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UNVEILING THE IMPACT OF *AZOLLA FILICULOIDES* SUPPLEMENTATION ON POULTRY GROWTH AND FEED EFFICIENCY

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Abstract
Azolla filiculoides, a nutrient-rich aquatic fern, was evaluated for its potential as a dietary supplement to enhance weight gain and feed conversion efficiency (FCR) in poultry. The study was conducted over an 18-week period using 300 chicks, randomly divided into six groups of 50 each. The groups included a control (0% A. filiculoides) and five experimental groups supplemented with varying levels of A. filiculoides (5%, 10%, 15%, 20%, and 25%). The results demonstrated a significant improvement in growth performance and feed efficiency with increasing supplementation levels. The 25% A. filiculoides group achieved the highest weight gain of 1.8139 kg and the lowest FCR of 1.02, compared to the control group, which recorded a weight gain of 1.212 kg and a higher FCR. A clear inverse relationship was observed between FCR and weight gain, indicating enhanced feed utilization efficiency with higher inclusion levels of A. filiculoides. The lower supplementation levels (5% and 10%) showed minimal effects on growth performance, whereas higher levels (15%, 20%, and 25%) significantly improved weight gain and feed efficiency. These findings highlight the potential of A. filiculoides as an economical, sustainable, and nutritionally effective feed additive for poultry. The study underscores its viability in reducing feed costs while optimizing growth performance, particularly at the 25% inclusion level, making it a promising candidate for sustainable poultry nutrition systems.

Keywords:
Azolla filiculoides, Sustainable poultry nutrition, Broiler growth performance, Feed conversion ratio (FCR), Cost-effective poultry feed, Poultry production efficiency

1. INTRODUCTION

Poultry production is a vital contributor to global nutrition, economic stability, and food security, providing an affordable source of high-quality protein essential for human health (Donma & Donma, 2017; Jilo & Hasan, 2022). In India, poultry farming supports rural livelihoods, poverty alleviation, and gender equality, particularly benefiting smallholders and women (Dadheech, 2014; Al-Khalaifah & Al-Nasser, 2022). However, the industry faces rising production costs, primarily due to the high prices of conventional feed ingredients like soybean meal (SBM) and maize, which constitute up to 75% of total production expenses (Rout *et al.*, 2017; Dinani *et al.*, 2018). This has necessitated the exploration of cost-effective and sustainable feed alternatives.

Chick weight plays a crucial role in poultry production, influencing growth, hatchability, and overall productivity. Heavier chicks, often derived from heavier eggs, show better growth rates, higher meat productivity, and improved feed efficiency, especially during early stages of life (Mbajiorgu & Ramaphala, 2014; Fedorova & Vakhrameev, 2023). This relationship is critical for broiler production, where early chick weight serves as a strong predictor of uniformity and performance (Singh & Nagra, 2006). Managing chick weight through careful selection of egg weight and early monitoring is essential for maximizing productivity and profitability in poultry farming. SBM is a widely used protein source in poultry diets due to its high protein content and balanced amino acid profile (Dei, 2011; Gaur & Pandey, 2020). However, rising costs and reliance on imports make SBM

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economically unsustainable for small-scale farmers in India. Additionally, anti-nutritional factors (ANFs) in raw soybeans, such as protease inhibitors, require further processing to improve digestibility, which increases production costs (Nahashon & Kilonzo-Nthenge, 2011; Lambo *et al.,* 2023;). These challenges have prompted the search for sustainable and cost-effective alternatives.

