Chromium and its role in poultry nutrition

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Abstract

Chromium exhibits a multifaceted role in poultry nutrition, positively impacting both egg production and quality in layers. It also plays a crucial part in alleviating the adverse effects of various stresses in poultry underscoring its versatility in enhancing stress resilience in poultry health. Additionally, the positive effects on broilers performance emphasizing chromium's ability to counteract adverse effects of heat stress, thus improving body weight and feed efficiency. The results indicate that incorporating chromium as nutritional supplement in poultry diets shows its potential for improving overall health and productivity.

Keywords: Chromium; stress; poultry.

Introduction

As the poultry industry undergoes rapid expansion, researchers worldwide are directing their attention towards understanding the significance of micronutrients in poultry nutrition to enhance productivity. Despite their requirement in small quantities, micronutrients contribute significantly to promoting the health and vitality of birds. Chromium is a micronutrient essential for the metabolism of carbohydrates, proteins, lipids, and nucleic acids (Esmailzade & Sadeghi, 2017). There is a major role of chromium in metabolism on improving glucose uptake by living tissues. Research has identified chromium as a Glucose Tolerance Factor (GTF), with its deficiency being linked to conditions like hypercholesterolemia and stunted growth (Tang et al., 2015). Furthermore, studies have highlighted effects of chromium on the activity of various antioxidant enzymes (Lushchak et al., 2009). Chromium also has a role in reducing negative effects of environmental stress (Sahin et al., 2001). Supplementation of chromium has been shown to reduce the adverse effects of heat stress in broilers and improve body weight gain and feed efficiency (Sands and Smith, 1999). Chromium's positive effects on productive and reproductive performance, as well as physiological traits, have also been observed under both low and high ambient temperatures (Sahin et al., 2005).

The objective of this review article is to comprehensively explore the significance of chromium supplementation in poultry nutrition, with a focus on its role in mitigating the adverse effects of heat stress, improving growth performance, enhancing carcass yield, boosting immune function, and optimizing egg production and quality. The article aims to provide a detailed analysis of the mechanisms through which chromium exerts its effects, comparing the efficacy of organic and inorganic forms, and highlighting its potential to improve poultry health and productivity under stressful environmental conditions.

Sources of chromium

Organic chromium sources like chromium yeast and chromium methionine are highly effective in improving body weight, weight gain, and feed conversion ratios. Supplementation with 1000 ppb chromium yeast has been shown to enhance feed efficiency and improve protein and lipid profiles in broilers (Safwat et al., 2020). Chromium picolinate is another organic source known for boosting immune responses and meat quality by increasing antibody titers against avian influenza, enhancing oxidative stability, and retaining essential minerals like zinc and iron in broiler meat (Lu et al., 2019; Untea et al., 2019). Chromium propionate also delivers benefits to broilers by improving carcass traits, growth performance, and feed efficiency, particularly at supplementation levels of 200–400 µg/kg (Van Hoeck et al., 2020).

Inorganic chromium sources, such as chromium chloride, can modulate immune responses by increasing lymphoid organ weights, though they are less effective than organic forms in boosting antibody titers (Lu et al., 2019). Chromium oxide, while studied for its effects on growth, generally underperforms compared to organic chromium sources (Safwat et al., 2020). Among available sources, organic chromium options are preferred due to their superior efficacy in improving physiological and production traits in poultry.

Role of chromium in broiler performance

Chromium supplementation has been studied extensively for its role in alleviating the detrimental effects of heat stress in poultry, particularly broilers. Heat stress adversely affects various aspects of broiler performance, including feed intake, growth rate, feed efficiency, and carcass quality. Under such conditions, chromium supplementation has demonstrated a significant potential to mitigate these negative effects and improve productivity in heat-stressed broilers.

