

## RESEARCH ARTICLE

### NUTRITIONAL AND ECONOMIC IMPLICATIONS OF *SAMIA RICINI* (ERI SILKMOTH) RAISED ON ARTIFICIAL DIET - A MORPHOLOGICAL AND BIOCHEMICAL STUDY

<sup>1</sup>Sharada Devi, J N., <sup>2</sup>Bhoomika, S., <sup>3</sup>Insiya Sultana, <sup>4</sup>Karthik, N., <sup>5</sup>Priya, M.D. and <sup>6</sup>Kiran Kumar, H. B.

<sup>1</sup>Department of Zoology and Genetics, Government Science College, Nrupathunga University, Nrupathunga Road, Bengaluru -560001, Karnataka, India; <sup>2</sup>Contractual Biology Faculty (PGT), PM SHRI KENDRIYA VIDYALAYA NO 1, Jalahalli West, Bengaluru – 560015, Karnataka, India; <sup>3</sup>Lecturer, Shifa Institute of paramedical and allied health sciences, Vasanth Nagar, Bengaluru-560051, Karnataka, India; <sup>4</sup>Post graduate teacher (PGT), SISA INDO SWISS ACADEMY, affiliated to CBSE, Delhi, Whitefield main road, Bengaluru – 560066, Karnataka, India; <sup>5</sup>Department of Zoology and Genetics, Government Science College, Nrupathunga University, Nrupathunga Road, Bengaluru -560001, Karnataka, India; <sup>6</sup>Government Science College, Nrupathunga University, Nrupathunga Road, Bangalore-560001, India

#### ARTICLE INFO

##### Article History:

Received 20<sup>th</sup> June, 2026

Received in revised form

24<sup>th</sup> July, 2026

Accepted 19<sup>th</sup> August, 2026

Published online 30<sup>th</sup> September, 2026

##### Key words:

Eri Wool Union fabric, (EWU); Non-Mulberry Silkworm; Multivoltine; Oviposition; Nataliy.

##### \*Corresponding author:

Sharada Devi, J N.,

#### ABSTRACT

*Samia ricini* is an important non-mulberry silkworm species with considerable nutritional and economic significance in the sericulture industry. In addition to silk production, its developmental stages have potential nutritional value, while Eri culture provides opportunities for income generation and small-scale rural livelihoods. Castor (*Ricinus communis*) is one of the principal host plants of *S. ricini* and supports its growth and development under laboratory conditions. However, the seasonal availability of host leaves can limit continuous rearing, highlighting the potential importance of artificial diets. The present study aimed to assess the morphological, developmental, and biochemical characteristics of *S. ricini* reared on castor leaves and to evaluate semi-synthetic artificial diets for larval rearing. Selected macromolecules were analyzed at different developmental stages, and the breaking properties of *S. ricini* and *Bombyx mori* silk fibres were compared. Fifth-instar larvae exhibited the highest soluble protein concentration (6.75 mg/mL) and carbohydrate concentration (4.4 mg/mL), whereas prepupae showed higher ash (3.50%) and crude fibre (2.38%) contents. Larval development was accompanied by distinct morphological changes across successive instars, reflecting the developmental transitions associated with metamorphosis. Larvae reared on fresh castor leaves showed better growth and survival than those reared on the artificial diets, while Diet 01 performed better than Diet 02. The findings indicate that castor leaves remain a suitable host for the growth and development of *S. ricini*, whereas the artificial diets tested require further optimization to improve larval performance. Nevertheless, the ease of preparation and storage of the diets suggests their potential utility for laboratory rearing and for reducing dependence on seasonal host-plant availability. Overall, the study provides information on the nutritional characteristics, biology, and dietary requirements of *S. ricini* that may contribute to the development of improved rearing strategies.

Citation: Sharada Devi, J N., Bhoomika, S., Insiya Sultana, Karthik, N., Priya, M.D. and Kiran Kumar, H. B. 2026. "Nutritional and Economic implications of *Samia ricini* (ERI SILKMOTH) raised on artificial diet - a morphological and biochemical study.", *Asian Journal of Science and Technology*, 17, (07), xxxxx-xxxxx.

