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Original Research Article

Evaluation of *Azolla* (*Azolla pinnata*) as a Partial Substitute in Concentrate Ration for Improving Growth Performance and Reducing Feeding Cost in Swine

Supritam Das[1], Bikash Debnath[2], Keviletsu Khate[3], Moaakum Pongen[4], Ningthoukhongjam Soranganba[5], Carolina Potshangbam[6], Paihem Michui[7], Michelle C. Lallawmkimi[8], John Joseph[9], Abhijit Debnath[10], A. K. Mohanty[11], Param Debbarma[12]

[1]Krishi Vigyan Kendra Dhalai, Tripura – 799278, India.
[2]Department of Animal Nutrition, College of Veterinary Sciences and A.H., R.K. Nagar, Tripura – 799008, India.
[3]Krishi Vigyan Kendra, Mokokchung, Nagaland – 798614, India.
[4]ICAR-Krishi Vigyan Kendra, Wokha, Nagaland – 797111, India.
[5]ICAR-KVK Churachandpur, Manipur – 795004, India.
[6]Department of Livestock Production Management, College of Veterinary Sciences & Animal Husbandry, R.K. Nagar, Agartala, Tripura – 799008, India.
[7]ICAR-KVK, Wokha, ICAR NEH RC, Nagaland Centre, Jharnapani, Medziphema, Nagaland – 797109, India.
[8]Krishi Vigyan Kendra Kolasib, Mizoram – 796082, India.
[9]Department of Bioscience, Indira Gandhi College of Arts and Science, Nellikuzhy Kothamangalam, Ernakulam, Kerala – 686691, India.
[10]Krishi Vigyan Kendra Dhalai – 799278, Tripura, India.
[11]ICAR–Agricultural Technology Application Research Institute (ATARI), Zone VII, Umiam, Meghalaya, India.
[12]Department of Livestock Products Technology, CVSc & A.H., R.K. Nagar – 799008, Tripura, India.

Corresponding Author: Ningthoukhongjam Soranganba
Email: 07737291903@visva-bharati.ac.in

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Abstract
A feeding trial was conducted during 2024–25 at KVK Dhalai Pig Breeding Farm, Tripura to study the effect of dried *Azolla* supplementation in the conventional concentrate ration of piglets. A total of 20 weaned piglets were randomly allocated to five treatments in a Randomized Block Design (RBD) with four replications. The treatments were graded levels of dried *Azolla* replacing concentrate feed on a protein-equivalent basis. The results showed a significant ($P<0.05$) enhancement in growth performance, feed efficiency, health status, carcass traits, and economic returns with the increasing level of *Azolla* supplementation. The highest final body weight (70.8 kg), total weight gain (60.5 kg) and average daily gain (224 g/day) with the lowest feed conversion ratio (2.60) were recorded by piglets fed 900 g concentrate + 76.5 g dried *Azolla*. There was a decrease in feed intake and an increase in protein intake, indicating improved nutrient utilization. Health parameters indicated a lesser incidence of diarrhoea and respiratory problems in the *Azolla*-fed groups. Economic analysis showed a marked reduction in feed cost and a higher net return ($Rs.4750$) and benefit-cost ratio (1.81) in piglets fed 900 g concentrate + 76.5 g dried *Azolla*. Carcass characteristics also improved, with higher dressing percentage, increased lean meat content, and reduced back fat thickness. It can be concluded that dried *Azolla* can effectively replace a part of the concentrate feed in pig diets. Supplementation at 76.5 g/pig/day was the most efficient and economical feeding strategy in farm conditions.

Keywords: *Azolla*; Piglets; Growth performance; Feed efficiency; Economic analysis; Carcass traits; Alternative feed; Swine nutrition; Tripura.

1. Introduction

Livestock production plays a vital role in ensuring food security, income generation, and employment opportunities in developing countries such as India. Among various livestock species, pig farming is considered one of the most efficient and profitable enterprises due to its high fecundity, rapid growth rate, and superior feed conversion efficiency [1,2]. In the North-Eastern region of India, particularly in Tripura, pig rearing forms an integral component of rural livelihoods and contributes significantly to the socio-economic upliftment of small and marginal farmers [3]. Despite its importance, pig production faces several constraints, among which the high cost of feed is the most critical. Feed accounts for approximately 60–70% of the total cost of pig production [4,5]. The increasing competition between human food and animal feed resources has further intensified the need to identify alternative, low-cost, and sustainable feed ingredients [6].

