Review Article

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Agricultural Waste Biochar as a Novel Feed Additive for Livestock and Poultry: A Review

Edited by: Jaydip Rokade
ICAR-Central Avian Research Institute
Izatnagar, Bareilly

Reviewed by: Neeti Lakhani
ICAR-Research Complex for Eastern Region, Patna, Bihar

Keshab Barman
ICAR-National Research Centre on Pig, Guwahati, Assam

S B N Rao
National Institute of Animal Nutrition and Physiology
Bengaluru, Karnataka

*Correspondence: P S Swain
psswain@ouat.ac.in

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R. Kumar[1#], S. L. Kolhe[1#], N. Panda[1], D. P. Swain[2], S. Venkateswarlu[3], P. Pathak[4], P. S. Swain[5*]

[1]Department of Animal Nutrition, College of Veterinary Science and Animal Husbandry, Odisha University of Agriculture and Technology, Bhubaneswar; [2]Veterinary Assistant Surgeon, Barakhama, Kandhamal, Fisheries and Animal Resources Development Department, Govt. of Odisha, India; [3]Department of Animal Nutrition, College of Veterinary Science, Sri Venkateswara Veterinary University, Tirupati, Andra Pradesh; [4]Krishi Vigyan Kendra, Dhemaji, Assam Agricultural University, Simen Chapori, Assam, India; [5]ICAR- AICRP on MAH, Odisha University of Agriculture and Technology, Bhubaneswar, Odisha, India.
*Corresponding author: psswain@ouat.ac.in
#Contributed equally, considered as First author

Biochar, a carbonaceous material produced by pyrolysis from various types of biomass in low-to-no oxygen thermal process at temperature ranging from 350 to 1000 ºC, predominantly used as toxin binder due to its high adsorption capacity. Studies conducted so far involving different Biochar have shown significant desirable biological responses in different animal models i.e. growth promotion, improved immunity, reduction in harmful microbiota in faecal matter and litter, meat quality attributes in poultry etc. Similarly, Biochar has modulated the rumen microbial population more towards desirable ecosystem thus benefiting the livestock productivity. Biochar can adsorbs a range of toxic compounds, including plant and animal-derived toxins, endogenous toxins, and gases such as methane and thus, use of biochar in aflatoxin contaminated feed stuffs can be a measure to lessen the feed wastage. Furthermore, addition of biochar increased nutrient digestibility, nitrogen retention and also resulted in increased fat and protein content of the milk. Likewise, biochar addition also resulted in decreased oxidative stress, improved blood biochemical indices and inflammation following immunization, which is an indicative of improvement in animal health. Addition of Biochar also tend to augment the intestinal histo-architecture in animals. However, though the studies done so far on Biochar have shown a lot of promise as feed additive for livestock and poultry, further in-depth research is essential to validate its efficacy and safety across livestock and poultry production systems in short time and long term addition in the ration.

Keywords: Agricultural waste; Biochar; Livestock Performance; Feed Additive; Poultry

Introduction

Since time immemorial, the animal husbandry is one of the major activities for human civilization in India, which serves as food for human consumption, provides animal energy for different agricultural activities and many more. Therefore, attempts are always made to increase the livestock production and augment in animal health by improving the animal feeding management (Naveena and Kiran, 2014). With ever increasing industry standards and consumer awareness, the demand for animal origin healthy food products keep the researchers on toes to find out novel and natural feed additives free from any residual and/or adverse effects. According to European Commission (EC) feed additives are substances, microorganisms or preparations other than feed materials or premixtures which are intentionally added to feed or water in particular to fulfil specific functions in animal body. Animals with high growth performance need to maintain a high health status, which requires the prime use of feed additives. In recent years ban on the use of antibiotic growth promoter, high cost of conventional feed additives and increased awareness about harmful residual effect of non-natural feed additives necessitates the emergence and search of natural, non-residual feed additive to gain importance in sustainable livestock production (Pandey et al., 2019). The natural and non-residual alternatives of conventionally used feed additives, biochar produced from various agricultural biomass has become increasingly popular in past few years. Biochar is a carbonaceous material produced by pyrolysis from various types of biomass in no oxygen thermal process at temperature ranging from 350 to1000C (European Biochar Foundation, 2012; International Biochar Initiative, 2015). Globally, wide range of biomass sources like animal manure, crop residues, agro-industrial byproducts and forestry waste are used (Weber and Quicker, 2018). All the biomass sources have the common characteristics like cost effectiveness, environment friendly and also its ability to enhance the recycling of organic wastes generated from agricultural, forestry and processing industries (Tang et al., 2013). In recent times, use of biochar as a regular feed supplement by livestock farmers is gaining attention thanks to its beneficial attributes towards animal health, nutrient intake efficiency resulting in enhanced productivity in livestock and poultry. Though in early days, biochar addition in livestock ration showcased its beneficial effects in terms animal health and production. In this section we will discuss regarding beneficial effects documented so far in different animal models, their probable mode of action, and way forward.

