IJFANS INTERNATIONAL JOURNAL OF FOOD AND NUTRITIONAL SCIENCES

ISSN PRINT 2319 1775 Online 2320 7876

Research paper © 2012 IJFANS. All Rights Reserved, UGC CARE Listed (Group -I) Journal Volume 11, S Iss 4, 2022

A Review of the Role of Zinc, Manganese, and Copper in the Metabolic Processes That Take Place in the Rumen and in Immune Function

Dr. Jyoti Batra[1], Dr. Juhi Aggarwal[2], Dr. Eram Hussian Pasha[3], Rana Sakshi Singh[4]

[1] Professor, Department of Biochemistry, Santosh Medical College and Hospital,
Santosh Deemed to be University, Ghaziabad, Uttar Pradesh, India.
[2] Professor & Head, Department of Biochemistry, Santosh Medical College and Hospital,
Santosh Deemed to be University, Ghaziabad, Uttar Pradesh, India.
[3] Assistant Professor, Department of Biochemistry,
Santosh Medical College and Hospital, Santosh Deemed to be University,
Ghaziabad, Uttar Pradesh, India.
[4] MBBS Student, Batch 2021-22, Santosh Medical College and Hospital,
Santosh Deemed to be University, Ghaziabad, Uttar Pradesh, India.
Email- [1] dean.research@santosh.ac.in, [2] jaggarwal38@gmail.com,
[3] pasha.eram7@gmail.com, [4] ranasakshi2604@gmail.com

ABSTRACT:

Trace minerals are dietary elements that are required by the organism in minute levels. The amount of trace minerals required by beef cattle diets ranges from 0.10 to 50.0 mg/kg dry matter [1]. These essential traces of minerals are all essential for the biochemical activities that take place within the body to ensure healthy growth and maintenance of the body. For instance, copper is required for the proper operation of superoxide dismutase and the elimination of harmful by products from metabolic pathways [2]. The elimination of these harmful by products makes it possible for metabolism to run normally, unhindered by the potentially destructive effects of oxygen free radicals. Zinc, an essential trace mineral for the proper functioning of enzymes, has a role in the regulation of processes such as the generation of nucleic acids, the metabolism of carbohydrates, and the synthesis of proteins; as a result, it provides a solid foundation for the process of development [3]. The immune system is a part of the host's defence against destructive forces, whether they come from outside the body, such as bacteria, viruses, and parasites, or from within the body, such as malignant cells or cells that produce autoantibodies [4]. These destructive forces can come from either the outside or the inside of the body. Innate immunity, also known as the non-specific immune system, and adaptive immunity, sometimes known as the specific immune system, are the two components that make up this system [5]. In this review study, an attempt was made to review the effects of mineral supplements on Rumen Metabolism, as well as the effects on Immune Function in a variety of animal species.

Keywords: Dietary Trace Mineral, Rumen Metabolism, Immune Function, Performance, Reproductive and Rumen Fermentation

INTRODUCTION:

The International Union of Pure and Applied Chemistry [6] has sanctioned the use of 111 different chemical elements as legitimate in today's modern chemistry. Approximately fifty of them have been recognised as being beneficial to maintaining a normal health condition in mammals. Of these, 93 are considered to be naturally occurring in the environment. In addition to the six fundamental elements—carbon, hydrogen, nitrogen, oxygen, and phosphorus—that compose nucleic acids, proteins, carbohydrates, and lipids—and, as a result, the majority of living matter [7], the nutritional needs of superior animals call for the presence of a great number of other elements. Minerals required in relatively large quantities (g/d) are designated "macro" minerals.

On the other hand, minerals that are required in levels of mg or g are referred to as "micro" or "trace" minerals [1]. According to the functions they perform in the body, minerals are typically divided into the following four categories:

- Structural: minerals that constitute structural components of the body's organs and tissues, such as calcium, phosphorus, magnesium, fluoride, and silicon in the bones and teeth, and phosphorus and sulphur in the proteins that make up the muscles.
- On a physiological level, minerals that are present in body fluids and tissues in the form of electrolytes and play a role in the regulation of osmotic pressure, acid-base equilibrium, membrane permeability, and the response of tissues to stimuli (e.g. Na, K, Cl, Ca and Mg in blood and cerebrospinal fluid).
- Catalytic: minerals that function as catalysts in enzymatic systems, as integral compounds in the structure of metalloenzymes, or as cofactors that are necessary for the activation of enzymes (e.g. Fe, Cu, Zn, Mn, and Se involved in cytochromes, ceruloplasmin, carbonic anhydrase, pyruvate carboxylase, and glutathione peroxidase, respectively).
- Regulatory minerals, which are minerals that play a role in the regulation of cell replication and differentiation (e.g. Ca, in signalling transduction; Zn, in DNA transcription).

This classification, on the other hand, is arbitrary and does not constitute an exclusive set of categories because a single constituent can serve more than one function [8].

In an ideal world, the mineral intake of cattle should be adequate to enable the preservation of body stores and to offer acceptable concentrations in edible products.

On the other hand, there are situations in which drinking water can be an extraordinarily rich source of minerals, and these minerals can occasionally be the cause of mineral toxicity [9]. The achievement of an adequate supply of minerals is made particularly difficult by the fact that the requirements for the majority of minerals are not constant but rather are influenced by physiological factors such as genetics, age, sex, type of production (maintenance, growth, reproduction, and lactation), and level of production [10].

