

Studies on the Analysis of Eri Silkworm Pupae (*Samia ricini* D.) as a Broiler Feed Substitute

Susikaran Sundararaj^{1*}, Karthick Mani Bharathi Babu², Muruges K Alagu², Kiruthika Chinnasamy⁴, Vasanth Veerasamy⁵, Kama Ramya Harika⁶, Bhuvana Srinivasan⁷ and Balasubramaniam P¹

¹Directorate of Open and Distance Learning, Tamil Nadu Agricultural University, Coimbatore, Tamil Nadu, India

²Central Silk Board - National Silkworm Seed Organization, P2 Basic Seed Farm, Yelagiri Hills, Tirupattur, Vellore, Tamil Nadu, India

³Department of Sericulture, Forest College and Research Institute, Tamil Nadu Agricultural University, Mettupalayam, Tamil Nadu, India

⁴Central Silk Board, National Silkworm Seed Organization, Silkworm Seed Production Centre, Dakshin, Bhawanipur, West Bengal, India

⁵Central Silk Board, Silkworm Seed Production Centre, Hindupur, Andhra Pradesh, India

⁶Basic Seed Multiplication and Training Center, Central Silk Board, Chennur, Telangana, India

⁷Regional Sericultural Research Station, Central Silk Board, Mulugu, Telangana, India

ABSTRACT

This study evaluates the potential of eri silkworm pupa as a substitute for conventional protein sources in broiler diets. Eri silkworm pupae are rich in protein, essential amino acids and beneficial fats were incorporated into broiler feed to assess their impact on growth performance, feed conversion efficiency and overall health. Experimental trials demonstrated that broilers fed diets containing eri silkworm pupa exhibited enhanced growth rates and feed efficiency compared to control. Use of eri pupal powder as a substitute in broiler diets showed higher body weight and weight gain of broiler at 35% substitution (2020.07 g). Feed consumption was found to be maximum in 35 percent substitution (1030.77 g) followed by 45 percent substitution (1025.09 g) and lowest in the control diet (1014.53 g). Feed conversion ratio (FCR) registered a maximum in 35 percent substitution (3.37 g) followed by 45 percent substitution (3.21 g). Additionally, the use of eri silkworm pupae presents an opportunity for waste reduction in the sericulture industry thus promoting sustainability in animal feed production. The findings indicate that eri silkworm pupa can serve as a viable, nutritious alternative in poultry diets thereby aligning with the increasing demand for sustainable and eco-friendly feed options.

Article Information

Received 08 May 2025

Revised 25 July 2025

Accepted 10 August 2025

Available online 16 September 2026 (early access)

Authors' Contribution

SS and KAM conceived the study. SS suggested the study ideology and carried out research. BKMB, CK and VV collected the material and wrote the manuscript. KRH and SB helped in manuscript writing and in proof reading while PB helped in the revision of manuscript.

Key words

Broiler diet, Body weight gain, Conversion ratio, Eri pupa, Growth parameters, Total feed consumption

INTRODUCTION

The eri silkworm (*Samia ricini* D.) also known as the castor silkworm is a domesticated species widely cultivated in northeastern India and parts of Southeast Asia (Weru *et al.*, 2021). It primarily feeds on castor leaves and its silk is known for its durability, warmth and distinctive creamy-white color (Zhou *et al.*, 2022a). Unlike other silkworms,

eri silkworms produce an open-ended cocoon thus making the silk easier to spin without harming the pupae. This makes eri silk a favorite option for sustainable and cruelty-free fabric production. Additionally, the eri pupae are a rich source of protein and nutrients thus making them valuable as a feed ingredient in animal nutrition (Sarkar *et al.*, 2023).