Production and Characterization of Biochar

Biomass is converted into biochar by the thermochemical conversion technique using heat and chemical catalyst, where pyrolysis is one of the most promising thermochemical conversion technique used to produce the biochar (Tripathi et al., 2016).There are six major types of pyrolysis technologies – fast pyrolysis, flash pyrolysis, slow pyrolysis, hydro pyrolysis, vacuum pyrolysis and microwave pyrolysis for the production of biochar (Sohi et al., 2009; Ippolito et al., 2020; Liu et al., 2021), bio-oil and gases which are the end products of thermochemical conversion technique but out of it, slow pyrolysis and microwave pyrolysis are the promising technologies for production of biochar (Ippolito et al., 2020; Liu et al., 2021). Slow pyrolysis is thermal decomposition of biomass in the absence or partial absence of oxygen at moderate temperature ranges from 400-800 °C (Tripathi et al., 2016). In case of biochar, the physicochemical properties are governed by many factors such as composition of feedstock temperature of pyrolysis, duration of pyrolytic reaction, rate of heating, particle size of biomass etc. (Akhtar and Amin, 2012). With the increasing pyrolysis temperature, yield of biochar decreases due to the higher volatilization of the biomass which leads to decrease in moisture content, ash and fixed carbon (Gai et al., 2014). Shorter the residence time, higher the yield of biochar (Pecha and Garcia-Perez, 2020). Biochar can be produced from any biomass which is mostly considered as waste starting from, wood, leaves, straw, maize cob, etc. Report suggests that, the raw materials have a profound influence on biochar properties (Ippolito et al., 2020). For instance, in case of bood based biochar, the specific surface area is the greatest, which in combination with pyrolysis temperature could likely promote greater changes in soil physical characteristics than biochar produced from other biomass. Similarly, biochar produced from crops and grass have higher cation exchange capacities than other biochars, which in combination with pyrolysis temperature could potentially lead to longer-term changes in soil dynamics (Ippolito et al., 2020). However, the use of agricultural wastes for biochar making is well practised for soil fortification and soil nutrient management, and use as a potential feed additive may open up new possibilities and opportunities in the field of animal nutrition.

The systematic characterization of biochar includes chemical (pH, elemental composition), physical (surface area, pore structure) and structural (functional groups) properties, which is found important to understand the various functions of biochar including its use as a novel feed additive in livestock feeding (Table.1). Presence of functional groups like carboxylic, hydroxyl, amide, amine and lactonic groups at the surface of biochar increase its adsorption capacity, which depends on the biomass used for biochar production and temperature (Li et al., 2017). Determination of surface characteristics of biochar can be done by Fourier Transform Infrared (FTIR) and Raman spectroscopies, Scanning Electron Microscopy (SEM) with energy-dispersive X-ray spectroscopy (EDX) and X-ray photoelectron spectroscopy images (Chia et al., 2012). According to the international union of pure and applied chemistry the pores present in biochar may be micro (<2nm), meso (2-50nm) and micro (>50nm) which are described in detail by SEM. SEM and EDX are utilized for the examination of elemental composition on surface of biochar but it is not suitable for the organic contaminants (Yaashikaa et al., 2020). Brunauer-Emmett-Teller Analysis (BET) can be used to examine the surface area of biochar, which is an important property of biochar mainly responsible for its adsorption capacity (Yaashikaa et al., 2020).

