American Journal of Botany and Bioengineering
https://biojournals.us/index.php/AJBB
ISSN: 2997-9331

Nutraceutical Potential of Saffron in Counteracting Lead-Induced Physiological and Biochemical Changes in Poultry: A Review

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Received: 2025 19, Jul
Accepted: 2025 28, Aug
Published: 2025 23, Sep

Annotation: Lead still remains one of the major environmental concerns for poultry, as the metal induces oxidative stress and alters other organ systems. It also has an effect on the immune status and productivity of the flocks. Traditional methods to lower lead toxicity are not much help. A glimmer of hope for solution appears in the form of safe and natural alternatives. Saffron (Crocus sativus) is a lucrative medicinal plant containing numerous phytochemicals such as crocin, crocetin, safranal, and picrocrocin which have gained a lot of dominance as nutraceuticals. But right heart pumping through the cardiac immune response, saffron replacement affects the antioxidant safety equipment (SOD, CAT, GSH) and protects birds from lipid (MDA) and of Pb-exposed poultry protects the live and kidney functionality and enhances hematologic and immune responses (heart). Furthermore the growth performance, feedconversion ratio, the meat quality (texture and flavor) and reproductive health are also improve by saffron hence it can serve as an ideal dietary supplementation in poultry diet that will lead the bottom line to fattened up. All of these have been tested and stood through the test of time to statistically outperform the traditional feeds in use today. It can be deduced that the application of saffron and its by-products can so be a possible harmless selection to help in the management of metallic toxicities in chickens, and therefore secure animal welfare and farming efficiency, albeit saffron and its derivatives are confronted with obstacles vitamin the cost, availability and stability vitamin dose.

Keywords: Lead toxicity, Poultry, Antioxidant defense, Nutraceuticals, Sustainable feeding.

Introduction

BackgroundHeavy metals environmental pollution has become one of the most serious challenges for sustainable poultry production globally. Lead (Pb), as a member of this class of pollutants, is persistent in the environment, biomagnifies in tissues and exerts toxic effects in the human body. In poultry, exposure is primarily via contaminate water, feedstuffs or dust material and leads to decreased production and represents threat to food security (Aljohani et al., 2023; Mukherjee et al., 2023).

The physiological and biochemical actions of lead toxicosis have been well characterized in poultry. Exposure of lead inhibition of enzyme functions initiation and health and generation of oxidative stress which is associated with:· Lipid peroxidation· Hepatotoxicity· Nephrotoxicity · Neurotoxicity. Pb exposure decreases growth rate, feed efficiency, egg production and reproductive performance, which means economic or production loss. Moreover, immunosuppression induced by lead exposure increases susceptibility of poultry to infections that cause higher economic losses to farmers (Oke et al., 2024; Merck Veterinary Manual, 2025).

Conventional methods for HM removal have several side effects; thus, the use of non-toxic and natural approaches for their removal and detoxification have been an attractive area of research. Plant-based nutraceuticals are appealing due to their potential antioxidant, anti-inflammatory, and immunomodulation activity. They represent an environmentally-friendly approach to optimizing immune functions and reducing chemical prophylaxis in animals (Ebrahimi et al., 2023). Background Saffron (Crocus sativus L.) has drawn attention as nutraceutical candidates based on their unique phytochemical profile. The key components (crocin, crocetin, safranal and picrocrocin) exert significant antioxidant activity (Mhamad & Palani 2025; Bostan et al. 2017), which occur mainly via free radical scavenging, modulation of redox states and inhibition of cellular injury. Several studies conducted in animals and in humans have indicated that Saffron protects hepatic, renal, and reproductive tissues from the deleterious impact of AFs, likewise, saffron has the potential to counteract AF-induced toxicity on hematological (Adnan et al., 2021; Falahati et al., 2022) and immunological parameters (Shahiri et al., 2019; Ferreira et al., 2020; Khalil et al., 2023) (Abedi et al., 2023; Mhamad et al., 2025). Abstract This review discusses the available evidence on the effect of saffron as a nutraceutical for amelioration of lead-induced physiological and biochemical changes in poultry. This review therefore aims to discuss the approaches taken by experimental trials, the potential pharmacological applications of saffron, and the sustainability merits of saffron as a natural safe feed additive with practical applications for poultry health, production performance, and food safety.