The exploration of alternative feed sources in poultry nutrition has gained significant attention in recent years due to rising feed costs and the quest for sustainable farming practices (Zhou *et al.*, 2022b). One such promising alternative is the use of eri silkworm pupa (*Samia ricini*), a by-product of the silk production industry, as a feed ingredient for broiler chickens (Singh *et al.*, 2023). The demand for sustainable and alternative protein sources in animal nutrition is increasingly becoming a priority in the face of global challenges such as population growth,

* Corresponding author: susi.agri@gmail.com
0030-9923/2026/0001-0001 \$ 9.00/0



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environmental concerns and rising feed costs (Tanga *et al.*, 2023). Traditional sources of protein for broiler diets, primarily derived from soy and fish meal are under scrutiny due to their environmental impact and the volatility of their availability (Arasakumar *et al.*, 2021). This has spurred interest in alternative protein sources, one of which is the eri silkworm pupa. Eri silkworms are cultivated primarily for silk production, particularly in India where they have significant economic and cultural importance. However, the pupa a byproduct of the silk industry is often underutilized (Mokaya *et al.*, 2023).

Eri silkworm pupae are rich in protein, essential amino acids, vitamins and minerals thus making them a potentially valuable component of animal feed (Borah *et al.*, 2024). Their nutritional profile suggests they could effectively substitute for conventional protein sources in broiler diets, potentially enhancing growth performance, feed efficiency and overall health in poultry (Sirimungkararat *et al.*, 2010). Studies have demonstrated that the inclusion of insect-based proteins in animal diets can lead to improved feed conversion ratios (FCR) and growth rates. For instance, a study by Huis *et al.* (2013) highlighted the advantages of using insect protein, noting that it could provide an efficient and sustainable alternative to conventional feeds (Mishra *et al.*, 2003). Eri silkworm pupae, specifically have been shown to contain high levels of protein (up to 60% of dry weight) and beneficial fatty acids, which are essential for the development and metabolism of broilers (Tulu *et al.*, 2022).

Moreover, utilizing eri silkworm pupae aligns with the principles of circular economy by minimizing waste from the silk industry and providing additional income streams for farmers. Moreover, various technologies were used in sericulture for promoting the economic needs of farmers (Naskar *et al.*, 2021). By repurposing pupae, which are often discarded, the agricultural sector can achieve more sustainable production systems. This approach not only enhances food security but also contributes to the economic viability of silk production in rural areas (Tassoni *et al.*, 2010). In addition to their nutritional benefits, eri silkworms may also possess functional properties that could be advantageous in broiler diets (Sahib *et al.*, 2024). Their amino acid profile is particularly favorable thus containing essential amino acids such as lysine and methionine which are crucial for growth and muscle development in poultry (Banday *et al.*, 2023).

Furthermore, incorporating insect proteins from eri silkworms with various functional bioactive compounds can enhance gut health and overall immune function in broilers, potentially reducing the need for antibiotics and other growth-promoting additives (Amza and Tamiru, 2017). Despite the promising prospects of eri silkworm

pupa as a feed ingredient, there are several challenges that must be addressed. These include the need for standardized processing methods to ensure the nutritional quality and safety of the feed, as well as consumer acceptance of insect-based products. The sensory attributes and palatability of diets containing eri silkworm pupae require thorough investigation to ensure they meet the preferences of both poultry and end consumers (Deori *et al.*, 2014). This study aims to evaluate the potential of eri silkworm pupae as a sustainable substitute for conventional protein sources in broiler diets.

MATERIALS AND METHODS

This study was carried out in the Department of Sericulture, Forest College and Research Institute, Mettupalayam (11° 20' N, 76° 55' E, above 300 MSL). Broiler chicken rearing was carried out by using eri pupa as feed.

Preparation of pupae powder

After being completely dried out in a hot air oven at 600 °C for 12 h, the eri pupae were grinded into ground crumbles using a blender so they could be easily fed to the broiler chickens.

Broiler fed with eri pupal powder

In the control experiment, the feed was a standard diet consisting of fish meal. Eri pupae powder was used as substitute in place of fish meal at 25, 35 and 45% (Gokulakrishnaa *et al.*, 2023). All birds were fed a control diet during the starting phase. At 7 days of age, broilers were randomly assigned to receive one of the experimental diets under various dietary treatments. One control and three experimental group were maintained as follows: T1 with 25% substitution of Eri pupal powder (25% SEPP); T2 with 35 percent substitution of Eri pupal powder (35% SEPP); T3 with 45 percent substitution of Eri pupal powder (45% SEPP), and T4 with control diet without Eri pupal powder (0% SEPP). This trial was carried out for 42 days. With three treatments and four replications thus comprising 10 broilers for each replication, the experiment was carried out using a completely randomized design (CRD).