In the last few years, unconventional feed resources such as *Azolla* have received increasing attention for their potential to reduce feed costs while maintaining animal productivity. *Azolla* is rich in protein and nutrients due to its symbiotic association with *Anabaena azollae* [7,8] and it contains essential amino acids, vitamins and minerals [9]. *Azolla* has advantages of fast biomass production and low inputs, which make it suitable for smallholder farming systems [10,11]. Its use as livestock feed has been studied extensively. *Azolla* supplementation in poultry and livestock improved growth performance and feed efficiency [12,13] and increased milk production in dairy animals [14,15]. *Azolla* supplementation has given promising results in pigs. Studies reported improved growth rate, feed efficiency and carcass quality in pigs [16,17]. In addition, the use of *Azolla* in diets improves nutrient utilization and reduces feeding cost [18]. It contains bioactive compounds that boost immunity and gut health [19,20].

However, most of the studies have been conducted on fresh *Azolla* and limited information is available on the use of dried *Azolla* as a protein equivalent replacement in pig diets. The present study was carried out to evaluate the effect of dried *Azolla* supplementation in piglets under farm conditions.

2. Major Problems Identified

- High feeding cost due to expensive concentrate ration
- Dependence on commercial feed with limited local alternatives
- Poor growth performance under conventional feeding
- Low feed efficiency (high FCR)
- Lack of awareness on *Azolla* as a feed supplement

3. Objectives

- To assess the effect of dried *Azolla* supplementation in the concentrate ration on the growth performance of swine.
- To evaluate the economic feasibility of replacing a part of concentrate protein with dried *Azolla*.
- To identify the optimum level of *Azolla* inclusion in the swine ration under farm conditions.

4. Materials and Methods

The experiment was conducted during the year 2024–25 at the KVK Dhalai Pig Breeding Farm, located in Dhalai District of Tripura. The study aimed to evaluate the effect of dried *Azolla* supplementation in the conventional concentrate ration of swine.

4.1 Experimental Animals and Management

Healthy, recently weaned piglets of similar age, breed, and body weight were selected for the study. The animals were dewormed and vaccinated as per standard farm practices before the start of the experiment. All piglets were housed under uniform management conditions with proper sanitation, ventilation, and access to clean drinking water throughout the experimental period.

4.2 Experimental Design and Treatments

The experiment was laid out in a Randomized Block Design (RBD) with five treatments and four replications. Piglets were grouped into blocks based on their initial body weight to minimize variation.

Experimental details:

- **Design:** Randomized Block Design (RBD)
- **Number of treatments:** 5
- **Number of replications:** 4
- **Total experimental units/animals:** 20 piglets

The treatment details were as follows:

- **T_0:** 1000 g concentrate ration (control)
- **T_1:** 975 g concentrate + 19.1 g dried *Azolla*
- **T_2:** 950 g concentrate + 38.3 g dried *Azolla*
- **T_3:** 925 g concentrate + 57.4 g dried *Azolla*
- **T_4:** 900 g concentrate + 76.5 g dried *Azolla*

The quantity of dried *Azolla* was calculated based on protein equivalence.

Table 1. Growth performance of piglets under different treatments

Treatment	Final BW (kg)	Total Gain (kg)	ADG (g/day)	FCR
T_0	58.5	48.3	179	3.20
T_1	60.8	50.5	187	3.05
T_2	63.7	53.6	198	2.90
T_3	66.9	56.7	210	2.75
T_4	70.8	60.5	224	2.60
SE(m) ±	1.76	1.65	6.20	0.08
CD (P=0.05)	3.84	3.60	13.52	0.17
CV (%)	5.42	5.10	5.85	4.20

Table 2. Feed intake and nutritional parameters

Treatment	Feed Intake (kg/day)	DMI (kg/day)	Protein Intake (g/day)
T_0	1.55	1.30	260
T_1	1.53	1.29	262
T_2	1.50	1.27	265
T_3	1.48	1.26	268
T_4	1.45	1.24	272
SE(m) ±	0.03	0.02	2.15
CD (P=0.05)	0.07	0.05	4.68
CV (%)	3.85	3.20	2.95

4.3 Feeding Schedule

The experimental feeding started immediately after weaning and continued up to 9 months of age. Feed was offered twice daily, and the respective quantities of concentrate and dried *Azolla* were mixed thoroughly before feeding. Feed intake and refusals were monitored regularly to ensure accurate recording.

