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Duckweed as an alternative protein source in poultry nutrition

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Abstract

Feed costs are the major expenditure in poultry production, with protein-rich ingredients contributing a significant share; therefore, alternative and sustainable protein sources have gained importance in this context. Conventional protein sources, such as soybean meal, groundnut cake, and fish meal, are becoming more expensive due to increased demand, high transportation costs, competition with human food and limited availability. Duckweed (family *Lemnaceae*) is one of the fast growing aquatic plants that has attracted attention due to its exponential growth, high protein content, balanced amino acid profile and efficient biomass production. On a dry matter basis, duckweed has been reported to contain 20-40% crude protein along with essential amino acids, minerals and natural pigments. Feeding trials in broilers, layers and native chickens indicate that duckweed can partially replace conventional protein sources without negatively affecting growth performance, feed efficiency or egg production when included at appropriate levels. Processing techniques such as drying, fermentation and enzyme supplementation further improve its feeding value. This review discusses the biological characteristics, nutritional composition, feeding applications, processing methods, limitations and future potential of duckweed as a protein source in poultry nutrition.

Keywords: Duckweed, poultry nutrition, alternate protein, feed efficiency and growth performance

1. Introduction

Feed cost is the major economic constraint in poultry production, accounting for nearly 60-70% of the total production cost, with protein ingredients contributing a significant share (Leng, 1995) ^[1]. Conventional protein sources are becoming increasingly expensive due to rising demand, limited availability and competition with human food and industrial uses (Islam *et al.*, 2002) ^[2]. These challenges have prompted continuous efforts to identify alternative feed resources that are cost-effective, locally available and environmentally sustainable.

Duckweed has emerged as a promising unconventional protein source due to its exceptionally rapid growth rate and high biomass productivity (Hillman and Culley, 1978) ^[3]. It can be cultivated on freshwater bodies and nutrient rich waste water, allowing efficient utilization of nitrogen and phosphorus while requiring minimal land area (Skillicorn *et al.*, 1993) ^[4]. These characteristics make duckweed particularly attractive for sustainable poultry production systems.

Several studies conducted over the past decades have demonstrated the potential of duckweed as a partial replacement for conventional protein sources in poultry diets (Islam *et al.*, 2002) ^[2]. More recent research has further confirmed its suitability across different poultry production systems, including broilers, layers and indigenous chickens (Anderson *et al.*, 2011) ^[5]. In view of the increasing feed cost and the need for sustainable protein alternatives, summarization of available researches on the use of duckweed in poultry nutrition, with emphasis on its nutritive value, feeding responses and practical constraints has been done.

2. Duckweed Biology and Cultivation

Duckweed refers to a group of small, free floating aquatic plants belonging to the family

Lemnaceae, which includes the genera *Lemna*, *Spirodela*, *Wolffia* and *Wolffiella* (Landolt and Kandeler, 1987)^[6]. These plants have a very simple structure and reproduce rapidly through vegetative propagation, enabling quick biomass accumulation under favourable conditions (Leng, 1995)^[1]. Duckweed commonly grows on stagnant or slow-moving water bodies and forms dense mats when nutrients are abundant (Islam *et al.*, 2002)^[2]. Its ability to efficiently absorb nutrients has led to its use in wastewater treatment systems (Iram *et al.*, 2015)^[7]. Environmental factors such as temperature, light and nutrient availability influence both growth rate and nutrient composition (Baek *et al.*, 2021)^[8]. Due to its high productivity and low land requirement, duckweed represents a sustainable feed resource for poultry production.

