

ID: 466

Sustainable Feed to Reduce the Environmental Impact of Poultry Production

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Abstract

The increasing global demand for poultry products presents significant environmental challenges, particularly concerning resource-intensive feed production. Traditional feed ingredients, such as soybean and maize, contribute to deforestation, water depletion, and greenhouse gas emissions. Additionally, nutrient runoff from poultry waste leads to water contamination and ecosystem degradation. Sustainable feed alternatives, including insect-based proteins offer viable solutions to mitigate these environmental impacts while maintaining nutritional efficiency. The integration of these alternative feed sources reduces dependence on conventional crops, enhances circular economy principles, and promotes waste valorization. Furthermore, utilizing insect meal and single-cell proteins improves feed conversion efficiency and minimizes land and water use, making poultry production more sustainable. The adoption of these feed innovations not only supports environmental conservation efforts but also ensures food security for a rapidly growing population. Transitioning toward sustainable feed practices is essential for aligning poultry production with global sustainability goals, reducing its ecological footprint, and fostering a more resilient agricultural system. This paper highlights the critical role of sustainable feed ingredients in shaping the future of poultry production, emphasizing their necessity in addressing climate change, resource scarcity, and environmental degradation.

Keywords: Poultry, feed, insects, sustainability, environment.

1. Introduction

Poultry farming is one of the most important areas in global agriculture, providing billions of people with essential protein in the form of meat and eggs. With the world's population predicted to reach over 10 billion by 2050, the demand for poultry products is projected to soar. By 2028, the sector is predicted to have grown from \$360.5 billion in 2023 to \$494.55 billion, a spectacular rate of development (World Bank Group, 2013)

This expansion however raises considerable environmental concerns, particularly in the manufacturing of conventional poultry feed. Crops like corn and soy which need a lot of resources to grow make up most of the traditional poultry feed. These feed ingredients' production results in excessive water use, deforestation, and greenhouse gas emissions (Morgan et al., 2025). The environmental impacts of conventional poultry feed extend beyond resource use. Nutrient runoff from feed crop cultivation and poultry waste can lead to water pollution, causing eutrophication in aquatic ecosystems. These challenges highlight the urgent need for sustainable alternatives that can reduce the ecological footprint of poultry production while ensuring food security (FAO, 2023a).

Sustainable feed ingredients, such as insect-based proteins, algae, and agricultural by-products, offer promising solutions. These alternatives not only have a lower environmental impact but also contribute to a circular economy by utilizing waste streams and reducing dependency on traditional feed crops (Bist et al., 2024).

This article highlights the advantages and prospective applications of sustainable feed components in addressing the environmental issues associated with poultry production.

2. Environmental Challenges in Poultry Production

The production of poultry presents substantial environmental issues even though it is necessary to supply global dietary needs. The environmental effects of poultry farming are not limited to certain regions rather a worldwide effect; Among crucial challenges are greenhouse gas emissions, solid waste management, odor pollution and contamination of water streams are of concern associated with energy use in the the manufacture of concentrate feed, transportation of processed goods and in animal production activities (Castellini et al., 2012).



2.1. Climate Change: Greenhouse Gas Emissions

Air pollutants emissions from animal feeding operations are a significant environmental hazard due to their high potential risk to air quality, human and animal health. Climate change particulate matter (PM) and other gases, such as greenhouse gases and ammonia (NH₃), are the main air emissions (Maheshwari, 2013). Poultry industry must work on lessening its environmental impact, even though its carbon emissions are fewer than those of the beef, pork, or lamb/mutton industries. On average, poultry have a carbon footprint of about 6.0 kg CO₂-equivalent per kilogram of meat (Bist & Chai, 2022). The intensification of feed production, which necessitates energy input for the synthesis of mineral fertilizer and the subsequent use of this fertilizer in the feed production process, indirectly affects emissions of greenhouse gases like carbon dioxide and nitrous oxide. An estimated 18 million tonnes of carbon dioxide are emitted annually, or roughly 44% of the total emissions attributed to the livestock sector, based on the energy use per tonne of nitrogen fertilizer. The (Intergovernmental Panel on Climate Change) emission factor the total nitrogen fertilizer use in the production of feed for poultry production (estimated at 7.2 million tonnes) (Gerber et al. 2006).

