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Review Article

Role of Chromium in Poultry Nutrition and Health: Beneficial Applications and Toxic Effects

[1]Mayada Ragab Farag, [2]Mahmoud Alagawany, [2]Mohamed Ezzat Abd El-Hack, [3]Muhammad Arif, [4]Tugay Ayasan, [5]Kuldeep Dhama, [6]Amlan Patra and [7]Kumaragurubaran Karthik

[1]Department of Forensic Medicine and Toxicology, Veterinary Medicine Faculty, Zagazig University, Zagazig, Egypt
[2]Department of Poultry, Faculty of Agriculture, Zagazig University, 44511 Zagazig, Egypt
[3]Department of Animal Sciences, University College of Agriculture, University of Sargodha, 40100, Pakistan
[4]East Mediterranean Agricultural Research Institute, Adana, Turkey
[5]Division of Pathology, ICAR-Indian Veterinary Research Institute, Izatnagar, 243122 Uttar Pradesh, India
[6]Department of Animal Nutrition, West Bengal University of Animal and Fishery Sciences, Belgachia, Kolkata, India
[7]University of Laboratory, Tamil Nadu Veterinary and Animal Sciences University, Tamil Nadu, India

Abstract

Chromium (Cr) is one of the essential minerals which is required for improving productive performance in poultry due to its important functions in metabolism, growth and reduction of lipid and protein peroxidation. Under heat stress conditions, Cr plays a crucial role in poultry nutrition, production and health as well as enhances growth performance and quality of eggs in meat and egg type chickens, respectively. Supplementation of Cr may increase body weight gain, improve feed efficiency and there is also increase in carcass yield of broilers. Chromium is also a potent hypocholesteremic and antioxidant agent. The beneficial impacts of Cr have been linked with improved the metabolism and immune system. Dietary addition of Cr has promising impacts on the immune system through increasing relative weights of lymphoid organ such as thymus, spleen and bursa of Fabricius, declined heterophil/ lymphocyte (H/L) ratio, enhancing the Cell Mediated Immune (CMI) response and improving the antibody response versus the infectious diseases. Dietary supplementation of Cr may stimulate the secretion of digestive enzymes by improving the functions of liver and pancreas. Chromium present in many forms differs greatly in stability and oxidation states; therefore the added forms and concentrations should be managed well. Further, the increase in Cr dose in the diet could produce hazardous and toxic influences in chickens as well. This paper illustrates the positive and negative impacts of Cr including its physical and chemical proprieties, practical applications in poultry nutrition, production, enhancing immunity and health and a special reference to its toxic effects.

Key words: Chromium, production, reproduction, health, antioxidant, hypolipidemic, hypocholestermic, enhancing immunity, toxicology, poultry

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Corresponding Author: Mayada Ragab Farag, Department of Poultry, Faculty of Agriculture, Zagazig University, 44511 Zagazig, Egypt

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INTRODUCTION

Chromium (Cr) is a well-known essential trace element for animals. Chromium presents in many oxidation forms, among them trivalent (CrIII) and hexavalent (CrVI) chromium are the most stable and common forms[1].The most common Cr forms used as supplements to poultry and animal diets are Cr picolinate, Cr nicotinate, Cr tripicolinate, Cr yeast, Cr propionate and Cr trichloride ($CrCl_3$)[1]. Chromium is employed in food, feed and pharmaceutical purposes owing to its role in nutrient metabolism such as proteins, carbohydrates, fats, amino acids and nucleic acids[2]. Previous studies have identified Cr as a Glucose Tolerance Factor (GTF) and its absence could result in hypercholesterolemia and retarded growth[3]. The effects of Cr on the activities of different antioxidant enzymes have been recorded[4]. Additionally, beneficial impacts of Cr on productive and reproductive performance as well as physiological traits had been reported either under low or high ambient temperatures[5]. Meanwhile, few studies also did not show any beneficial impacts[6,7].

Supplemental dietary Cr as chromium picolinate (CrPic) alters glucose metabolism and decreases mortality rate in broiler chickens[8]. In addition, supplementation of Cr increased serum total protein, albumin and insulin, but corticosterone and cholesterol concentrations were decreased in blood. Reduction in corticosterone has positive effect in broilers by increasing the carcass quality since corticosterone can affect protein synthesis in the muscles[8]. Organic Cr sources have shown better beneficial impacts on heat-stressed birds in comparison with inorganic sources due to their increased absorption and bioavailability[9].

In laying hens, supplementation of Cr resulted in higher weight, production, mass and best quality of eggs[10]. On the other hand, supplemental organic Cr did not affect feed consumption and body weight of laying hens[11]. Sahin *et al.*[12] reported that chromium addition at 1200 ppb increased the productive performance, egg quality and serum insulin level of laying Japanese quails. CrIII is less toxic than CrVI so it is used in low concentrations as an essential trace element in animals and poultry diets to enhance growth and improve the production and meat quality[13]. However, its addition face a challenge as it should be used in the actually needed concentrations to avoid toxic and harmful impacts[14] such as nephrotoxic, hepatotoxic, oxidative and DNA damaging effects following Cr administration[15]. Therefore, the nutritional properties of Cr are still needed a great attention. The present article illustrates the beneficial and toxicological aspects of Cr and its impacts in different doses in poultry nutrition and production.