Table.1. Comparison of composition of Biochar produced from various crop straws (Sun et al., 2014)

Sample	Carbon	Oxygen	Nitrogen	Silica	Potassium	Calcium
Rice straw biochar	78.5%	13.39%	0.70%	3.92%	1.56%	0.49%
Cotton straw biochar	74.8%	17.64%	0.69%	-	4.08%	1.17%
Wheat straw biochar	72.9%	17.2%	0.81%	3.44%	1.82%	2.08%
Corn straw biochar	72%	18.3%	1.09%	1.13%	4.57%	0.52%

Among the different biomass used for biochar production few commonly used sources are rice husks (Leng et al. 2012a, b; Phongpanith et al. 2013), pinewood chips (Saleem et al. 2018), jarrah wood (Joseph et al. 2015), bamboo, coconut, etc. (Rajpoot et al. 2024). However, for animal feeding purposes, there is a need to study and standardize the different variables affecting the production and nature of Biochar. However, still the science of Biochar as a feed additive in livestock and poultry feeding is at its infancy, but early studies have shown glimpses of an illustrious future.

Use of biochar as a feed additive in farm animals

Biochar, a carbon-rich product obtained through the pyrolysis process (Willson et al., 2019), has been associated with neutralizing the Gastro Intestinal Tract (GIT) toxins (Prasai et al., 2016), improving feed efficiency and overall bird (Gerlach and Schmidt, 2012; Kumar, 2025) and other livestock (Rajpoot et al. 2024) performances by acting as a good source of mineral and as an alternative to the antibiotic growth promotors as well. The adsorption capacity and mineral nutrient content make the use of biochar a versatile and multifunctional material for livestock and poultry production. Activated biochar has gained popularity as a universal adsorbent material with the capacity to selectively adsorb and neutralize ingested toxins and other contaminants in feed while supplying some essential minerals to animals (Schmidt et al., 2019). Early reports on biochar as a non-nutritional feed additive in poultry feed have shown promising effects (Fig.1), and can replace antibiotic growth promotors (Prasai et al., 2016; Willson et al., 2019), toxin binders (Gerlach and Schmidt, 2012) and improve growth performance (Kalus et al., 2019; Ruttanavut et al., 2009). Different studies have indicated multifarious beneficial effects of addition of biochar in the animal and poultry ration (Table. 2) such as promotes bone mineralization (Evans et al., 2017), enhancement in growth performance (El-kelawy et al., 2024) and litter quality (Kalus et al., 2020a) without harming broiler performance (Linhoss et al., 2019) alteration in rumen fermentation (Rajpoot et al. 2024). The detailed biological responses are discussed in hereafter. However, the studies conducted so far are highly diverse and difficult to draw any conclusions. Consequently, further in-depth research is essential to validate its efficacy and safety across poultry production systems in short time and long term addition in the ration.

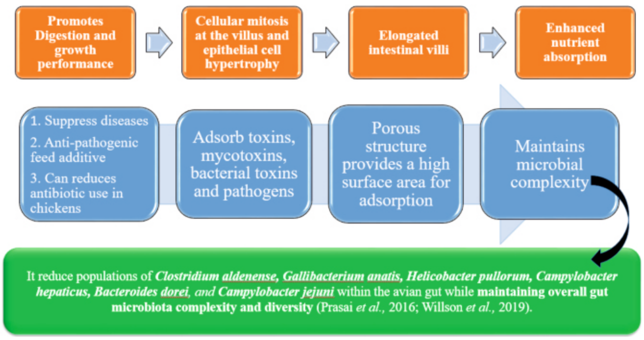

Fig.1 An overview of the different biological responses of biochar used as feed additive in the ration of livestock and poultry

