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The Pharma Innovation

**ISSN (E):** 2277-7695
**ISSN (P):** 2349-8242
**NAAS Rating:** 5.23
TPI 2022; SP-11(12): 543-548

www.thepharmajournal.com
Received: 06-09-2022
Accepted: 13-10-2022

**Dr. Pallabi Das**
Department of Animal Nutrition, Mastana Baba Veterinary College, Rajasthan, India

**Dr. Akshay R Bariya**
Department of Livestock Products Technology, College of Veterinary Science & Animal Husbandry, Kamdhenu University, Junagadh, Gujarat, India

**Dr. Viral V Gamit**
Department of Livestock Production and Management, College of Veterinary Science & Animal Husbandry, Kamdhenu University, Junagadh, Gujarat, India

**Dr. Bimal Bey**
Department of Animal Genetics and Breeding, Mastana Baba Veterinary College, Rajasthan, India

**Dr. Sachin T Desai**
Field Veterinarian, Dessa, Banaskantha, Gujarat, India

**Corresponding Author:**
**Dr. Akshay R Bariya**
Department of Livestock Products Technology, College of Veterinary Science & Animal Husbandry, Kamdhenu University, Junagadh, Gujarat, India

# Role of chromium in nutrition for livestock and poultry: Understanding its importance: A review

**Dr. Pallabi Das, Dr. Akshay R Bariya, Dr. Viral V Gamit, Dr. Bimal Bey and Dr. Sachin T Desai**

**Abstract**
The addition of chromium to the diet, however, is one of these methods that is less frequently used. Cr has been shown in research to affect dairy cow performance, immunological responses, glucose and fatty acid metabolism, and antioxidant status. There is increasing data that suggests that domestic livestock may benefit from several supraphysiological effects of Cr. It is possible to keep cattle healthy overall while preventing disease, enhancing growth, and using a variety of methods and products. Cr supplementation benefited dairy cows' dry matter intake, milk production, and milk composition in the early, mid, and late stages of lactation in several studies. In certain trials, Cr supplementation improved the performance of growing animals, their immunological response, and some blood indicators. Heat stress is a key environmental stressor in the chicken business, resulting in significant financial loss. Heat stress causes oxidative stress, acid-base imbalance, and immunocompetence suppression, resulting in higher mortality and decreased feed efficiency, body weight, feed intake, and egg production, as well as affecting meat and egg quality. To reduce heat stress in chickens, several strategies have been explored, with varying degrees of success. Cr supplementation decreased corticosterone and cholesterol levels while increasing serum total protein, albumin, and insulin concentrations. This review focuses on the scientific information around the effects of heat stress on poultry health and performance, as well as possible heat stress mitigation measures in broiler chickens and laying hens.

**Keywords:** Chromium, performance of ruminants, heat stress

## 1. Introduction

The use of metabolic modifiers has grown in importance for many studies looking for a supraphysiological diet to enhance production characteristics as a result of the expansion of the worldwide herd. The ideal balance of all nutrients, including micro-minerals, is crucial for boosting the performance of high-producing cows. Over the past 20 years, livestock nutritionists have focused on enhancing both the nutritional value of cattle and livestock products as well as production efficiency (Amata, 2013) [4]. Even if Cr supplementation is discontinued, dairy cows may produce more milk later in lactation if Cr is given to them during the transition phase (Rockwell and Allen, 2016) [46]. Cr's beneficial effect on milk production has been linked to its effects on energy metabolism, as seen by decreased NEFA mobilization from adipose tissue and enhanced insulin sensitivity (Sumner *et al.*, 2007) [55]. Cr supplementation in the middle and late stages of lactation may be especially useful because it aids glucose metabolism (Bedford *et al.*, 2018) [9]. Cr supplementation during pregnancy and early lactation has been shown to improve milk supply in previous research (Mirzaei *et al.*, 2011, Mrigen, 2011) [34, 38]. Stress affects not only reproductive performance but also productive performance, such as decreasing milk production and growth due to metabolic disturbances (Girmaand Gebremariam, 2019) [23], which can enhance glucose metabolism and mobilization of Cr from the body stores (Moreira *et al.*, 2020) [37]. Heat stress (HS) occurs when an animal's ability to remove excess heat into the environment exceeds their ability to do so (Alagawany *et al.*, 2017, El-Kholy *et al.*, 2018, Farghly *et al.*, 2018) [2, 19, 22]. Cr supplementation is expected to minimize Cr losses in high-producing cows during stressful situations, allowing them to sustain milk production. The supraphysiological involvement of Cr in carbohydrate and lipid metabolism may explain why ruminants perform better when they are developing and fattening. The specific low molecular weight Cr-binding compound, which when transformed into chromodulin, initiates the insulin signaling cascade and requires Cr for production (Dalólio *et al.*, 2018) [15]. The use of chromium as an important nutrient for livestock to alter growth performance and improve carcass composition (Van Hoeck, *et al.*, 2020, Baggerman *et al.*, 2020) [58, 8].