BENEFICIAL EFFECT OF CHROMIUM

Growth rate and feed utilization: In this regard, dietary supplementation of Cr (as chromium picolinate) at 1600 μg kg^{-1} increased growth rate expressed as live body weight and body weight gain of broiler chickens in comparison with control or other diets containing 800 and 3200 μg kg^{-1} of chromium[16]. Lien *et al.*[16] also noted that dietary supplementation of 1600 μg Cr kg^{-1}, as chromium picolinate, significantly increased feed intake in broiler chicks fed diets containing either 800, 1600 and 3200 μg kg^{-1} of chromium. While, feed conversion was not affected at all levels. Body weights of broiler chickens and laying Japanese quail were linearly increased with increasing chromium (as chromium picolinate) levels (200, 400, 800 and 1200 μg kg^{-1}) under heat (32.5°C) stress conditions[12,17]. In addition, feed intake and feed efficiency were increased and improved with Cr supplementation, respectively.

Uyanik *et al.*[10] reported that dietary chromium supplementation (as chromium chloride) at level 20 ppm resulted in 18.57% reduction in feed consumption and improvement in feed conversion by 16.77%. But the higher levels of chromium (40 and 80 ppm) had no significant effects neither on feed consumption nor on feed conversion of broiler chicks. Uyanik *et al.*[18] fed laying hens on diets containing chromium (as chromium chloride) at level of 20 ppm and reported a reduction in feed consumption by 1.88% and an improvement in feed efficiency by 4.28%. In growing Japanese quail, Uyanik *et al.*[7] reported no significant effects on body weight, body weight gain, feed intake and feed conversion of chromium supplementation (as chromium chloride) in growing Japanese quail diets at levels of 20, 40, 80 and 100 ppm.

Sahin *et al.*[5] fed growing Japanese quails on diets supplemented with 400 μg Cr kg^{-1}, as chromium picolinate and noted a significant increase in feed intake and a significant improve in feed conversion under heat stress condition (34°C for 8 h). The same authors noted no effect of chromium supplementation on body weight gain under thermo-neutral condition. However final body weight was not affected by chromium supplementation neither under heat stress condition nor under thermo-neutral condition.

Anandhi *et al.*[19] reported that organic chromium supplementation in broilers diets at levels of 250, 500 and 750 μg kg^{-1} diet had no significant effects on body weight gain, feed consumption and feed conversion. These results are in line with those reported by El-Kholy *et al.*[20] who pointed dietary chromium supplementation did not affect all performance (live body weight, body weight gain, feed intake and feed conversion ratio) parameters during the overall period (2-6 week of age). Moreover, chromium supplementation increased daily body weight gain of broiler chickens subjected to heat stress[21]. The contradicting findings among the abovementioned studies may be partially returned to the following factors: Cr forms and sources, Cr dose, supplementation method, the type and age of experimental animals, or the kind and duration of induced stress.

Egg production: Lien *et al.*[8] noted a beneficial impact on egg production when laying hens fed diet supplemented with 800 μg kg^{-1} of chromium, as chromium picolinate. Also, Liu *et al.*[22] observed that supplementation of chromium at 10 mg kg^{-1} in laying hen diets significantly improved egg weight and egg number as well as prolonged the period of laying peak.

Egg production and egg weight of laying Japanese quail were linearly increased as chromium increasing when birds fed diets containing 200, 400, 800 and 1200 μg kg^{-1} chromium (chromium picolinate) under heat stress condition[17]. On the other hand, a study by Uyanik *et al.*[18] showed that supplemental chromium (chromium chloride) in hen diets at level of 20 ppm had no significant impacts on egg weight and egg production. On the same context, Lien *et al.*[6] confirmed no effect of dietary chromium doses (800 and 1600 μg Cr kg^{-1}) on egg production and egg weight of laying hens.

Egg quality criteria: There are conflicting results on egg quality due to supplementation of Cr in laying birds. For example, Lien *et al.*[8] noted no impact on egg quality when the diet of the laying hens supplemented with 800 μg kg^{-1} of chromium, as chromium picolinate. Also, Uyanik *et al.*[18] fed laying hens on rations containing 20 ppm of chromium and recorded no significant impacts on egg shape index, egg specific gravity, Haugh unit and shell thickness. Lien *et al.*[6] noted no significant effects on shell thickness of dietary chromium supplementation, supplemented as chromium picolinate, at levels 800 and 1600 μg Cr kg^{-1} of laying hen diets. On the other hand, Liu *et al.*[22] stated that chromium (chromium chloride) supplementation at level of 10 mg kg^{-1} diet significantly improved egg quality in layers.

Shell thickness, egg specific gravity and Haugh unit score were linearly increased with increasing chromium level, when laying Japanese quails fed on the diet supplemented with either 200, 400, 800 and 1200 μg Cr kg^{-1} diet (as chromium picolinate) under heat stress condition (32.5°C) compared with control diet[17]. Abdallah *et al.*[23] pointed out that yolk index and egg yolk % were increased as dietary chromium doses increased, but no significant differences in the percentage of egg albumin and shell weight as well as egg shape and albumin indices were observed between the treatment and control group.