Copyright©2026, Sharada Devi et al. This is an open access article distributed under the Creative Commons Attribution License, which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

## INTRODUCTION

According to Maheswari and Arulkavi, (2023), silk is a naturally occurring protein fibre that may be knitted or woven into textiles. The cocoons of the larvae of the mulberry silkworm *Bombyx mori*, are raised in captivity (sericulture), yield the most well-known silk (Singh et al., 2025). Fibroin (75–80%) and a small layer of sericin (20–25%) make up the majority of the protein fibre in silk (Khan, 2265). Non-mulberry silkworms, also known as wild or Vanya silkworms, live in forests and consume a variety of plants, including

castor, oak, and Arjun (Das et al., 2020). Three amazing non-mulberry silkworms, Muga (*Antheraea assamensis*), Eri (*Samia ricini*), and Tasar (*Antheraea mylitta*), are found in India and collectively serve as the foundation of the nation's wild silk industry (Das et al., 2020). These insects, which feed on a variety of host plants and produce silk with textures, colours, and characteristics in comparison to mulberry silk. Also, they are adapted to natural forest conditions, in contrast to the farmed mulberry silkworm (Boro, and Borah, 2020).

Every species has a unique life cycle, geographic range, and cultural heritage. *S. ricini* is an important non-mulberry species that is vital to the sericulture sector. It feeds on castor leaves (Mandali and Narayanamma, 2015). The Eri silkworm produces a long-lasting, matte-finish silk and is primarily raised indoors. Eri cocoons are known as "Ahimsa" or cruelty-free silk since the adult moths spontaneously exit before the silk is spun due to the cocoons' open ends (Reddy *et al.*, 2026). *S. ricini* is a domesticated multivoltine, polyphagous species that is raised year-round in the non-mulberry sectors (Mahesh *et al.*, 2026). While some permanent tree species, such as kessaru and payam in northeastern India, may serve as additional food during the off-season, castor and tapioca are the two most significant host plants for Eri silkworms (Vijay and Susikaran, 2023; Kumara, 2023). Because Eri silkworms are neither as domesticated as mulberry silkworms nor as wild as muga or Tasar worms, they require relatively less care. The producer benefits from the cocoons being preserved until a fair price is reached. Eri silk is frequently used to make quilts and chadars (Duarah, 2017). Eri silkworms are more productive per acre than other silkworms because they are resilient and disease-tolerant (Thanga *et al.*, 2021). The Eri silkworm is one among the many insects that the native people of northeastern India eat (Pradhan *et al.*, 2022). Eri silkworm prepupae and pupae are only sold in local marketplaces and are still harvested informally. Eri (*Attacus ricinii*) is not the only silkworm pupae chewed in Assam; Mulberry (*Bombyx mori*) and Muga (*Antheraea assama*) are also consumed. As a result, *S. ricini* is both cost-effective and nutritious.

To emphasize the distinctive qualities, the developmental, biochemical, and silk properties of *S. ricini* few research data are examined. It is widely known how *S. ricini* develops from egg laying to adult emergence. According to Ahmed *et al.* (2015), adult moths demonstrate sexual dimorphism, with males having a smaller, slimmer abdomen and being more active than females, who have a broader, wider abdomen. The average number of eggs laid by female moths was 360, with a hatching rate of more than 97%. The larvae take about 23 days to mature with notable increases in size and pigmentation. Also, at the five larval instars exhibits distinctive physical characteristics. According to Ahmed *et al.*, (2015), the prepupal and pupal stages last 2.63 and 15.73 days, respectively. The colour of freshly placed eggs is yellowish, turns milky white, and then turns blackish before hatching. The pupae's rich nutritional profile is highlighted by the proximate composition study. Eri pupae have 15.97% protein, 11.09% fat, and 1.21–1.80% carbohydrates (Deori *et al.*, 2016). The range of the moisture content was 65–70%. With an energy content of 988.16 kJ, these pupae are a great source of dietary fat and protein (Ray and Gangopadhyay, 2021). Eri silk is prized for its physio-mechanical characteristics. The physio-mechanical behaviour of pure Eri silk and its blending with wool for various applications was evaluated by Borah *et al.* (2019). The results showed that the inclusion of wool had a substantial impact on fabric strength and density, with Eri Wool Union fabric, (EWU) exhibiting higher ultraviolet protection factor (UPF) and tensile qualities. The EWU1 type showed maximum air permeability and elongation at maximum load, but energy efficiency (EE) had the highest brightness and crease recovery. Additionally, Boruah, S. (2018), provide a thorough analysis of the characteristics, advantages, and uses of Eri silk spun yarn and fabric, emphasizing on the moral and environmentally responsible aspects of Eri silk manufacturing. Additionally, its non-