Table 1: Proximate analysis of Duckweed (as% of dry matter)

S. No	Species	Dry Matter	Crude Protein	Crude Fibre	Ether Extract	Ash	Reference
1	<i>L. gibba</i>	4.6	25.2	9.4	4.7	14.1	Rusoff <i>et al.</i> , (1980) ^[10]
2	<i>S. punctata</i>	5.2	28.7	9.2	5.5	13.7	
3	<i>S. polyrhiza</i>	5.1	29.1	8.8	4.5	15.2	
4	<i>W. columbiana</i>	4.8	36.5	11.0	6.6	17.1	
5	<i>L. minuta</i> , <i>L. minor</i>	4.8	18.36	13.01	3.10	14.90	Demann <i>et al.</i> , (2023) ^[12]
6	<i>S. polyrhiza</i>	5.1	27.42	12.15	2.50	19.73	
7	<i>L. obscura</i>	4.9	39.62	13.17	7.00	6.00	
8	<i>L. minor</i>	5.42	23.24	11.53	3.43	13.23	Putra <i>et al.</i> , (2018) ^[13]

4. Inclusion of Duckweed in Poultry Diets

Several feeding trials have evaluated duckweed as a dietary component for poultry at different inclusion levels. In broilers, inclusion of duckweed meal at 5-10% has generally improved growth performance and feed conversion ratios comparable to those obtained with conventional diets (Effiong *et al.*, 2009)^[14]. However, higher inclusion levels have occasionally resulted in reduced growth performance, likely due to increased fibre content and reduced digestibility (Islam *et al.*, 1997)^[15]. In native and backyard chickens, duckweed has been successfully incorporated at higher levels ranging from 20 to 40% without significant adverse effects on growth and feed intake (Putra and Ritonga, 2018)^[16]. These findings suggest that duckweed can serve as a partial replacement for conventional protein sources when diets are properly balanced.

5. Processing and Feed Integration

The high moisture content of fresh duckweed limits its direct inclusion in poultry diets, making processing an essential step before feeding (Leng, 1995)^[1]. Drying methods such as sun drying and oven drying are commonly employed to reduce moisture and improve storage stability. Fermentation has been reported to enhance protein digestibility, reduce fibre content and improve palatability of duckweed meal (Paguia *et al.*, 2023)^[17]. Enzyme supplementation in duckweed based diets has shown beneficial effects on nutrient utilisation and growth performance in broilers (Zaffer *et al.*, 2020)^[18]. Appropriate processing and feed integration strategies are therefore crucial for maximising the nutritional benefits of duckweed in poultry feeding.

6. Effects of Duckweed In Broilers

Studies involving the supplementation of broiler diets with duckweed revealed that its inclusion has positively impacted the growth performance and efficiency of broilers when supplemented at low to moderate concentrations. (Kabir *et al.*, 2005)^[19] noted that the partial substitution of traditional protein sources in broiler diets with duckweed meal had no

3. Nutritional Composition and Protein Quality

The nutrient composition of duckweed varies with species and growing conditions (Vandeyke *et al.*, 1977)^[9]. Nevertheless, most reports indicate crude protein levels ranging from 20 to 40% on a dry matter basis, which is comparable to conventional plant protein sources (Islam *et al.*, 2002)^[2]. Duckweed protein contains essential amino acids such as lysine, methionine and threonine in appreciable amounts (Rusoff *et al.*, 1980)^[10]. In addition, duckweed provides minerals, vitamins and natural pigments including beta-carotene and xanthophylls (Journey *et al.*, 1993)^[11]. These nutritional characteristics support its use as a supplementary protein source in poultry diets (Skillicorn *et al.*, 1993)^[4].

negative impacts on weight gain and feed conversion ratio. The success derived from the use of duckweed has been attributed to its high content of crude protein, desirable amino acid composition and high palatability (Anderson *et al.*, 2011)^[5]. (Zaffer *et al.*, 2020)^[18] also reported that proper processing techniques used in the duckweed feeding of broilers positively impacted the nutrient uptake and growth rates. Nonetheless, high concentration could negatively impact the growth performance, mainly attributed to the high fibre content.