THE AMOUNT OF MINERALS THAT ARE ACCESSIBLE TO ANIMALS:

The evaluation of feedstuffs and mineral supplements for the host animal is contingent not only on the mineral content of the sources but also on the potential availability of the minerals, absorption of the minerals by the gastrointestinal tract, and utilisation of the minerals by the animal tissues [11]. However, the potentially absorbable fraction of a mineral is significantly affected by a number of factors. These factors include the age and species of the animal, the intake of the mineral in comparison to the amount that is required, the chemical form of the mineral, and the amount and proportions of other dietary compounds that are involved in specific interactions with the mineral [12]. Trace minerals in the form of inorganic salts, most frequently oxides, chlorides, sulphates, and carbonates, are frequently added to the diets of livestock as a dietary supplement. In the most recent years, there has been a substantial amount of interest in the utilisation of organic trace elements in the diets of ruminants [13]. Organic trace minerals can be obtained in the United States in one of the following forms, as stated by the Association of American Feed Control Officials [14]:

- Metal Proteinate: the product that results from the chelation of a soluble salt with amino acids and/or partially hydrolyzed protein; for example, copper proteinate, zinc proteinate, cobalt proteinate, and manganese proteinate are all examples of metal proteinates.
- Metal Amino Acid Chelate: the product that results from the reaction of a metal ion from a soluble metal salt with amino acids with a mole ratio of one mole of metal to one to three (preferably two) moles of amino acids forming coordinate covalent bonds. This reaction takes place in the presence of a mole ratio of one mole of metal to one to three (preferably two) moles of amino acids. For instance, copper-L-lysine sulphate is the sulphate salt of a 2:1 molar ratio of copper and copper-L-lysine. Similarly, copper methionine bisulfate is the salt that is produced when the molar ratio of copper to DL-methionine is equal to one. In addition to chelates for macro minerals like calcium and magnesium, there are a few other types of metal amino acids that are sold commercially. These include zinc amino acid chelate, copper amino acid chelate, and manganese amino acid chelate.
- Metal Amino Acid Complex — This refers to the end product that is created when a soluble metal salt is complexed with an amino acid. Metal complexes that are available for purchase include zinc-methionine, zinc-lysine, manganese-methionine, iron-methionine, and copper-lysine.
- Metal Polysaccharide Complex: the product that results from complexing a soluble salt with a polysaccharide solution that is declared as an ingredient in the formulation

(for example, Cu polysaccharide complex, Zn polysaccharide complex, etc.). This product is referred to as a metal polysaccharide complex.

[9] and [15] established that for chelation to be effective, the chelating agent should have a stronger stability for the metal than the metal binding substances in feed, but a smaller stability constant than the tissue system where the metal is required. This is despite the fact that the effectiveness of organic minerals for ruminants has been strongly criticised. In addition, the absorption process of metal ions may also be affected by other parameters such as metal ion equilibria, kinetic factors, pH gradients, and redox equilibrium (in the case of redox active metals such as Cu2+) [16]. A number of research have been carried out to investigate the positive effects that incorporating organic sources of minerals can have on the level of productivity achieved by ruminants.

However, in many instances a combination of many organic substances has been employed, which makes it impossible to determine which one is responsible for the effects that have been observed, as will be explained further on.

This review's objective is to investigate the factors that influence the bioavailability of zinc, manganese, and copper in the gastrointestinal system, all of which have an effect on the mineral status of the host animal. In addition, the effects of zinc, manganese, and copper on the physiology of the rumen are discussed.

ZINC:

3.1. The Role of Dietary Factors in Zinc's Interactions

The percentage of zinc in the diet that is absorbed by ruminants is shown to decrease as the amount of zinc in the diet increases, according to early studies found in [17]. When rats were fed increasing quantities of dietary zinc, ranging from 0 to 8400 ppm, researchers observed that endogenous zinc loss increased linearly throughout the course of the experiment [18]. In a trial with developing pigs that were given 67 zinc, the addition of phytase enhanced zinc absorption, but it also resulted in higher endogenous faecal loss [19]. This finding was consistent with previous research. When the amount of zinc in a person's diet was cut from 85 to 12 mol/d, researchers discovered that individuals' urine and faecal zinc excretion dropped by 48 and 46 percent, respectively, at the same time.

In spite of the fact that dietary levels do seem to play a role, it appears that the requirement for zinc is determined by other aspects of food. On the other hand, not all of the factors and interactions that have an effect on zinc's bioavailability have been thoroughly investigated [20]. According to [21], the presence of organic chelating agents and the interaction with metallic ions are the two primary dietary variables that have a significant impact on the bioavailability of zinc, with copper and calcium being the most significant antagonists.

3.2. The Importance of Zinc in the Fermentation Process in the Rumen

When rumen fluid was treated with extra zinc in the form of ZnCl2 or ZnSO4, earlier investigations that were published in [22] demonstrated that in vitro microbial protein synthesis increased along with a reduction in the concentration of NH3-N. According to the authors of the study, this response can be attributed to a property of zinc that increases the activity of enzymes produced by microbes. Nevertheless, additional research from [23] demonstrated that the behaviour of microbial populations in the rumen changed in response to the presence of Zn. Although protozoa effortlessly assimilated zinc and demonstrated tolerance to high zinc concentrations (25 g/mL), cellulose breakdown from rumen bacteria was severely inhibited, as was the activity of bacterial urease. According to the findings of [24], the addition of 5 g Zn/mL of rumen fluid increased cellulose digestion by 24%, whereas the addition of 20 g/mL of Zn decreased it by 31%. These findings are in partial accord. According to the findings of study [25], low supplementation levels (10 to 15 ppm Zn in incubation fluid) were able to prevent in vitro urea hydrolysis and postpone ammonia accumulation. In a similar manner, the molar proportion of propionate was increased when zinc was added in vivo at a concentration of 250 ppm Zn on a dry matter basis. This resulted in a decrease in the ratio of acetate to propionate, and rumen ammonia was reduced as a result of the inhibition of microbial urease. On the other hand, when zinc was added to reach a concentration of 470 ppm on a dry matter basis, a tendency toward decreased DM digestibility was seen. In addition, [26] discovered that total VFA decreased when zinc was given to steers in the form of zinc methionine or zinc glycine rather than zinc sulphate at concentrations that were closer to values that are physiologically significant (20 ppm). Within the same body of research, Zn methionine was found to enhance the molar proportion of propionate while simultaneously decreasing the molar percentage of butyrate. This led to a reduction in the ratio of acetate to propionate. According to the findings of the scientists, supplementation with zinc methionine may cause changes in ruminal fermentation.