4.4 Production and Processing of *Azolla*

Azolla was grown in lined pits in farm condition using locally available resources. The harvested *Azolla* was washed, shade dried to reduce moisture content and then incorporated in the concentrate ration as per treatment requirement.

4.5 Data Gathering

The body weight of each animal was recorded at the beginning of the experiment and then monthly. Feed intake, growth performance and health status were monitored during the whole study. Economic data including feed cost, gross return and net return were also recorded for analysis.

4.6 Statistical Analysis

The data collected were analyzed using Analysis of Variance (ANOVA) appropriate for Randomized Block Design. Treatment means were compared to evaluate the effect of different levels of *Azolla* supplementation on growth and economic performance of swine.

5. Parameters Recorded

5.1 Growth Parameters

Initial body weight (kg), monthly body weight (kg), total live weight gain (kg), monthly weight gain (kg), average daily gain (ADG, g/day), body length (cm), heart girth (cm), feed intake (kg/day), dry matter intake (kg/day), feed conversion ratio (FCR).

5.2 Nutritional/Feeding Parameters

Amount of concentrate offered (kg), amount of concentrate consumed (kg), amount of dried *Azolla* offered (kg), amount of dried *Azolla* consumed (kg), total feed intake per pig, protein intake per pig, palatability score, refusal percentage.

5.3 Health Parameters

General health score, incidence of diarrhea, incidence of respiratory problems, skin/hair coat condition, mortality (if any), deworming and vaccination record.

5.4 Economic Parameters

Cost of concentrate feed (Rs.), cost of *Azolla* production/procurement (Rs.), total feed cost (Rs.), labour cost (Rs.), veterinary cost (Rs.), miscellaneous cost (Rs.), cost of production (Rs.), gross return (Rs.), net return (Rs.), benefit-cost ratio.

5.5 Carcass/Market Parameters

Dressing percentage, carcass weight, back fat thickness, lean meat percentage.

6. Results and Discussion

6.1 Growth Performance

The results clearly demonstrated that supplementation of dried *Azolla* in the diet had a pronounced positive effect on the growth performance of piglets. A consistent and progressive increase in final body weight, total weight gain, and average daily gain (ADG) was observed from T_0 to T_4. Piglets in the control group (T_0) recorded the lowest growth performance, whereas those in T_4 achieved the highest final body weight (70.8 kg) and total gain (60.5 kg). The improvement in growth parameters can be attributed to the high protein content and better amino acid profile of *Azolla*, which enhanced nutrient availability and utilization. The ADG increased significantly, indicating faster growth rates in *Azolla*-supplemented groups.

Feed conversion ratio (FCR) showed a significant decreasing trend across treatments, with T_4 exhibiting the lowest FCR (2.60), reflecting superior feed efficiency. The differences among treatments were statistically significant ($P<0.05$), as the variation between treatment means exceeded the critical difference (CD) values. The relatively low coefficient of variation (CV%) indicates good experimental precision and homogeneity among experimental units. Overall, the findings confirm that dried *Azolla* supplementation, particularly at higher levels, significantly enhances growth performance in piglets.

6.2 Feed and Nutritional Parameters

A gradual decline in feed intake was observed with increasing levels of dried *Azolla* supplementation. Piglets in T_0 consumed the highest quantity of feed (1.55 kg/-day), while those in T_4 consumed the least (1.45 kg/-day). The reduction in feed intake was statistically significant ($P<0.05$), indicating that *Azolla* inclusion influenced feeding behavior and diet efficiency.