allergenic and biodegradable qualities make it ideal for technical applications, household textiles, and clothing. The nutritional content and customary consumption habits of silkworm pupae in different Assamese communities have been the subject of numerous studies. The highest consumption was seen in Eri pupae (87.7%), followed by Muga (57.4%) and Mulberry (24.6%) (Mishra, *et al.*, 2003). In addition to environmental parameters, the number and quality of leaves fed have a significant impact on silkworm economic features such as cocoon weight, shell weight, and shell ratio (Samami *et al.*, 2019). Castor (*Ricinus communis*) and tapioca (*Manihot esculenta*) are the host plants that provide the main physiological and nutritional basis for the raising of eri silkworms (Deuri *et al.*, 2017). According to a study by Gokulakrishnaa *et al.*, 2025, castor's higher nitrogen (N), crude protein, carbohydrate, and mineral content and lower antinutrient levels make it a much better host plant for eri silkworms than tapioca. Silkworm growth, development, and cocoon generation have been found to be significantly impacted by variations in the nutritional content of leaves within the same species with different cultivars (Wongsorn *et al.*, 2024; Kakati *et al.*, 2018). According to research comparing the nutritional values of castor and tapioca in four distinct seasons, castor plants had reduced anti-nutrient content and higher nutritional values in the spring (Deuri *et al.*, 2017). Numerous studies have shown that raising eri-silkworms on an artificial diet from hatching to the mouth stage is successful. The effects of feeding artificial meals at various larval stages were examined by Mangammal and Sri Devi (2012). Artificial diets were shown to be useful in the first and second instars, however feeding in the later stages resulted in poor cocoon production and higher mortality. The results validated the hybrid raising model for the best possible development of silkworms. According to Fukuda (1961), the artificial food is made of powdered castor oil plant leaves, "Kinako" (a powdered dried soy bean), sucrose, agar-agar, inhibitor solution, and water. The results of the eri-silkworms raised on artificial food were similar to those of the eri-silkworms raised on fresh leaves of the castor-oil plant, which is the insect's natural meal, or even better, in terms of the larvae raising cocoon fibres and eggs.

With this background the current objectives of the present study were to assess a) Nutritive value of *Samia ricini* b) Tensile property of *S. ricini* silk and *B. mori* silk fibre. Other objectives were to study the c) the Biology of *S. ricini* on *Ricinus communis* leaves and d) development and test of a Semi-synthetic diet for rearing of *S. ricini*.

## MATERIALS AND METHODS

The eggs of *S. ricini* were collected from National Bureau of Agriculture Insect Resource (NBAIR), Bengaluru and was maintained at Krishi Sai Ekatha laboratory, Yashwanthpura, Bengaluru to obtain *S. ricini* cocoons. *Bombyx mori* cocoons were provided by Sericulture department, University of Agricultural Sciences, Bengaluru.

**Estimation of Nutritive value:** Fine-grade laboratory chemicals were used in the study. All reagents were prepared fresh in sterile environment with distilled water.

- **Protein estimation:** Crude protein was determined using the Lowry method (Lowry *et al.*, 1951) and the Kjeldahl method (AOAC International, 2019). The Lowry assay

was used for the estimation of soluble protein based on the reaction of proteins with the Folin–Ciocalteu reagent, whereas the Kjeldahl method was employed to determine total nitrogen, which was converted into crude protein using the appropriate conversion factor.

- **Carbohydrate Estimation:** Total carbohydrate content was estimated by the Anthrone method following the procedure described by Hedge and Hofreiter (1962). Absorbance was measured spectrophotometrically, and carbohydrate concentration was calculated using a glucose standard curve.
- **Ash Content:** Ash content was determined according to the standard procedures of AOAC International (2019). The samples were incinerated in a muffle furnace until complete combustion of organic matter, and the remaining inorganic residue was expressed as percentage ash.
- **Crude Fibre Estimation:** Crude fibre content was determined according to the standard acid–alkali digestion method described by AOAC International (2019). Fibre content was expressed as a percentage of dry sample weight.

**Tensile strength estimation:** Universal tensile strength tester instrument from Fashion technology department, Bangalore City University. Methodology-50 silk fibres of *S. ricini* silk and *B. mori* silk of length 15cm were considered for the estimation of tensile property. Both the ends of silk fibre were adjusted correctly at the centre of the clamp of Universal Tensile Strength Tester instrument keeping the initial load zero. The load was raised by 10kg at every interval up to the breaking point of the silk fibre.

