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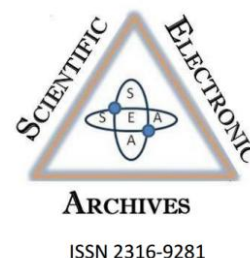
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# Dietary chromium and growth performance animals: a review

P. S. A. Moreira, C. Palhari, R. C. A. Berber

Federal University of Mato Grosso - Campus Sinop  
Federal University of Rondonópolis

Author for correspondence: [paulomoreira@ufmt.br](mailto:paulomoreira@ufmt.br)

**Abstract.** The objective of the present review is to provide an overview on the effects of the addition of dietary chromium. The complex of chelated minerals that are molecular structures less toxic and more bioavailable, and grants a supplementation with high margin of safety for both animal and consumer of meat and milk. Functions are attributed to chromium that include mainly the carbohydrate metabolism, but also to a lesser extent the protein and lipid metabolism and in cases of stress causes decrease serum cortisol concentration. The chromium was characterized as participant component of the amplification mechanism of the insulin cellular signaling, ie. contributing factor of the sensitivity increase of insulin receptors on the plasma membrane. The chromium and thyroid hormones influenced production and actions of growth hormone (GH) mediated by IGF-1. In cardiac and skeletal muscle, IGF-1 stimulates the uptake and transportation of glucose, as well as the lactate production. From anabolic point of view, IGF-1 stimulates the synthesis of RNA and protein. However, growth responses were inconsistent among different sources and varying inclusion rates of chromium. Information on the dietary chromium mode of action is quite limited, and large variations exist in results regarding the effects. Further research is required to clarify the chromium mode of action and its association with subsequent growth performance in animals.

**Keywords:** *carcass traits, growth performance, mineral, supplement.*

## Introduction

Brazil has the second largest cattle herd in the world, after India, but has the largest commercial cattle; with 80% of the herd influenced by *Bos taurus indicus* (Ferraz and Felicio, 2010). The production of Brazilian cattle beef has low cost, being 60% lower than in Australia and 50% lower than in the United States. The average slaughter age is 4 years and the slaughter rate is around 21%, when compared to 2 years and 37% in the United States (Dick and Nelson, 2003), the average of the Brazilian beef industry is less efficient. However, proper management associated with nutritional supplementation reduces the age of slaughter, improves animal performance, besides producing carcass with better quality (Santos, 2011). To obtain biological and economic efficiency in this process, it is necessary to provide conditions for animals showing satisfactory body growth, from birth to slaughter. Based on that the cattle Brazilian cut is based on pasture conditions, and that cattle under these conditions are subject to possible deficiencies, among them, the minerals, and to correct or mitigate such effects, guaranteeing them an adequate supply and healthy development, mineral supplementation is a necessary practice (Moraes, 2001).

The minerals comprise 4% of the body weight of animals, and perform vital functions in the body. Thus, the deficit of these elements may result in less productive performance to the potential of the animal (Coneglian, 2006; Ospina et al, 2000).

In pasture conditions, the minerals are basically derived from ingestion of grasses and, in some cases, from water and soil. However, it is not always found in sufficient quantities in such foods. Besides, the ruminal microbiotic can help make nutrients unavailable. When minerals are solubilized may be absorbed, eliminated in excretions or be incorporated into microbial cells, depending on the metabolic needs (Peixoto et al, 2005; Tokarnia et al, 2000.).

The European Union has added new limitations in the production of meat products, stimulating awareness of the potential polluter of minerals. With this, it has created discussion on how to reduce the levels of mineral supplementation in nutrition of farm animals with actions that do not compromise the health and productive performance, especially in terms of heavy metals (BARUSELLI, 2007).

The sources of minerals commonly used in animal nutrition are inorganic, geological or industrial

origin (oxides, sulfates, chlorides, carbonates and phosphates), because they represent less cost than the organic minerals (Araújo et al, 2008). Thus, the use of chelated mineral or organic mineral, has been recommended as a possible solution to environmental problems, based on the evidences that have greater bioavailability than inorganic minerals. This fact can be confirmed by the highest concentration of minerals in tissues and blood of animals that consume this type of mineral. Thus, the organic minerals can be added in a lower concentration in the diet than the salts routine, without any negative effect on performance beyond potentially reduce the excretion of minerals and the risks to public health (Figueiredo Junior, 2010; Junqueira, 2008).

This supplementation associated with different concentrations of certain minerals, reveals itself as a strong alternative to the intensification of beef cattle industry. Thus, Chromium has been indicated by its action on the metabolism of glucose and amino acids (Sumner et al, 2007).