Feed costs, accounting for 60-75% of total poultry production expenses, remain a significant challenge in India (Rout *et al.,* 2017; Dinani *et al.,* 2018). The high prices of maize and soybean meal, commonly used at inclusion rates of 55-65% and 25-30%, respectively, have driven interest in alternative feed ingredients (Dinani *et al.,* 2019). Options like rice gluten meal and crude rice bran oil have shown potential to reduce costs by 7-9% while maintaining performance (Anitha *et al.,* 2009). The use of feed additives and nutrient optimization further enhances feed efficiency and reduces expenses (Mandal *et al.,* 2005; Abbas, 2023). In this context, *Azolla filiculoides*, a fast-growing aquatic fern, has emerged as a promising alternative to SBM. Rich in protein, amino acids, and minerals, Azolla supplementation has been shown to reduce feed costs while improving growth performance and feed conversion ratios (Jadhav & Pattar, 2024; Chekol, et al., 2024). Inclusion of up to 15% Azolla in poultry diets has demonstrated enhanced weight gain and feed efficiency without adverse effects on health (Kumar *et al.,* 2018; Adil *et al.,* 2022). Furthermore, Azolla's low input requirements and environmental benefits make it a sustainable option for reducing production costs in poultry farming (Yadav & Chhipa, 2016; Hafeez *et al.,* 2024;).

Given its rapid growth, low input requirements, and environmental benefits, Azolla holds promise as a sustainable replacement for SBM in poultry feed. This study aims to evaluate the efficacy of Azolla as a cost-effective feed ingredient, focusing on its impact on growth performance, feed efficiency, and economic viability, contributing to sustainable poultry production in India.

2. MATERIALS AND METHODS

2.1 Cultivation of *A. filiculoides*

The cultivation of *A. filiculoides* was carried out at a site within Mr. Raghavendra Bhat's coconut plantation in Mittlakatte, Davangere district, chosen for its accessibility and ease of maintenance. Three cement tanks, each measuring 6x3x2 feet, were constructed and prepared with a nutrient-rich slurry of fine soil, cow dung, and vermicompost. The tanks were filled to three-fourths capacity with water and stocked with a fresh culture of *A. filiculoides* sourced from Krishi Vigyan Kendra, Davangere. Shading was provided with a green net to reduce evaporation and prevent contamination, while water temperature and pH were regularly monitored. The ponds were emptied and replenished with fresh cultures every six months to sustain optimal growth. Under suitable conditions, *A. filiculoides* was ready for harvest within two weeks. Harvesting involved using a mesh tray, followed by washing to remove residual odors. The harvested biomass was sun-dried for 2-3 days and stored in airtight bags to ensure long-term usability.

2.2 Study Area and Experimental Setup

The experiment was conducted at Balaji Poultry Farm, owned by Mr. Ramakrishna, on Hadadi Road, Davangere, Karnataka. A total of 300 chicks were randomly divided into six groups of 50 each, with one control group receiving regular feed and five experimental groups supplemented with *A. filiculoides* at 5%, 10%, 15%, 20%, and 25% inclusion levels. The chicks were housed in clean, disinfected, and well-ventilated sheds, with separate enclosures for each group to ensure uniform conditions. Clean water and feed were provided ad libitum, and temperature and humidity were closely monitored to maintain optimal health and growth conditions.

2.3 Feed Preparation

The poultry feed was formulated with maize as the primary energy source, supplemented with soybean meal, DDGS, rapeseed (35-42% protein), DORB, and salt to provide essential nutrients. Growth and protein synthesis were supported by lysine and DL-methionine (DLM), while additives such as acidifiers, enzymes, toxin binders, trace minerals, phytase, choline chloride, vitamin premix, liver powder, limestone powder, de-oiled groundnut cake (GN), and di-calcium phosphate (DCP) enhanced digestion, mineral balance, and overall health. The feed was further supplemented with sun-dried and powdered *A. filiculoides* at 5%, 10%, 15%, 20%, and 25% inclusion levels, replacing an equivalent portion of the regular feed, with the control group receiving unsupplemented feed.

2.4 Experimental Design

A feeding trial was conducted from the 6^{th} to the 18^{th} week to evaluate the growth performance and feed efficiency of broiler chicks. Initially, 300 chicks were weighed individually, and they were randomly divided into six groups of 50 chicks each. Feed was supplied in two shifts daily, at 7:30 AM and 6:30 PM, with fresh water provided *ad libitum*. Weekly, body weights and feed intake were recorded to monitor growth and consumption. Feed conversion ratio (FCR) was calculated at weekly intervals to assess the efficiency of feed utilization across the treatment groups.