**Studies on biology of *S. ricini* on castor conducted under laboratory conditions:** Methodology-The freshly hatched larvae of *S. ricini* were brushed on to the tender castor leaves for feeding. The leaves were fed to the freshly hatched larvae twice a day placed in an open crate covered with a muslin cloth. First instar larvae were fed twice a day, while those of the second and third instar were fed three times a day, four times while the larvae were in their fourth and fifth instars. The third-instar larvae were fed mature coarse leaves. Cleaning the larval crate was done once a day during the first and twice a day during the second, third, and fourth instar, and once a day during the first instar larval stage.

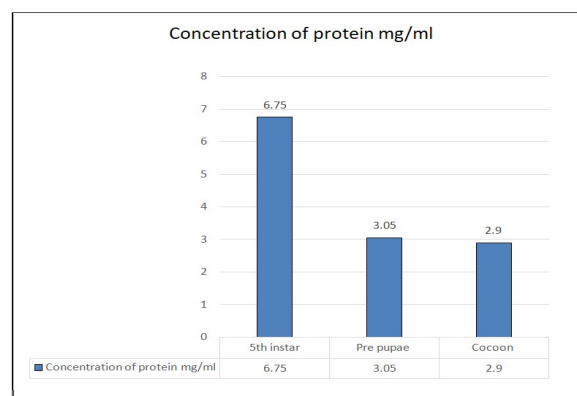
**Preparation and testing of artificial diet:** The population of *S. ricini* was maintained on castor plant at room temperature. The eggs were collected daily, and the newly hatched larvae were fed on castor leaves until population develops. Upon emergence five pairs were confined to a cage and adults were fed with 10% honey solution. Methodology-Fresh castor leaves were collected, washed and then dried thoroughly in room temperature for about seven days and then grinded to make castor leaf powder and used for the preparation of artificial diet. Diet for multiplication of *S. ricini* was based on artificial diet. The composition is described in detailed in Table.1 Two nutritional media were tested for the artificial diet studies of *S. ricini*. Leaf powder, green gram powder, sorbic acid, streptomycin, multivitamin, 10% formalin were mixed well in blender to generate a smooth paste. Methylene paraben was dissolved in 70% alcohol, agar and 100 ml distilled water. Agar dissolved in 50ml of boiling water and methyl paraben solution are blended with pasted ingredients and stirred for 2mins. After mixing all the ingredients and cooling to room temperature, the diets were dispensed into separate containers

and allowed to solidify at room temperature. The suitability of two diet for continuous lab rearing was estimated by comparing its effectiveness with those reared on castor host plant. Each diet was replicated five times. Larvae were reared to pupal stage in sterile cups. Diet cups containing larvae were maintained at room temperature (28°Celsius). The artificial diet was replaced four days once, and the castor leaves were replaced two days once. The detailed composition of the diet formulations is presented in Table 1.

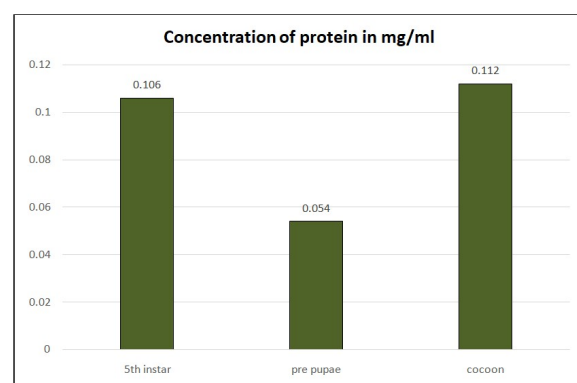
**Statistical analysis:** Microsoft xl was used for all statistical analysis and generation of graphs.

## RESULTS

**Estimation of Nutritive value:** Concentration of protein (mg/ml) through Lowry's method of 5<sup>th</sup> instar larvae was 6.75, in pre pupae 3.05 and in cocoon it was 2.9. The concentrations through Kjeldahl's method were 5<sup>th</sup> instar larvae (0.106), pre pupae (0.054) and cocoon (0.112). The higher protein content in the cocoon corresponds to the accumulation of fibroin and sericin proteins during cocoon formation. The concentration of carbohydrates (mg/ml) was 5<sup>th</sup> instar larvae (4.4), pre pupae (3.2) and cocoon (3). These findings suggest greater carbohydrate accumulation during the actively feeding larval stage to support growth and subsequent silk synthesis. Percentage of Ash in *Samia ricini* 5<sup>th</sup> instar was 1.69, pre pupae (3.5), and cocoon (1.9). The increased ash content during the prepupal stage indicates greater mineral accumulation before pupation. Percentage of crude fibre was 5<sup>th</sup> instar (1.97), pre pupae (2.38) and cocoon (2.37). The data is summarized in as bar graphs in figure 1-5 respectively.