Several scientific studies have shown the importance of Cr for cattle when there are emotional, physical and metabolic stress resulting from the intensification of production practices, which favors greater susceptibility to diseases and metabolic disorders (Rao, 2010).

The effects of chromium in protein deposition have been intensively studied (Vincent, 2004), due its action as an essential nutrient involved in catabolism and anabolism of protein, and the insulin stimulation improve in the intake of amino acids and protein synthesis (Pollard et al 2001).

Thus, the aim of this study was to conduct a literature review on the use of chromium in the production of cattle.

## Contextualization and analysis

### *Chrome Mineral Supplementation on Performance and Animal Behavior*

It is known that at least fifteen mineral elements are recognized as essential to the life of animals: calcium, phosphorus, magnesium, potassium, sodium, chlorine, sulfur, iodine, manganese, iron, copper, cobalt, molybdenum, selenium and fluoride.

Minerals perform three types of essential functions for the animals and man organism. The first concerns their participation as structural components of body tissues (eg Ca, P), it also acts in tissues and body fluids as electrolytes for maintaining acid-base balance, osmotic pressure and permeability of cell membranes (Ca, P, Na, Cl) and finally, act as activators of enzymatic processes (Cu, Mn) or as part of the structure of metallo-enzymes (Zn, Mn) or vitamins (Co) (Tokarnia et al, 2000).

With the advancement of livestock productivity, increased nutritional requirements and new mineral microelements, but also forms of supplementation, entered the scenario of production of beef cattle (Moraes, 2001). Among the minerals

highlight the Chrome, which only recently came to be supplemented to ruminants, being indicated by its action on the metabolism of glucose and amino acids (Sumner et al, 2007).

The influence of chromium supplementation on immune response and in cases of stress, either by weaning, transportation, neutering, and other stressful situations, its being the subject of many research due to the observation that chromium causes decreased on serum cortisol concentration (Baruselli, 2000).

According Pagan (1995), the stress causes an increase in excretion of chromium, because during stress, glucose metabolism is decreased concurrently with the increase of the cortisol hormone secretion in the blood. Cortisol reacts antagonistically to the insulin, preventing the entry of glucose into peripheral tissues (muscle and fat) and saving it to tissues with high demand (brain and liver), this mobilization according to Mertz (1992) is irreversible, being chromium eliminated in the urine. However, all factors that cause elevation of blood glucose are significant causes of chromium deficiency, which results in elevated blood glucose and subsequent chromium mobilization ( $\text{Cr}^{3+}$ ) of body storages. Arthington et al (1997) demonstrated that organic chromium supplementation caused a decrease in serum cortisol concentration of animals under stress conditions. Thus, it is possible to reduce the hematic level of "negative factors" of organic response to stress in ruminants that bring losses in animal production, such as decreased intake of dry matter; retarded growth; decrease in milk production, fertility and weight gain; decreased immunological response, etc.

### *Chelated Mineral*

Moraes (2001) defines chelated minerals as elements fixed with organic molecules of low molecular weight, whose absorption is more effective. The bioavailability of these elements is dependent on the form of connection with the metal, the molecular weight of the chelated form and stability constant of the chelate. A metal chelate is formed by a cyclic structure produced by attraction between positive charges and some polyvalent cations with two or more electronegative sites of high activity (Miles, Henry, 2000).

The chelates are formed by reaction between salts, such as mixtures of amino acids or peptides obtained by enzymatic reaction, under controlled conditions. These amino acids and peptides bind to metals in more than one point, ensuring that the metal atom becomes part of a biologically stable structure. Only the so-called transition mineral such as copper, iron, manganese and zinc present physico-chemical characteristics which permits the formation of coordinate covalent bond with amino acids and peptides, and thus, the biologically stable complexes (Rutz; Murphy, 2009).

The chelated minerals are produced by Brazilian industry since the 70s. However, only in recent years returned to awaken the interest of the

research and industry. And this was due to the development of new equipment and analytical methods that enable determination of mineral content with precision and the development of product denominated organic minerals, chelated minerals or complex minerals (Moraes, 1998).

In the scientific field of mineral supplementation, a revolution of nutrition knowledge is supported by some basic points, the complex of chelated minerals that are molecular structures less toxic and more bioavailable, and these basic features incorporated in the mineral complex grants a supplementation with high margin of safety for both animal and consumer of meat and milk (Baruselli, 2005).

