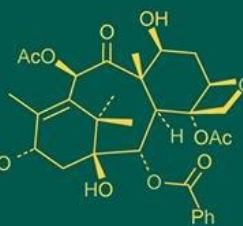
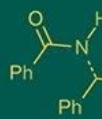
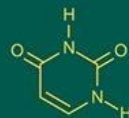


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Effect of dietary duckweed (*Lemna* spp.) with or without enzyme supplementation on nutrient digestibility and economics of broiler chicken production

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Abstract

The present study was conducted to evaluate the effect of dietary duckweed (*Lemna* spp.) with or without enzyme supplementation on nutrient digestibility and economics of broiler production. A total of 150 day-old broiler chicks were randomly allocated to five dietary treatments with three replicates of ten birds each and reared for five weeks under deep litter management. The treatments comprised a control diet without duckweed (T₁), diets containing 5% duckweed without enzyme (T₂) and with enzyme (T₃), and diets containing 10% duckweed without enzyme (T₄) and with enzyme (T₅). Proximate analysis of duckweed revealed 89.85% dry matter, 20.33% crude protein, 18.06% crude fibre and metabolisable energy of 1660.77 kcal/kg. Nutrient digestibility differed significantly ($p \leq 0.05$) among treatments. Dry matter digestibility was highest in the T₁ (78.66%) and lowest in T₄ (73.66%), while crude protein digestibility was also highest in T₁ (71.20%) compared with duckweed based diets. Crude fibre digestibility was higher in enzyme supplemented groups (T₃: 34.74%; T₅: 34.08%) compared with diets without enzyme supplementation. Ether extract digestibility did not differ significantly ($p > 0.05$) among the treatments. Incorporation of duckweed reduced feed cost, with the lowest starter feed cost observed in T₄ (Rs. 30.08/kg) followed by T₅ (Rs. 30.14/kg). Economic analysis revealed that the highest profit per bird was obtained in T₃ (Rs. 19.59), followed by the control (Rs. 13.79) and T₅ (Rs. 13.69), whereas the lowest profit was recorded in T₄ (Rs. 8.54). The results indicate that duckweed can partially replace conventional feed ingredients to reduce feed cost, and its utilisation in broiler diets becomes more advantageous when supplemented with exogenous enzymes to improve nutrient utilisation and economic returns.

Keywords: Duckweed, nutrient digestibility, economics, broiler chicken

Introduction

Domestic economic expansion coupled with evolving consumer demand has facilitated the transformation of India's poultry and especially the broiler chicken sector into a vibrant and commercially significant business. The development of the poultry industry is contingent upon several factors, notably the consistent provision of cost-effective, quality feed ingredients (Kumar *et al.*, 2025) [16]. Feed is the single largest component in poultry production which accounts for about 70-75% of total cost of production (Adaszyńska-Skwirzyńska *et al.*, 2025) [1]. The use of new edible plants that can meet the energy and protein requirements in poultry nutrition is always an important and strategic option in new studies and food security (Seidavi, *et al.*, 2023; Biyatmoko *et al.*, 2025) [21, 6]. In Jammu and Kashmir, due to non-availability of quality feed ingredients, most of the poultry feeds are imported from neighbouring states. The cost of feed is higher in Kashmir valley compared to other parts of country because of additional transportation cost incurred during importation. The adoption of locally produced unconventional feed ingredients can decrease feed expenditure and consequently raise the profitability of poultry ventures (Bhosale *et al.*, 2025) [5]. Non-conventional green forages, which are locally accessible, can function as cheap feeds offering both protein and vitamins. Incorporating locally available nonconventional feeds, particularly aquatic macrophytes, can reduce poultry feed costs and improve profitability (Kumar *et al.*, 2022) [17]. The duckweed plant family represents an alternative protein crop.