Effect of biochar feeding on growth and performance of animal

Inclusion of various types of biochar in feeding ration at 1-3% have been studied to improve health conditions and performances of farm animals such as weight gain, immunity response, feed intake, feed conversion rates, carcass characteristics (Table 2) and overall quality of animal products (Lao and Mbega, 2020). Rajpoot et al (2024) reviewed the biological responses of different biochars used as feed additive in ruminants and reported that biochar at 0.5–3% inclusion level in ruminant ration have resulted in superior feed intake, body weight gain, feed conversion ratio, immune response, carcass characteristics . Similarly, cattle supplemented with 1% biochar made from cassava foliage, cassava roots in the diet resulted in growth increment by 20% (Leng et al., 2012c). Likewise, addition of bamboo biochar at 1.0% of feed DM in goat resulted in significant increase of DM and CP digestibility and also the nitrogen retention (Silivong and Preston, 2016). Biochar can adsorb organic molecules like amino acids, fatty acids, proteins and urea as well as mineral compounds such as ammonium, ammonia and nitrate very efficiently (Schmidt et al., 2019), which may lead to increased fat and protein content of the milk . Van et al (2006) studied the 0.6% biochar supplementation in feed resulted in growth enhancement in young goats by 17%. Similar growth promotion effect of biochar was also reported by Kana et al. (2010) in ducks and Ruttanvat et al. (2009) in broilers. Choi et al. (2012) conducted the study of supplementation of biochar in finishing pig feeding at the rate of 0, 0.3% and 0.6% of the DM of the feed and observed a significant increase in feed conversion rate, the carcass characteristics, live weight gain and immune response at 0.3% supplementation compared to the other treatments. Likewise, Lee et al. (2011) observed significant enhancement in meat marbling, meat colour traits as well as the tenderness of the meat when cooked due to use of biochar in their ration. Ohanaka et al. (2025) reported an improved (P<0.05) live body weight and body weight gain during 0-42 days with supplementation of activated charcoal at 0.05% level in the diet of male Arbor Acres broiler chicks, whereas average daily feed intake was higher in birds fed with 1.00% activated charcoal. Prasai et al. (2018) taken layer pullet of age 18 weeks and supplemented their feed with mixture of biochar, zeolite and bentonite at the rate of 0, 1.0%, 2.0% and 5.0% for 25 weeks and reported the best improved production performance traits of egg yield and FCR at 2.0% supplementation. Ohanaka et al. (2025) also reported significantly better FCR in the birds fed with 1.00% activated charcoal signifying that biochar and charcoal can influence the growth, feed intake in poultry birds. Similarly, El-kelawy et al. (2024) reported that Supplementation of 2% biochar in broiler diets improved body weight, weight gain, FCR, and production index along with improved CP and EE digestibility, augmented dressing percentage. This indicates the holistic welfare of the poultry birds by supplementation of biochar in their ration. Raz et al. (2025) reported that *Prosopis farcta* biochar supplementation significantly improved growth performance, immune function, liver health, and serum lipid profile in quails exposed to AFB1 ($P < 0.05$).

Biochar has the ability to modulate the pH levels in the digestive tract and maintain the stable pH which is very important for optimum enzyme activity and nutrient absorption by adsorbing excess acids or bases. This stable pH also less efficient for the growth of pathogenic microorganisms which further support the gut health (Wang et al., 2017; Viaene et al., 2024). Ruttanavut et al. (2009) demonstrated that supplementing Aigamos duck feed with a bamboo charcoal powder and bamboo vinegar solution resulted in increased body weight, attributed to enhanced nutrient absorption via elongated intestinal villi. Feeding of 0.3% and 0.6% bamboo biochar improved the quality of marketable meat and composition of pig fat with increase in unsaturated fat and decrease in saturated fat (Chu et al., 2013a). Likewise, Kumar (2025) also reported non-significant change in growth, feed intake and FCR in broiler chicken by adding either corn cob waste biochar or paddy straw biochar (at 1% and 2 % levels). However, still a lot to be explored as far as the biological responses of addition of different biochar in livestock and poultry ration is concerned.

Table 2. Biological responses of addition of different biochar to the poultry ration

biochar preparation / Type of biochar used	Scientific Name	Species of Bird	Salient Findings	Reference
Corn Cob Biochar	*Zea mays*	Quails	Corn cob biochar, at 2% level • Improved FCR, body weight gain • Supported intestinal integrity, immune function	Usman et al. (2025)
Pine Biochar	*Pinus spp.*	Broiler Chicken	• Biochar-amended litter (30 % vol/vol surface applied) did not reduce NH_3 levels or affect bird performance. • Significantly lowered litter moisture, making it beneficial for moisture control in commercial broiler houses.	Mohammadi-Aragh et al. (2025)
Non-Specific Biochar	NA	Broiler Chicken	Supplementation of 2% biochar in broiler diets • Improved body weight, weight gain, FCR, and production index • Improved CP and EE digestibility, dressing percentage, and immune parameters (IgA, IgM, IgG, LTT, phagocytic activity) • Increased RBCs, Hb, PCV, WBCs, lymphocytes, total protein, globulins, and thyroid hormones; reduced abdominal fat, serum lipids, oxidative stress markers • Decreased harmful gut bacteria and increasing beneficial microbes.	El-Kelawy et al. (2024)
Wet litter biochar (WLB)	NA	Broiler Chicken	Inclusion of 0.5% and 1% WLB in broiler diets under cold stress • Improved body weight gain, ileal and jejunal villous length and surface area • Reduced FCR	Hasanvand et al. (2023)

