the metabolism of other minerals.

Antagonistic interactions are often expressed as a co-inhibition which may be two-way or multi-way. The antagonistic relationships can occur several ways within the gastrointestinal tract. The chemical reaction to form an insoluble complex, adsorbed onto the surface of colloidal particles, competition between minerals to absorption, inhibitory effects on intestinal wall processes or on the activity of some enzymes which interfere with the breakdown of feed ingredients and liberation of inorganic ions for absorption. Also, mineral interactions may be multiple (e.g. sulfur-copper-molybdenum) or one by one (calcium and phosphorous). Moreover, interactions may be one-way, in which the reverse effect is not observed or reciprocal interrelationships in which both elements influence the metabolism of the other. Ultimately, the minerals interactions were proposed based on chemical and physical properties of the elements [10]. They propose that ions with similar ionic size or electron configurations of outer orbitals are likely to interact competitively.

Calcium: Calcium (Ca) is the fifth most abundant element in the earth's crust and the most abundant cation in the animal body. Approximately 99 percent of the calcium in the animal body is found in the skeleton, with the remaining 1 percent widely distributed in various soft tissues. Calcium has a very close interrelationship with phosphorus and vitamin D [11].

There are many factors that influence the absorption, distribution and excretion of Ca [12]. The level of dietary phosphorus, the ratio of calcium to phosphorus and the level of dietary vitamin D are the most important. Calcium is absorbed from the intestine by an active transport mechanism. Vitamin D is required for this active transport and there is strong evidence that a vitamin D-induced calcium-binding protein, calbindin, plays a role [13]. There is evidence that the active transport of calcium is regulated to meet the calcium needs of the body and is most active when dietary calcium is restricted or when the needs are great [14]. The role of calbindin in facilitating absorption of calcium according to supply and demand is well illustrated by data for fast- and slow-growing chicks given diets varying in calcium [15]. Calcium is also absorbed by passive ionic diffusion, a process that may be vitamin D dependent. The active process is believed to occur mainly in the proximal duodenum and the passive process in the remainder of the small intestine [16].

Calcium-Phosphorus: One of the first relationships between macrominerals was observed between calcium and phosphorus. Considerable investigates have been conducted with these minerals since a major interaction between them is quite evident under both laboratory and practical feeding considerations. However, optimum broiler performance is linked very closely with calcium and phosphorus levels in the diet. Broilers require fairly narrow calcium to phosphorus ratio usually no wider than 2:1. It has been reported that excess Ca can cause the formation of insoluble Ca-phosphate salts, resulting in decreased P availability [3]. The roles of calcium and phosphorus together in the many reactions are clear and their interaction is depends on cholecalciferol level [17].

Calcium-Magnesium: Pharmacological interactions of calcium and magnesium have been recognized for nearly a century. Moderate doses of Mg^{2+} produce anesthesia and loss of reflexes, which are counteracted by small quantities of Ca^{2+}. Injection of Mg^{2+} increases calcium excreta, but the effect of magnesium ingestion on calcium metabolism is less clear and of little or no practical significance, in as much as excessive dietary levels of magnesium is unlikely to occur under normal circumstances.

Nutritionally, excess dietary calcium decreases magnesium absorption and status in animals [18, 19]. Magnesium deprivation decreases growth rate and leads to soft-tissue calcification. Both signs of deficiency are aggravated by high dietary calcium levels in the rat, dog and pig. The detrimental effect of high calcium relates to decreased magnesium absorption [20] and this is reflected in depressed growth rate. While animals studies (rat, dog, pig) clearly show a calcium-magnesium interaction, they should be put in perspective relative to broiler nutrition.

Phosphorus: The element phosphorus (P), although widely distributed in nature, never occurs in the free state. It combines spontaneously and vigorously with oxygen, combines readily with water to form orthophosphoric acid [21]. Phosphorus was first recognized as an essential constituent of bones [22]. It probably plays a more varied role in the chemistry of living organisms than any other single element.

Broilers are dependent on the presence of phytases found either in the ingredients themselves or in intestinal secretions to utilize phytate phosphorus. Undegraded phytate can be extensively converted to insoluble mineral-phytate complexes before the site of phosphorus absorption are reached, thus lowering the amount absorbed. Older have a greater ability than younger one to digest phytate. Phosphorus in the form of orthophosphate is absorbed chiefly in the upper small intestine, the duodenum. The amount absorbed is dependent on source, calcium to phosphorus ratio, intestinal pH, lactose intake and dietary levels of calcium, phosphorus, vitamin D, iron, aluminum, manganese, potassium, magnesium and fat [23]. As it is obvious in the case of most nutrients, the greater the need the more efficient the absorption.

Phosphorus-Magnesium: Consumption of excess phosphorus as well as of calcium accentuates the signs of magnesium deficiency and decreases magnesium absorption in animal (rat, dog, pig) [19, 20]. The effect of calcium and phosphorus seems be additive. But these observations probably have little practical significance in broiler nutrition.

Vitamin D and calcium are essential for proper phosphorous functioning involved in virtually all physiological chemical reactions. Excess dietary phosphorus and to a lesser extent, calcium have an antagonistic effect on absorption of manganese in swine, poultry and dairy calves [24]. Dietary phytate has also been reported to inhibit absorption of manganese [25].