The term duckweed describes a group of plants of the family Lemnaceae with five genera and 36 species (Bog *et al.*, 2019) [7]. Duckweed (*Lemna* spp.), which is abundant in the Kashmir Valley, is a high protein aquatic macrophyte well suited for formulating low cost diets for poultry, fish, and other domestic animals as well. This diminutive floating macrophyte proliferates in still waters and is commonly found throughout tropical countries in ponds, lakes, and waterlogged paddy fields. The biomass of duckweed can contain up to 45% crude protein (CP), with a favorable amino acid composition (Xu *et al.*, 2021) [25]. The digestibility of most amino acids in *L. minor* ranged from 70% to 96%, with lysine and methionine at 87% and 86%, respectively (Niermeyer *et al.*, 2026) [19]. While its high moisture content can limit direct use in poultry diets, duckweed remains a valuable feed ingredient; it contains 28% crude protein, 3.7% crude fat, 33.8% ash, 11.5% fibre and 42.6% carbohydrates. Comparable bodyweight was recorded in broiler chicken while Duckweed was used at 5% level with enzyme supplementation (Zaffer *et al.*, 2021) [26]. Although numerous studies have examined duckweed as poultry feed ingredient (Ahammad *et al.*, 2003; Khandaker *et al.*, 2007) [2, 15], there appears to be very minimum systematic investigation of its effects in the Kashmir Valley, despite its abundant presence in local water bodies. Therefore, the present experiment was aimed to incorporate Duckweed in the diet of broiler chicken to study the cost of production and nutrient utilization.

Materials and Methods

Location of the study: The work was conducted at the Poultry Farm of Division of Livestock Production and Management (LPM), Faculty of Veterinary Sciences and Animal Husbandry (F.V.Sc. and A.H.), Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir (SKUAST-K), Shuhama, Jammu and Kashmir, India.

Collection of duckweed: It was collected from natural water bodies in and around Srinagar and Ganderbal districts. The harvested material was subsequently dried under appropriate conditions and stored properly for subsequent use in the experiment.

Experimental diet formulation: A total of ten (10) experimental diets (five starters and five finisher) were formulated to be iso-nitrogenous and iso-caloric following BIS (1992) [8] recommendations. Duckweed was incorporated into the basal diet at two inclusion levels with or without enzyme supplementation. The treatments were: T₁ (control)-basal diet without duckweed; T₂-basal diet with 5% duckweed without enzyme; T₃-basal diet with 5% duckweed with enzyme; T₄-basal diet with 10% duckweed without enzyme; and T₅-basal diet with 10% duckweed with enzyme.

Proximate analysis of diets and duckweed: The dry matter (DM), crude protein (CP), ether extract (EE), crude fibre (CF) and total ash (TA) contents of the experimental diets and dried duckweed samples were determined following the standard procedures of AOAC (2005a) [4].

Management and rearing of experimental chicks: A total of one hundred fifty (150) day-old broiler chicks were

procured from a reputed hatchery and brooded in cages during the first week. On the eighth day, the chicks were randomly allotted to five treatment groups (as mentioned above), each further divided into three replicates containing ten chicks per replicate. The birds were subsequently reared for a period of five weeks under deep litter management system with feed and water provided *ad libitum*.

Digestibility trial: At the end of the experiment, a three-day balance trial was conducted to determine the apparent digestibility of DM, CP, CF, EE. Two birds from each replicate were randomly selected and housed individually in battery cages. The trial included one day of adaptation followed by three days of excreta collection. Daily feed intake and total excreta output were recorded. The 24-hour excreta were weighed and homogenised. For DM estimation, about 1/20 of the total excreta was oven-dried at 80 °C to constant weight. For nitrogen estimation, about 1/10 of the excreta was preserved in a stoppered bottle and analysed promptly. Representative feed samples were also collected. All samples were analysed following the methods of AOAC (2005a) [4]. The metabolizable energy (ME) was calculated as per Ponzenga (1985) [20].

Economics of feeding: The economics of feeding were evaluated based on the market prices of feed ingredients at the time of purchase; miscellaneous expenses (electricity, vaccination, medication, tonics, and sawdust), feed consumption, and body weight of the birds were taken into consideration.

Statistical analysis: The obtained data were analysed following the procedures of Snedecor and Cochran (1994) [23]. Significance was assessed at $p \leq 0.05$.

Results

Proximate analysis of duckweed: The proximate composition of duckweed showed the percentages of dry matter (DM), crude protein (CP), ether extract (EE), crude fibre (CF), total ash (TA), acid insoluble ash (AIA), nitrogen free extract (NFE), phosphorus (P), calcium (Ca) as 89.85±1.25, 20.33±0.65, 3.10±0.12, 18.06±0.86, 30.35±0.58, 7.0±0.24, 18.52±0.28, 1.10±0.06 and 2.80±0.08, respectively. The metabolizable energy (ME) was calculated as 1660.77 Kcal/kg.