Lead Toxicity in Poultry

Commercial poultry sources of lead (Pb) emmission are airborned polluters (e.g. airborne lead)/ polute producers (e.g. suspended air, soil particles, etc.) from (1) water polution, (2) feeds components which had been contaminated by artificial pollutants and (3) flora, soil, airborne dust spreading infectious pathogenic entities (e.g. bacteria, virus). For outdoor and free-range systems, the routes of exposure are also the ingestion of residues of deteriorated paint, industrial deposits, and dust. Studies of chicken farm monitoring indicated concentrations of Pb residues in eggs, feed and soil 500. Such feces may be contaminate this heavy metal from multiple sources: land fertilised with feces, industry polluted soil, and food or water contact with Pb residues on industrial equipment during processing feed (Aendo et al.,2024; Hoseini et al.,2023) the authors state.

The digestive tract absorbs lead. Juvenile birds absorb it better and that's why. The metal that was ingested does not all get absorbed as ions, less than 10% is absorbed and most (90%) is excreted in the feces or bile and is not excreted in urine. Poultry is contaminated with lead in environment which is stored in soft tissue like liver, kidney, brain and gonads. Comparatively, upon the capacity of bones to cumulatively store this contaminant (in bones) and sustain its release into circulation (Cui et al., 2019Cui et al.,, 2021), bones constitute a more stable reservoir of this toxic element, and can be a possibly significant source of chronic subclinical poisoning. 2021; Pain et al. 2019).

Some birds have gizzards that grind the lead into smaller pieces, and there is a greater absorption into the body. In this regard, the risk of bioavailability and tissue traces is greater (Torimoto et al., 2021; Pain et al., 2019, 2019). Enzymatic insufficiency dirties the blocked detoxification pathways in Milogysize It causes the hepatocellular degeneration of the liver and eventually leads to the changes of serum enzymes. Chapter it reduce eggs hatching accomplishments and differentiate hatched out in frog– beak mind, our bit unexciting up– chick and bone gentle it bit chrome on.

The tissue samples taken from experimental chickens exposed to lead over two years (758 birds in 2 groups), giver a sound evidence that the lead is injurious to health. It induces lesions in liver, kidney, and blood; reduces reproductive efficiency. Incubation at 16 °C countered the ‘normal’ vs. ‘reduced’ fertility discrepancy witnessed after 1 month (when incubated at 24 °C) in the same two groups that tested with low fertility when incubated at 16 °C compared to when incubated at 24 °C (Aendo et al., 2024; Mukherjee et al., 2022).

Saffron and Its Bioactive Compounds

Important Asian, Middle East, European and functional plant with functional potential, saffron (Crocus sativus L.) Saffron contains a unique profile of bioactive compounds (ie, crocin, crocetin, safranal and picrocrocin) that provide saffron its color, taste and odor and its health-promoting/ pharmacological activities (Mhamad et al, 2025). Crocin, a water-soluble carotenoid glycoside, is the most abundant active ingredient of saffron which can produce potent antioxidant effects. It was established that it scavenges ROS, anti lipid peroxidation activity, mediates neuroprotection, and reproductive organ protective agent . ObjectiveCrocetin (Cro), as the aglycone of crocin, exhibits anti-inflammatory and hepatoprotective activity through inhibition of inflammatory cytokines and restoration of mitochondrial function. Background: Saffron is used for anti-depressant purpose in traditional medicine, where neuroprotective and antidepressant roles of saffron components have also been putatively associated with certain psychoactive features (aroma) of saffron, namely with at least one volatile saffron bioactive component safra- nal, which suggested activity on GABAergic system and serotonergic neurotransmission. The whole bitter gained its reputation of bitteras due(top)thePicrocrocin has been shown to cause (Bostan et al., 2017; Anaeigoudari et al., 2023),it was revealed that its function is to bene linked to metabolic regualtions and gastroprotective effects.

The physiological levels of saffron have multiple pharmacological effects. Subsequently, the action of the endogenous antioxidants, SOD, CAT, and GPx were shown to be enhanced [74], along with recovery of potent antioxidant activities and free radical scavenging capabilities. It exhibits anti-inflammatory effect by blocking various proinflammatory mediators, including TNF-α and IL-1β on NF-κB pathway [45]. Additionally, saffron showed hepatoprotective, that protects liver structure and function, and renoprotective, that protects kidney structure and function, effects at toxicosis (especially in heavy metal toxicity such as lead) (Palani et al., 2025; Abedi et al., 2023). Historically, saffron have been used in folk medicine for the treatment of digestive, cardiovascular and sexual diseases. Saffron have been employed by traditional systems of medicines for the treatment of numerous disorders for thousands of years. A well-known Persian and Ayurvedic medicine, saffron has a history of use in treating fertility problems and mood disorders and being used as a restorative tonic (READ).

Pieces of evidence from the clinical and experimental studies in various oxidative stress-related diseases, neurodegenerative disorders, liver disorders and sexual dysfunction (Mhamad & Palani, 2025; Vakili et al., 2022) supported many of their traditional uses. Together, by its this invaluable properties of saffron and its multi-faceted pharmaceutical impact it raises its importance as an excellent nutraceutical leader to combat heavy metal toxicity along with potential agent to uplift the poultry physiology and productivity in holistic manner.