7. Effects of Duckweed in Layers

Duckweed supplementation in the diet of laying hens has resulted in sustained egg production, besides having positive effects on the traits of egg quality. (Anderson *et al.*, 2011)^[5] reported that inclusion of duckweed in layer diets did not adversely affect hen-day egg production and significantly improved yolk pigmentation due to its natural carotenoid content. (Baghban-Kanani *et al.*, 2023)^[20] observed increased omega-3 fatty acid concentration in eggs from hens fed duckweed based diets, suggesting its potential for producing value-added eggs. Egg quality parameters have also been reported to remain largely unaffected concerning shell thickness, shell strength, and albumen quality when duckweed is incorporated at appropriate inclusion levels (Kabir *et al.*, 2005)^[19]. These observations allow the assumption that when dietary inclusion is optimised, duckweed can be effectively used as a functional feed ingredient in layer nutrition.

8. Effects of Duckweed in Ducks

(Huque *et al.*, 2011)^[21] showed that the inclusion of duckweed into duck diets improved nutrient digestibility and nitrogen retention and thus supported better growth performance. More recently, feeding experiments have demonstrated that the partial replacement of conventional protein sources with dried or fresh duckweed up to 10 to 15% in duck diets did not affect feed intake or body weight gain or feed conversion ratio (Putra *et al.*, 2019; Sari *et al.*, 2021)^[22,23]. It was indicated that supplementation with duckweed improves egg production, does not affect egg weight and shell

quality, but decreases feed cost and therefore, has economical benefits in laying ducks (Rahman *et al.*, 2020) ^[24]. Furthermore, duckweed contains xanthophyll carotenoids and bioactive compounds, which may increase pigmentation of duck meat and immune response in ducks (Zahra *et al.*, 2022) ^[25]. However, excessive inclusion or use of duckweed grown in contaminated water resources may create health risks due to high fibre content and heavy metal accumulation and thus duckweed cultures may need to be grown under controlled conditions and fed in balanced mixtures. In short, duckweed is a promising, sustainable and economic protein feed ingredient for duck production.

9. Challenges and Limitations

Although duckweed has become popular as a sustainable protein source, several nutritional and practical challenges limit its use in poultry diets. One major concern is its high fiber content, which can reduce nutrient digestibility and negatively impact feed intake and growth when included in large amounts (Islam *et al.*, 1997) ^[15]. Another issue is the significant variation in nutrient composition, which depends on the species, environmental conditions and harvest stage. This variability makes it hard to create consistent feed formulations (Vandeyke *et al.*, 1977) ^[9]. Fresh duckweed also has a very high moisture content, requiring drying or other processing before feeding. This adds to labour, processing costs and storage challenges (Leng, 1995) ^[1]. Additionally, duckweed grown in wastewater or nutrient-rich effluents can absorb heavy metals and other contaminants, raising concerns about poultry health and food safety (Iram *et al.*, 2015) ^[7]. Challenges related to large-scale cultivation, harvesting and processing infrastructure also limit its use in commercial poultry production systems (Skillicorn *et al.*, 1993) ^[4]. Furthermore, there are challenges in integrating duckweed production into existing poultry farming practices (Syampurnomo *et al.*, 2019) ^[26]. Therefore, while duckweed is a promising and eco-friendly protein source, these nutritional, safety and logistical issues need to be resolved to use it sustainably in poultry nutrition.

10. Future Prospects

Duckweed holds considerable promise as a sustainable protein source for poultry production. Improvements in cultivation practices, strain selection and nutrient management could further enhance biomass yield and protein quality (Baek *et al.*, 2021) ^[8]. Integration of duckweed production with waste water treatment and circular farming systems offers both environmental and economic advantages (Syampurnomo *et al.*, 2019) ^[26]. Continued research focusing on long term feeding trials, processing optimization and safety evaluation will facilitate its broader adoption in commercial poultry nutrition.

11. Conclusion

Duckweed represents a nutritionally valuable and environmentally sustainable alternative protein source for poultry. Evidence from feeding trials indicates that duckweed can partially replace conventional protein ingredients without compromising growth performance, egg production or egg quality when included at appropriate levels. Although challenges related to fibre content, nutrient variability and processing remain, advances in cultivation and feed technology may enable wider utilisation of duckweed in poultry feeding systems.

Conflict of Interest

Not available

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