An alternative mechanism is proposed by [27], which found that the addition of 50 g/mL of Zn to in vitro incubations decreased cellulose digestion at 24 h, but not at 48 h. This resulted in an overall decrease in the rate, but not the extent, of digestion. While these differences can be partially explained by the dose of Zn and the fermentation substrate used by the different authors, [27] found that the addition of Zn to in vitro incubations decreased cellulose digestion at Since heavy metal salts can precipitate and denature soluble proteins and enzymes, the authors draw the conclusion that the initial drop in cellulose digestion could be attributable to a direct action of zinc on the inactivation of bacterial cellulase.

However, there is a possibility that there is sufficient cellulase activity present to counteract the unfavourable consequences of high Zn concentrations. In addition, the buildup of zinc in bacterial walls [28] may have an effect on the adherence of microbial cells to cellulose particles. This adhesion is a limiting stage in the fermentation of cellulose, as was determined in a previous study [29].

3.3. The Amount of Zinc That Can Be Obtained From Organic and Inorganic Sources

There is information from the scientific community that suggests organic forms of zinc are digested differently than inorganic sources. Zn was more effectively maintained in lambs and heifers when it was administered as Zn methionine rather than ZnO, according to four successive tests carried out by [20]. However, the improvement that was seen was not attributable to increased absorption but rather to a decreased urine Zn excretion in rats that received Zn methionine, and only minimal improvements in blood parameters were detected during this study. Organic or inorganic zinc supplementation did not have an effect on the concentration of serum enzymes (alkaline phosphatase, glutamate oxaloacetate transaminase, glutamate pyruvate transaminase, and super oxide dismutase) or the mean concentrations of various serum vitamins (retinol, -carotene, and -tocopherol), nor did it have an effect on the levels of (triiodothyronine, thyroxin, insulin and testosterone).

In addition, blood values from supplemented groups did not differ from those of controls that did not get supplements. Steers that were given either ZnSO4 or Zn amino acid complex had identical levels of zinc in their livers and plasmas, according to the results of a study that compared the two treatments [22]. In spite of this, it is possible that confounding factors are to blame for these findings, considering the disparities in mineral status that existed between the animals at the start of the trial. There was no significant difference identified in the plasma zinc concentration of steers that were given ZnSO4, Zn methionine complex, or Zn glycine, which is in partial agreement with the findings of [26]. Zn glycine led to higher levels of zinc in the liver, despite the fact that considerable variability prohibited researchers from collecting differences in the amount of zinc that was absorbed or retained.

In contrast, a study that used both organic and inorganic zinc reported higher quantities of zinc in the plasma of supplemented beef steers than in controls, regardless of the source of the zinc. [33] It is interesting to note that animals given an implant containing estradiol benzoate and testosterone propionate gained more weight when the mineral zinc was given in the form of zinc sulphate (ZnSO4) as opposed to zinc propionate (Zn propionate) [23]. When the sulphate forms of copper, zinc, manganese, and cobalt were replaced with the organic varieties of these minerals in a major production study that included 250 dairy cows, the researchers found that there was just a suggestion of an increase in milk output. The concentration of minerals in the liver was not influenced by the source of the minerals, however taking organic minerals as a supplement led to a rise in milk solids and a reduction in the incidence of sole ulcers [24]. In another large-scale investigation that was carried out on 573 dairy cows [25], feeding 75% of the required amount of zinc as zinc methionine obtained the same level of zinc concentration in the liver as supplying 100% of the required amount of zinc as ZnSO4. The authors argue, on the basis of the lack of differences in health and productive performance, that mineral content of liver is not an accurate predictor of how cows will respond to various sources and quantities of trace minerals. According to [24], the presence of zinc, manganese, and copper in the liver is not a reliable predictor of the body's trace mineral condition. According to, the purported advantages of organic sources of zinc on zinc availability that were found in research carried out in monogastrics cannot be replicated in ruminants due to the fact that the phytic acid that acts as a primary barrier to zinc absorption is completely digested in the rumen. Zinc is absorbed according to the needs of the animal, and homoeostasis in ruminants is achieved primarily by controlling the amount of zinc that is absorbed by the intestines [26]. This adds an additional layer of complexity to the process of determining how much zinc is available from various sources.

MANGANESE:

4.1. The Interaction of Manganese with the Factors Involved in Dietary

According to the [1], there is a lack of precise data regarding the needs for the maintenance of Mn in dairy cattle. However, it is known that the coefficient of intestinal absorption for manganese in adult cattle is as low as 1% of ingested manganese or even lower (17; 20), but the absorption in young calves is significantly higher [17]. In spite of the prevalent notion that animals have a low capacity for manganese absorption, [8] suggested that this situation may be partly a reflection of the substantial surplus of manganese provided by the majority of practical rations. This theory was supported by the finding that higher coefficients of absorption were obtained when animals were fed diets that were marginal in manganese. Because of this, the [1] utilised a cautious coefficient for Mn absorption, which was set at 0.75%. According to [19], the coefficient of Mn absorption in dairy cows is 0.54%. This finding is in keeping with previous research. Because Mn deficiency is not regarded to be a major concern in ruminants [20], the research of dietary variables that influence Mn bioavailability has received little attention. This is mainly because Mn deficiency is not thought to be a major problem. In addition, the majority of the material that is now accessible was derived from studies conducted using monogastric animals.[20] found that chicks fed a meal containing 12 ppm of virginiamycin had a 10% and 13% increase, respectively, in the amount of manganese found in their kidneys and bones. In a subsequent investigation [21], the incorporation of lincomycin at a concentration of 4 ppm led to increased levels of manganese in the bone. However, despite the fact that virginiamycin and other antibiotics are currently employed as feed additives for ruminants [22], the effect that these additions play in the manganese absorption of cattle is unknown. According to, the intestinal absorption of manganese is negatively impacted by the quantities of calcium and phosphorus that are present in the diet. A study with similar findings was conducted by [24], which discovered a reduction in manganese content by 45% in the tibias of chicks that were given an excessive amount of calcium and phosphorus. However, additional evidence provided by [25] indicated that while P has a negative effect on Mn absorption, no deleterious effects on Mn metabolism are obtained with excess of dietary Ca. On the other hand, it is difficult to differentiate between the effects of Ca and P because diets are typically enriched with both minerals in order to maintain a Ca:P physiological ratio [19].