Greater cell permeability to insulin is the outcome of this and which in turn stimulates the metabolism of proteins, lipids, and carbohydrates. In meat and egg-laying chickens, chromium has been found to improve weight gain and egg quality (Ma *et al*., 2014, Arif *et al*., 2019) [30, 7]. To meet the rising demand for poultry meat and eggs, the poultry industry is expanding around the world. Poultry meat is high in protein, vitamins, and minerals and has a low content of saturated fatty acids (Marangoni *et al*., 2015) [63]. Chicken eggs are the most cost-effective form of animal protein (Réhault-Godbert *et al*., 2019) [45]. Numerous physiological changes brought on by heat stress, including oxidative stress, an acid-base imbalance, and immunocompetence reduction, increase mortality and decrease feed efficiency, body weight, feed intake, and egg production while meat and egg quality are also affected (Wasti *et al*., 2020) [59]. It is critical to synthesize these findings for poultry researchers and industry because there is significant scientific information about the negative impacts of heat stress on chicken health and performance, as well as potential mitigation techniques. Cr supplementation raised serum total protein, albumin, and insulin concentrations while lowering corticosterone and cholesterol levels (Trivedi *et al*., 2020) [56]. When corticosterone levels are decreased, the carcass quality of broilers improves. According to published research, birds in general (chickens included) metabolize carbohydrates considerably different from mammals, as evidenced by the higher physiological plasma glucose levels in these species (Mátis *et al*., 2014) [32]. Hence, in fast-growing broilers, increasing insulin response by adding Cr might be absolutely essential (Farag *et al*., 2017) [21].

## 2. Beneficial aspects of chromium
### 2.1 Ruminant
#### 2.1.1 Milk production
High-producing dairy cows are put under a lot of pressure and stress during the early stages of lactation. This causes a negative energy balance, as well as an increase in the formation of non-esterified fatty acids (NEFA) and -hydroxybutyric acid (BHBA) in the bloodstream, which leads to ketosis and other metabolic diseases, as well as stress. Chromium supplementation in the diet has been demonstrated to be useful during these times. Insulin resistance develops before parturition and continues during early lactation, according to several research (Debras *et al*., 1989, Prior and Christenson, 1978, Sano *et al*., 1991) [16, 44, 52]. Soltan (2010) [54] and Nikkhah *et al*. (2011) [39] examined the effect of Cr supplementation on the performance of multiparous dairy cows reared under heat stress in early lactation and found that MP and DMI were greater in the Cr supplemented cows than in the control group. DMI in dairy cows getting Cr supplementation was found to be considerably higher than in the control group in several other trials (Smith *et al*., 2005, McNamara *et al*., 2005) [53, 64]. Al-Saiady *et al*. (2004) [3] evaluated the effect of Cr supplementation on the performance of multiparous dairy cows at mid lactation reared under heat stress, and found that Cr supplementation improved DMI and MP the most. The positive responses to Cr supplementation in dairy cows in some experiments might have been caused by removal of the dietary Cr deficiency. Kafilzadeh *et al*. (2012) [26] found that supplementing the diet of multiparous dairy cows in early lactation with Cr increased milk lactose content. Chromium supplementation enhances dry matter intake in first parity cows during the first 4–6 weeks following birth. Chromium supplementation enhances dry matter intake in first parity cows during the first 4-6 weeks following birth. Dairy animals given chromium propionate eat more grain and generate more milk than cows not given chrome propionate (MacNamara and Valdez, 2003) [31]. Increased milk production could be an unintended consequence of higher glucose synthesis. Primiparous cows, not multiparous cows, have increased production as a result of chromium supplementation. When compared to a control group, first lactation cows treated with 4 mg/day of an organic chromium supplement exhibited greater average daily milk output, milk fat, protein, and lactose values (Popovic *et al*., 2000) [43]. Reduce the negative energy balance's influence. Reduce the impact of metabolic problems caused by a lack of energy. Chromium also helps to activate enzymes and keep proteins and nucleic acids stable. Chromium supplementation in aged cows, reduce placental retention and udder edema (Bryan *et al*., 2004) [62].