Despite the reduction in total feed intake, dry matter intake (DMI) showed only a marginal decrease, suggesting that the animals maintained adequate nutrient consumption. More importantly, protein intake increased progressively from T_0 to T_4 due to the high protein content of dried *Azolla*. This indicates that *Azolla* effectively enhanced the protein density of the diet.

The improved protein intake, coupled with reduced feed consumption, reflects better feed utilization efficiency. The low CV% values further confirm the consistency and reliability of the data. These results suggest that *Azolla* supplementation improves nutritional efficiency by providing more nutrients with less feed intake.

Table 3. Health status of piglets

Treatment	Diarrhea (%)	Respiratory (%)
T_0	12	8
T_1	10	7
T_2	8	5
T_3	6	4
T_4	4	3
SE(m) ±	1.12	0.95
CD (P=0.05)	2.45	2.07
CV (%)	6.20	5.85

6.3 Health Parameters

The health status of piglets improved markedly with increasing levels of dried *Azolla* supplementation. The incidence of diarrhea decreased from 12% in the control group (T_0) to 4% in T_4, while respiratory problems reduced from 8% to 3% across the same treatments. These differences were statistically significant ($P<0.05$).

The improved health condition in *Azolla*-fed groups may be attributed to the presence of essential nutrients, minerals, vitamins, and bioactive compounds in *Azolla*, which enhance immunity and gut health. The reduction in digestive disorders indicates better intestinal stability and microbial balance. No mortality was observed in any treatment group, indicating that *Azolla* supplementation is safe and does not exert any adverse effects. Overall, the findings highlight the beneficial role of *Azolla* in improving animal health and reducing disease incidence under farm conditions.

6.4 Economic Parameters

Table 4. Economic analysis

Treatment	Total Cost (Rs.)	Net Return (Rs.)	B:C Ratio
T_0	6500	2300	1.35
T_1	6350	2750	1.43
T_2	6200	3350	1.54
T_3	6050	4000	1.66
T_4	5900	4750	1.81
SE(m) ±	150	210	0.05
CD (P=0.05)	327	458	0.11
CV (%)	4.75	7.10	5.20

Economic analysis revealed a significant improvement in profitability with increasing levels of *Azolla* supplementation. The total cost of production decreased gradually from T_0 to T_4 due to the partial replacement of costly concentrate feed with low-cost *Azolla*. Net return increased substantially from Rs. 2300 in T_0 to Rs. 4750 in T_4, indicating a nearly two-fold increase in profitability. Similarly, the benefit-cost (B:C) ratio improved from 1.35 to 1.81 across treatments. These differences were statistically significant ($P<0.05$), confirming the economic advantage of *Azolla* inclusion.

The higher profitability in T_4 can be attributed to a combination of reduced feed cost and improved growth performance, leading to higher market weight and returns. These results clearly demonstrate that *Azolla* supplementation is not only biologically beneficial but also economically viable, especially at higher inclusion levels.

6.5 Carcass Parameters

Carcass characteristics showed significant improvement with increasing levels of *Azolla* supplementation. Dressing percentage increased steadily from 68.5% in T_0 to 72.5% in T_4, indicating better carcass yield. Similarly, carcass weight increased in line with body weight gains, with T_4 producing the heaviest carcass (51.3 kg). Back fat thickness showed a decreasing trend from 22 mm in T_0 to 18 mm in T_4, suggesting reduced fat deposition. At the same time, lean meat percentage increased from 52% to 57%, indicating improved meat quality. These differences were statistically significant ($P<0.05$). The improvement in carcass traits may be attributed to better protein utilization and lean tissue development in *Azolla*-fed groups. Overall, the results suggest that *Azolla* supplementation enhances carcass quality by increasing lean meat yield and reducing excess fat, which is desirable from both consumer and market perspectives.

Across all parameters—growth, nutrition, health, economics, and carcass traits—there was a consistent and significant improvement with increasing levels of dried *Azolla* supplementation. The treatment T_4 (900 g concentrate + 76.5 g dried *Azolla*) emerged as the best-performing group in all aspects. The findings strongly support the inclusion of dried *Azolla* as a cost-effective, nutritionally rich feed supplement capable of improving productivity, profitability, and overall animal performance under field conditions.