Proximate analysis of experimental diets: The proximate compositions of all the experimental diets were also estimated and have been presented in Tables 1 and 2 for starter phase and finisher phase, respectively.

Table 1: Proximate composition of experimental diets (broiler starter)

Sl. No.	Attributes (%)	T ₁	T ₂	T ₃	T ₄	T ₅
1.	Moisture	9.80	10.90	10.90	11.10	11.10
2.	Crude protein	21.56	21.61	21.61	22.50	22.50
3.	Crude fibre	5.18	5.24	5.24	5.60	5.60
4.	Ether extract	4.17	4.09	4.09	4.06	4.06
5.	Total ash	7.24	8.17	8.17	8.17	8.17
6.	Nitrogen free extract	51.25	49.90	49.90	47.64	47.64
7.	Metabolisable energy (Kcal/kg)	2954	2902	2902	2852	2852
	*					

*Calculated as per Ponzenga (1985) [20] ME = 37×%CP + 81×%EE + 35.5×%NFE

Table 2: Proximate composition of experimental diets (broiler finisher)

Sl. No.	Attributes (%)	T ₁	T ₂	T ₃	T ₄	T ₅
1.	Moisture	9.2	9.5	9.5	9.7	9.7
2.	Crude protein	21.02	21.48	21.48	21.50	21.50
3.	Crude fibre	5.37	5.44	5.44	5.73	5.73
4.	Ether extract	4.30	4.21	4.21	4.16	4.16
5.	Total ash	5.80	7.87	7.87	8.18	8.18
6.	Nitrogen free extract	54.30	51.50	51.50	50.73	50.73
7.	Metabolisable energy (Kcal/kg) *	3008.3	2964.02	2964.02	2933	2933

*Calculated as per Ponzenga (1985) ^[20] ME = 37×%CP + 81×%EE +35.5×%NFE

Digestibility of nutrients: The digestibility of nutrients of broiler chicken fed different levels of duckweed with or without enzyme supplementation is depicted in Table 3. Dry matter (%) digestibility differed significantly ($p \leq 0.05$) among the treatments, with T₁ showing higher digestibility than T₄ and T₅. Crude protein (%) digestibility also varied significantly ($p \leq 0.05$), with T₁ recording higher values than

T₂, T₃, T₄, and T₅, which did not differ significantly ($p > 0.05$) among themselves. Total fibre (%) digestibility showed significant differences ($p \leq 0.05$) too, with T₁, T₃, and T₅ exhibiting higher values compared to T₂ and T₄. However, ether extract (%) digestibility did not differ significantly ($p > 0.05$) among the treatments.

Table 3: Digestibility of nutrients in broilers fed duckweed with or without enzyme supplementation

Parameters	Treatments				
	T ₁	T ₂	T ₃	T ₄	T ₅
Dry matter (%)	78.66 ^b ±1.45	76.01 ^{ab} ±1.15	76.66 ^{ab} ±1.20	73.66 ^a ±1.20	74.66 ^a ±0.66
Crude protein (%)	71.20 ^b ±0.42	68.62 ^a ±0.45	69.05 ^a ±0.18	68.04 ^a ±0.45	68.14 ^a ±0.37
Total fibre (%)	35.01 ^b ±1.15	33.02 ^a ±0.60	34.74 ^b ±0.22	32.48 ^a ±0.17	34.08 ^b ±0.23
Ether extract (%)	87.41±0.33	86.48±0.22	86.85±0.51	86.19±0.05	87.49±0.38

Means across rows bearing different superscripts differ significantly ($p \leq 0.05$)

Cost of production of broiler starter diet: The cost of broiler starter diets under different treatments is presented in Table 4. Inclusion of duckweed reduced the feed cost compared to T₁. The cost per 100 kg feed decreased with

increasing levels of duckweed, with the lowest cost observed in T₄ and T₅. Thus, partial replacement of conventional ingredients with duckweed lowered the overall cost of starter diets.