2.5 Data Collection and Analysis

The data were statistically analysed to compare the growth performance and feed efficiency among the different groups.

3. RESULTS

3.1 Harvesting *A. filiculoides*

In a short span of 2 to 3 weeks, *A. filiculoides* demonstrated exceptional biomass accumulation, rapidly colonizing the pond surface with a dense, green mat. This species, renowned for its robust and adaptive growth characteristics, thrived under optimal environmental conditions, highlighting its capacity for accelerated expansion (Figure 1).

3.2 Growth Performance

3.2.1 Weekly Body Weight

The progressive increase in body weight of chicks fed with varying levels of *A. filiculoides* supplementation, compared to the control group, over 18 weeks was observed. In the control group, the chicks exhibited a final body weight of 1.212 kg**,** the lowest among all groups. The inclusion of 5% *A. filiculoides* resulted in a slightly higher final body weight of 1.0486 kg, showing minimal improvement compared to the control. With 10% *A. filiculoides* supplementation, the final weight reached 1.208 kg**,** further indicating moderate enhancement in growth performance.

Significant improvements were observed in groups with higher *A. filiculoides* inclusion levels. Chicks fed with 15% *A. filiculoides* achieved a final weight of 1.2458 kg**,** and those with 20% *A. filiculoides* reached 1.4054 kg**,** demonstrating substantial growth benefits. The most pronounced improvement was observed in the 25% *A. filiculoides* group, with a final body weight of 1.8139 kg, reflecting a 49.6% increase compared to the control (Figure 2). The results highlight a clear positive correlation between the level of *A. filiculoides* supplementation and the body weight of the chicks, with higher supplementation levels (15%, 20%, and 25%) yielding significantly better growth. This demonstrates the potential of *A. filiculoides* as an effective feed additive to enhance growth performance in poultry.

3.2.2 Feeding Efficiency, Weight Gain and FCR

The results demonstrate that increasing *A. filiculoides* supplementation in poultry feed significantly enhances growth performance and feed efficiency. The average body weight progressively increased from 1.212 kg in the control group to 1.8139 kg in the 25% supplementation group, with intermediate weights of 1.315 kg, 1.51 kg, 1.69 kg, and 1.72 kg for 5%, 10%, 15%, and 20% supplementation, respectively. Similarly, weight gain improved from 0.869 kg in the control to 1.56 kg in the 25% group. Feed intake showed an inverse trend, reducing from 0.75 kg in the control group to 0.525 kg in the 25% group, indicating better feed utilization. The FCR also improved with higher supplementation, decreasing from 2.01 in the control group to 1.02 in the 25% group, with intermediate FCRs of 2.13, 1.98, 1.56, and 1.49 for 5%, 10%, 15%, and 20% supplementation, respectively. These results highlight the efficacy of *A. filiculoides* in enhancing growth and feed efficiency while reducing feed consumption in poultry (Table 1).

Figure 1: Preparation and feeding of *A. filiculoides* for broiler chicks.
(A) Harvested *A. filiculoides* being prepared for feeding.
(B) Control group chicks housed in clean, well-ventilated cages and fed with conventional poultry feed.
(C) Poultry feed mixed with sun-dried *A. filiculoides*, ready for feeding.
(D) Experimental group chicks consuming feed supplemented with *A. filiculoides*.