A mineral chelated truly effective have to present high solubility in water, remains stable throughout the digestive process, be highly absorbable and generate productive responses in the animal. For ruminants, stability becomes particularly important because to a complexed or chelated mineral is nutritionally functional, should be stable in the rumen and abomasum and able to reach the small intestine intact (Haddad and Ahmed, 2006).

According to the Association of American Feed Control Officials (AAFCO, 2000), which establishes standards of quality and safety for foods for animal nutrition, organic minerals can be classified as: amino acid chelate metal; amino acid complex metal; amino acid complex metal specific; proteinated metal; metal-polysaccharide complex.

Within this latter group it is included a molecule denominated carboaminofosfoquelato or commercially known - carboquelato (Garcia, 2002).

#### *Chromium Picolinate*

Chromium has been recognized as an essential mineral element for beef cattle NRC, (1996), but the information obtained so far are not sufficient to determine the requirements of Cr in the feed, where the most appropriate way according to proper NRC (1996), for chromium supplementation to cattle, is the organic form, also known as complex of organic mineral or chelated of minerals, as previously mentioned.

Chromium in the organic complexes form such as chromium picolinate, chromium nicotinate, chromium amino acid, chromium yeast and chromium chelate has higher absorption and may reach 25%. The most common inorganic source is chromium chloride, and is not really absorbed or biologically active as the organic forms of Cr (Burton, 1995).

Performance results for cattle supplemented with Cr have ranged from 0 to 30% of increase in average daily gain (Kegley E Spears, 1995). However, organic sources of Cr as Cr picolinate or Cr methionine, has been more consistent with favorable effects on glucose metabolism (Kegley et al 2000). Currently the Cr picolinate is the only permitted source of Cr for supplementation in diets for cattle in the United States (Bernhard et al, 2012).

#### *Biological function Cr<sup>3+</sup>*

Functions are attributed to chromium that include mainly the carbohydrate metabolism, but also to a lesser extent the protein and lipid metabolism (Stoeker, 1999), however, their participation in carbohydrate metabolism relates more specifically to the stimulation of uptake glucose by the cells of target tissues. This effect is not caused by chromium alone or even in the form of enzyme co-factor, as the most minerals. For Mertz (1969) the chromium would act as an organic complex of low molecular weight called "glucose tolerance factor" (GTF) formed by Cr<sup>3+</sup>, nicotinic acid, glycine, cysteine and glutamic acid. However, Sun et al (2000) reported that Cr modifies the metabolism of glucose by an oligopeptide of low molecular weight known as chromodulin, which is composed of glycine, cysteine, aspartame and glutamate and binds with high affinity to 4 ions of Cr<sup>3+</sup> (Vincent 2001). For some researchers, GTF is simply how the Cr is shown in beer yeast (an organic form), working as a provider of Cr to the body and not as its biologically active form (Vincent 2000; Lamson and Plaza, 2002).

After absorption, the Cr circulates through the plasma in concentration that range from 0.01 to 0.3 ug/L connected to transferrin and possibly to albumins. By binding to transferrin, chromium has a significant effect on the transport of iron. The concentration of Cr<sup>3+</sup> in plasma may be decreased in case of an infection or glucose overload. The chromium can be stored in various tissues of the organism without a specific site. The greater amount of chromium appears to be localized in the liver, kidney, spleen, and epididymis, but higher Cr concentration has been noted in the heart and kidneys of rats (Anderson, 1998).

On the description of the mechanisms of chromium action, it was proposed that this mineral would increase the fluidity of the cell membrane to facilitate the binding of insulin to its receptor (Evans and Bowman, 1992) and that GTF would act as a carrier of Chromium for cellular proteins deficient in chromium (Vincent, 1994). But subsequently the chromium was characterized as participant component of the amplification mechanism of the insulin cellular signaling, ie. contributing factor of the sensitivity increase of insulin receptors on the plasma membrane (Vincent, 1999). The mechanism of chromium participation in insulin action was initially called chromium-binding substance of low molecular weight (low-molecular weight chromium-binding substance - LMWCr) (Vincent, 2000). The LMWCr due to the similarity with the calmodulin in structure and function, receives also the name of chromodulin when bound to four Cr ions, whereas in the free mineral form is termed apochromodulin, and is found predominantly in the intracellular environment, specifically in the cytosol and core (Vincent, 2000).