**Figure 1. Soluble protein concentration (mg/mL) in different developmental stages of *Samia ricini* determined by the Lowry method**



**Figure 2. Crude protein content determined by the Kjeldahl method in different developmental stages of *Samia ricini***

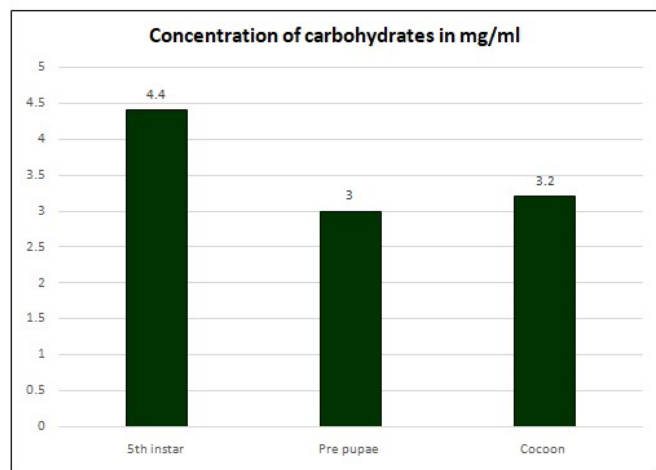


Figure 3. Bar graph depicting the concentration of carbohydrates in mg/ml for 5<sup>th</sup> Instar, pre pupae, and cocoon respectively

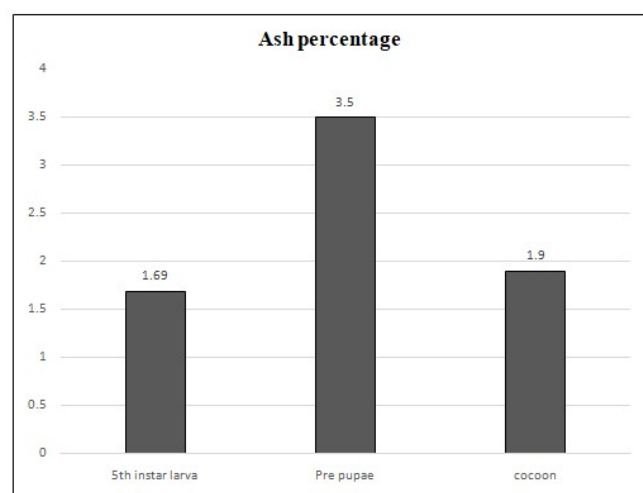


Figure 4. Bar Graph depicting the percentage of Ash in *Samia ricini* 5<sup>th</sup> instar, pre pupae, and cocoon respectively

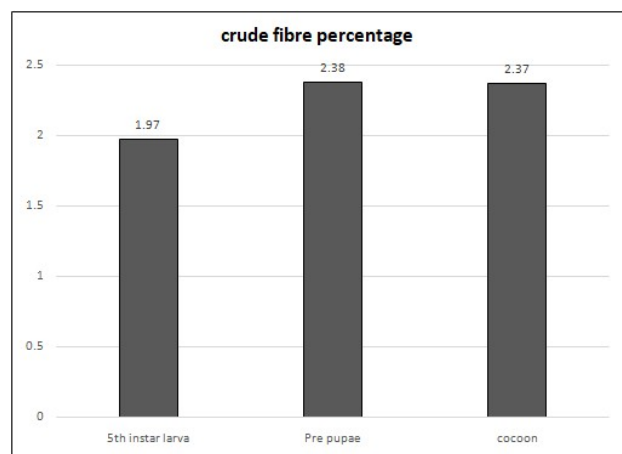


Figure 5. Bar graph depicting the percentages of crude fibre in 5<sup>th</sup> instar, pre pupae and cocoon respectively

The increase in crude fibre during the prepupal and cocoon stages may be associated with structural modifications occurring during metamorphosis and silk production. Overall, the nutritional analysis demonstrated distinct biochemical changes during the life cycle of *S. ricini*. The fifth instar larvae were characterized by the highest soluble protein and carbohydrate contents, whereas the prepupal stage

accumulated greater mineral content and crude fibre. Cocoon samples showed relatively higher protein content by the Kjeldahl method, reflecting the deposition of silk proteins during cocoon formation.

**Tensile strength determination:** Bursting length of *Samia ricini* was 28.4 cms and *Bombyx mori* silk fibre was 39 cms respectively (Figure-6). These observations indicate that *B. mori* silk possesses greater tensile strength and elasticity than *S. ricini* silk under identical testing conditions.