Biological Mechanisms of Saffron in Counteracting Lead Toxicity

Introduction The bioactive molecules, active principles of Saffron (Crocus sativus L.): crocin, crocetin, safranal and picrocrocin, can simultaneously modulate multiple biochemical or physiological pathways that may explain the treatment efficacy against Lead (Pb) toxicity. MERELY ERASING CELLULAR MEMORY An example being the most researched one which, wipes out the information on free radicals created in the redox couplings. Decreasing of activity of antioxidant enzyme in produce of R.O.S will damage body cells [6]. The supplementation of saffron restores lower levels of reduced form of glutathione (GSH), active superoxide dismutase (SOD) or efficient catalase (CAT), replacing free Radicals scavenging antioxidants (Sonego et al., 2025; Shahzadi et al.,2024). A potent decrease in malondialdehyde (MDA), a marker of lipid peroxidation, can be caused by saffron. It prevents oxidation of lipid, protein, and DNA, as well as scavenging free radicals which limits oxidative stress and stabilizing the cell membranes, thereby preventing cytokine generation and consequently cellular damage and degeneration in one organ (Oke et al., 2024; Anaeigoudari et al., 2023). Apart from this, saffron also prevents significant Pb target organs such as liver and kidneys from Pb deposition [65]. Studies on saffron have indicated an ability to reduce liver damage induced by Pb, normalize serum liver enzymes, and protect against Pb-induced tubular damages on animal models [2]. Such activity correlates with inhibition over detoxification pathway and inhibition of oxidative stress induced apoptosis (Bostan et al., 2017; Aljohani et al., 2023).

In addition, it also ameliorates hematological parameters and protects against Pb-induced anemia with saffron. Saffron has been shown to stimulate increased packed cell volume and hemoglobin level, and increased leucocyte response to dietary saffron in poultry and mammalian studies. Moreover, saffron may have the potential to mitigate the adverse effects of such disturbances to restore blood from the hypoxic functional capacity and carrying capacity of the organ to the normoxic capacity by suppressing the oxidative injury on hemopoietic tissues (Mhamad, Palani, & Al-Zubaidy, 2025; Liu et al., 2025). Lastly, it has the ability to modulate immunity and has anti-inflammatory effects. Both in vitro and in vivo actions of saffron can be administered to animals by reducing an inflammatory mediator like TNF-α and IL-1β and stimulating lymphocyte proliferation and antibody responses. In addition, saffron appeared safe,109 and can be taken in food and purchased as a dietary supplement. By stimulating the immune system and thus offering greater protection against infection to animals and birds (Vakili et al., 2022; Palani, Ameen &Shekhani, 2025). We propose from these results that saffron has all the required mechanisms of action for the preventive lead poisoning purpose — complementing different antioxidant machinery, epigenetically inhibiting path leads causing free radicals rampage, strengthening up organs which need serve organism but are the weaker (heart), reconstituting basement of building blocks (structural/functional) by Renal, blood cell and end effectors of immune system.

Experimental and Applied Evidence

In yet another quite recent study (Mhamad & Palani, 2023; Abedi et al, 2023), both saffron, or saffron anthocyanins, appeared to offer some promise in preventing lead-induced toxicity.

Saffron and active ingredients that can improve birds, But I will also have good feed additives similar to saffron that can help birds antioxidant status or protect tissues against oxidative damage can protect them from lead exposure stress, Etc.

Further laboratory experiments demonstrated that the presence of zeolite increased animal size masses in these cases too (Mhamad & Palani, 2025; Abedi et al., 2023) and for Mellat et al. zeolite assisted inclusions of dietary saffron increased body weight gain, body weight gain acceptability feed intake, and feed conversion rates of articles containing in and between experimental broiler feed ()(Saffron as a feed supplement). No adverse effects were observed, and these beneficial effects correlate with decreased concentrations of malondialdehyde (MDA) in brain cortex homogenates along with higher activities of tissue antioxidant enzymes such as superoxide dismutase (SOD) and catalase (CAT). Similarly much lower liver and kidney function permissions throughout dietary inclusion with saffron are also wonderfully enhanced in chickens (e.g., serum enzyme activity values totally normalized and pathological images better than Pb-exposed controls (Oke et al., 2024; Aljohani et al., 2023). In contrast, large variability effects will manifest at much lower levels in field experiments; individualized through living circumstances, through lead encountered per unit of time in feed and drinking water per one saffron dose form exposure. On the commercial scale, there have been practical experiences (in the farm conditions) on the use of saffron by-products (petals and extracts) in poultry diets to combat environmental stressors in birds. However, the the achievement of verification on an industrial level is still somewhat missed, while no complete specter of standardized protocols are offered for the dosage and formulations (Marrone et al., 2024).