Sodium Chloride: It is convenient to consider sodium (Na) and chlorine (Cl) together because of their related functions and requirements in the animal body and their interactions with each other and because sodium and chlorine form common salt, the cheapest, most palatable and most freely used of all mineral supplements. Interest in the biological effects of sodium chloride is high because of its importance in nutrition and concern about salt deficiencies and excesses, its relationships with potassium and other minerals. Sodium and chloride ions are absorbed by broilers principally from the upper small intestine. Approximately 80 percent of the sodium and chloride entering the gastrointestinal tract arises from internal secretions such as gastric fluids, bile and pancreatic juice. Thus, large variations in salt intake have relatively small effects on the total amount of sodium and chloride entering the gastrointestinal tract. Both sodium and chloride are readily absorbed, but each element can influence the absorption of the other [24]. Sodium uptake from the gut lumen is achieved by coupling to glucose and amino acid uptake via cotransporters and also by exchange with hydrogen ions (H^+) via a Na-H antiporter, intracellular H^+ being generated by carbonic anhydrase in the enterocytes of the gut mucosa [26]. Absorption of chloride from dietary and endogenous (gastric secretions) sources is achieved by exchange for another anion, bicarbonate (HCO_3^-), also generated intracellularly by carbonic anhydrase and secreted into the gut lumen.

Sodium Chloride-Potassium: There has been long standing interest in the nutritional relationship between sodium and potassium ions. Meneely and Battarbee [27] have reviewed the interrelationship between sodium and potassium. It postulated that high potassium intake increases the requirement for sodium.

Potassium: Potassium (K) makes up 2.6 percent of the earth's crust. It is found mainly within the cells of the body and is a dietary essential for broilers.

Dietary sources of potassium are highly soluble and almost completely absorbed. Potassium is absorbed mainly from the upper small intestine, but some absorption also occurs in the lower small intestine and large intestine [12]. Absorption from the intestine appears to be by simple diffusion.

Potassium-Magnesium: It seems that high dietary levels of potassium interfere with magnesium absorption, ingestion of such levels may predispose broilers to magnesium deficiency.

Magnesium: Magnesium (Mg) is an alkaline earth metal which ranks eighth in abundance in the earth's crust. Approximately 60 percent of total body magnesium is located in bone, where the function of the element is not known [28]. About one-third of that in the bone is combined with phosphate and the remainder is adsorbed loosely on the surface of the mineral structure. Magnesium occur intra- and extracellularly in soft tissues. Magnesium is absorbed from the small intestine [29].

Magnesium-Calcium-Phosphorus: It explained above that magnesium is related to the Ca and P [6]. Increased calcium and phosphorus levels in the diet have been shown to increase the magnesium requirement of chicks [4]. Addition of 0.2 or 0.4 percent magnesium tended to overcome the adverse effects of deficiencies of both calcium and phosphorus in chicks [30]. However, when 0.6 percent magnesium was supplemented, growth and bone mineralization were adversely affected regardless of the calcium and phosphorus levels. The interrelationships between magnesium and calcium and phosphorus suggest that hormones and enzymes involved with bone metabolism may be related to magnesium metabolism. There can be a competition among ions for the active centers in enzyme systems as occurs with magnesium and manganese in alkaline phosphatase.

Sulfur: Sulfur (S) is required for the formation of the many sulfur-containing compounds found in essentially all body cells. The major terrestrial source of sulfur is mineral sulfide, which is converted to inorganic sulfate by weathering and to organic sulfur by microbial action in the soil [31]. Inorganic sulfate is taken up by higher plants and converted to organic sulfur in the form of the sulfur-containing amino acids, which in turn serve as an organic sulfur source for broilers. Broilers have few, if any, intestinal assimilatory bacteria to form organic sulfur from inorganic sources and, therefore, must rely upon exogenous sulfur amino acid sources for their requirement of organic sulfur. Broilers can utilize inorganic sulfate in the formation of sulfate esters required in the synthesis of mucopolysaccharides. Absorption by active transport of the inorganic sulfate takes place in the small intestine, especially the ileum [32]. Organic forms of sulfur are readily absorbed in the small intestine. The absorption mechanism is very efficient.

Sulfate-Copper-Molybdenum: An interaction of major importance which is well-known in ruminant animals is among copper, molybdenum and sulfur. Dick [33] indicated that inorganic sulfate was important in the copper molybdenum. Both the inorganic and organic form of sulfur was effective and total dietary sulfur was the appropriate value to consider in calculations. Molybdenum becomes less dependent upon sulfur for its adverse effect as the level of dietary molybdenum increases. Sulfur also exerts an independent effect on copper absorption through the formation of insoluble copper sulfide (CuS), in gastrointestinal tract. A combination of dietary molybdenum and endogenous sulfide results in formation of tetrathiomolybdate or oxythiomolybdates, which react with copper to form insoluble complexes [34]. It is not a macro-macro interaction but its importance made to include in this section. However, this three-way interaction might exist in broiler production.

RECOMMENDATIONS AND CONCLUSION

The hypothesis “mineral bioavailability” for various cell targets in digestion process must take in accounts to have real perception from completion of each mineral. It need to keep in mind that life is a dynamic, complex process and consequently basic mineral requirements and interaction might constantly shifting. In this overview, only macromineral in diets was discuses and water not included. Also, it is clear that macrominerals interactions exist but we don’t fully understand how they influence the absorption, excretion, storage and utilization.

It seems that in the future, the majority of minerals interaction research would have to center on the metabolic roles of the elements making use of numerous molecular biology techniques rather than feeding trials and importantly on mineral cellular level interactions.

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