There have been no publications that relate the absorption of manganese to the nature of the fodder consumed by ruminants; nonetheless, phytate and fibre are recognised to be the primary antagonists in monogastric species such as humans and pigs [26,27]. Both phytates and fibre undergo decomposition in the rumen as a result of the action of microbes [28]. As a result of this, [9] implies that the absorption of manganese in ruminants may not be influenced by the presence of phytates, as it is higher than what is often reported for monogastrics.

4.2. The Impact of Manganese on the Fermentation Process in the Rumen

There is not a lot of information available about the part that Mn plays in the fermentation process in the rumen. [29] reports that there is a marginally stimulating effect that Mn has on the activity of urease. When Mn was introduced to the incubations at a level of 100 ppm, [25] found that there was a 6% increase in IVDMD. When Mn was absent from the in vitro incubations, the prior research [20] discovered a reduction in the amount of cellulose that was digested. On the other hand, it was reported in [24] that cellulose digestion reached its highest point at Mn concentrations ranging from 10 to 20 ppm, but it was entirely stopped when Mn was introduced at concentrations of 300 ppm. Using 54 Mn, [21] and [22] showed that the accumulation of Mn was greater in the bacterial cell walls of the rumen than in the cytoplasm, and that the uptake of Mn was comparable in bacteria and protozoa. However, the biological consequences of this result have not been proven. [23] gave meals consisting of 13–45 mg of manganese per kilogramme of dry matter to ram lambs for a total of 84 days. Although the total number of rumen bacteria was unaffected by the presence of manganese, the proportion of large rumen bacteria (defined as those with a diameter ranging from 12.9 to 16.2 m) was found to be lower in the diets with the lowest manganese intake and highest in the diets with the highest manganese intake (30 mg/kg). This may be of special importance due to the fact that large rumen bacteria contain a greater amount of protein than small rumen bacteria [24]. However, despite this change in the populations of microorganisms, there was no influence of Mn found on the digestibility of DM. [25] revealed that sheep consuming a diet high in fibre and low in protein may respond to Mn supplementation in excess of 36 micrograms per gramme of dry matter (DM), however Mn requirements of the rumen microorganisms may be enhanced by the ingestion of low quality roughages. On the basis of the findings from in vitro research, [26] suggests that the optimal content of Mn in the diet may be as high as 120 g/g DM. This is in agreement with the previous statement.

4.3. The Amount of Manganese That Can Be Obtained From Organic and Inorganic Sources

The purpose of mineral supplementation is to increase the biological availability of the mineral or minerals that are the focus of the treatment [27]. Biological availability can be defined as the extent to which an ingested element is absorbed and can be utilised in the animal's metabolism. There is currently a variety of manganese, or Mn, available as a supplement for the diets of animals. Inorganic sources such as manganese carbonate (MnCO3), hausmannite (Mn3O4), manganese oxide (MnO), manganese dioxide (MnO2), manganite (Mn2O3), manganous chloride (MnCl24H2O), and manganese sulphate (MnSO4) are among the most often utilised [18-20]. On the other hand, Mn-methionine, Mn-proteinate, and Mn-polysaccharide are all examples of sources of Mn that fall under the category of "organic" [22] [21-23]. Unfortunately, there have only been a few number of studies done that compare the relative bioavailability of different sources of manganese in ruminants that were administered physiological doses of manganese [64]. According to [25], certain chelates and complexes have the potential to boost the mineral bioavailability beyond that of soluble inorganic forms. This was later demonstrated by [22] in lambs through a comparison of Mn-methionine and MnO. Mn-methionine was compared to MnSO4 in the same investigation, however the researchers found no significant differences between the two.

In a study that was very similar, [26] looked at the bioavailability of manganese in broilers and compared it to various organic sources and MnSO4. Because of their capacity to withstand Ca antagonisms throughout the digestive process, the authors came to the conclusion that only organic sources of manganese with a chelation strength of either moderate or strong are capable of providing higher relative bioavailabilities. In addition, research carried out on female chicks shown an increase in the amount of manganese retained from a Mn-methionine chelate in comparison with MnO [27].

COPPER:

5.1. The Role of Dietary Factors in Copper's Interactions with Other Factors

A number of factors, including the age of the animal, the chemical form of the copper in the diet, and the presence of dietary substances that interfere with copper absorption, all play a role in determining the amount of dietary copper that must be consumed in order to meet the requirements for copper needed for maintenance, growth, and lactation [1]. Absorption in adult ruminants is low, ranging from 1% to 10% of dietary copper, in contrast to monogastrics, which have a fairly high level of copper absorption (between 30% and 75%) [8], [28]. Cu absorption in lambs can reach as high as 70-85% of the food supply before they establish a functional rumen [29]. This can happen before the lambs build a rumen. The interactions that take place in the rumen environment, such as the Cu-S-Mo [9] [20] [21], Cu-S [22] [23], and Cu-Fe [14] [15] antagonisms, appear to be the cause of the decrease in copper absorption that has been observed. More recently, results have been reported [26] and [27] that relate high levels of dietary Mn to Cu deficiency. [26] [27]

5.2. The Interaction of Copper, Molybdenum, and Sulfur

Dietary sulphur is converted to sulphide when ruminal H+ ions are present. This sulphide subsequently interacts with molybdenum to generate a variety of distinct thiomolybdates (mono-, di-, tri-, tetra-thiomolybdates) Thiomolybdates have been shown to bind copper in the gastrointestinal tract, thereby preventing copper from being absorbed. At the same time, thiomolybdates have been shown to increase the copper fraction associated with the solid phase of the rumen content, at the expense of a reduction in the fluid phase. Even in an acidic environment such as the abomasal environment, thiomolybdates that are coupled with solid rumen digesta (bacteria, protozoa, and undigested feed particles) form insoluble complexes that do not release copper [19]. In addition, it has been demonstrated that absorbed thiomolybdates cause systemic effects on copper metabolism. These effects include increased biliary excretion of copper from liver stores, strong binding of copper to plasma albumin, which results in decreased availability for biochemical processes, and inhibition of copper-dependent metalloenzymes like ceruloplasmin, diamine oxidase, cytochrome oxidase, ascorbate oxidase, and ty [20] [18] [20]. According to the findings of [20], the presence of Mo in the rumen has very little impact on the synthesis of thiomolybdates when the concentration of rumen sulphide is low. Cu bioavailability, on the other hand, is drastically decreased (by up to 70%) when sulphide concentrations are raised despite the fact that molybdenum levels have not been altered [21].