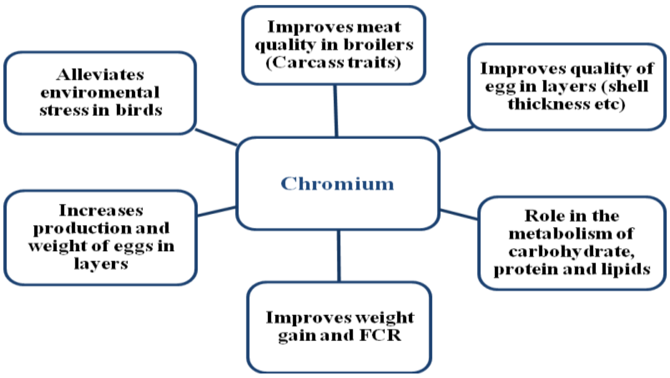

Fig.1 Role of chromium in poultry nutrition

Growth Performance

Several studies have confirmed that chromium supplementation can lead to an improvement in body weight gain and feed intake in broilers subjected to heat stress. For instance, Naghieh et al. (2010) reported that chromium supplementation led to increased body weight gain and enhanced feed intake in broilers under heat stress conditions. Similarly, Wang et al. (2022) observed improvements in performance parameters such as body weight gain and feed conversion ratio (FCR) in broilers supplemented with chromium picolinate (Cr-Pic) at a concentration of 0.4 mg/kg. They also noted an upregulation in SGLT1 expression and modifications in the intestinal microbiota, contributing to better nutrient absorption and overall performance. A systematic review and meta-analysis found that inorganic Cr supplementation at levels between 1200-1700 ppb, or organic Cr at 2700 ppb or less, significantly enhanced body mass gain (BMG) in broilers under heat stress conditions (Piray and Foroutanifar, 2021a). Similarly, another study reported that Cr propionate supplementation at 200 or 400 µg/kg improved final body weight and feed conversion ratios (FCR) across all feeding phases, indicating a positive impact on growth performance (Van Hoeck et al., 2020). In contrast, a meta-analysis focusing on unstressed broilers found no significant association between Cr supplementation and body mass gain, suggesting that the benefits of Cr may be more pronounced under stress conditions (Piray and Foroutanifar, 2021b). This highlights the potential role of Cr in mitigating stress-related growth performance issues.

Different forms of Cr, such as chromium propionate, chromium-methionine, and chromium yeast, have been evaluated for their efficacy. Organic forms of Cr, like chromium propionate and chromium yeast, have shown superior results in terms of body weight gain and feed efficiency compared to inorganic forms like chromium oxide (Safwat et al., 2020). Chromium propionate, in particular, has been noted for its ability to improve carcass yield and meat quality alongside growth performance (Van Hoeck et al., 2020; Arif et al., 2019).

Carcass Yield

Chromium supplementation has been associated with improved carcass yield and a reduction in abdominal fat, which is an important aspect of broiler quality. Chromium propionate supplementation has been shown to improve carcass characteristics, including increased carcass yield, dressing percentage, and breast meat yield (Van Hoeck et al., 2020). Similarly, a study on chromium-methionine supplementation reported improvements in carcass yield and other performance traits under heat stress conditions (Dalolio et al., 2021). The supplementation of organic chromium sources, such as chromium yeast, also resulted in increased carcass yield and improved growth performance (Safwat et al., 2020).

Chromium supplementation has been associated with a reduction in abdominal fat in broilers. Research indicates that chromium nanoparticles and chromium picolinate can reduce abdominal fat without negatively affecting carcass yield (Ognik et al., 2020). Additionally, nano-chromium supplementation has been found to significantly lower abdominal fat levels, suggesting its efficacy in fat reduction (Kumari et al., 2023). Naghieh et al. (2010) found that chromium supplementation not only improved body weight gain and feed intake but also positively impacted carcass yield and abdominal fat reduction. Norain et al. (2013) observed similar benefits when chromium chloride was supplemented in the diet of heat-stressed broilers, showing a reduction in abdominal fat and an improvement in carcass yield. The reduction in fat content is also supported by studies showing decreased crude fat concentrations in broilers supplemented with chromium picolinate (Untea et al., 2019). The mechanisms by which chromium exerts its effects include enhancing nutrient utilization and improving metabolic processes. Chromium supplementation has been shown to improve feed conversion ratios and nutrient metabolizability, which contribute to better growth performance and carcass traits (Kumari et al., 2023). Furthermore, chromium's role in modulating blood biochemistry, such as reducing cholesterol and triglyceride levels, supports its potential in fat reduction (Piray and Foroutanifar, 2021a; Piray and Foroutanifar, 2021b)