Poultry Litter Biochar (PLB)	NA	Broiler Chicken	• 5 g/kg feed PLB effectively mitigated the harmful effects of AFB1 (0.5 mg/kg feed) on broiler performance, biochemical indices and immunity.	Rashidi et al. (2020)
Rice husk biochar	*Oryza sativa*	Local chicken	Inclusion of 1% biochar in poultry feed or litter • No effect on feed intake, weight gain, or FCR • Did not alter RBC, WBC count, or Hb levels • Reduced plasma triglycerides, total coliform in litter and E. coli in faces.	Hien et al. (2018)
Bamboo Charcoal	NA	Broiler chicken	Dietary supplementation with 0.5% Bamboo Charcoal vs 0% charcoal • Higher final body weight, greater weight gain, and improved feed conversion efficiency • Slightly lower mortality rate and better meat quality, with reduced shear force, lower fat content, and a tendency for a higher unsaturated fatty acid ratio • Sensory evaluation indicated slightly higher overall acceptability in chickens fed with 0.5% Bamboo Charcoal. • No changes in haematological and serum biochemical parameters between the Charcoal and control groups.	Kim et al. (2011)
Charcoal	NA	Broiler Chicken	0.3% Charcoal was added to diets at the feed mill vs 0% charcoal group (control) • Increased final body weight by 3.5% • Improved FCR by 2.0% compared to control • No significant effects on carcass dressing percentage or muscle proportion	Majewska et al. (2011)
Charcoal	NA	Turkey	Diet supplemented with 0.3% charcoal vs 0% Charcoal (control) • Lowest mortality rate at 4.4%, which is half of that observed in the 0% charcoal diet. • Body weight increased by 3.9%, and the rearing efficiency index improved by 9.7%.	Majewska et al. (2009)

Effect of biochar feeding on Blood biochemistry, oxidative stress and immunity in farm animals

Though in early days, addition of agricultural waste biochar have indicated better responses in livestock and poultry when included in the ration. The better biological responses may be attributed to their better health condition. Mohsen et al. (2025) in Sprague Dowley rats observed that rats supplemented with 5.0% and 7.5% rice straw biochar resulted in decreased oxidative stress and inflammation following immunization, which is an indicative of improved antioxidant enzyme activity and reduced proinflammatory cytokines level. Similarly, superior ($P<0.05$) total antioxidant capacity, glutathione peroxidase and superoxide dismutase levels were observed in 1.0% Pistachios by-product Biochar added in the ration of Japanese quail (Zahed et al. 2025). Furthermore, Zahed et al. (2025) also reported highest lymphocyte percentage and lowest heterophil to lymphocyte ratio in Japanese quails fed with 1.0% Pistachios by-product Biochar indicating the impact of biochar on the health and wellbeing in Japanese quails. El-kelawy et al. (2024) reported superior immunity in terms of superior IgA, IgM, IgG, LTT, phagocytic activity and reduced serum lipids and oxidative stress marker by supplementation of commercial biochar at 2% level in broiler chicken. Zahed et al. (2025) fed Pistachios by-product biochar to Japanese quail at the rate of 0.35%, 0.65% and 1.0% but failed to observe any impact on humoral immunity due to addition of biochar in Japanese quail ration.