5.3. The Interaction of Copper and Sulfur

Organic or inorganic sulphur, in addition to playing a role in the interaction between copper and molybdenum, has been shown to impair the bioavailability of copper [21]. When lambs were given high quantities of sulphur (two grammes per kilogramme of dry matter), [82] discovered that the hepatic copper content dropped by 55%. Since the diet contained relatively little molybdenum, the authors believe that the creation of copper sulphide in the digestive tract was responsible for this reduction.

When S was supplied to ewes as methionine or as NaSO4, under low Mo dietary levels, they discovered a 39% - 56% reduction in the bioavailability of copper. This reduction may have been caused by the generation of insoluble copper sulphate at sites beyond the rumen. On the other hand, [23] makes the hypothesis that the digestion of insoluble proteins by protozoa leads to an increase in the amount of accessible sulphur, which in turn makes the synthesis of insoluble CuS and Cu2S in the rumen more likely to occur. In ruminants, the bioavailability of copper has been shown to be reduced due not only to the effect of dietary sulphur as discussed before, but also to the contribution of sulphur from other sources. Molasses, a by-product of the sugarcane and beet industries, is a source of dietary carbohydrates that dairy cows can get from molasses [16]. Molasses can be added to diets to increase palatability, act as a binder, and reduce dust in fine-particle feeds [24]. Other benefits include molasses' ability to act as a binder. However, due to the high amount of sulphur contained in molasses, consuming it in large quantities can lead to dietary sulphur levels that are far higher than what is required [25]. Following supplementation of heifers with a molasses-based diet for 29, 26, or 84 days, [23] found that copper levels in the liver dropped. The scientists believe that the high quantities of sulphur that are naturally present in molasses are responsible for this observation.

In a review of copper antagonists in cattle, the author [26] identifies other sources of sulphur that may be involved in the interactions between copper, molybdenum, and sulphur. These other sources of sulphur include fertilisers, high sulphur water, and sulfur-containing supplements. Cows that grazed on bahiagrass pastures that had been treated with ammonium sulphate had lower quantities of copper in their livers compared to cows that had grazed on non-fertilized pastures or pastures that had been fertilised with ammonium nitrate [26]. Previous research from the year 1987 [27] demonstrated that gypsum fertilisation at a rate of 132 kilogrammes of gypsum per hectare enhanced the percentage of soluble solids in tall fescue grass and orchadgrass, respectively, from 0.33% to 0.40% and from 0.29% to 0.37% of dry matter. However, feeding those pastures to steers did not result in any changes in the bioavailability of copper. This is possibly because the pastures that were not fertilised had a high amount of sulphur. Because of this, [23] suggests that the choice of fertiliser source can be an important consideration in regions where grazing cattle may be at risk for Cu deficiency. The levels of sulphur in drinking water can also have a negative impact on the bioavailability of copper.

Yearling steers that were given high-S water (3651 mg of SO4/L) had lower levels of copper in their plasma and hepatic tissue than yearling steers that were given low-S water (566 mg of SO4/L), according to a study that was published in [88]. Similar to what was found by [29], when the level of sulphur in the drinking water was raised from 404 mg of SO4/L to 4654 mg of SO4/L, growing steers had a lower level of copper in their livers. Even though the indicated S concentrations are higher than what is typically found in water for animals, it has been observed that the United States of America and Canada both have high levels of S in their water [30], [31].

5.4. The Interaction Between Copper and Iron

Ruminants whose diets are mostly composed of forage are frequently subjected to high concentrations of iron due to the absorption of water, fodder, and abnormally large quantities of soil [69], [92]. Sheep were given a supplement of 800 mg of iron per kilogramme of dry matter in the form of either iron oxide or iron sulphate, and their copper absorption was reduced from 0.06 to 0.04. [23] Young heifers that were given 800 mg of iron per kilogramme of dry matter were shown to have a precipitous drop in their liver and plasma copper contents, as well as their activities of erythrocyte superoxide dismutase and plasma ceruloplasmin. Other research (24) showed similar results. However, if one is to believe what is said in [24], the role that S plays in the absorption of Cu is partially reliant on Fe. In point of fact, [21] suggests that the synthesis of FeS in the rumen is an essential step for iron to inhibit copper absorption in the body. [821] [Citation needed] A different explanation is presented by [95], who demonstrate that an excessive amount of Fe might compete with Cu for its absorption at the intestinal level, by saturation of the DMT-1 Cu transporter. This is an alternative explanation.

5.5. The Importance of Copper in the Fermentation Process of the Rumen

In a production trial conducted on beef steers [96], the addition of 20 or 40 mg of Cu/kg of DM lowered animal performance when compared with animals receiving a basal diet with 10.2 mg of Cu/kg of DM. This finding suggests that high dietary Cu levels may impair ruminal fermentation. Previous research [97] discovered that when yearling steers were given a high dose of supplemented copper (57.3 mg/kg of DM), there was a decrease in the post-feeding total VFA concentration as well as a decrease in the VFA molar proportions. On the other hand, average daily gain, feed efficiency, and carcass yield and quality grade were not affected. Following the addition of high doses of CuSO4, researchers [28] observed that there was a decrease in the in vitro fermentation of concentrates mimicking rumen conditions. Similar to what was shown in [29], when high dosages of Cu were introduced to in vitro rumen incubations, a decrease in the propionate molar percentage was observed. According to the findings of a dose-response study that was carried out by [10], the amount of copper that was needed in the incubation fluid was determined to be 21 g of copper per mL. However, the results showed a significant variation in the susceptibility of the various bacterial populations to Cu. Bacteroides succinogenes, Ruminococcus albus, and Butyrivibrio fibrisolvens could all have their growth stopped with only 10, 20, and 30 g Cu/mL of incubation fluid, respectively. However, for Megasphaera elsdenii, Selenomonas ruminantium, and Streptococcus bovis, significantly higher concentrations of copper were necessary (100, 100, and 250 g Cu/mL When Cashmere wether goats were given supplemental copper in their diet, the opposite outcomes were reported by [11], who discovered a decrease in rumen pH and an increase in total VFA concentrations. This was the case when the goats were fed.