Hence, other food quality trait papers are also focused on TTL birds, not European meats from thousands of km distant cattle. Better meat spoilage resistance in experimental animals fed saffron in the broiler experiments (lower TBARS are of apparent benefit to the consumer after 7 days in which to spoil unless there was a defect in the consumer response to the stimulus-gas transport such as might be performed of an fruit or vegetable) was confirmation of the results gained above.

However, saffron also pits on some physiologic characteristics, given active differentials, including characteristics of the reproduction process and immune system related traits. Thus, saffron-supplemented poultry models would provide restoration of fertility indices and hatchability most recently impaired by lead in male birds on diet supplemented with saffron. British microbiologists, in the last decade have described many improved animal-level indices in the blood cells effluxes: massive increase vertebrate level hemoglobin (Hb) values by red cell count (Literature sources: Mhamad, Palani & Al-Zubaidy, 2025; Liu et al., 2025). Saffron is suitable for use as a novel feed additive for the protection of welfare and productivity in poultry. Butterflies? However, most — one in four — was already dead including a female. The potency of saffron against lead poisoning of chickens is likely being revealed in the bench as well as the field. Deer farms do this often, but the differences of such recovery bet routine tends to spread a lot quicker than usual on a deer farm.

While the present findings are indeed encouraging, additional research is needed to ascertain its practical applications for greatest advantage to commercial poultry via dose standardization, cost analysis and incorporation to full production scale with other phytogenic feed additives.

Future Perspectives and Applications

As the increasing literature of saffron protective effects against lead-induced toxicity suggests its possible application as feed-based nutraceutical in poultry production. This review exemplifies that saffron or its derivatives (petals extracts, and/or standardized compounds) when incorporated via the diet of poultry could be prophylactic to improve oxidative stability, protect the active tissues from oxidative stress, thereby improving organ protection, and enhancing the possible immunity and reproductive experience from both male and female poultry on a proportionate basis through the mentioned therapeutic powers of saffron.

As inline with global trend that calls for safer and natural feed additives to replace synthetic drugs and improve sustainable animal production systems (Mhamad & Palani, 2025; Abedi et al., 2023). But it's not good news all around where they're concerned. Saffron stigma is cost prohibitive to saturate at scale, low yield of stigma and variance in concentration of active compounds are primary barriers to useful incorporation into the diet.

But, more recent evidences showed that the valorisation of saffron by-products such as discarded petals and tepals classified as waste material since they are deleted during spice processing, could represent a sustainable and free-of-cost source of new antioxidant agents (but also of bioactive agents in the field of the nutraceutics (Marrone et al., 2024). Also worrying is the lack of uniformity with the dose regimens. The limited number of available studies was characterized by different formulations (i.e. extracts vs powders), doses and duration prohibit the creation of common feeding standards. This suggests that saffron should be subject to additional dose-response evaluations and saffron products should be standardized before being applied to commercial feed programs (Anaeigoudari et al., 2023; Sheikh et al., 2023). However, to substantiate the findings observed in the lab trial and longevity of response to saffron supplementation in terms of poultry performance, product quality and product economics, undertaking large field scale trials on the farms under production scenario are warranted. It will also crucially need to place saffron supplementation within the broader framework of the cost-economics of animal production, to evaluate how competitive the practice is in comparison to conventional feed additives. Saffron may as well join with every other phytogenics to improve its action and be employed to decrease unit expenses of production (Oke et al. 2024; Palani 2025a, b).

Conclusion In conclusion, saffron is an innovative, harmless and natural element that may have potential as a dietary supplement for mitigating heavy metals environmental stress in poultry, and improving their production performance. However, its success in commercial poultry nutrition will depend on its relatively high cost, low availability (especially in the global context), cost standardization challenges and on-farm economic studies.

Conclusion

The beneficial effects in avian lead toxicity. Saffron (Crocus sativus) possesses antioxidant, anti-inflammatory and organ protective properties and can provide protective effects against PT described in birds. ConclusionSaffron has a potential role in preservation of the health of the associated birds & production in HM exposure through the induction of the activities of antioxidant enzyme & hence reduction of oxidative status while may consequently improve the various available hematological & immune statuses. Bioactivity seen is such that saffron should be considered as a novel candidate safe and efficacious nutraceutical feed additive. Saffron or its low-cost derivative would be among the potential nutraceuticals for improvement of welfare and quality of poultry products, and for fasting implementation of sustainable feeding strategies to the modern poultry systems.

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