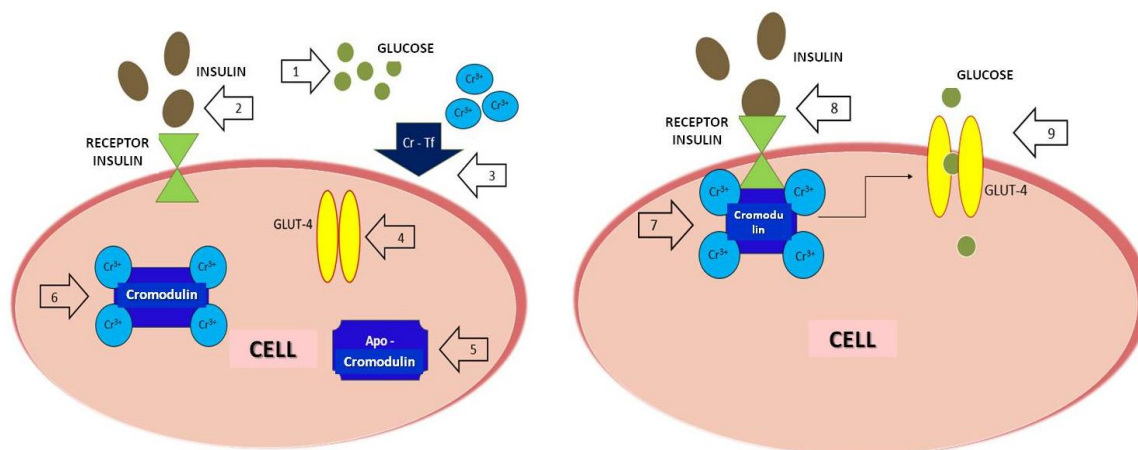
It is well established that in response to the increased of glycemia, insulin is rapidly secreted into

the circulation and binds to its subunit receptor, located on the outer face of the plasma membrane, causing a conformational change which results in the self phosphorylation of tyrosine residues in the  $\alpha$  subunit, located in the inner side of the membrane. This change triggers a series of phosphorylation reactions, in cascade, with the aim of stimulating the translocation of glucose transporters (GLUTs) to the plasma membrane (Champe E Harvey, 1994).

The model proposed to explain the action of chromodulin as part of the self amplification system of insulin signaling suggests that chromodulin is stored in form of apo in the cytosol and in cell's nucleus sensitive to insulin. The increase of circulating insulin causes two concurrent conditions: (i) higher chromium mobilization to target cells, mainly mediated by the transferrin and (ii) transferrin receptor mobilization from intracellular vesicles to fuse with the membrane. Thus, the transferrin saturated with chromium binds to its receptors and the complex formed is internalized by endocytosis. In the intravesicular space, the acid pH promotes digestion of this complex and the chromium release

into the cytosol. Four  $Cr^{3+}$  ions join the apochromodulin making it active as chromodulin, which in turn binds to the active site in the insulin receptor, completing the activation and amplifying the insulin signal (Figure 1) (VINCENT , 2000, Sun et al, 2000)..

Besides its main action on carbohydrate metabolism, chromium is also involved in protein metabolism by stimulating amino acid uptake by the cells, since it is directly linked to insulin activity (Kreider, 1999). In the protein metabolism the insulin presents a direct effect, promoting amino acid uptake by the cells and converting them into protein. Insulin shares with growth hormone and IGF-1 the ability to increase the uptake of amino acids into cells and acts directly on the ribosomes, increasing the translation of messenger RNA and forming new proteins. In the absence of insulin, the ribosomes simply stop working, increased protein catabolism, protein synthesis ceases and large amounts of amino acids are released into the blood plasma (Gyton and HALL, 1996).



**Figure 1** - Proposed mechanism for performance of chromium in the cell. In response to a glucose increase (1), insulin is secreted into the circulation (2). The increased of circulating insulin causes higher chromium mobilization to target cells, mainly mediated by transferrin (3). GLUT-4 inside the cell without performing the glucose transport (4). The chromodulin is stored in the Apo form (5). Four  $Cr^{3+}$  ions join the apochromodulin making it active as chromodulin (6), which in turn binds to the active site in the insulin receptor (7), completing the activation and amplifying the insulin signal (8). A series of phosphorylation reactions in cascade occurs and stimulates the translocation of GLUT4 to the plasma membrane (9), carrying the glucose uptake (adapted from Vincent, 2000).

When bound to its receptor, insulin enables the absorption and the cellular metabolism of glucose participating of the biochemical mechanism of blood removal. Once absorbed by the cell, this glucose is used as power source which, by anabolic regulation, such as by the growth hormone (GH) and insulin growth 1 factor (IGF-1), control the protein synthesis and provide maintenance and organ function (BURTON, 1995).