Observations from experiments

The following observations were recorded during the experimental period. Every week, the body weight of each individual, their feed intake and their morality were documented. Initial body weights were recorded at the beginning of the experiment. Up to the seventh week, the body weights of each individual bird were noted every week.

The broilers average weekly weight gain was

estimated for each treatment and replication and recorded in grams.

Based on the quantity of feed provided and any remaining residue, the average food consumption in each treatment was determined. The average weekly feed consumption and total feed consumption were calculated from this record.

The ratio of feed consumed to broiler body weight increase was used to determine the weekly and overall feed conversion efficiency of the various treatments (replication wise).

Feed consumption (g)= Quantity of feed consumed (g)/ Body weight gain (g)

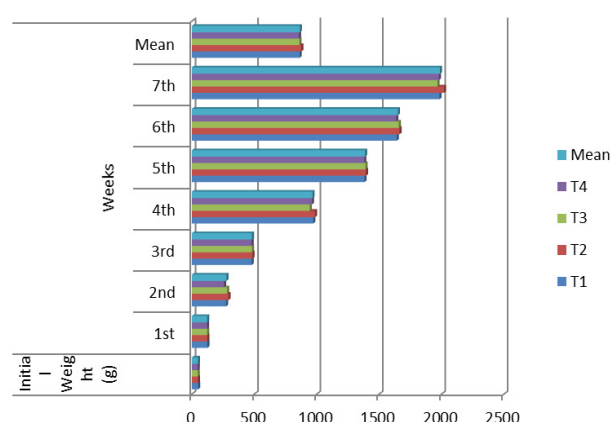


Fig. 1. Mean weekly body weight (g) of broiler fed by different treatments of eri pupal meal.

RESULTS

The results of the present study clearly indicate that supplementation of eri silkworm pupal meal in broiler diets had a notable influence on growth performance, feed consumption and feed conversion efficiency over the 7-week experimental period. As shown in Figure 1, the weekly body weight of broilers increased steadily across all treatment groups thus confirming healthy growth

trends. Among the dietary treatments, 35% eri pupal meal substitution resulted in the highest mean body weight (877.06 g), followed by 25% SEPP (25%) at 863.43 g, 45% SEPP at 861.66 g and finally the control group 0% SEPP at 858.19 g. Though these differences were statistically significant, the data suggest a positive trend in weight gain with moderate levels of eri pupal inclusion, particularly at 35%. Notably, broilers in the 35% SEPP group also recorded the highest final body weight (2020.07 g) thus indicating the potential of eri pupae to enhance overall growth when included at optimal levels.

Feed consumption patterns presented in Table I showed a progressive increase across all groups, consistent with normal broiler growth behaviour. The highest mean weekly feed intake was observed in the 35% inclusion group (604.03 g), while the control group (0% SEPP) had the lowest (579.26 g). This slight increase in feed intake among eri pupal-fed groups may be attributed to the palatability or nutritional composition of the pupal meal, especially its high protein and lipid content. However, these differences were statistically significant thereby indicating that the inclusion of eri pupae did not negatively affect feed acceptance.

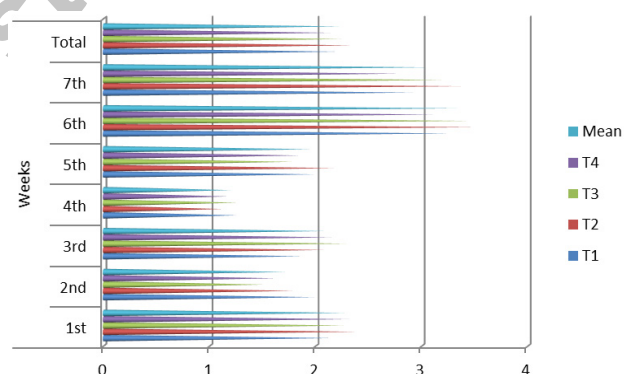


Fig. 2. Mean weekly overall feed conversion ratio (g) of broiler fed by different treatments of eri pupal meal.

Table I. Mean weekly total feed consumption (g) by broiler fed by different treatments of eri pupal meal.