#### 2.1.2 Calf growth
Weaning, crowding, and feedlot acclimation are all common calf husbandry procedures that can cause physiological stress and, as a result, chromium insufficiency. During stressful times, chromium excretion in the urine typically raises chromium requirements. Chromium supplementation reduces serum cortisol in stressed calves fed chromium-deficient diets (Moonsie-Shageer and Mowat, 1993) [36]. According to research (Dhiman *et al*., 2007) [17], supplementing the feed with chromium propionate reduced plasma cholesterol concentration in the blood of 6-month-old buffalo calves. As evidenced by multiple researchers, Cr supplementation can boost feed intake and thus growth performance in heat-stressed animals (Hayirli *et al*., 2001, Hung *et al*., 2014, Mayorga *et al*., 2019, Sahin *et al*., 2002) [24, 25, 33, 49]. Chromium supplementation boosted total weight gain, average daily weight gain, and lowered blood cholesterol in young goats, according to recent studies (Mondal *et al*., 2007) [35]. In dairy Holstein calves exposed to high ambient temperatures, Kargar *et al*. (2018b) [27] discovered that dietary chromium supplementation enhanced feed intake and growth rate (83.3 units). Cr supplementation boosts growth and body weight by improving nutrition absorption and digestion (Ghorbani *et al*., 2011, Kargar *et al*., 2018) [34, 27].When added to the diet of buffalo calves raised in hot environments, inorganic chromium increased heat tolerance, immunological status, and growth performance without influencing nutritional intake (Kumar *et al*., 2015) [29].

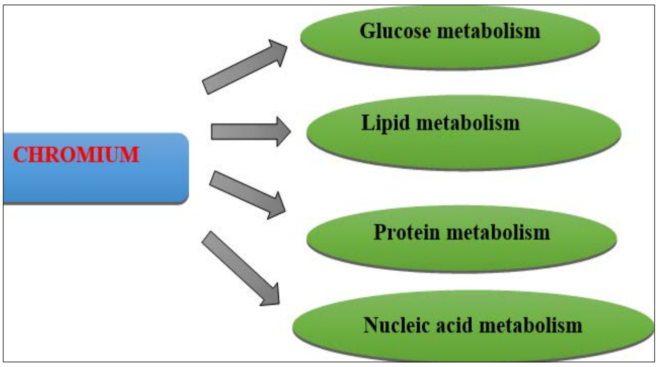
### 2.2 Poultry
Chromium supplementation of chicken diets has been found to improve egg production and performance in laying birds (Sahin *et al*., 2001, Sahin *et al*., 2002) [47, 49]. In settings of dietary, environmental, and hormonal stress, the positive benefits of chromium may be more easily seen. It has been demonstrated that chromium supplementation reduces the negative effects of cold stress, particularly in laying hens reared in cold environments (Sahin and Sahin, 2002) [49]. In a similar line, chromium supplementation was reported to boost egg production and egg quality in laying Japanese quails reared under heat stress (Sahin *et al*., 2002, El-Kholy *et al*., 2018) [49, 19]. The diverse sources of chromium and the experimental settings cause variation in the optimum chromium dosage. With chromium supplementation in the diets of laying hens kept under low ambient temperatures,

research findings (Sahin *et al*., 2001) [47] showed increased egg quality parameters such as specific gravity, eggshell thickness, eggshell weight, and Haugh unit. Supplementing broilers with chromium have been demonstrated to reduce the negative effects of heat stress. A Study was conducted by Norain *et al*. (2013) [40] to investigate the effects of dietary supplementation with chromium chloride in Broilers under Heat Stress, and results suggest that dietary chromium supplementation provides a good nutritional management approach to ameliorate heat stress induced depression in production performance and immune response of broiler chickens. There was also an increase in carcass yield and a decrease in abdominal fats, according to the researchers. When broilers' diets were supplemented with chromium-methionine supplementation, their carcass yield increased and their belly fat content decreased (Dalólio *et al*., 2021) [14]. Supplementing with chromium has been shown to increase feed conversion ratio by 6.2% (Zhang *et al*., 2002) [61]. Untea *et al*., 2019 [57] conducted a study by dietary chromium supplementation to the broiler and found that broilers fed with CrPic supplements showed improved mineral composition and oxidative stability of breast meat, showing an effective protection of lipid molecules from oxidation in PUFA-enriched meat. Supplementing broilers with chromium have been proven to lower serum corticosterone and cholesterol levels in heat stressed broilers (Sahin *et al*, 2002) [49]. Under heat stress, Cr at 200 to 1200 $gkg^{-1}$ promotes laying hen growth and egg production (Sahin *et al*., 2018) [51] or laying Japanese quail (Sahin *et al*., 2002) [49]. Under heat-stressed conditions, dietary supplementation with Cr at levels of 200, 400, 600, or 800 $gkg^{-1}$as chromium propionate could improve laying performance, egg quality, and antioxidant activities of laying ducks (Chen *et al*., 2021) [13]. Cr from chromium propionate was approved at 800 mg $kg^{-1}$as an adequate addition amount (Chen *et al*., 2021) [13].