Health and immune status

Chromium (Cr) supplementation in broiler diets has been extensively studied for its potential benefits on growth performance, immune response, and overall health, particularly under stress conditions such as high stocking density and heat stress. Chromium's role in enhancing antioxidant capacity and mitigating stress is well-documented. Under heat stress conditions, chromium supplementation has been shown to improve antioxidant activity, reduce lipid peroxidation, and enhance the activity of antioxidant enzymes such as superoxide dismutase (Rao et al., 2016; Jahanian and Rasouli, 2015). Chromium propionate supplementation in heat-stressed broilers also modified intestinal morphology and improved serum immunoglobulin concentrations, indicating enhanced intestinal health and immune response (Huang et al., 2020). Additionally, chromium methionine supplementation alleviated the immunosuppressive effects of heat stress, improving both cellular and humoral immune responses (Hayat et al., 2019).

Chromium supplementation has been shown to enhance the immune response in broilers. For instance, dietary supplementation with organic chromium improved immune function in broilers vaccinated with the

Avian Influenza virus vaccine, increasing serum antibody titers and lymphoid organ weights (Lu et al., 2019). Similarly, chromium yeast supplementation under high stocking density conditions improved immune performance, suggesting an optimal supplementation range for immunity between 319.30 and 961.00 µg Cr/kg (Xin et al., 2022). The supplementation of 2 mg chromium chloride per kg diet significantly enhanced immune response in broiler chickens, evidenced by higher antibody titers against New castle disease virus. It also reduced stress markers, such as heterophil/lymphocyte ratio and serum cortisol levels (Norain et al., 2013). Furthermore, a meta-analysis indicated positive linear associations between chromium supplementation and immune indices such as antibody titers to vaccines and the relative weight of immune organs like the bursa and thymus (Piray and Foroutanifar, 2021b).

Role of chromium on layer production

Egg production

Chromium supplementation in poultry diets has been explored for its potential benefits on egg production and quality, particularly under stress conditions such as heat stress. These improvements are often associated with better metabolic control, insulin regulation, and enhanced egg quality parameters, which are vital for commercial egg production. A study on layer breeders supplemented with chromium propionate demonstrated significant improvements in egg production, feed conversion ratio, and eggshell quality without altering serum biochemical parameters (Souza et al., 2021). Similarly, in laying ducks under heat stress, chromium propionate supplementation increased laying rates and improved egg quality, including yolk color and albumen height, while also enhancing antioxidant status (Chen et al., 2020). Sahin et al. (2002) found that chromium supplementation improved egg production in laying Japanese quails under heat stress. Similarly, Lien et al. (2008) noticed higher egg production in laying hens fed diet supplemented with 800 µg/kg of chromium, as chromium picolinate. They did not observe any significant effect on egg quality. These findings suggest that chromium can be beneficial in enhancing egg production particularly under stressful environmental conditions.