The blood biochemical indices of an animal are a true representative of the animal health status and thus during animal experimentations, keen attention is given towards the blood biochemistry. Emam et al. (2026) supplemented 1.5% and 3.0% biochar prepared from mango tree branches and wood as a feed additive to broiler chicks (*Arbor acres*), and reported significant decrease in serum AST, uric acid, creatinine values and blood ammonia content in biochar group chicken than that of control group. Emam et al. (2026) also observed higher total protein and albumin level in chicks supplemented with 1.5% biochar as compared to the 3.0% biochar supplementation. Likewise, Ohanaka et al. (2025) reported improved ($P<0.05$) important haematology and blood biochemical indices namely, Packed cell volume, Red blood cell count, Mean cell volume, Mean cell haemoglobin, Mean cell haemoglobin concentration, Blood clotting time, White blood cell count in male Arbor Acres broiler chicks by supplementing biochar at 0.5 and 1 % dose for 42 days, indicating the impact of biochar addition in broiler ration may aid in better health in poultry birds. Similarly, El-kelawy et al. (2024) observed improvement in the haematology in terms of increased RBCs, Hb, PCV, WBCs, lymphocytes, total protein, globulins, thyroid hormones profile in broiler chicken by supplementation of biochar at 2% level. Nevertheless, Emam et al. (2026) observed a significant increase in the blood calcium and phosphorus level in biochar supplemented chicks compared to the control, which might be due the presence of calcium and phosphorus from biochar. This indicates that, while including biochar as a feed additive, the mineral content of the total ration needs to be revisited to ensure the mineral balance of the ration. Similarly, Ohanaka et al. (2025) also found that, addition of 1% biochar in chicken feed significantly improved the total serum protein, albumin/globulin ratio, Alanine amino transferase, Aspartate amino transferase as compared to the birds fed diet devoid of biochar. Chu et al. (2013b) reported that in pigs, supplementation of bamboo biochar resulted in superior total protein, albumin, cholesterol, HDL-CH and LDL cholesterol level in blood plasma.

Effect of biochar feeding as a toxin adsorbent

Biochar is one of the low cost adsorbent which is highly effective for removing the various kinds of toxins like heavy metals and organic compounds due to its unique physicochemical properties developed during the pyrolysis process, viz high specific surface area, porous structure, surface functional groups, cation exchange capacity, surface charge, hydrophobicity etc. Biochar also helps to suppress diseases because it can adsorb toxins such as mycotoxins (Gerlach and Schmidt, 2012) and other pathogen and their toxins (Kalus et al., 2019). Its porous structure provides a high surface area, crucial for pathogen binding. Furthermore, it adsorbs a range of toxic compounds, including plant and animal-derived toxins, endogenous toxins, and gases such as methane (Man et al., 2021). The adsorbent nature of the biochar has been studied using one of the most common mycotoxin that is aflatoxin as a model drug (Galvano et al., 1996), where addition of activated biochar at 2.0% level to animal feed lowered the concentration of extractable aflatoxins by 74% and at the same time, decreased aflatoxin concentration in milk by up to 45% (Galvano et al., 1996). Similarly, Prosopis farcta biochar demonstrates the highest efficiency in aflatoxin removal, reducing aflatoxin levels by 95.88% after 6 h of incubation (Raz et al., 2025). the preservation of microbial complexity may be attributed to the preferential adsorption of pathogens over native intestinal microflora (Watarai and Tana, 2005). *Prosopis farcta* biochar are containing higher surface area and porosity, which attributes towards its efficient adsorbent capability for various pollutants, including heavy metals and organic compounds (Raz et al., 2025; Khan et al., 2023; Reyhanitabar et al., 2020). This effect contributes to diminishing antibiotic dependence in chickens (Prasai et al., 2016; Willson et al., 2019). When biochar given with the silage as a feed additive, it can bind with the pesticides, reduce the formation of mycotoxins and also it has ability to enhance the lactic acid bacteria population (Calvelo Pereira et al., 2014). Chicken suffering from the aflatoxicosis when fed with the biochar made from the poultry litter at the rate of 5gm/kg, body weight of bird is maintained and the performance of the birds found to increase (Rashidi et al., 2020), which is an indicative of the effectiveness of the biochar in nullifying the adverse effect of mycotoxins in animal feeds. Nair et al. (2023) also documented that supplementation of biochar can adsorb harmful substances like mycotoxins, ammonia and heavy metals in the digestive tract and diminish their harmful effects on animal health.