Treatments	Weeks							
	1 st	2 nd	3 rd	4 th	5 th	6 th	7 th	Mean
T1	171.33 ^b	266.28 ^c	426.81 ^b	580.20 ^c	788.72 ^c	876.26 ^c	1018.38 ^c	589.71
T2	170.36 ^c	269.08 ^b	424.37 ^c	584.70 ^b	836.23 ^a	912.75 ^a	1030.77 ^a	604.03
T3	173.67 ^a	271.97 ^a	432.74 ^a	589.58 ^a	807.81 ^b	885.42 ^b	1025.09 ^b	598.04
T4	169.98 ^d	265.33 ^d	423.46 ^d	578.93 ^d	756.72 ^d	845.93 ^d	1014.53 ^d	579.26
Mean	171.33	268.16	426.84	583.35	797.37	880.09	1022.19	592.76
S.Ed	0.83	1.50	2.09	2.42	16.70	13.77	3.60	
CD (0.05)	1.74**	3.14**	4.39**	5.08**	35.07**	28.93**	7.55**	

Note: Observed values are mean of four replications by LSD (p=0.05). T1, 25% SEPP; T2, 35% SEPP; T3, 45% SEPP; T4, 0% SEPP.

The feed conversion ratio (FCR), a key indicator of feed efficiency is summarized in Figure 2. The control group (0% SEPP) showed the most efficient FCR (2.14) followed closely by 25% pupal powder inclusion at 2.21. Treatments 45% SEPP and 35% SEPP had FCR's at 2.25 and 2.34, respectively. This suggests that while higher inclusion levels of eri pupal meal (35–45%) may enhance body weight, they could slightly compromise feed efficiency. This may be due to higher fiber or chitin content in the eri pupae, which could affect nutrient digestibility at elevated levels. Nonetheless, the differences in FCR were statistically significant, reaffirming that eri pupal meal is a viable alternative protein source in broiler diets up to 45% inclusion.

Overall, the findings support the use of eri silkworm pupae as a sustainable and nutritionally beneficial feed substitute for broilers. The best balance between growth performance and feed efficiency was observed at the 25–35% inclusion level with 35% yielding the highest weight gain and 25% offering better feed utilization. These results hold promising implications for integrating insect-based proteins into poultry nutrition, particularly in regions where eri pupae are abundantly available as byproducts of sericulture activities.

DISCUSSION

The present study highlights the potential of eri silkworm pupae (*Samia ricini*) as a sustainable and nutritionally viable alternative protein source in broiler feed formulations. The gradual and consistent increase in body weight across all treatment groups confirms that eri pupal meal can support normal broiler growth (Bovera *et al.*, 2015). Particularly, the 35% inclusion level resulted in the highest mean and final body weight thus indicating its capacity to enhance growth performance. Lokeshwari *et al.* (2019) determined that eri silkworm pupae contained 44.24% moisture, 12.96% fat, 40.95% protein, 1.22% carbohydrate and 1.12% ash. This observation is consistent with Lokeshwari *et al.* (2019) where insect protein sources, especially from silkworm pupae have been shown to improve growth in poultry due to their rich protein and lipid content.

However, it was also observed that higher inclusion levels (*i.e.*, 35% and 45%) were associated with slightly higher FCR thus suggesting reduced feed efficiency compared to the 25% inclusion level and control diet. This decline in feed efficiency at higher inclusion levels may be attributed to the chitin content present in the exoskeleton of the pupae which is known to reduce nutrient digestibility when present in large amounts. Studies have shown that replacing fishmeal with mulberry, muga or tasar silkworm

pupae at 50% or 5–10% in broiler feed does not negatively impact productivity (Jozefiak and Engberg, 2017). Similar findings have been reported by Sheikh *et al.* (2018), who noted that although insect meals can be excellent protein sources, their fiber and chitin levels need to be considered during feed formulation.

