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Alternative Protein Sources for Livestock and Poultry: Towards Sustainable Animal Nutrition

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The continuous growth of the global population, projected to increase by nearly 30% from the current 7.5 billion to around 9-10 billion by 2050, along with shifting dietary preferences toward greater consumption of animal derived products, is placing increasing pressure on the livestock sector (FAO, 2017). This rising demand has led to a substantial expansion in feed production, which reached approximately 1.1 billion tonnes globally, with a steady annual growth rate (Alltech, 2019). Despite this progress, the availability of high-quality protein sources for animal feed remains a major global concern. Conventional protein ingredients such as soybean meal and fish meal are becoming increasingly expensive and are often associated with environmental challenges (Malila *et al*., 2024). Consequently, there is a growing need to identify alternative, sustainable protein sources that can support efficient livestock production. Sustainability has now become a key priority in food and feed systems, with emphasis on reducing greenhouse gas emissions, improving resource-use efficiency, and minimizing waste (Khan *et al*., 2024). In this context, the exploration of novel protein sources derived from waste streams, microorganisms, and other unconventional resources offers a promising pathway toward sustainable animal nutrition.

Need for Alternative Protein Sources

Traditional protein feeds like soybean meal and groundnut cake are widely used, but they come with several limitations, including increasing market prices, competition with human food consumption, dependence on imports, and environmental concerns such as deforestation (Malila *et al*., 2024). To overcome these challenges, researchers and farmers are exploring new and unconventional protein sources that can reduce costs and improve sustainability.

Types of Alternative Protein Sources

1. Insect Protein

Insects have emerged as one of the most promising alternative protein sources for animal nutrition due to their high nutritional value and sustainability potential. They are naturally part of the diet of many animal species and can be efficiently produced using organic waste substrates, thereby contributing to circular economy approaches in livestock production (Van Huis & Gasco, 2023). In terms of nutritional composition, insect meals are rich in protein, typically ranging from 30 to 68% on a dry matter basis, and possess a well-balanced amino acid profile that meets the requirements for animal growth and health (Finke, 2015). Additionally, insects contain appreciable amounts of lipids (10-30%), vitamins (especially B-complex vitamins), and essential minerals such as iron and zinc (Finke, 2015; Payne *et al*., 2016). Their nutritional profile, however, may vary depending on species, developmental stage, and the substrate used for rearing. Commonly used insect species in animal feeding include black soldier fly (*Hermetia illucens*), yellow mealworm (*Tenebrio molitor*), and house crickets. These insects have shown considerable potential as substitutes for

conventional protein sources such as soybean meal and fishmeal (Van Huis & Gasco, 2023). Studies indicate that insect-derived proteins can support comparable growth performance and feed efficiency in poultry, pigs, and aquaculture species (Gasco *et al*., 2020). Moreover, insect protein production requires significantly less land, water, and feed resources while generating lower greenhouse gas emissions compared to traditional protein sources (Van Huis & Gasco, 2023). The presence of bioactive compounds such as antimicrobial peptides and chitin further enhances gut health, improves nutrient utilization, and strengthens immune responses, ultimately contributing to better animal health and productivity.

2. Algae-Based Protein

Algae-based proteins are emerging as a smart and sustainable alternative to conventional feed ingredients like soybean meal. Rich in high-quality protein (often 40-70%) and essential amino acids, algae such as Spirulina and Chlorella also provide valuable nutrients including omega-3 fatty acids, vitamins, minerals, and antioxidants that support animal growth, immunity, and product quality (Kumar *et al*., 2021). Unlike traditional crops, algae can be cultivated on non-arable land using minimal water, and they help capture carbon dioxide during growth, making them environmentally friendly (FAO, 2011; Djuragic *et al*., 2021). Studies have shown that incorporating algae into poultry diets can improve feed efficiency, enhance meat and egg quality, and strengthen immune response (Madeira *et al*., 2017). In addition, the presence of bioactive compounds contributes to improved gut health and disease resistance, making algae not just a protein source but also a functional feed ingredient (Yaakob *et al*., 2014).

3. Single Cell Protein (SCP)

Single-cell protein (SCP) refers to the dried biomass of microorganisms such as bacteria, yeasts, archaea, algae, and fungi, which are mass-produced and used as a protein source for animal feed. SCP derived from bacteria is rich in high-quality protein (typically 50-70%) along with essential amino acids, vitamins, and bioactive compounds, making it nutritionally comparable to traditional sources like soybean and fish meal (Hellwing *et al*., 2007). It has the ability to convert low-value substrates including agricultural residues, industrial by-products, methane, and even carbon dioxide into valuable biomass, thereby promoting a circular bioeconomy and improving resource-use efficiency (Cedeno *et al*., 2025). Furthermore, SCP contributes to reduced greenhouse gas emissions through improved feed efficiency and better nitrogen utilization, thereby lowering nitrogen excretion. Previous studies have shown that single-cell protein can replace up to 40% of dietary nitrogen in chickens and 50% in pigs without negatively affecting nitrogen retention, heat production, or energy utilization.

4. DDGS

Corn Dried Distillers Grains with Solubles (DDGS) has gained attention as an effective alternative protein source in livestock feeding, particularly for ruminants. Produced as a co-product of bioethanol manufacturing, DDGS contains concentrated nutrients due to the removal of starch during fermentation, resulting in a feed rich in protein, energy, and digestible fiber (Liu, 2011). Its high proportion of rumen undegradable protein (RUP) makes it especially valuable for improving protein utilization in cattle, sheep, and goats. DDGS can partially replace conventional protein sources such as soybean meal while maintaining or even enhancing animal performance, including growth and milk production (Liu, 2011). In addition to its nutritional benefits, its use supports sustainable agriculture by utilizing agro-industrial by-products and reducing feeding costs (Khan *et al*., 2024).

Challenges

Despite the promising potential of alternative protein sources such as insect meal, algae, SCP, and DDGS, several challenges limit their widespread adoption. One major constraint is the variability in nutrient composition, which depends on raw materials and processing methods (Malila *et al*., 2024). Additionally, high production costs and limited large-scale infrastructure reduce their economic competitiveness. Regulatory and safety concerns, along with the need for standardized quality control measures, further hinder adoption (Khan *et al*.,

2024). Issues related to consumer perception and the presence of anti-nutritional factors or contaminants also require careful consideration.

Conclusion

Alternative protein sources such as insects, algae, SCP, and DDGS offer a sustainable and innovative solution to meet the increasing demand for livestock feed. These sources not only provide high-quality nutrients but also contribute to resource efficiency, waste utilization, and reduced environmental impact. Their ability to partially replace conventional protein sources without compromising animal performance highlights their importance in future feeding strategies. However, overcoming challenges related to cost, scalability, safety, and standardization will be essential for their widespread adoption. With continued research and technological advancements, these novel protein sources can play a key role in building sustainable and resilient livestock production systems.

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