Semen quality and reproductive parameters: Only few studies investigated the effect of Cr on semen quality and reproduction performance in birds. Supplementing the diet of Montazah chickens with 800 ppb CrPic improved semen quality (ejaculate volume, advanced motility and a live sperm%), reproductive organs weights (ovary and tests weight) as well as fertility and hatchability percentage[23]. On the same context, Hanafy[24] showed a significant improvement in semen quality by supplementation of chromium. The improvement in semen quality may be attributed to the antioxidant activity of chromium which maintained the integrity of cell membrane and reduced the oxidants damage. Long and Kramer[25] confirmed that the reduction in malondialdehyde concentration is a marker to the integrity degree of sperm membranes and their ability of fertilizing.

In the winter season, supplementation of 400 ppb of Cr as Cr-Methionine improved the hatchability of laying Japanese quail compared with control[26]. Also, Contreras *et al.*[27] reported that 200 ppb of chromium methionine enhanced hatchability of laying Japanese quail under the temperate areas (25°C).

Carcass traits: Dietary supplementation of 800 μg Cr kg^{-1} diet, as chromium picolinate, significantly increased liver percent in broiler fed diets containing 800, 1600 and 3200 μg Cr kg^{-1}[16]. In line, Sahin *et al.*[12] reported that increased supplemental chromium resulted in an increase in carcass traits of broiler chicks fed on the basal diet supplemented with chromium at levels of 200, 400, 800 and 1200 μg kg^{-1} diet (as chromium picolinate) under heat stress condition (32.5°C), as compared with those fed on the basal diet. Moreover, Sahin *et al.*[5] reported that supplementing diets of growing Japanese quails with 400 μg Cr kg^{-1}, as chromium picolinate, resulted in a significant increase in cold carcass percent under heat stress conditions (34°C for 8 h). However, cold carcass percent was not affected by chromium supplementation under thermo-neutral condition. Huang *et al.*[21] reported that chromium addition increased dressing percentage and decreased abdominal fat percentage of broiler chickens exposed to heat stress in comparison with control.

Supplemental Cr had no significant impacts on carcass traits (carcass, dressing, giblets, liver, gizzard and heart) of growing quails as compared with untreated group[20]. In accordance to these findings, Anandhi[19] reported that organic chromium supplementation in broilers diets at levels of

250, 500 and 750 μg kg^{-1} diet had no significant effects on carcass yield. On the same context, Uyanik *et al.*[10] reported no significant impacts on carcass yield of Cr supplementation, as chromium chloride, in growing Japanese quail diets at levels of 20, 40, 80 and 100 ppm.

Hematological parameters: Dietary chromium supplementation (chromium chloride) in broiler diets at levels of 20, 40 and 80 ppm significantly decreased H/L ratio, as compared with un-supplemented group[10]. Contrarily, El-Kholy *et al.*[20] noted that no significant effect of Cr addition on parameters of Hb, PCV or H/L ratio in growing Japanese quails, as compared with un-treated group. Consistent with these findings, Toghyani *et al.*[28] reported that Hb and PCV values were not influenced by dietary Cr (0, 500, 1000 and 1500 ppb). These results favorably compared with Kani[29] who stated that hemoglobin was not affected by chromium addition.

Antioxidant activity: Stressors and diseases can increase urinary excretion of chromium and may aggravate a marginal chromium deficiency in poultry and domestic animals[30]. These stressors including heat stress increased production of free radicals which damage the body cells and result in increased poultry morbidity and mortality[2]. Cooling of poultry buildings is very expensive, nutritional manipulations[31] such as use of feed additives along with their different preparations is suggested to improve the poultry performance. Lipid peroxidation levels in the serum and liver were increased under heat stress conditions[5]. Sahin *et al.*[32] found that heat stress increased the secretion of inflammatory markers like C-reactive protein, interleukin-6 and TNF-α (tumour necrosis factor-α). Supplementation of chromium in heat-stressed Japanese quail diets decreased MDA in quail serum[12].

Liver and kidney functions and thyroid hormones: In broiler chickens, serum total protein and thyroid hormones (T3 and T4) concentrations were linearly increased with chromium (chromium picolinate) supplementation (200, 400, 800 and 1200 μg Cr kg^{-1} diet), under heat stress (32.5°C) conditions[12]. In broiler chickens, Uyanik *et al.*[10] reported that total proteins and globulin concentrations in serum were increased at all levels (20, 40 and 80 ppm) of chromium, while serum albumin was increased at level 20 ppm chromium only. Also, birds fed Cr at levels of 800, 1200, 1600 and 2000 μg kg^{-1} diet had higher blood protein concentrations[33].

In growing Japanese quail, Uyanik *et al.*[7] mentioned that serum total proteins, albumin and globulin were not significantly affected by chromium supplementation at levels of 20, 40, 80 and 100 ppm. On the same context, Total protein and its fractions in plasma of growing Japanese quails were not influenced by dietary Cr supplementation, in comparison with un-supplemented group[20]. Taha *et al.*[34] showed that T3 and T4 hormones were not significantly affected by watery supplementation of chromium chloride. In line, dietary chromium did not significantly ($p>0.05$) affect plasma levels of AST, ALT, T3, T4 and T3/T4 ratio of growing Japanese quails[20].