The authors believe that an increase in the amount of NDF that is digested could be the root cause of these findings. On the other hand, more recent research carried out by [23] and [13] discovered that the digestion of NDF was either unaffected or enhanced by the addition of 10 mg of Cu/kg of DM, but that it was inhibited when 30 mg of Cu/kg of DM was included. When in vitro investigations were carried out with rumen fluid donors receiving either zero, ten, or twenty milligrammes of copper per kilogramme of dry matter (DM), researchers found that the pH of the rumen, as well as the IVDMD and VFA molar proportions, did not alter in any way [14]. A putative role for copper as an inhibitor of ruminal lipids biohydrogenation has been hypothesised based on prior studies demonstrating that 20 or 40 mg of copper per kilogramme of dry matter (DM) enhanced unsaturated fatty acids in the adipose tissue of steers [14]. These observations were made. [15] Nevertheless, there have been no tests carried out to determine whether or not this hypothesis is correct.

5.6. The Amount of Copper That Is Available From Organic and Inorganic Sources

A number of debates have been had about whether or not organic sources of copper are as effective as inorganic ones at promoting the health of animals. When compared with supplementation with CuSO4, [16] found that steers given Cu-lysine had a greater copper retention than those given CuSO4. The use of organic copper (in the form of copper proteinate), as opposed to inorganic copper, was shown in another study [17] to result in greater hepatic copper retention in multiparous beef cows. However, there was no improvement in the performance of the cows or the calves. On the other hand, [18] discovered that supplementing goat babies with organic copper rather than inorganic copper led to a greater rise in body weight gain. A recent meta-analysis [13] that evaluated the advantages of organic trace elements found only minor gains in milk output, milk fat, and milk protein. These findings were consistent across all three categories. On the other hand, the somatic cell count, the amount of time that passed between calving and the first service, and the percentage of pregnant animals after 21 days were not affected by organic trace minerals. In a similar vein, researchers [10] found no differences in the 60-day pregnancy rate, health, or performance of cows that were 2 years old and received copper either as CuSO4 or as an amino acid complex. Additionally, [10] discovered that primiparous cows who were provided with organic and inorganic minerals (Cu, Co, Mn, and Zn) had lower pregnancy rates when compared to cows that did not receive the supplements. According to the authors' findings, taking excessive supplements above and beyond what is required hampered reproductive success. In a prior experiment [21] on steers, the growth rate was found to be greater when the animals were given CuSO4 rather than Cu-lysine for the first 21 days; however, after 98 days, there was no longer a significant difference between the two treatment groups. Other measures, including as humoral and cellular immunological response, ceruloplasmin activity, and feed efficiency, were not impacted by the Cu source [21]. [8] is of the opinion that solutions for the protection against rumen antagonisms are lavish and provide no more benefits than ordinary CuSO4, and they have levelled major criticisms against organic sources of Cu. In addition, the authors cast doubt on the scientific veracity of a number of in vivo research by pointing out that these studies lacked sufficient covariance analysis, which would have allowed them to account for variations that existed between groups of animals [8]. According to [9], the commercially driven pursuit of trivial advantages over inexpensive and effective inorganic sources of Cu should come to an end. Instead, attention should be focused on predicting when supplementation is required as well as the common problem of over- rather than under-provisioning of Cu and its impact on the environment. In conclusion, copper, zinc, and manganese are essential for the health and productivity of livestock; however, the precise roles that these elements play in the digestive tracts of ruminants are not yet completely understood. As is the case with a great number of other minerals, the ability of copper, zinc, and manganese to interact with organic compounds of the diet, macro minerals, and micro minerals almost always results in the availability of these minerals being reduced for the host. Minerals can be protected using a variety of different methods, including proteinates, amino acid chelates, amino acid complex, and polysaccharide complex, which are all currently accessible. On the other hand, it would appear that these technologies are more successful in monogastrics than in ruminants. More research is needed to determine the mechanisms that can guarantee adequate quantities of ruminally accessible minerals and maximise mineral supply to the lower GI tract without limiting postruminal absorption. Both of these goals can be accomplished simultaneously.

MINOR ELEMENTS AND MINERALS THE ROLES OF COPPER, ZINC, AND MANGANESE IN IMMUNE SYSTEM FUNCTION:

Minerals that are required by the body in extremely small quantities are known as trace minerals. Trace minerals are typically consumed in the diet in quantities measured in parts per million. There are many structural proteins, enzymes, and cellular proteins that rely on the presence of a number of these trace minerals in order to operate properly [25]. Some of these trace elements are zinc, manganese, copper, and cobalt. Trace minerals are necessary for the proper functioning of many aspects of cellular metabolism, including acting as cofactors, activators of enzymes, or stabilisers of secondary molecular structure [11]. The performance of dairy cattle has been demonstrated to be enhanced by the feeding of amino acid complexes including zinc, manganese, and copper in a number of studies [12] [13] [14]. These studies found that the feeding of these complexes improved fertility rates and reduced the incidence of disease. It would appear that an increased availability of trace minerals for metabolism is the cause of these improvements in animal performance [15], [16].