Currently, the influence of organic chromium supplementation on immune response and in cases of stress, either by weaning, transportation, neutering, and other stressful situations, is being the subject of many research due to the observation that chromium causes decrease serum cortisol concentration (BARUSELLI, 2000).

According to Pagan (1995), frequent exercise and stress cause elevation in chromium excretion. During stress, the glucose metabolism is reduced simultaneously with an increase of hormone cortisol secretion in the blood. Cortisol reacts antagonistically to insulin, preventing the entry of glucose into peripheral tissues (muscle and fat) and saving it to tissues with high demand (brain and liver). This mobilization, as Mertz (1992) is irreversible, being chromium eliminated in the urine. The factors that cause elevation of blood glucose are significant causes of chromium deficiency. This results in high blood glucose and subsequent mobilization of chromium ( $Cr^{3+}$ ) of body stores.

It is not known exactly how the Cr affects cortisol production, but as it integrates the glucose

tolerance factor, potentiating the action of insulin, which is inhibited by glucocorticoids could inhibit them inversely. Stress and disease increase the urinary excretion of Cr and may exacerbate the deficiency of this element (MERTZ, 1992). Reducing morbidity by supplementation of organic Cr was also achieved in several studies (Moonsie-Shageer and Mowat, 1993; Burton, 1995; Benhard, 2012), this being probably the most important economic factor, higher than the temporary increase in daily gain, having reduced infections, medications cost, work, productivity decrease and waste problems of antibiotic use.

Arthington et al (1997) demonstrated that organic chromium supplementation caused a decrease in serum cortisol concentration in animals under stress conditions. This way you can reduce the hematic level of "negative factors" of organic response to stress in ruminants that bring losses in animal production, such as decreased intake of dry matter; retarded growth; decrease in milk production, fertility and weight gain; decreased immunological response, etc.

Chang & Mowat (1992) verified an increment in the consumption of total dry matter and increased daily gain in calves under stress with organic chromium supplementation; and concluded that this micronutrient is given to animals under stressful situation, such as weaning, sale, transportation, adaptation to confinement, among others; Moreover, demonstrate that the absorption of chromium in inorganic form is very low, ranging from 1 to 3% of the total ingested, while the absorption of organic chromium observed by him varied under the same conditions, between 10 and 15%.

Melo (2002), evaluated the effect of organic chromium supplementation on performance and blood parameters of calves of Dutch breed subjected to stress. The organic chromium supplementation for treatment batch was 1mg of organic chromium a day administered orally. The results indicate that cortisol, glucose and insulin were not effective attributes to demonstrate the effects of supplementation with chromium organic. However biochemical changes with chromium supplementation were observed as increasing bone mineral content and activation of several enzymes, including the lactate dehydrogenase.

The chromium supplementation improved weight gain and calves the feed conversion with more expressive responses from the third period of experimentation, when stress by elevating the temperature was higher (MELO, 2002).

### *IGF-1*

The actions of growth hormone (GH) are mediated by IGF-1, its production and availability are influenced by thyroid hormones and also chromed. IGF-1 consists of a peptide of basic character composed by 70 amino acids. Have amino acid sequence and three dimensional structure very similar to insulin.

The plasma concentrations of IGF-1 in humans and domestic animals is relatively stable, showing no apparent production peaks due to its very long biological half-life. In cardiac and skeletal muscle, IGF-1 stimulates the uptake and transportation of glucose, as well as the lactate production. From anabolic point of view, IGF-1 stimulates the synthesis of RNA and proteins (Moreira et al, 2010).

At puberty there is a clear increase in plasmatic IGF-1 which is directly related to increment of steroid hormones production, through a complex process that culminates with the growth of bone and muscle tissues and anabolic and catabolic events that occur in the organism. This relationship is so obvious that many authors even propose a control of the activity of IGF-1 for the determination of these events.

According Breier and Saverwein (1995), the plasmatic concentration of IGF-1 is a parameter of great importance in the production process, given that the strains selection of mice and sheep based on the magnitude of the plasmatic concentration of IGF-1 resulted in striking differences in growth rate. Weeks (1996) reported that strains of sheep selected for high and low weight at weaning, showed no differences in the plasmatic levels of GH, cortisol and insulin. However, selected strains for high weight at weaning showed plasmatic levels of IGF-1 higher, besides greater muscle coverage in the carcass. In this same sense Davis et al (1995) studying the concentrations of IGF-1 as a selection parameter of male and female calves cutting, observed great efficiency in the selection process for this feature, when the objective is to obtain animals with greater weight and better termination of early carcass.

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