Hypolipidemic, hypocholestermic and hypoglycemia effects: Most pronounced effect of Cr in birds appears to be the reduction of cholesterol and glucose concentration in blood. Dietary Cr picolinate (800, 1600 or 3200 μg Cr kg^{-1} diet) supplementation increased high density lipoprotein and decreased low density lipoprotein and very low density lipoprotein of the broiler chickens[16], while serum glucose concentrations were reduced only at levels 1600 and 3200 μg kg^{-1} of chromium. Similarly, supplementation of chromium decreased total lipids, total cholesterol, very low density lipoprotein and low density lipoprotein, but increased the high density lipoprotein and triglycerides in serum[34]. Type of chromium also has effect on LDL level of the blood. Study reported that organic chromium decreased serum LDL while inorganic chromium in poultry feed can increase the LDL level[29].

Sahin *et al.*[12] fed broiler chickens reared under heat stress condition (32.5°C), on the basal diet (control) diet or on the basal diet supplemented with either 200, 400, 800 and 1200 μg Cr kg^{-1} (as chromium picolinate). They reported that with the increasing in dietary chromium supplementation serum glucose and cholesterol concentrations were linearly decreased significantly, whereas serum total proteins concentrations were linearly increased. In laying Japanese quail, Sahin *et al.*[17] found that plasma glucose concentrations were decreased linearly as chromium increasing in birds fed on the basal diet supplemented with 200, 400, 800 and 1200 μg Cr kg^{-1}, as chromium picolinate, under heat stress condition (32.5°C), as compared with group fed on the basal diet. Also, Uyanik *et al.*[7] mentioned that chromium supplementation, as chromium chloride, in growing Japanese quail diets at levels of 20, 40, 80 and 100 ppm resulted in a significant reduction in serum levels of glucose and cholesterol.

Sahin *et al.*[5] reported that supplementing diets of growing Japanese quails with 400 μg Cr kg^{-1}, as chromium picolinate, significantly decreased serum glucose and cholesterol under heat stress (34°C for 8 h) and thermo-neutral conditions. On the same context, birds fed Cr at levels of 800, 1200, 1600 and 2000 μg kg^{-1} diet, had lower some lipid parameters like cholesterol and triglyceride[33].

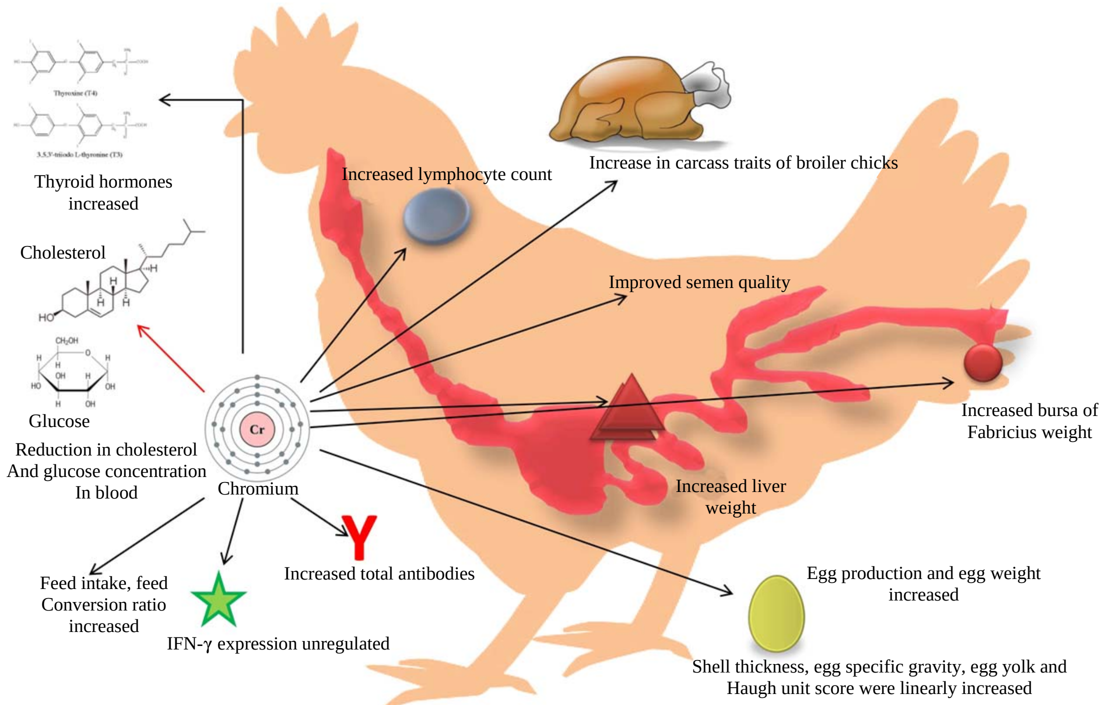

Fig. 1: Beneficial effects of chromium in poultry nutrition and health

Mirfendereski and Jahanian[35] found that supplementation of chromium-methionine at levels of 500 and 1000 ppb in the diet, decreased cholesterol and glucose levels in plasma, but triglyceride was not influenced by the same levels. Chromium chloride supplementation at 30 mg L^{-1} water reduced the concentrations of serum cholesterol, low density lipoprotein, very low density lipoprotein, triglyceride and glucose but increased the concentrations of total lipids and high density lipoprotein[34]. Uyanik *et al.*[10] reported that dietary chromium supplementation (chromium chloride) in broiler diets at levels of 20, 40 and 80 ppm had no significant effects on serum glucose and cholesterol concentrations. In laying hens, Uyanik *et al.*[18] reported that dietary chromium supplementation (as chromium chloride) at level 20 ppm in laying diets had no significant effects on serum cholesterol concentrations. Lien *et al.*[6] noted no effect on serum cholesterol concentration of dietary chromium supplementation, as chromium picolinate, in laying hen diets at levels 800 and 1600 μg Cr kg^{-1}.