## 3. Dose of Chromium

There is no recognized chromium need for ruminants at this time. The additional Cr provided to these meals is frequently higher than the basal Cr values recorded for experimental diets for ruminants (range: 0.3 to 1.6 ppm) (0.25 to 0.5 ppm). There are no NRC guidelines for chromium in poultry diets at this time (Anonymous, 1994).However, there is growing evidence that poultry may have a chromium requirement that is higher than that of cornsoya meal diets.

## 4. Metabolic role of chromium




### 4.1 Glucose metabolism

Chromodulin, a low-molecular-weight chromium-binding molecule, is thought to play a role in glucose metabolism. The name chromodulin comes from the fact that its putative mode of action is similar to that of the Ca-binding protein calmodulin. Glycine, cysteine, aspartate, and glutamate make up chromodulin, a naturally occurring oligopeptide (Yamamoto *et al*., 1987) [60]. Despite its modest size, the molecule binds four equivalents of $Cr^{3+}$. It can help with chromium detoxification by carrying chromium into the urine after substantial doses of chromium, both trivalent and hexavalent forms are consumed. Another benefit of chromium is that it improves insulin sensitivity by enhancing membrane fluidity and insulin internalization rate (Evans and Bowman, 1992) [20]. Supplemental Cr has anti-stress and metabolic-modifying effects via altering insulin sensitivity and increasing glucose uptake, glucose oxidation to $CO_2$, and glucose absorption into triglycerides (Brooks *et al*., 2016) [11]. Insulin is a key hormone in protein, carbohydrate, and fat metabolism, stimulating amino acid and protein synthesis, decreasing lipolysis and increasing fatty acid assimilation in adipocytes, and increasing glucose utilization (Sahin *et al*., 2010) [48], which could explain the decrease in serum GLU, BUN, and TC concentrations while increasing serum TP and ALB. Heat stress increased serum GLU and TC levels in laying hens, and supplementary Cr decreased serum GLU and TC levels (Khan *et al*., 2014, Sahin *et al*., 2018) [28, 51].

### 4.2 Lipid metabolism

From 21 days pre-partum to 35 days post-partum, the effects of chromium propionate on lipogenesis and lipolysis in adipose tissues in Holstein dairy cows were examined. Cr has been demonstrated to promote fat production in adipose tissue while lowering net release. This could be due to chromodulin's interaction with the insulin receptor, which results in enhanced glucose flow into the adipocyte. Insulin inhibits lipolysis (decreases the availability of fatty acids to the liver), hepatic ketogenesis, and ketone body use in general. Experiments on humans and lab animals commonly show that circulating cholesterol and (or) non-esterified fatty acids levels are reduced (NEFA). The same effect has been reported in ruminants. Although the mechanism is unknown, chromium has been reported to affect cholesterol and triglyceride metabolism.

### 4.3 Protein metabolism

Chromium's activity in protein metabolism is mediated by insulin's anabolic action. Evans and Bowman (1992) [20] found that rats incubated with chromium-picolinate had enhanced amino acid and glucose absorption in their skeletal muscles. This change in food intake was linked to changes in insulin parameters, implying that chromium was involved.

### 4.4 Nucleic acid metabolism

The structural integrity and expression of genetic information in animals are thought to be aided by chromium in its trivalent state. Chromium protects RNA from denaturation by heat. Chromium binds to nucleic acids more strongly than any other metal ion (Okada *et al*., 1982) [41]. It regulates gene expression by binding to chromatin and increasing the number of initiation loci, which leads to an increase in RNA synthesis.

## 5. Conclusion

Chromium is an important micronutrient since it helps with glucose, protein, and lipid metabolism as well as immunological function. Supplementing with chromium reduces the detrimental effects of stress on cattle and poultry, resulting in improved performance and health, as well as increased farm profitability. Cr might be considered one of the most important components in poultry feed during HS. Furthermore, the interaction of Cr diet with livestock health status during HS is a novel field that should be investigated further in the future.

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