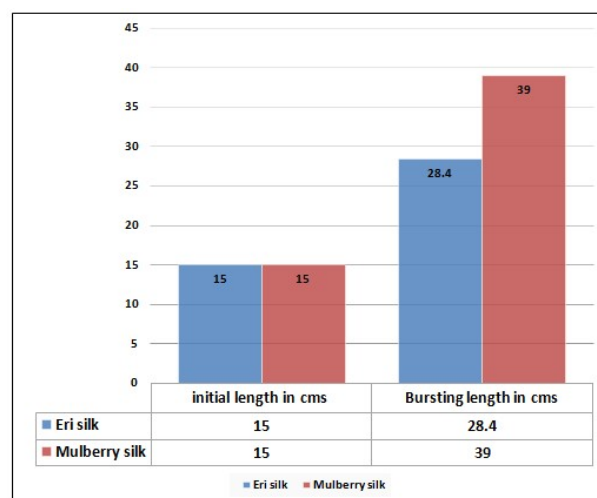


Figure 6. Bar Graph depicting the initial and Bursting length of *Samia ricini* and *Bombyx mori* silk fibre

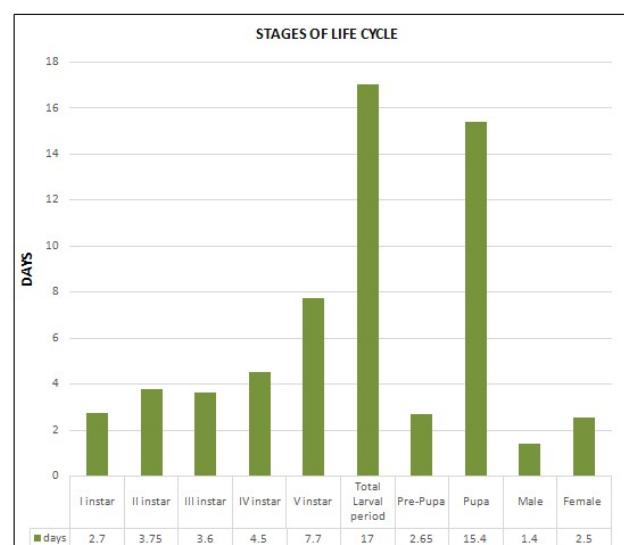


Figure 7. Bar graph depicting the duration of different life stages of *Samia ricini*

**Study the biology of *S. ricini* on Castor leaves:** Table-3 summarizes the duration of different life stages of *Samia ricini* (in days) on *Ricinus communis*. The Bar graph (Figure. 7) summarizes the data of duration of different life stages of *Samia ricini*. The mean pre-oviposition, oviposition and post-oviposition periods were 1.5, 2.5, and 4.0 days, respectively. Eggs hatched after an incubation period of  $6.79 \pm 0.42$  days. The larval stage consisted of five instars with mean durations of  $2.70 \pm 0.47$ ,  $3.75 \pm 0.44$ ,  $3.60 \pm 0.50$ ,  $4.50 \pm 0.51$ , and  $7.70 \pm 0.49$  days, respectively. The overall larval period averaged  $17.0 \pm 1.72$  days. The prepupal stage lasted  $2.65 \pm 0.49$  days, followed by a pupal period of  $15.40 \pm 2.28$  days.

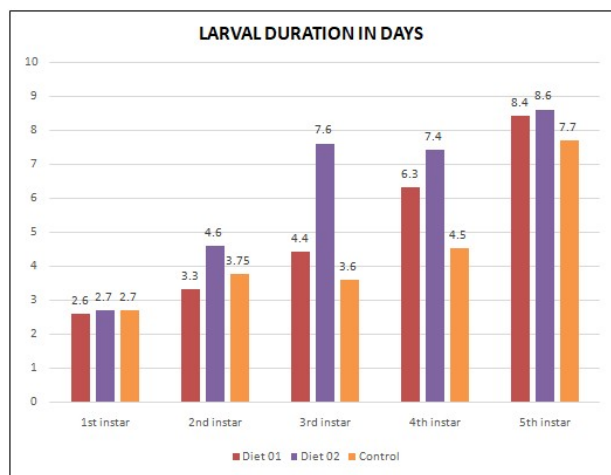


Figure-8. Bar Graph depicting the Larval duration in days (mean value)