Plasma cholesterol and triglyceride were increased with supplementation of organic chromium in the 21st and 42nd days of broilers[29]. In addition, total lipids and glucose in plasma of growing Japanese quails were not influenced by dietary Cr, while cholesterol was increased with increasing Cr doses. In contrast, glucose level was numerically decreased with Cr in comparison with un-supplemented group[20].

An overview on the beneficial applications of chromium in poultry nutrition and health is presented in Fig. 1.

TOXIC EFFECTS OF CHROMIUM

Effects on productive performance and antioxidant capacity: Chromium chloride (2 g kg^{-1}) reduced the relative mass of heart, kidney and lung to mass of body in broilers with no change in the histological structures of these organs[36]. Chromium intoxication also decreased the content of B (1, 2 and 6) and E vitamins in liver, kidney, muscles and serum of developing chicks[37]. Oral administration of chromium inhibited the growth performance of chickens and induced renal damage as reported by Liu *et al.*[38] where , male Hyland Brown chickens received three different doses of chromium trichloride ($CrCl_3$) representing 1/8 LD50, 1/4 LD50 and 1/2 LD50 in mg kg^{-1} body weight in drinking water, the samples were collected at 14, 28 and 42 days after treatment and the results showed that chromium decreased the gain of body, leg muscles and chest muscles, reduced the glutathione peroxidase, superoxide dismutase and catalase activities, lowered the total antioxidant capacity while significantly increased glutathione, hydrogen peroxide and malondialdehyde levels in the kidney and induce histopathological alterations in renal tissues dose and time dependently. On the same context, the oxidative damage and pathological lesions were reported in the liver tissues of this type of chicken after chromium administration[39]. Similar results were obtained for the chicken brain in the study of Cheng *et al.*[40] in which, male Hyland Brown chickens exposed to three different doses of chromium trichloride ($CrCl_3$) representing 12.5% LD50, 25% LD50 and 50% LD50 in mg kg^{-1} body weight for 42days in drinking water showed significant increase in hydrogen peroxide and malondialdehyde while total antioxidant capacity, activities of antioxidant enzymes (glutathione peroxidase, superoxide dismutase and catalase) and total glutathione concentration were decreased significantly in addition to sever histopathological changes in the brain of chicken especially at higher doses.

Oral administration of $CrCl_3$ adversely affects the growth performance of chickens and induced nephrotoxicity represented by histopathological alterations in renal tissues and reduced antioxidant capacity in relation to the time and dose of exposure[38].

Kumari *et al.*[41] calculated the LD50 of potassium chromate (K_2CrO_4) in broiler chicks as (277.95 mg kg^{-1}) and found that addition (1/5th and 1/3rd of LD50) to the diet of broiler chicks for 30 days decreased the haemoglobin percentage, haematocrit values, total erythrocyte count and total leucocyte count while increased the clotting time in broiler chick. While chromium in the form of potassium dichromate ($K_2Cr_2O_7$) induced oxidative stress by decreasing SOD activity and glutathione level and increasing MDA content in the brain of male Hyland Brown chickens consumed 6% LD_{50} $K_2Cr_2O_7$ mg/kg B.W.). It also decreased the mitochondrial membrane potential (MMP) and Ca^{2+}-ATPase activity in addition to histological damage in the brain tissue[42].

Reproductive and developmental toxicity: Chromium (VI) induced DNA damage, in the form of chromium-DNA binding in liver and 8-oxo-2'-deoxyguanosine (8-oxo-dG) in red blood cells of 14 days chick embryos depending on the dose. Chromium cause toxic and teratogenic effects in the developing embryos of mallard and decrease their hatchability and viability[43].

Chromium decreased the hatchability of sexually mature Japanese quail males (*Coturnix coturnix japonica*) by about 14%, increased the early embryonic mortality of quails received 0.142 g kg^{-1} chromium as K(2)Cr(2)O(7) subchronically for 12 weeks[44].

EFFECT ON HEALTH

The impact of dietary chromium addition on health and the immune responses in broiler chickens showed an elevation in liver and bursa of Fabricius weights, declined heterophil and monocyte counts as well as heterophil/lymphocyte (H/L) ratio and increased total antibody, lymphocyte counts, Cell Mediated Immunity (CMI) to phytohemagglutinin (PHA) along with antibody titers (IgG and IgM)[18,20]. Using of inorganic or organic chromium (chromium L-methionine, chromium chloride) revealed a statistical elevation in antibody titers, enhanced H/L ratio in addition to relative weights of spleen and thymus in broilers suffering from heat burden. Using the organic type was reported to be better in reducing immunodepression related to heat stress in broilers[45]. In broiler chickens, chromium propionate addition to drinking water or feed improves the immune responses through up-regulating interferon-gamma (IFN-γ) expression after vaccination with R_2B strain of Newcastle Disease (ND)[46]. On day 1, IFN-γ expression in spleen was about 2-4 times higher than control and on day 3 post-immunization, IFN-γ expression was about 27-40 times higher. However, on day 7 post-immunization IFN-γ expressions reached basal concentration in all the vaccinated groups[45].