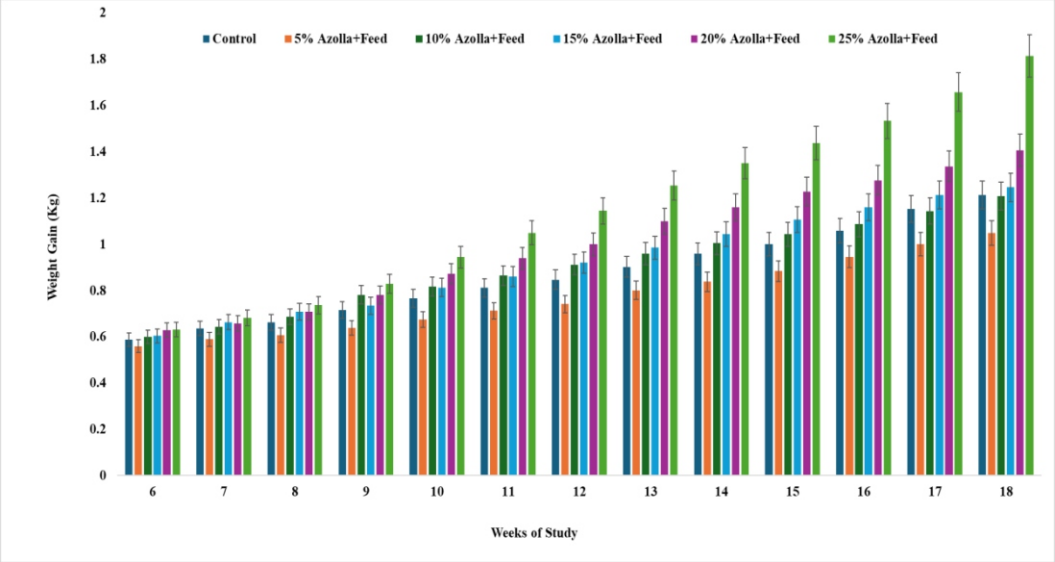

Figure 2: Weight gain of broiler chicks fed with varying levels of *A. filiculoides* supplementation over 18 weeks. Error bars represent standard errors for each group.

Table 1: Effect of *A. filiculoides* supplementation on growth performance and feed efficiency in broiler chicks. The table summarizes the average body weight (Kg), weight gain (Kg), feed intake (Kg), and feed conversion ratio (FCR) of chicks under different dietary treatments.

The Studied Characters		Treatments of *A. filiculoides*				
	Control	5%	10%	15%	20%	25%
Average Body Weight (Kg)	1.212	1.315	1.51	1.69	1.72	1.8139
Average Weight Gain (Kg)	0.869	0.959	1.13	1.23	1.3	1.56
Average Feed Intake (Kg)	0.75	0.67	0.852	0.595	0.697	0.525
FCR	2.01	2.13	1.98	1.56	1.49	1.02

4. DISCUSSION

A. filiculoides, a fast-growing aquatic fern, is a cost-effective and nutritionally rich alternative to soybean in poultry diets, offering high protein, amino acids, vitamins, and minerals suitable for broilers and layers (Alagawany *et al.*, 2023; Jadhav & Pattar, 2024; Chekol, et al., 2024). Studies show that Azolla can reduce feed costs by up to 30% while maintaining growth performance comparable to soybean-based diets (Jadhav & Pattar, 2024). In broilers, supplementation up to 15% improves feed efficiency and body weight without adverse health effects (Adil *et al.*, 2022; Najim *et al*., 2022), and in quails, it enhances growth rates and feed conversion ratios (Hafeez *et al.*, 2024). Economic analyses indicate reduced costs and comparable weight gains when replacing up to 10% of soybean meal (Paudel *et al.*, 2015; Kumar *et al.*, 2018). While Azolla can reduce egg production in some cases, it lowers nutrition costs, making it suitable for backyard systems (Marjan, 2024). Optimized inclusion can balance cost savings and nutritional adequacy, improving egg quality without affecting production in layers (Abate *et al.*, 2020). Azolla presents a sustainable, economical feed alternative with environmental benefits like bioremediation (Khushbu *et al.*, 2022; Paryanto *et al.*, 2023; Yoldashev *et al.*, 2024).