Effect of biochar feeding on gut microorganisms

Gut health of livestock and poultry is an indicative of their overall well-being, which influences their nutrient utilization, growth rate, and disease resistance (Naeem and Bourassa, 2025). Biochar can be a potent anti-pathogenic feed additive; which has been found effective to reduce populations of *Clostridium aldenense, Gallibacterium anatis, Helicobacter pullorum, Campylobacter hepaticus, Bacteroides dorei*, and *Campylobacter jejuni* within the avian gut while maintaining overall gut microbiota complexity and diversity (Prasai et al., 2016; Willson et al., 2019). Leng et al. (2013) reported in cattle that, addition of rice hull biochar at 0.6% of feed dry matter reduced the enteric methane emission, which is an indicative of the alteration of rumen fermentation in ruminants by addition of biochar in their ration. Methane is produced by the methanogenic bacteria and consumed by the methanotrophic bacteria so, biochar containing soil amendments encourage the growth of the methanotrophs which reduce the emission of the intestinal methane by providing the habitat for the oxidation of the methane in the stomach (Leng et al., 2012a). Han *et al.* (2018) conducted experiment of feeding oral Rice Straw Biochar at the rate of 1120 mg/kg of body weight to rats for 5 weeks to evaluate the effect on caecal microbial community, where Firmicutes and Bacteroidetes were found to be prevalent and increased ratio of relative abundance ($P<0.05$) in biochar fed rats. In quails, Raz et al. (2025) found that oral addition of *Prosopis farcta* biochar increased the prevalence of useful gut microbiota, simultaneously reducing detrimental bacteria population. Addition of 2.0% biochar in layer diet significantly reduce the pathogenic bacteria and alter the intestinal microbiota positively and this effect demonstrate its potential as alternative to antibiotic in poultry industry (Willson et al., 2019). Feeding chestnut biochar at low concentration exhibit prebiotic effect by stimulating growth of *Lactiplantibacillus plantarum* and inhibiting the growth of pathogenic *E. coli* strains (Reggi et al., 2025). Furthermore, when biochar is combined with sea tangle (*Laminaria japonica*; Islam et al., 2014) or aged palm sap (Ohanaka et al., 2025) offers a viable antibiotic growth promoter alternative in poultry feed. Biochar prepared from *Prosopis farcta* can be fed to the poultry birds which is reported to be an eco-friendly, cost-effective, and promising strategy for mitigating aflatoxicosis in poultry production (Raz et al., 2025). The mechanisms of actions of superior biological activities of biochar addition in livestock and poultry ration may be corroborated with the enhanced adsorption abilities in detoxifying mycotoxins in feed raw materials, plant-produced toxins, pollutants, and simultaneously improving the populations of beneficial gut microorganisms (Rajpoot et al., 2024).

Reports indicated that biochar may reduce the production of ruminal CH4 emissions both in vitro (Hansen et al., 2012; Leng et al., 2012a,b) and *in vivo* (Leng et al., 2012c) conditions. Saleem et al. (2018) found that pine-based biochar could improve *in vitro* ruminal fermentation, nutrient disappearance, and microbial protein synthesis and reduce enteric methane (CH_4) production. In another study, inclusion of plant-based biochar at 81 g/kg DM reduced the digestibility of forage, however, encouraged volatile fatty acid production (McFarlane et al. 2017). Saleem et al. (2018) studied the effect of pine biochar supplementation in graded doses (0, 0.5, 1, and 2%) on rumen fermentation and digestibility of nutrients by Rumen simulation technique and found that disappearance of Dry Matter (DM), Organic Matter (OM), Crude Protein (CP), Acid Detergent Fiber (ADF) and Neutral Detergent Fiber (NDF) is proportional to the dose of biochar supplementation and enhanced ($P < 0.01$) production of total Volatile Fatty Acid (VFA), acetate, propionate, branch-chained VFAs, increase NH3- N, increase in Microbial protein synthesis and reducing the overall CH_4 production as compared with the control. However, long term supplementation and *in vivo* studies are essential before concluding and establishing the use of biochars in ruminant rations on regular basis.