Rao *et al.*[47] postulated that the addition of organic chromium in broilers diet has no impact on heterophyl and lymphocyte ratio and relative weight of immune organs like thymus, bursa and spleen as well as antibody production versus vaccination of Newcastle Disease (ND). But ratio of lymphocyte proliferation improved with dietary chromium addition. Furthermore, Rajalekshmi *et al.*[48] studied the impact of chromium propionate supplementation to male broiler diet and reported that weights of lymphoid organ were not significantly influenced through the whole study period (42 days of age). Increasing chromium dose enhanced the antibody response versus lymphocyte proliferation ratio response and ND vaccination and. As well, H/L ratio declined as an indicator to depressed heat stress level. Chromium methionine supplementation to broilers increased antibody level against NDV and IBV at 21 and 42 days after treatment. Similarly Cr at concentration of 800 ppb in feed increased lymphocyte while decreasing the heterophil to lymphocyte ratios[49,50]. Recent study reported that Cr supplementation to laying hens improved the $CD4^+$ cells and also improved the adaptive immunity in caecal tonsils of hens[51].

CONCLUSION

The dietary Cr has useful impacts on feed utilization, antioxidant defense system, immune enhancing effects, lean carcass quality, growth and production indices and quality of egg. Moreover, it is very helpful especially in birds exposed to heat-stress conditions. Birds fed diet enriched with Cr revealed higher doses of Cr and other trace elements compared to those without any supplementation. Beneficial impact of Cr such as lowering serum concentration of total cholesterol, triglycerides and glucose had been noticed in poultry species fed diets supplemented with chromium, indicating the positive health-effects. Discovering the possible modes of action of Cr like its different nutritional biochemistry, biological and pharmacological activities and molecular mechanisms of actions are important to succeed in the management of poultry and farm animals that may support further understanding of the performance and health ramifications of immune-endocrine interactions. Poultry fed diet supplemented with chromium significantly revealed higher levels of chromium and other trace elements compared to those without any supplementation. The requirements of various species of poultry and the quality of the different trace elements used are the areas that warrant attention. Chromium present in many forms differed greatly in their stability and oxidation states, the added forms and concentrations should be managed well, as the increase in chromium level could be produce hazardous and toxic influences in chickens.

SIGNIFICANCE STATEMENT

Chromium plays an important role in poultry nutrition, production and health as well as enhances growth performance. Chromium is also a potent hypocholesteremic and antioxidant agent. The dietary Cr has useful impacts on feed utilization, antioxidant defense system, immune response, lean carcass quality, growth and production indices and quality of egg.

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REFERENCES

1. Zhang, M., Z. Chen, Q. Chen, H. Zou, J. Lou and J. He, 2008. Investigating DNA damage in tannery workers occupationally exposed to trivalent chromium using comet assay. Mutat. Res./Fundam. Mol. Mech. Mutagen., 654: 45-51.
2. Khan, R.U., S. Naz and K. Dhama, 2014. Chromium: Pharmacological applications in heat-stressed poultry. Int. J. Pharmacol., 10: 213-317.
3. Tang, H.Y., Q.G. Xiao, H.B. Xu and Y. Zhang, 2015. Hypoglycemic activity and acute oral toxicity of chromium methionine complexes in mice. J. Trace Elements Med. Biol., 29: 136-144.
4. Lushchak, O.V., O.I. Kubrak, O.V Lozinsky, J.M. Storey, K.B. Storey and V.I. Lushchak, 2009. Chromium(III) induces oxidative stress in goldfish liver and kidney. Aquat. Toxicol., 93: 45-52.
5. Sahin, N., K. Sahin, M. Onderci, M.F. Gursu, G. Cikim, J. Vijaya and O. Kucuk, 2005. Chromium picolinate, rather than biotin, alleviates performance and metabolic parameters in heat-stressed quail. Br. Poult. Sci., 46: 457-463.
6. Lien, T.F., K.L. Chen, C.P. Wu and J.J. Lu, 2004. Effects of supplemental copper and chromium on the serum and egg traits of laying hens. Br. Poult. Sci., 45: 535-539.
7. Uyanik, F., M. Eren, B.K. Guclu and N. Sahin, 2005. Effects of dietary chromium supplementation on performance, carcass traits, serum metabolites and tissue chromium levels of Japanese quails. Biol. Trace Elem. Res., 103: 187-197.
8. Lien, T.F., S.Y. Chen, S.P. Shiau, D.P. Froman and C.Y. Hu, 1996. Chromium picolinate reduces laying hen serum and egg yolk cholesterol. Professional Anim. Sci., 12: 77-80.
9. Moeini, M.M., A. Bahrami, S. Ghazi and M.R. Targhibi, 2011. The effect of different levels of organic and inorganic chromium supplementation on production performance, carcass traits and some blood parameters of broiler chicken under heat stress condition. Biol. Trace Element Res., 144: 715-724.
10. Uyanik, F., A. Atasever, S. Ozdamar and F. Aydin, 2002. Effects of dietary chromium chloride supplementation on performance, some serum parameters and immune response in broilers. Biol. Trace Elem. Res., 90: 99-115.
11. Eseceli, H., N. Degirmencioglu and M. Bilgic, 2010. The effect of inclusion of chromium yeast (Co-Fator II, Alltech Inc.) and folic acid to the rations of laying hens on performance, egg quality, egg yolk cholesterol, folic acid and chromium levels. J. Anim. Vet. Adv., 9: 384-391.
12. Sahin, K., N. Sahin, M. Onderci, F. Gursu and G. Cikim, 2002. Optimal dietary concentration of chromium for alleviating the effect of heat stress on growth, carcass qualities and some serum metabolites of broiler chickens. Biol. Trace Elem. Res., 89: 53-64.
13. Debski, B., W. Zalewski, M.A. Gralak and T. Kosla, 2004. Chromium-yeast supplementation of chicken broilers in an industrial farming system. J. Trace Element Med. Biol., 18: 47-51.
14. Deng, G., K. Wu, A.A. Cruce, M.K. Bowman and J.B. Vincent, 2015. Binding of trivalent chromium to serum transferrin is sufficiently rapid to be physiologically relevant. J. Inorg. Biochem., 143: 48-55.
15. Jin, Y., Z. Liu, F. Liu, Y. Ye, T. Peng and Z. Fu, 2015. Embryonic exposure to cadmium (II) and chromium (VI) induce behavioral alterations, oxidative stress and immunotoxicity in zebrafish (*Danio rerio*). Neurotoxicol. Teratol., 48: 9-17.
16. Lien, T.F., Y.M. Horng and K.H. Yang, 1999. Performance, serum characteristics, carcase traits and lipid metabolism of broilers as affected by supplement of chromium picolinate. Br. Poult. Sci., 40: 357-363.