Furthermore, a significant source of methane (CH₄) and N₂O emissions is poultry manure. Methane is generated by methanogenic archaea, microorganisms that thrive in oxygen-free (anaerobic) environments. When poultry manure is stored in piles, lagoons, or other confined systems, it creates ideal conditions for these microbes to break down organic matter. This process, known as anaerobic digestion produces methane as a byproduct, a greenhouse gas that has a 28–34 times greater potential to cause global warming over a 100-year period than CO₂. As nitrogen compounds in manure break down, nitrous oxide is generated as well, and it has a 265-fold higher potential to cause global warming than CO₂ (Morgan, 2025).

These emissions add up to the carbon footprint of the poultry business, which makes it a major contributor to global agriculture GHG emissions. In order to meet climate targets and guarantee the sustainability of chicken production, these emissions must be addressed (FAO, 2023b).

2.2. Ecosystems Pollution: Runoff from Poultry Waste and Feed Production

Solid waste is generated at every stage of the chicken production process, including housing, feeding, and watering. Poultry waste consists of feces, wasted feed, bedding material, litter material, feathers, soil, urine, process water, and condemned corpses (Bist et al., 2024). Numerous factors, such as the breed of poultry, the feed content, the length of time the animals are housed in the poultry house, the density of the animals, and seasonal variations, all affect the chemical composition of poultry dung and litter.

A fair amount of nitrogen, phosphorus, and other expelled materials, including antibiotics, pathogens, and heavy metals, are present in poultry feces (Neeteson-van et al., 2013). These compounds' leaching and runoff could inevitably contaminate local groundwater and surface water supplies (Himu & Raihan, 2023). Water contaminated with these pollutants might result in waterborne illnesses including diarrhea. The World Health Organization estimates that 1.8 million people die from diarrheal illness each year (Kumar & Patyal, 2020).

Excreta from poultry contain uric acid, which is converted to volatile ammonia under certain conditions. Emissions of ammonia from poultry buildings contribute to the acidification of soils and water, and can have a negative impact on populations of acid-sensitive flora (Bist & Chai, 2022).

The spread of feed crop production into natural ecosystems has indirect repercussions such as ecosystem degradation and a biodiversity catastrophe (Rodić et al., 2011). Landscape Changes in land use, cropping intensity, and crop production technologies (for example, large-scale mechanisation) can alter the kind of landscape and the mosaic of land use, vegetation types, and habitats found in the environment. Such changes have an impact on biodiversity because they alter and destroy habitats (forests, grasslands, hedgerows, wetlands) and affect the numbers and compositions of biological species present. These changes can also have an impact on the landscape's aesthetic and amenity value, which may be culturally and historically significant. Such effects are becoming more recognized in prosperous advanced nations, and they are increasingly being considered in land-use planning and environmental legislation (Gerber et al., 2006).

The next sections of this article will explore how sustainable feed ingredients can address these challenges and pave the way for a greener future in poultry production.



3. Sustainable Feed Ingredients

Sustainability is a concept that refers to meeting the needs of the present without compromising the ability of future generations to meet their own needs. It encompasses the responsible use of resources, the protection of ecosystems, and the promotion of social and economic well-being (Vaarst et al., 2015). According to the Brundtland Commission, sustainability is a broad and aspirational policy goal which includes equally significant environmental, economic, social, and institutional factors (Valentin et al., 2000).

Sustainable feed ingredients are alternative feed supplies that are grown and used in methods that reduce environmental impact, conserve natural resources, and promote long-term ecological equilibrium. These ingredients are frequently generated from renewable resources, byproducts, or innovative production methods that lessen reliance on conventional, resource-intensive crops (Bist et al., 2024). Algae and microalgae, like spirulina and chlorella, are nutrient-rich and can be cultivated using CO₂ emissions, promoting carbon recycling. Single-cell proteins (SCP), derived from yeast, bacteria, and fungi, offer efficient and scalable protein sources (Leinonen & Kyriazakis, 2016). By providing innovative and environmentally responsible substitutes for conventional chicken feeds, sustainable feed ingredients lessen the negative effects of poultry farming on the environment.