The combination of chromium with other supplements, such as vitamin C and L-carnitine, has been explored to enhance its effects on egg production. Chromium chloride combined with vitamin C improved feed conversion, egg number, and egg mass in Golden Montazah chickens during the summer season (Mousa et al., 2022). Similarly, a combination of chromium picolinate and vitamin C improved egg production and nutrient digestibility in hens reared under low ambient temperatures (Sahin and Sahin, 2018). These studies indicate that chromium's efficacy can be enhanced when used in combination with other dietary supplements. Under high stocking density conditions, chromium-methionine supplementation improved egg production and feed conversion efficiency, while also reducing stress markers such as plasma corticosterone (Mirfendereski and Jahanian, 2015). In heat-stressed hens, chromium methionine supplementation helped maintain performance and metabolic profiles, although it did not significantly improve egg quality traits (Karami et al., 2018). Chromium yeast supplementation has been evaluated for its effects on productive performance and metabolic responses. While specific details on egg production were not highlighted, chromium yeast was found to influence lipid and carbohydrate metabolism, which could indirectly affect egg production and quality (Siloto et al., 2021). These findings suggest that chromium supplementation could be a valuable strategy in poultry nutrition to improve egg production especially in challenging environmental conditions.

Egg quality

Chromium supplementation has been associated with several improvements in egg quality traits, including egg weight, shell thickness, specific gravity, and Haugh unit score. Sahin et al. (2001) reported that increasing chromium levels in the diet of laying Japanese quails led to higher egg weight and improved egg quality traits such as shell thickness, egg specific gravity, and Haugh unit score. The combination of Bacillus subtilis PB6 and chromium propionate improved eggshell quality, including shell percentage, thickness, and strength in layer breeders (Souza et al., 2021). Similarly, chromium picolinate supplementation improved both internal and external egg quality traits, including shell thickness, in Pearl guinea fowls (Gopi et al., 2018). Chromium supplementation has been particularly beneficial under heat stress conditions. Dietary chromium propionate increased laying rate and improved egg quality, such as yolk color and albumen height, in laying ducks under heat stress (Chen et al., 2020). In laying hens, chromium picolinate and chromium histidinate were effective in partially alleviating the adverse effects of heat stress on egg production and quality, although they did not completely restore egg quality parameters (Sahin et al., 2018). Sahin et al. (2002) observed a reduction in serum corticosterone levels in heat-stressed laying quails supplemented with chromium, which was associated with improved shell quality. Similarly, Sahin et al. (2001) found that chromium picolinate supplementation led to increased eggshell thickness and improved overall egg quality in laying hens. Abdallah et al. (2013) reported positive effects of chromium on yolk index and egg yolk percentage in hens, although they did not observe significant changes in other parameters like albumin percentage and shell weight. The improvement in yolk quality can be attributed to chromium's role in enhancing insulin sensitivity and nutrient utilization, which ultimately affects the synthesis and composition of egg yolk. Conversely, Lien et al. (2004) showed that supplementation of dietary chromium (800 and 1600 µg Cr/kg) as chromium picolinate had no effect on egg production and egg weight of laying hens. Also, the shell thickness was not affected by supplementation of dietary chromium. In the similar context, Uyanik et al. (2002) confirmed no effect of supplemental chromium (chromium chloride) in hen diets on egg weight and egg production at level of 20 ppm. They also concluded that chromium supplementation in hen diets had no significant effects on shell thickness, egg shape index, egg specific gravity, and Haugh unit. The potential mechanisms by which chromium (Cr) contributes to maintaining egg quality include: (1) acting as a structural component of egg albumen or participating in protein cross-linking, (2) playing a vital role in the synthesis of ovomucin, which is essential for the gel structure of albumen, and (3) facilitating the transfer of cations, potentially magnesium, into the egg albumen during the plumping process in the uterus (Hossain, 1998)

The use of chromium nanoparticles (NanoCr) has also been investigated for its effects on egg quality. Supplementation with NanoCr in layers resulted in increased egg weight and improved albumen quality, as indicated by higher Haugh unit scores (Malathi and Gowda, 2015). This suggests that chromium nanoparticles can enhance certain aspects of egg quality, which may contribute to overall improved egg production performance.

Health and immune status

Chromium is also noted for its role in alleviating stress, particularly heat stress, which is a common issue in poultry production. Studies have shown that chromium supplementation can improve antioxidant status and reduce stress indicators in poultry. Chromium yeast supplementation in dairy cows under heat stress conditions improved antioxidant capacity and immune function, suggesting similar benefits could be expected in poultry (Shan et al., 2020). Additionally, chromium propionate has been shown to improve egg production and eggshell quality under stressful conditions, indicating its potential to enhance performance during environmental stress (Souza et al., 2021).