17. Sahin, K., O. Ozbey, M. Onderci, G. Cikim and M.H. Aysondu, 2002. Chromium supplementation can alleviate negative effects of heat stress on egg production, egg quality and some serum metabolites of laying Japanese quail. J. Nutr., 132: 1265-1268.
18. Uyanik, F., S. Kaya, A.H. Kolsuz, M. Eren and N. Sahin, 2002. The effect of chromium supplementation on egg production, egg quality and some serum parameters in laying hens. Turk. J. Vet. Anim. Sci., 26: 379-387.
19. Anandhi, M., R. Mathivanan, K. Viswanathan and B. Mohan, 2006. Dietary inclusion of organic chromium on production and carcass characteristics of broilers. Int. J. Poult. Sci., 5: 880-884.
20. El-Kholy, M.S., M.M. El-Hindawy, M. Alagawany, M.E.A. El-Hack, S.A. El-Gawad and A.E.H. El-Sayed, 2017. Dietary supplementation of chromium can alleviate negative impacts of heat stress on performance, carcass yield and some blood hematology and chemistry indices of growing Japanese quail. Biol. Trace Element Res. 10.1007/s12011-017-0936-z.
21. Huang, Y., J. Yang, F. Xiao, K. Lloyd and X. Lin, 2016. Effects of supplemental chromium source and concentration on growth performance, carcass traits and meat quality of broilers under heat stress conditions. Biol. Trace Elem. Res., 170: 216-223.
22. Liu, P.X., L.J. Chen, D.B. Xie and X.M. Xiong, 1999. Effects of dietary chromium on the productivity of laying hens and the distribution of chromium. Acta Agric. Univ. Langxiensis, 21: 564-568.
23. Abdallah, E.A., M.H. Abdel Samad and A.M. Abdel Latif, 2013. Effect of supplementing diet with chromium picolinate on productive, reproductive, physiological performance and immune response of golden montazah chickens. Egypt. Poult. Sci., 33: 751-767.
24. Hanafy, M.M., 2011. Influence of adding organic chromium in diet on productive traits, serum constituents and immune status of Bandarah laying hens and semen physical properties for cocks in winter season. Egypt. Poult. Sci., 31: 203-216.
25. Long, J.A. and M. Kramer, 2003. Effect of vitamin E on lipid peroxidation and fertility after artificial insemination with liquid-stored turkey semen. Poult. Sci., 82: 1802-1807.
26. Contreras, G. and R. Barajas, 2001. Effect of chromium-methionine level in diet on hatchability of Japanese quail in dry tropic weather: II. Response under temperature controlled in winter season. Poult. Sci., 80: 323-323.
27. Contreras, G., R. Barajas and A. Montoya, 2000. Effect of chromium methionine supplementation on egg hatching response of Japanese quail under controlled temperature condition in dry tropic weather. J. Anim. Sci., 78: 241-241.
28. Toghyani, M., M. Shivazad, A.A. Gheisari and S.H. Zarkesh, 2006. Performance, carcass traits and hematological parameters of heat-stressed broiler chicks in response to dietary levels of chromium picolinate. Int. J. Poult. Sci., 5: 65-69.
29. Kani, M.M., 2015. The effects of different sources of organic and inorganic chromium on blood parameters of broiler chickens. Indian J. Sci. Technol., 8: 1-7.
30. Haq, Z., R.K. Jain, N. Khan, M.Y. Dar, S. Ali, M. Gupta and T.K. Varun, 2016. Recent advances in role of chromium and its antioxidant combinations in poultry nutrition: A review. Vet. World, 9: 1392-1399.
31. Attia, K.M., F.A. Tawfeek, M.S. Mady and A.H. Assar, 2015. Effect of dietary chromium, selenium and vitamin C on productive performance and some blood parameters of local strain Dokki-4 under Egyptian summer conditions. Egypt. Poult. Sci., 35: 311-329.
32. Sahin, N., F. Akdemir, M. Tuzcu, A. Hayirli, M.O. Smith and K. Sahin, 2010. Effects of supplemental chromium sources and levels on performance, lipid peroxidation and proinflammatory markers in heat-stressed quails. Anim. Feed Sci. Technol., 159: 143-149.
33. Ebrahimnazhad, Y. and S. Ghanbari, 2014. The effect of dietary chromium supplementation on blood biochemical parameters of broiler chicks. Greener. J. Biol. Sci., 4: 98-102.
34. Taha, N.M., A.A. Mandour and O.H. Habeila, 2013. Biochemical effect of chromium element on lipid profile of broilers. Alexandria J. Vet. Sci., 39: 74-81.
35. Mirfendereski, E. and R. Jahanian, 2015. Effects of dietary organic chromium and vitamin C supplementation on performance, immune responses, blood metabolites and stress status of laying hens subjected to high stocking density. Poult. Sci., 94: 281-288.
36. Ahmad, F., M.J. Tariq, M.S. Abdullah and R. Kausar, 2004. Effects of higher levels of chromium and copper on broiler health and performance during the peak tropical summer season. Veterinarski Arhiv., 74: 395-408.
37. Chundawat, R.S. and P.P. Sood, 2005. Vitamins deficiency in developing chick during chromium intoxication and protection thereof. Toxicology, 211: 124-131.
38. Liu, Y., C. Liu, J. Cheng, W. Fan, X. Zhang and J. Liu, 2015. Growth performance and oxidative damage in kidney induced by oral administration of Cr(III) in chicken. Chemosphere, 139: 365-371.
39. Fan, W.T., X.N. Zhao, J. Cheng, Y.H. Liu and J.Z. Liu, 2015. Oxidative stress and hepatocellular injury induced by oral administration of Cr^{3+} in chicken. J. Biochem. Mol. Toxicol., 29: 280-287.
40. Cheng, J., W. Fan, X. Zhao, Y. Liu, Z. Cheng, Y. Liu and J. Liu, 2016. Oxidative stress and histological alterations of chicken brain induced by oral administration of chromium (III). Biol. Trace Elem. Res., 173: 185-193.