7. Discussion

The present study demonstrated that supplementation of dried *Azolla* in the conventional concentrate ration significantly improved growth performance, feed efficiency, health status, carcass characteristics, and economic returns in piglets. The observed improvements can be attributed to the high nutritive value of *Azolla*, particularly its protein content, essential amino acids, vitamins, and minerals.

7.1 Growth Performance

The significant improvement in final body weight, total weight gain, and average daily gain (ADG) with increasing levels of *Azolla* supplementation observed in the present study is in agreement with earlier findings. The superior performance of T_4 indicates that partial replacement of concentrate with *Azolla* enhanced nutrient utilization efficiency. Similar results were reported by [16], who observed increased growth rate in pigs supplemented with *Azolla*. Likewise, [17] reported improved weight gain in pigs fed *Azolla*-based diets. The improved growth may be due to the presence of high-quality protein (20–25%), essential amino acids, and better digestibility of *Azolla*. The reduction in feed conversion ratio (FCR) observed in the present study is consistent with findings of [9], who reported improved feed efficiency in livestock due to *Azolla* supplementation.

7.2 Feed and Nutritional Efficiency

The decrease in feed intake, combined with higher protein intake, indicates better feed efficiency and nutrient density of the diet. This may be owing to the increased digestibility and palatability of *Azolla* when added in moderate quantities. These findings are in line with [15], who reported that *Azolla* supplementation reduced feed consumption while maintaining or improving growth performance in pigs. Similarly, [12] observed that *Azolla* inclusion improved protein intake and nutrient utilization in poultry and livestock. The enhanced protein intake in T_4 can be attributed to the protein-rich nature of *Azolla*, which serves as a partial substitute for conventional protein sources like soybean meal.

7.3 Health Status

The reduction in incidence of diarrhea and respiratory problems in *Azolla*-fed groups indicates improved health and immunity. *Azolla* contains bioactive compounds, antioxidants, and micronutrients that contribute to enhanced immune response. These findings corroborate the observations of [14], who reported improved health and reduced disease incidence in animals fed *Azolla*. Similarly, [18] suggested that non-conventional feed resources like *Azolla* can improve gut health and microbial balance.

7.4 Economic Efficiency

The economic analysis revealed that *Azolla* supplementation significantly reduced feed cost and increased net return and benefit-cost ratio. This is mainly due to the partial replacement of expensive concentrate feed with low-cost, farm-produced *Azolla*. These results are in agreement with [10], who highlighted the economic potential of *Azolla* as a low-cost feed supplement. More recent studies by [21] also reported improved profitability in livestock production systems using *Azolla*-based feeding strategies.

Table 5. Carcass characteristics

Treatment	Dressing %	Carcass Weight (kg)	Back Fat (mm)	Lean Meat (%)
T_0	68.5	40.0	22	52
T_1	69.2	42.1	21	53
T_2	70.0	44.6	20	54
T_3	71.0	47.5	19	55
T_4	72.5	51.3	18	57
SE(m) $\pm$	1.25	1.80	0.85	1.40
CD (P=0.05)	2.72	3.92	1.85	3.05
CV (%)	4.95	5.20	6.10	4.80

7.5 Carcass Characteristics

The improvement in dressing percentage, carcass weight, and lean meat percentage, along with reduced back fat thickness, indicates better carcass quality in *Azolla*-fed piglets. This suggests that *Azolla* promotes lean tissue growth rather than fat deposition. These findings are consistent with [1], who reported that improved nutrition leads to better carcass traits in livestock. Additionally, [17] observed improved carcass quality in pigs supplemented with *Azolla*. The consistent improvement across all parameters in the present study suggests a strong positive effect of dried *Azolla* supplementation in pig diets. The increasing global emphasis on utilizing locally available unconventional feed resources has further strengthened the importance of *Azolla* as an economical alternative feed ingredient for sustainable pig production systems [22,23].

Conclusion

Based on the results and supporting literature, it can be concluded that dried *Azolla* is an effective alternative feed supplement for swine. Supplementation at higher levels significantly enhances growth performance, feed efficiency, health status, carcass quality, and economic returns. Therefore, *Azolla* inclusion at 76.5 g per pig per day (T_4) may be recommended as an optimal feeding strategy under field conditions.

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