Other studies have successfully replaced 75% of soybean meal in broiler finisher diets with silkworm meal without compromising growth (Ullah *et al.*, 2017; Rahmasari *et al.*, 2014). Increasing SWPM inclusion in diets also significantly lowered feed costs (Dutta *et al.*, 2012). For broiler chickens, replacing 50% of fish meal with silkworm pupae had no negative impact while 100% substitution did (Fagoonee, 1983). Progressive substitution of soybean meal (0%, 25%, 50%, 75% and 100%) with silkworm meal reduced feed costs thus offering greater economic benefits. Broiler performance and carcass quality were not negatively affected by replacing soybean meal with silkworm meal (Ullah *et al.*, 2017).

Feed consumption was relatively uniform across treatments with slightly higher intake observed in the eri pupae-fed groups, particularly 35% SEPP and 45% SEPP. This suggests that the eri pupal meal was palatable and readily accepted by the broilers. The absence of any significant reduction in feed intake further supports the suitability of eri pupal meal as a feed ingredient (Ramos and Elorduy, 1997). Additionally, no mortality or behavioural abnormalities were observed during the trial, indicating the safety of the pupal meal in the diets at all tested inclusion levels. While the differences among treatment groups were not statistically significant, the observed numerical variations in performance metrics such as body weight and FCR still provide valuable insights. From a practical standpoint, even slight improvements in body weight and feed efficiency can translate into considerable economic gains at a commercial scale (Chodova and Tumova, 2020). Therefore, the 25–35% inclusion range appears to strike a good balance between growth performance, feed efficiency and feed cost.

The use of eri pupae, a byproduct of the sericulture industry, not only addresses the need for alternative protein sources in poultry production but also promotes waste valorization and sustainability. Defatted eri silkworm pupae meal had a protein content of up to 75% thus making it suitable for animal nutrition (Longvah *et al.*, 2011). The integration of such insect-based proteins can reduce dependency on conventional and often expensive protein ingredients like soybean meal and fishmeal, which are subject to price volatility and environmental concerns. Furthermore, the study supports the feasibility of using eri silkworm pupae meal in broiler diets up to 45% inclusion. However based on performance trends, a 25% to 35% substitution appears most beneficial. Future research

should focus on optimizing processing techniques to reduce chitin content, assess gut health and meat quality effects and evaluate the economic viability in field-scale operations.

CONCLUSION

The present study investigated the effects of incorporating eri silkworm pupae (*Samia ricini*) meal as a substitute protein source in broiler diets at varying levels (25%, 35% and 45%) and compared the outcomes with a control diet. The findings demonstrated that eri pupal meal can be successfully included in broiler feed formulations without adversely affecting growth performance, feed intake or FCR. Among the different treatments, the 35% inclusion level recorded the highest mean body weight and final growth performance thus indicating its potential in enhancing broiler growth. Meanwhile, the 25% inclusion level offered a favourable balance between body weight gain and feed efficiency, with a lower FCR compared to higher inclusion levels. Although differences across treatment groups were statistically significant, the trends suggest that moderate levels of eri pupal inclusion (particularly 25% to 35%) may support both optimal growth and efficient feed utilization. Feed consumption was also found to be comparable across all treatment groups, with slightly higher intake in the eri pupae-fed groups. This indicates good palatability and acceptability of the eri pupal meal. While the highest level of inclusion (45%) did not result in performance decline, it showed slightly poorer FCR values, possibly due to the increased fiber or chitin content in the diet at this level. In conclusion, eri silkworm pupae meal is a promising alternative protein source for broiler production. Its use can reduce reliance on conventional protein ingredients such as fishmeal and soybean meal thus promoting sustainable poultry farming and add value to sericulture byproducts. Integrating eri pupae into poultry nutrition not only offers a cost-effective solution but also supports circular economy practices. Further research is recommended to evaluate long-term performance, nutrient digestibility and economic returns under field and commercial conditions.

DECLARATIONS

Acknowledgments

Authors greatly acknowledge the support from Department of Sericulture, Forest College and Research Institute, Mettupalayam for providing all the necessary facilities to carry out this research work by extending all the laboratory facilities. The authors are thankful to Tamil Nadu Agricultural University, Coimbatore, Tamil Nadu for the necessary support and encouragement.

Funding

The study receives no external funding.

Generative AI and AI-assisted technology statement

The authors declare that no generative AI and AI assisted technology was used in the creation of this manuscript.

Statement of conflict of interest

The authors have declared no conflict of interest.

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