The findings of this study strongly correlate with the existing literature, underscoring the potential of *A. filiculoides* as a cost-effective and nutritionally rich feed supplement for poultry. The progressive increase in body weight observed with higher levels of *A. filiculoides* aligns with previous studies highlighting Azolla's role in enhancing weight gain. For instance, broilers fed with 5% Azolla demonstrated improved body weight and FCR compared to controls (Najim *et al.*, 2022), consistent with the observed improvement at 5% *A. filiculoides* inclusion in this study. Similarly, the notable weight gain at 10% and higher supplementation levels corroborates findings from Kumar *et al.* (2018), who reported that *Azolla pinnata* can replace up to 10% of soybean meal without compromising growth performance. Similar to our results, where *A. filiculoides* supplementation significantly improved body weight and FCR at higher inclusion levels, Arram *et al.* (2023) observed notable enhancements in growth performance and feed efficiency with 5% and 10% *A. pinnata* supplementation, emphasizing its potential as a sustainable feed additive.

The substantial growth benefits at 15%, 20%, and 25% supplementation levels observed in this study resonate with Tawasoli *et al.* (2020) and Al-Shwilly (2022), where Azolla inclusion at moderate-to-high levels resulted in significant weight gain in Vanraja poultry birds and broilers. Furthermore, the pronounced improvement in feed conversion ratio (FCR) with increasing *A. filiculoides* levels, particularly at 25%, aligns with studies indicating that Azolla inclusion enhances feed efficiency across various poultry breeds (Yadav & Chhipa, 2016; Mishra *et al.*, 2016). For example, Kadaknath poultry and Pratapdhan chicks demonstrated improved FCR at 7.5% and 15% Azolla meal inclusion, respectively, indicating its broad applicability across poultry types (Yadav & Chhipa, 2016; Borkar *et al.*, 2021). The reduction in feed intake observed with higher *A. filiculoides* inclusion is also supported by previous findings that Azolla improves nutrient utilization, resulting in lower feed consumption without affecting growth (Paudel *et al.*, 2015; Kumar *et al.*, 2018). The efficiency of *A. filiculoides* as a feed additive is further emphasized by the FCR improvement, which decreased progressively with higher inclusion levels. This finding aligns with Al-Shwilly (2022), who reported significant FCR improvements in broiler Ross chicks at 15%-45% Azolla inclusion.

Interestingly, while some studies, such as Hartati *et al.* (2023), noted a plateau in growth benefits at higher Azolla inclusion levels, this study demonstrates continued improvement up to 25% supplementation. The variability in effectiveness, as noted by Rana *et al.* (2017), highlights the importance of optimizing supplementation levels based on the specific breed and production goals. Additionally, the economic benefits of Azolla supplementation, such as the reported 30% feed cost reduction (Jadhav & Pattar, 2024), further support its viability as an alternative feed ingredient. Overall, the results of this study align with and expand upon existing literature, reinforcing the efficacy of *A. filiculoides* in improving growth performance, feed efficiency, and economic sustainability in poultry production. The findings validate its potential as a sustainable replacement for traditional feed ingredients like soybean meal, offering both nutritional and financial advantages while supporting environmentally friendly poultry farming practices.

5. CONCLUSION

The study establishes *A. filiculoides* as a highly effective and sustainable alternative to conventional feed ingredients in poultry diets. The inclusion of *A. filiculoides* significantly enhanced growth performance, feed efficiency, and weight gain, with higher supplementation levels (15–25%) yielding optimal results. These findings not only align with existing literature but also highlight the dual benefits of cost reduction and improved nutritional outcomes. By replacing traditional protein sources like soybean meal, *A. filiculoides* addresses both economic challenges and environmental concerns in poultry farming. This research reinforces its role as a versatile, eco-friendly feed additive capable of supporting sustainable poultry production systems. Further studies could explore its integration with probiotics and its impact on broader biochemical and immunological parameters.

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CONFLICT OF INTERESTS
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