41. Kumari, R.R., P. Kumar and T.K. Mondal, 2013. Effect of vitamin E and selenium on hematological parameters in sub-acute toxicity of hexavalent chromium in broiler chick. Natl. J. Physiol. Pharm. Pharmacol., 3: 158-161.
42. Hao, P., Y. Zhu, S. Wang, H. Wan and P. Chen *et al*., 2016. Selenium administration alleviates toxicity of chromium(VI) in the chicken brain. Biol. Trace Elem. Res., 178: 127-135.
43. Kertesz, V. and T. Fancsi, 2003. Adverse effects of (surface water pollutants) Cd, Cr and Pb on the embryogenesis of the mallard. Aquat. Toxicol., 65: 425-433.
44. Butkauskas, D. and A. Sruoga, 2004. Effect of lead and chromium on reproductive success of Japanese quail. Environ. Toxicol., 19: 412-415.
45. Ghazi, S., M. Habibian, M.M. Moeini and A.R. Abdolmohammadi, 2012. Effects of different levels of organic and inorganic chromium on growth performance and immunocompetence of broilers under heat stress. Biol. Trace Elem. Res., 146: 309-317.
46. Bhagat, J., K.A. Ahmed, P. Tyagi, M. Saxena and V.K. Saxena, 2008. Effects of supplemental chromium on interferon-gamma (IFN-γ) mRNA expression in response to Newcastle disease vaccine in broiler chicken. Res. Vet. Sci., 85: 46-51.
47. Rao, S.V.R., M.V.L.N. Raju, A.K. Panda, N.S. Poonam, O.K. Murthy and G.S. Sunder, 2012. Effect of dietary supplementation of organic chromium on performance, carcass traits, oxidative parameters and immune responses in commercial broiler chickens. Biol. Trace Elem. Res., 147: 135-141.
48. Rajalekshmi, M., C. Sugumar, H. Chirakkal and S.V. Ramarao, 2014. Influence of chromium propionate on the carcass characteristics and immune response of commercial broiler birds under normal rearing conditions. Poult. Sci., 93: 574-580.
49. Ebrahimzadeh, S.K., P. Farhoomand and K. Noori, 2012. Immune response of broiler chickens fed diets supplemented with different level of chromium methionine under heat stress conditions. Asian-Australasian J. Anim. Sci., 25: 256-260.
50. Rouhalamini, S.M., M. Salarmoini and G. Asadi-Karam, 2014. Effect of zinc sulfate and organic chromium supplementation on the performance, meat quality and immune response of Japanese quails under heat stress conditions. Poult. Sci. J., 2: 165-181.
51. Madej, J.P., R.M. Nowaczyk, M. Janeczek, A. Chroszcz and M. Korczynski, 2017. The effect of dietary supplementation with chromium-enriched soya meal on lymphatic cells in caecal tonsil of laying hens. Anim. Feed Sci. Technol., 223: 53-58.