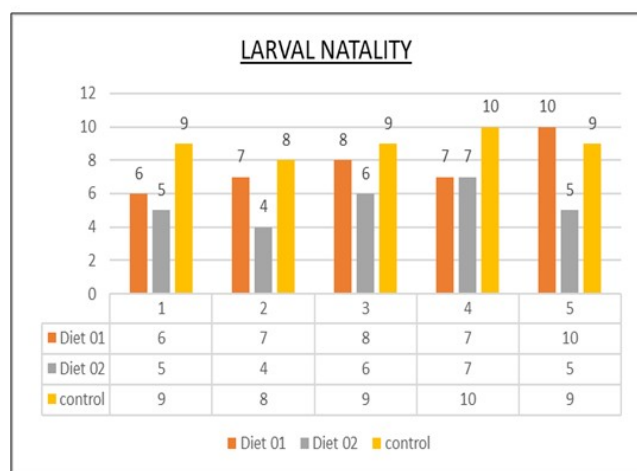


Figure-9. Bar Graph depicting the larval natality of *Samia ricini*

Table-1. Composition of different artificial diets prepared for rearing of *Samia ricini*

| Ingredients              | Diet 01 | Diet 02 |
|--------------------------|---------|---------|
| Distilled water (ml)     | 150     | 150     |
| Castor leaf powder (gms) | 10      | 05      |
| Green gram powder (gms)  |         | 05      |
| Agar powder (gms)        | 2.5     | 2.5     |
| Sorbic acid (gms)        | 0.25    | 0.25    |
| Streptomycin (gms)       | 0.10    | 0.10    |
| Multivitamin (gms)       | 0.2     | 0.2     |
| Methyl paraben (gms)     | 0.5     | 0.5     |
| 10% Formalin (ml)        | 1.5     | 1.5     |
| 70% Alcohol (ml)         | 10      | 10      |

Adult longevity averaged  $1.4 \pm 1.66$  days for males and  $2.5 \pm 2.39$  days for females. Under laboratory conditions, the complete life cycle of *S. ricini* was completed within 47–55 days, with a mean duration of  $50.8 \pm 1.73$  days. Freshly laid eggs were creamy white and gradually changed to bluish-purple immediately before hatching.

Newly emerged larvae were yellowish with black setae and actively fed on tender castor leaves. During subsequent moults, larvae underwent distinct morphological changes, including the disappearance of black hairs, development of yellow to green body coloration, and the appearance of characteristic thorn-like tubercles on the body surface. Four moulting events were observed during larval development, accompanied by the secretion of a white powdery substance.

From the third instar onwards, larvae consumed mature castor leaves in greater quantities, reflecting increased nutritional demand during later developmental stages. The pupae were brown in colour and shorter than fifth instar larvae. The cocoons were white, relatively loose, and thinner than those of *Bombyx mori*. Adult moths emerged with a light-brown body colour. Males were comparatively smaller with slender abdomens, whereas females possessed broader and stouter abdomens. Mating occurred within 1–2 h after adult emergence, after which males survived for a shorter duration while females remained alive until oviposition. The body length increased from 0.34–0.43 cm during the first instar to 5.35–5.97 cm during the fifth instar. Similarly, body breadth increased from 0.04–0.05 cm in first instar larvae to 1.12–1.17 cm in fifth instar larvae. Pupal length ranged from 2.77 to 2.88 cm, while cocoon length ranged from 4.15 to 5.19 cm. adult moths measured 3.36–4.18 cm in body length with a breadth ranging from 0.69 to 0.88 cm. Overall, the results demonstrate that *Ricinus communis* supported normal growth, successful moulting, cocoon formation, and adult emergence of *S. ricini* under laboratory conditions.

**Biology of *Samia ricini* on artificial diet:** Table-2 summarizes the measurements of larval size (length and breadth) for diet 01, diet 02, and control. Bar Graph depicting the Larval duration in days (mean value) is summarized in figure-8, and bar graph (figure-9), summarizes the depicting the larval natality of *Samia ricini*. Larval size increased progressively from the first to the fifth instar in all treatments. However, larvae reared on fresh castor leaves consistently attained greater body length and breadth than those reared on the artificial diets. Larvae reared on fresh castor leaves completed their larval period more rapidly than those reared on artificial diets. Diet 01 showed shorter developmental periods than Diet 02, indicating better nutritional suitability. Fresh castor leaves supported the highest survival throughout the experiment, whereas Diet 02 recorded the lowest survival.