Chromium's role in metabolic health is also significant. It has been associated with improved nutrient metabolizability and reduced cholesterol levels in laying hens. Chromium supplementation led to a decrease in plasma and egg yolk cholesterol levels, which is beneficial for both the health of the hens and the quality of the eggs produced (El motaal, 2022). Furthermore, chromium has been shown to influence glucose metabolism, which is crucial for maintaining energy balance and overall health in poultry (Piray and Foroutanifar, 2021b)

Chromium supplementation has been shown to enhance immune responses in poultry. For instance, dietary chromium increased cell-mediated immune function in laying hens, as evidenced by a significant increase in hypersensitivity response when chromium was combined with vitamin C (El motaal, 2022). Similarly, in broilers, chromium supplementation improved immune responses, including increased antibody titers and enhanced T-lymphocyte activity (Lu et al., 2019). These findings suggest that chromium can modulate immune function, potentially making poultry more resilient to infections

The form of chromium used in supplementation can affect its efficacy. Organic forms, such as chromium picolinate and chromium yeast, have been found to be more effective in enhancing immune responses and reducing stress compared to inorganic forms (Lu et al., 2019; Xin et al., 2022). This suggests that the choice of form of chromium is important for maximizing its benefits in poultry diets.

Cost economics of chromium supplementation in poultry

The cost of chromium varies depending on the source and form used. Organic sources like chromium picolinate and chromium propionate are generally more expensive than inorganic sources like chromium chloride (Pawlisz et al., 1997). While organic sources are often preferred due to their higher bioavailability, their cost can be a limiting factor. The optimal dosage of chromium supplementation is still a subject of ongoing research, and recommendations vary (Van Hoeck et al., 2020; Rajalekshmi et al., 2014). Higher dosages naturally translate to higher costs. Determining the most effective dosage with the greatest return on investment is essential for cost-effective supplementation. The market price of chromium, like any commodity, is subject to fluctuations. These fluctuations can impact the cost-effectiveness of supplementation, and producers need to consider market rates when making decisions about chromium inclusion in feed. The economic benefits of chromium supplementation are influenced by factors like improved growth performance, feed efficiency, carcass yield, and reduced mortality (Van Hoeck et al., 2020; Rajalekshmi et al., 2014). The measure of these benefits will determine the potential return on investment and influence the overall cost-effectiveness of supplementation.

Trivedi et al. (2019) reported that supplementing broiler diets with organic chromium (CrPro) at 1200 µg/kg significantly improves economic returns by enhancing income, profitability, and feed cost efficiency. The study demonstrates that chromium supplementation is a viable strategy for maximizing profitability in broiler production, with the 1200 µg/kg level offering the highest economic benefits. Similarly, Kulkari et al. (2018)

highlighted that supplementing broiler diets with chromium picolinate (20-40 mg/kg) during hot-humid conditions improved feed conversion, energy, and protein efficiency. This supplementation significantly reduced feed and meat production costs while enhancing meat yield, demonstrating its economic and practical benefits in poultry farming. A comprehensive cost-benefit analysis is essential to determine the economic viability of chromium supplementation. This analysis should consider both the direct costs of chromium supplementation and the potential economic benefits derived from its use.

Conclusion

Dietary chromium supplementation benefits poultry by improving feed utilization, antioxidant defense, immune function, growth, egg quality, and lean carcass yield, especially under heat stress. It enhances health by lowering serum cholesterol, triglycerides, and glucose levels. Further research is needed to explore chromium's nutritional biochemistry, molecular mechanisms, and pharmacological actions for better poultry management. However, the stability, oxidation states, and concentrations of chromium forms must be carefully managed to avoid potential toxicity, ensuring its safe and effective use in poultry nutrition.

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