3.1. Insect-Based Proteins:

Considering their nutritional value and possible environmental benefits, utilizing insects to feed poultry birds is a viable alternative when evaluating the sustainability of this type of farming (Leinonen & Kyriazakis, 2016). One innovative method and excellent example of a sustainable circular economy is the use of insects in the bioconversion of waste materials. While there is less competitiveness between feed and food, less land is needed to produce 1 kg of protein, and organic waste can be converted into high-value protein products (Sogari et al., 2019).

Insects have recently attracted a lot of interest as a vital supply of sustainable raw materials for animal feed, particularly for pigs, poultry, and fish. According to Sajid et al. (2023), the common house fly (*Musca domestica*, MD), the yellow mealworm (*Tenebrio molitor*, TM), and the black soldier fly (*Hermetia illucens*, HI) are the most promising species.

Insect meal has been shown to be a rich source of protein, amino acids (lysine, methionine), and minerals (calcium, phosphorus, zinc), with a high digestibility rate, making it a valuable feed ingredient for poultry production. Mealworms and black army fly larvae are examples of insects that are high in digestibility and high in protein (35–53%), vital amino acids, and minerals (Belhadj Slimen et al., 2023).

For example, Sun et al. (2013) observed that male broilers grown on grassland with a high population of grasshoppers scored much higher on chewiness, flavor, scent, and overall enjoyment for the meat of the breast and thighs than a control sample raised on a maize–soybean diet. However, there were no appreciable variations in color or juiciness between the two treatments. As the authors noted, it was challenging to determine whether the greater sensory qualities in their trial were brought about by the grasshopper meal or by the greater dietary variety and mobility provided in a free-range setting.



Image of Insects used in poultry nutrition, (Belhadj Slimen et al., 2023).



Insect farming is resource efficient, requiring less water and land than conventional feed production, resulting in a much lower ecological imprint (Khalifah et al., 2023). The use of insect protein sources in quail diets, such as the mopane worm (*Gonimbrasia belina*), has demonstrated possibilities in reducing dependency on conventional protein sources, especially fish and soybean meals, while meeting the growing demand for animal protein. With an average protein content of 55% and an appropriate amino acid composition, mopane worms are a very nutrient-dense feed item. (Sajid et al., 2023).

According to research, house fly larval meal can enhance broiler performance and substitute other protein sources without negatively affecting the carcass's qualities (Khalifah et al., 2023). Countries worldwide have houseflies (HF), which can be raised on food scraps and animal dung. Significant quantities of CP and CF, ranging from 40 to 64% and 2.5 to 28%, respectively, are present in HF meal (Table 1). As HF larvae age, their CP content falls but their CF content rises (51, 52). The two amino acids that restrict poultry nutrition the most are lysine and methionine. HF meal contains substantial levels of both of these amino acids (Belhadj Slimen et al., 2023). Allowing poultry to eat insects could reduce the amount of antibiotics used in the poultry industry, given the well-established harm that antibiotics cause to both humans and the environment (the emergence of drug-resistant bacterial species) (Bist et al., 2024).

4.0 Conclusion

The adoption of sustainable feed ingredients can address critical environmental issues, while ensuring food security for a growing global population. By integrating these innovative solutions, the poultry industry can transition toward more eco-friendly responsible practices, aligning with global sustainability goals. From an economic perspective, sustainable feed ingredients not only mitigate input costs in the long run but also open avenues for value-added market differentiation, catering to consumers increasingly demanding ethically produced and environmentally friendly animal products. Additionally, regulatory frameworks and industry incentives supporting sustainability in animal agriculture reinforce the need for proactive adoption of such practices. Ultimately, the findings of this paper underscore the imperative role of sustainable feed strategies in shaping a resilient and environmentally conscious poultry sector. Rather than being an optional innovation, sustainable feed ingredients emerge as a fundamental necessity, paving the way for a more secure, efficient, and ecologically balanced food system.

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