Effect on Organ architecture, Carcass Characteristics and egg production

Biochar addition in the ration of poultry birds consistently indicated improvement in the meat quality in broiler birds. For instance, El-kelawy et al. (2024) observed an improvement in dressing percentage, reduction in abdominal fat, serum lipids, and oxidative stress markers in broiler chicken by supplementation of biochar at 2% level by feeding them biochar for 35 days. Kutlu et al. (2001) observed a decrease in the cracked egg production by supplementation of wood charcoal in hen's diet and he postulated that the decrease in the cracked egg production might be due to improved mineral intake from biochar, which contained high levels of ash, calcium, potassium and magnesium. Likewise, Kumar (2025) observed significant reduction ($P<0.05$) in giblet, liver, and heart weights in corn cob and paddy straw biochar-fed groups. Paddy straw and corncob waste biochar increased meat lightness in 2% paddy straw biochar and 2% corncob biochar fed broiler birds whereas, higher redness of meat was observed in 1% paddy straw biochar groups. Kumar (2025) also reported significantly lower Free fatty in acids biochar-fed birds, particularly in 2% paddy straw biochar group birds, indicating improved lipid stability. However, biochar produced from paddy straw or corn cob at 1% or 2% level could not affect the meat pH and water-holding capacity (Kumar, 2025).

Ruttanavut et al. (2009) demonstrated that supplementing Aigamos duck feed with a bamboo charcoal powder and bamboo vinegar solution resulted in increased body weight, attributed to enhanced nutrient absorption via elongated intestinal villi. Ruttanavut et al. (2009) also reported active cellular mitosis at the villus, which further indicated improved intestinal functionality and suggests that Biochar supplements may induce villus and epithelial cell hypertrophy. Mohsen et al. (2025) also reported increased intestinal villi length and surface area in Biochar added treatment groups . Likewise, Usman et al. (2025) reported that corn cob Biochar supplementation in Japanese quails improved intestinal histomorphology and postulated that the alterations might be due to Biochar's detoxifying and adsorption capabilities. Mohsen et al. (2025) reported hepato and renal protective effect of rice straw Biochar in Sprague Dowley rats where, they observed hepatocyte architecture and renal tubular integrity preserved in rats with 5% and 7% rice straw Biochar treatment groups as compared to the control.

Litter management

Biochar is a porous material with a high surface area which is capable to absorb moisture and may mitigate NH3 volatilization (Mohammadi-Aragh et al., 2025). Reports advocate positive response by dietary supplementation of biochar improved air and litter quality in poultry houses through reduced volatilization from poultry faeces (Sha et al., 2019; Kalus et al., 2020a). Mohammadi-Aragh et al. (2025) used Biochar from *Pinus spp.* As a litter amendment agent and reported that Biochar-amended litter (30 % v/v surface applied) failed to reduce NH_3 levels or affect bird performance but significantly lowered litter moisture, making it beneficial for moisture control in commercial broiler houses. Similarly, Linhoss et al. (2019) reported beneficial effects of biochar used for litter amendment, which increased water-holding capacity and reduced NH3 volatilization in broiler litter without negatively impacting overall bird performances. If biochar is added in the poultry feed, the amount of biochar used for litter amendment can be reduced accordingly as poultry manure is more degraded microbiologically (Gerlach and Schmidt, 2012). Moreover, application of biochar in feeds and/ or in the litter materials in poultry husbandry tend to rises the marketing potential of poultry manure thanks to the fertilizer quality of the poultry manure which rises strongly due to addition of biochar (Gerlach and Schmidt, 2012). It is observed that when biochar was combined with bedding materials like straw or sawdust for ruminants at 5–10%, there is a decline in the incidences of hoof diseases (O'Toole et al. 2016) which is an indicator of the welfare of animal health (Rajpoot et al., 2024). Reports suggest that treatment of litter with adequate biochar may reduce the odour pollution as well (Gerlach and Schmidt, 2012).

Conclusion

Inclusion of biochar as a novel feed additive for livestock and poultry is capable of augmenting the animal health by optimizing the feed efficiency, adsorbing the toxins present in feed or toxins produced by the gut pathogenic microorganisms and altering the gut microbiota, thus influences overall wellbeing of the animals and poultry. The inclusion of Biochar in livestock and poultry ration has shown growth promotion, immunomodulation which are desirable attributes for an animal enterprise. Now it is essential to investigate the long term effects and disadvantages (if any) of biochar as a feed additive in animal feeding. Even, Biochar addition can be an effective measure to use the mycotoxin contaminated feeds for animal feeding. However, the level of inclusion of biochar in animal ration need to study further to establish its effectiveness before routine use in animal husbandry practices. The results obtained so far has open an window to try and test different biochars produced from different biomasses, their inclusion level in different animal models and molecular level effects for better understanding of its mechanism of action.

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