Table 4: Cost of production of broiler starter diet in different treatment groups

Cost of ingredients	Treatments				
	T ₁	T ₂	T ₃	T ₄	T ₅
Maize	1044	936	936	900	900
Soyabean meal	1714.5	1669	1669	1534.5	1534.5
Duckweed	0	25	25	50	50
Vegetable oil	0	100	100	100	100
Limestone powder	8.4	8.4	8.4	8.4	8.4
Dicalcium phosphate	128	128	128	128	128
DL Methionine	210	210	210	210	210
Lysine	25	25	25	25	25
Salt	7	7	7	7	7
Vitamin and mineral mixture	45	45	45	45	45
Enzyme	0	0	6	0	6
Cost per 100 kg of feed (Rs.)	3180	3153	3159	3007.9	3013
Feed cost/kg (Rs.)	31.80	31.53	31.59	30.08	30.14
Difference in feed cost compared to control (Rs.)	-	0.27	0.21	1.72	1.66

Cost of production of broiler finisher diet: The cost of broiler finisher diets under different treatments is presented in Table 5. Incorporation of duckweed reduced the feed cost compared to T₁. The cost per 100 kg feed declined with increasing levels of duckweed, with the lowest cost

observed in T₄ followed by T₅. Consequently, the feed cost per kg was lower in duckweed-based diets, indicating that partial replacement of conventional ingredients with duckweed reduced the cost of finisher diets.

Table 5: Cost of production of broiler finisher diet in different treatment groups

Cost of ingredients	Treatments				
	T ₁	T ₂	T ₃	T ₄	T ₅
Maize	1090.8	990	990	936	936
Soyabean meal	1593	1530	1530	1395	1395
Duckweed	0	25	25	50	50
Vegetable oil	50	150	150	200	100
Limestone powder	7	7	7	7	7
Dicalcium phosphate	100	100	100	100	100
DL Methionine	60	60	60	60	60
Lysine	0	0	0	0	0
Salt	6	6	6	6	6
Vitamin and mineral mixture	52.5	52.5	52.5	52.5	52.5
Enzyme	0	0	6	0	6
Cost per 100 kg of feed (Rs.)	2959.3	2920.5	2926.5	2806.5	2812.5
Feed cost/kg (Rs.)	29.59	29.20	29.26	28.06	28.12
Difference in feed cost compared to control (Rs..)	-	0.39	0.33	1.53	1.47

Economics of feeding: The economic evaluation of broilers fed diets containing duckweed with or without enzyme supplementation is presented in Table 6. Inclusion of duckweed in the diets reduced the feed cost per kg compared to T₁, with lower feed costs observed in T₄ and T₅. Final body weight gain and feed Conversion ratio varied among the treatments, which subsequently influenced the overall production cost and economic returns. The feed cost

per kg live weight gain was lowest in T₅, followed by T₃, indicating relatively better feed efficiency in these groups. Sale proceeds per bird and per group were highest in T₃, followed by T₁ and T₅, whereas T₄ recorded the lowest returns. A similar trend was observed for profit, where T₃ yielded the highest profit per group as well as per bird, while T₄ showed the lowest profitability.

Table 6: Economics of broiler chicken fed duckweed with or without enzyme supplementation

Economic Parameters	Treatments				
	T ₁	T ₂	T ₃	T ₄	T ₅
Feed cost (Rs./kg)	30.70	30.36	30.42	29.07	29.13
Final body weight gain (g)	1749	1692	1740	1590	1660
FCR (1-6 week)	1.74	1.78	1.74	1.85	1.78
Total birds at end of study	29	29	30	29	29
Feed cost/kg live weight gain (Rs.)	53.42	54.04	52.93	53.77	51.85
Feed cost/bird (Rs.)	93.42	91.43	92.09	85.49	86.0
Input/bird (Rs.) (feed cost+chick cost+misc.)	141.42	139.43	140.09	133.49	134.07
Input/group (Rs.)	4242.60	4182.9	4202.7	4004.7	4022.10
Sale proceed/bird (Rs.)	160.56	155.69	159.68	146.93	152.8
Sale proceed/group (Rs.)	4656.38	4515.06	4790.55	4261.07	4432.83
Profit/loss per group (Rs.)	413.78	332.11	587.85	256.37	410.73
Profit/loss per bird (Rs.)	13.79	11.07	19.59	8.54	13.69

Note: The economics was worked out on basis of 30 birds reared in each group taking a uniform chick cost @ Rs. 35 and miscellaneous cost of Rs. 13/bird and sale rate of Rs. 85/kg live weight prevalent at the time of study was used.