Ruminants are frequently vulnerable to severe nutritional shortages of trace elements such as copper, cobalt, selenium, iodine, manganese, and zinc [37]. [Citation needed] Enzymatic dysfunctions have been linked to a reduction in fertility, which has been linked to these deficiencies. Hypocuprosis in \sdairy cattle and sheep has been associated to female reproductive diseases such as inhibition of embryo implantation and high perinatal mortality, particularly early embryonic \sloss [27]. [27] and [17] showed that marginal copper deficiency in dairy heifers reduced the capacity of neutrophils to kill S. aureus. [18] demonstrated that copper deficiency in dairy heifers reduced the capacity of neutrophils to kill S. aureus. both cell-mediated and hu- moral immunity are greatly depressed by copper deficiency. [27] and [17] were conducted on rats and mice. Copper deficiency in animals also results in an increased vulnerability to the harmful effects of bacterial infections. Copper's function in the superoxide dismutase and cytochrome c oxidase enzyme systems has been hypothesised to be responsible for this phenomenon [19]. According to research presented in [24,] macrophages' ability to destroy yeast cells was hindered when copper was in short supply. [20] demonstrated that copper-deficient calves exhibited impaired phagocytic killing activity, which was reversed by copper supplementation after the calves were given additional copper. According to the findings of another study [21], a low copper status was linked to a reduced response of lymphocytes in the peripheral blood to stimulation with T-cell mitogens. Despite the results of these studies, a comprehensive investigation into the impact that copper deficiency has on macrophage function in cattle has not been conducted [22].

Zinc deficiency is linked to a reduction in immune responses and resistance to disease, according to extensive research that was conducted on human subjects as well as laboratory animals [23]. Zinc deficiency has been demonstrated to impair T-lymphocyte and neutrophil function in children, in addition to lowering the rate at which lymphocytes proliferate in the presence of mitogens and slowing the movement of neutrophils up the chemotactic gradient [19]. A lack of zinc can also cause the lymphoid tissues, including the thymus, to deteriorate and shrink in size. A lack of zinc can also have a detrimental effect on the activity of phagocytes, leading to a reduction in both intake and phagocytosis [24]. The development and function of B lymphocytes may be reduced, according to the findings of a study that was carried out on laboratory animals and fed a diet that was somewhat deficient in zinc [25]. Surprisingly little research has been done on cattle to investigate the association between the zinc in their food and their immunological function.

It appears that marginal zinc deficiency has only marginal effects on the immunological function of ruminants, however there is some data that suggests that the addition of zinc to practical diets may affect disease resistance [22]. However, giving cattle a zinc supplement was shown to increase conception rate by 23% compared to controls, and stopping this supplement resulted in decreased conception rate [26]. Zinc deficiency is most detrimental to the reproductive function of male animals. Zinc deficiency is most detrimental to the reproductive function of male animals.

The suppression of estrus, a reduction in conception rates, an increased incidence of abortions, and low birth weights have all been associated to manganese deficiency. Anestrus or an irregular return to estrus, often with extended durations of anestrus, is the primary clinical symptom of a reduced manganese intake in dairy calves [17]. This results in a decrease in the number of conceptions [31]. It has been demonstrated that the production and release of antibodies is impaired in experimental animals that are given a diet that is lacking in manganese [18]. The synthesis of antibodies improved once manganese was introduced into the diet. The method or mechanisms by which manganese impacts the manufacture or release of antibodies have not been fully understood, and there is a need for additional research in this area [28].

CONCLUSION:

In this literature review, we have come to the following conclusions:

1) Our health, as well as our capacity for growth, production, and reproduction, depends on trace elements.

They are required for the proper operation of a variety of immune system components, making them absolutely necessary.

As a result, they make a contribution to the upkeep of healthy health and immunity. They are necessary for the proper operation of a variety of enzymes and proteins, which are fundamental to the majority of the physiologic and biochemical activities that occur in the body.

2) Animal development and health depend on a wide array of biological and physiological processes, and essential trace elements like zinc, copper, and manganese play important roles in these processes. These minerals contribute to the antioxidant defence, the growth of tissue, and the operation of the immune system.
3) It is nearly universally agreed upon that organic trace minerals have a higher bioavailability than their inorganic salts, which leads to improved animal performance, health, production immunological response, and stress reduction.

REFERENCES:

1. NRC (2001) Nutrient Requirements for Dairy Cattle. 7th Revised Edition, National Academy Press, Washington DC.
2. Underwood, E.J. (1981) The Mineral Nutrition of Livestock. 2nd Edition, Commonwealth Agricultural Bureaux, Slough.
3. Smart, M.E., Gudmundson, J. and Christensen, D.A. (1981) Trace Mineral Deficiencies in Cattle: A Review. Canadian Veterinary Journal, 22, 372-376.
4. Babu, U. and Faila, M.L. (1990) Respiratory Burst and Candidacidal Activity or Peritoneal Macrophages Are Impaired in Copper-Deficient Rats. Journal of Nutrition, 120, 1692-1697.
5. Saker, K. (2006) Nutrition and Immune Function. Veterinary Clinics of North America: Small Animal Practice, 36, 1199-1224. http://dx.doi.org/10.1016/j.cvsm.2006.09.001
6. Karol, P.J., Nakahara, H., Petley, B.W. and Vogt, E. (2003) On the Claims for Discovery of Elements 110, 111, 112, 114, 116, and 118. Pure and Applied Chemistry, 75, 1601-1611. http://dx.doi.org/10.1351/pac200375101601
7. Wolfe-Simon, F., Blum, J.S., Kulp, T.R., Gordonm G.W., Hoeft S.E., Pett-Ridge, J., Stolz J.F., Webb, S.M., Weber, P.K., Davies, P.C.W., Anbar, A.D. and Oremland, R.S. (2010) A
8. Bacterium That Can Grow by Using Arsenic Instead of Phosphorus. Science, 332, 1163- 1166. http://dx.doi.org/10.1126/science.1197258
9. Underwood, E.J. and Suttle, N. (2001) The Mineral Nutrition of Livestock. 3rd Edition, CABI Publishing, Wallingford.
10. Suttle, N.F. (2010) Mineral Nutrition of Livestock. 4th Edition, CABI, Cambridge. http://dx.doi.org/10.1079/9781845934729.0000

11. Spears, J.W. (2002) Overview of Mineral Nutrition in Cattle: The Dairy and Beef NRC. 13th Annual Florida Ruminant Nutrition Symposium, University of Florida, Gainesville, 113- 126.