Discussion

The values of proximate analysis of duckweed fall within the ranges reported for duckweed in earlier studies, although considerable variation occurs depending on species and nutrient availability. Demann *et al.* (2022) ^[11] reported that duckweed species such as *Lemna minor*, *Lemna minuta* and *Lemna obscura* contain appreciable protein and mineral fractions, with nutrient composition varying widely with cultivation conditions. The crude protein content of duckweed was comparable with the findings of Kalita *et al.* (2008) ^[14] who also reported a similar crude protein level of 20.8% in duckweed. The crude fibre content of duckweed recorded in the present study was consistent with the values reported by Ansal and Dhawan (2007) ^[3]. The ash content of duckweed observed in the present study was consistent with the findings of Iram *et al.* (2015) ^[13], who also reported comparable ash levels in duckweed; however, the calcium and phosphorus contents recorded in the present study were lower than those reported by the same authors. The metabolizable energy estimated in the present study was

lower than the value reported for duckweed by Syamsuhaidi *et al.* (2025) ^[24].

The reduced digestibility of dry matter and crude protein in the duckweed supplemented group may be attributed to the high fibre content of duckweed, which can increase digesta viscosity and consequently reduce the digestibility of nutrients (Demann *et al.*, 2022) ^[11]. Furthermore, the digestibility of crude fibre in the duckweed supplemented group was significantly ($p \leq 0.05$) lower than that of the control and the duckweed + enzyme supplemented groups. This may be attributed to the ability of exogenous enzymes to degrade non-starch polysaccharides and phytates, thereby improving nutrient availability and enhancing crude fibre digestibility in birds (Morgan *et al.*, 2022) ^[18]. The ether extract values recorded in the present study indicate that inclusion of duckweed in the diet did not adversely affect fat digestibility; this could be attributed to the generally high digestibility of dietary lipids in poultry and the relatively low ether extract content of duckweed, which may have limited its influence on overall fat utilisation. However, in

the present study, crude fibre digestibility was significantly ($p \leq 0.05$) higher in the enzyme-supplemented groups than in those without enzyme supplementation. This finding is consistent with previous studies reporting that exogenous enzymes improve nutrient digestibility in poultry by reducing digesta viscosity and enhancing the breakdown of non-starch polysaccharides, thereby increasing nutrient availability (Hu *et al.*, 2020; Cai *et al.*, 2026) [12, 9]. The digestibility of crude protein and ether extract in the present study was higher than those reported by Sheikh and Sapkota (2010) [22] in broilers while diet supplemented with Silk worm pupae meal.

Regarding the economical findings of the study, it can be said that incorporating duckweed into broiler diets led to a decrease in feed costs compared to the control group. However, the profit per bird in the duckweed-fed group was lower than that of the control, which was enhanced when enzymes were added to the diet. This improvement is attributed to increased nutrient digestibility in the enzyme supplemented groups, allowing more nutrients to be utilized for growth and resulting in higher body weight gains. These results are consistent with the observations of Khandaker *et al.* (2007) [15] and Iram *et al.* (2015) [13], who also reported reductions in feed costs when duckweed was included in broiler diets.

Conclusion

The present study found that the use of duckweed as a partial substitute for conventional broiler feedstuffs is viable to reduce the cost of broiler production without impairing the overall cost of production. The use of higher levels of duckweed without enzyme supplementation, however, showed relatively lower nutrient digestibility and economic returns. This may be attributed to the relatively higher fibre content of the duckweed. The supplementation of exogenous enzymes was found to improve the nutrient utilisation efficiency. This consequently showed better economic returns of the broilers fed with duckweed supplemented with enzymes compared to the group fed with the duckweed material without enzyme supplementation. The present study indicated the potential of the use of duckweed material as an alternative cost effective and locally available broiler feed.

Conflicts of interest: None

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