12. Ammerman, C.B. (1995) Methods for Estimation of Mineral Bioavailability. In: Ammerman, C.B., Baker, D.H. and Lewis, A.J., Eds., Bioavailability of Nutrients for Animals: Amino Acids, Minerals, and Vitamins, Academic Press, Pittsburgh, 83-94. http://dx.doi.org/10.1016/B978-012056250-3/50031-7

13. Hazell, T. (1985) Minerals in Foods: Dietary Sources, Chemical Forms, Interactions, Bioavailability. World Review of Nutrition and Dietetics, 46, 1-123. http://dx.doi.org/10.1159/000411649

14. Rabiee, A.R., Lean, I.J., Stevenson, M.A. and Socha, M.T. (2010) Effects of Feeding Organic Trace Minerals on Milk Production and Reproductive Performance in Lactating Dairy Cows: A Meta-Analysis. Journal of Dairy Science, 93, 4239-4251. http://dx.doi.org/10.3168/jds.2010-3058

15. AAFCO (2000) Official Publication—Association of American Feed Control Officials. Atlanta.

16. Roy, R.K. and Misger, F.A. (2008) Chelated Minerals in Livestock Nutrition: A Review. Environment and Ecology, 26, 665-668.

17. Hynes, M.J. and Kelly, M.P. (1995) Metal Ions, Chelates and Proteinates. In: Lyons, T.P. and Jacques, K.A., Eds., Biotechnology in the Feed Industry, Nottingham University Press, Nottingham, 233-248.

18. Miller, W.J. (1970) Zinc Nutrition of Cattle: A Review. Journal of Dairy Science, 53, 1123- 1135. http://dx.doi.org/10.3168/jds.S0022-0302(70)86355-X

19. Ansari, M.S., Miller, W.J., Neathery, M.W., Lassiter, J.W., Gentry, R.P. and Kincaid, R.L. (1976) Zinc Metabolism and Homeostasis in Rats Fed a Wide Range of High Dietary Zinc Levels. Proceedings of the Society for Experimental Biology and Medicine, 152, 192-194. http://dx.doi.org/10.3181/00379727-152-39358

20. Chu, G.M., Komori, M., Hattori, R. and Matsui, T. (2009) Dietary Phytase Increases the True Absorption and Endogenous Fecal Excretion of Zinc in Growing Pigs Given a Corn-Soybean Meal Based Diet. Animal Science Journal, 80, 46-51. http://dx.doi.org/10.1111/j.1740-0929.2008.00595.x

21. Spears, J.W. (2003) Trace Mineral Bioavailability in Ruminants. Journal of Nutrition, 133, 1506S-1509S.

22. Baker, D.H. and Ammerman, C.B. (1995) Zinc Bioavailability. In: Ammerman, C.B., Baker, D.H. and Lewis, A.J., Eds., Bioavailability of Nutrients for Animals: Amino

Acids, Minerals, and Vitamins, Academic Press, San Diego, 367-398. http://dx.doi.org/10.1016/B978-012056250-3/50044-5

23. Sonawane, S.N. and Arora, S.P. (1976) Influence of Zinc Supplementation on Rumen Microbial Protein Synthesis in in Vitro Studies. Indian Journal of Animal Sciences, 46, 13-18.

24. Bonhomme, A., Durand, M., Dumay, C. and Beaumatin, P. (1979) Etude in Vitro du comportement des populations microbiennes du rumen en présence de zinc sous forme de sulfate. Annales de Biologie Animale, Biochimie, Biophysique, 19, 937-942. http://dx.doi.org/10.1051/rnd:19790634

25. Martinez, A. and Church, D.C. (1970) Effect of Various Mineral Elements on in Vitro Rumen Cellulose Digestion. Journal of Animal Science, 31, 982-990. http://dx.doi.org/10.2527/jas1970.315982x

26. Arelovich, H.M., Owens, F.N., Horn, G.W. and Vizcarra, J.A. (2000) Effects of Supplemental Zinc and Manganese on Ruminal Fermentation, Forage Intake, and Digestion by Cattle Fed Prairie Hay and Urea. Journal of Animal Science, 78, 2972-2979. http://dx.doi.org/10.2527/2000.78112972x

27. Spears, J.W., Schlegel, P., Seal, M.C. and Lloyd, K.E. (2004) Bioavailability of Zinc from Zinc Sulfate and Different Organic Zinc Sources and Their Effects on Ruminal Volatile Fatty Acid Proportions. Livestock Production Science, 90, 211-217. http://dx.doi.org/10.1016/j.livprodsci.2004.05.001

28. Eryavuz, A. and Dehority, B.A. (2009) Effects of Supplemental Zinc Concentration on Cellulose Digestion and Cellulolytic and Total Bacterial Numbers in Vitro. Animal Feed Science and Technology, 151, 175-183. http://dx.doi.org/10.1016/j.anifeedsci.2009.01.008

29. Bonhomme, A. (1990) Rumen Ciliates: Their Metabolism and Relationships with Bacteria and Their Hosts. Animal Feed Science and Technology, 30, 203-266. http://dx.doi.org/10.1016/0377-8401(90)90016-2

30. Pell, A. and Schofield, P. (1993) Microbial Adhesion and Degradation of Plant Cell Walls. Forage Cell Wall Struct. Dig. ACS, Ithaca, 397-423.

31. Spears, J.W. (1989) Zinc Methionine for Ruminants: Relative Bioavailability of Zinc in Lambs and Effects of Growth and Performance of Growing Heifers. Journal of Animal Science, 67, 835-843. http://dx.doi.org/10.2527/jas1989.673835x

32. Mandal, G.P., Dass, R.S., Varshney, V.P. and Mondal, A.B. (2008) Effect of Zinc Supplementation from Inorganic and Organic Sources on Growth and Blood

Biochemical Profile in Crossbred Calves. Journal of Animal and Feed Sciences, 17, 147-156.

33. Dorton, K.L., Wagner, J.J., Larson, C.K., Enns, R.M. and Engle, T.E. (2010) Effects of Trace Mineral Source and Growth Implants on Trace Mineral Status of Growing and Finishing Feedlot Steers. Asian-Australasian Journal of Animal Sciences, 23, 907-915. http://dx.doi.org/10.5713/ajas.2010.90414.