## DISCUSSION

India is unusual in that it produces all three types of non-mulberry silks (Bukhari *et al.*, 2019). The Sanskrit word "Erranda," describes Castor as the origin of word "Eri". The main host plant of Eri silkworm is *Ricinus communis* L. (Sangannavar *et al.*, 2023). Although it has its own benefits, Ericulture is comparatively less lucrative than the production of other silks (Ismayil, *et al.*, 2023). However, Ericulture has several nutrition and economic benefits. Throughout human nutrition history, insects have been a major source of food (Liceaga, 2022). According to research insect proteins are a rich source of essential amino acids, on par with or even better than soy protein. Also, insects have a very high crude protein content (based on dry weight) (Gautamet *et al.*, 2025). Further, insects are a cheap source of high-quality protein and have been consumed in many regions of the world, including India, Thailand, Africa, Latin America, and Australia (Montesano *et al.*, 2020). In Asian nations that produce silk, humans have been known to consume silkworm pupae, which are regarded as a delicacy (Zhou, *et al.*, 2022). The *S. ricini* is one among the many insects that the native people of northeastern India eat as part of their diet. In the present study the Fifth-instar larvae had protein higher concentrations of 0.106 mg/ml (Kjeldahl's method) and 6.75 mg/ml (Lowry's method). The numbers are consistent with a 2003 study by Mishra *et al.*

Table 2. Larval size in terms of length and breadth for diet 01, diet 02, and control

| STAGE                  | DIET 01      |               | DIET 02      |               | CONTROL      |               |
|------------------------|--------------|---------------|--------------|---------------|--------------|---------------|
|                        | Length (cms) | Breadth (cms) | Length (cms) | Breadth (cms) | Length (cms) | Breadth (cms) |
| 1 <sup>st</sup> instar | 0.35±0.01    | 0.05±0.04     | 0.35±0.03    | 0.04±0.02     | 0.43±0.007   | 0.05±0.01     |
| 2 <sup>nd</sup> instar | 0.82±0.02    | 0.25±0.18     | 0.76±0.01    | 0.18±0.01     | 0.99±0.22    | 0.21±0.01     |
| 3 <sup>rd</sup> instar | 1.9±0.12     | 0.27±0.011    | 1.74±0.18    | 0.24±0.02     | 3.16±0.07    | 0.29±0.07     |
| 4 <sup>th</sup> instar | 2.38±0.11    | 0.81±0.06     | 2.06±0.18    | 0.82±0.02     | 3.97±0.018   | 0.96±0.03     |
| 5 <sup>th</sup> instar | 3.92±0.11    | 1.06±0.02     | 3.42±0.27    | 0.84±0.37     | 5.97±0.004   | 1.17±0.02     |

Table 3. Duration of different life stages of *Samia ricini* (in days) on *Ricinus communis*

| Different life stages | Range (days) | Mean±SD (days) |
|-----------------------|--------------|----------------|
| Pre-Oviposition       | 1-2          | 1.5            |
| Oviposition           | 2-3          | 2.5            |
| Post-oviposition      | 3-5          | 4              |
| Egg incubation period | 6-7          | 6.789±0.418    |
| Larva                 |              |                |
| I instar              | 2-3          | 2.7±0.470      |
| II instar             | 3-4          | 3.75±0.444     |
| III instar            | 3-4          | 3.6±0.502      |
| IV instar             | 4-5          | 4.5±0.512      |
| V instar              | 7-8          | 7.7±0.489      |
| Total Larval period   | 10-24        | 17±1.7204651   |
| Pre-Pupa              | 2-3          | 2.65±0.489     |
| Pupa                  | 15-19        | 15.4±2.28      |
| Male                  | 2-3          | 1.4±1.66       |
| Female                | 3-4          | 2.5±2.39       |
| Total lifecycle       | 47-55        | 50.8±1.73      |

Table 4. Morphometry of *Samia ricini* on *Ricinus communis*

| Sl. No. | Stage       | Length (cms) |            | Breadth (cms) |           |
|---------|-------------|--------------|------------|---------------|-----------|
|         |             | Min          | Max        | Min           | Max       |
| 1.      | Eggs (mm)   | 0.15         | 0.18       | 0.1           | 0.13      |
| 2.      | Larva (cm)  |              |            |               |           |
|         | I instar    | 0.34±0.01    | 0.43±0.007 | 0.04±0.006    | 0.05±0.01 |
|         | II instar   | 0.73±0.01    | 0.99±0.22  | 0.2±0.006     | 0.21±0.01 |
|         | III instar  | 2.93±0.06    | 3.16±0.07  | 0.82±0.84     | 0.29±0.07 |
|         | IV instar   | 3.73±0.01    | 3.97±0.018 | 0.96±0.03     | 0.96±0.03 |
|         | V instar    | 5.35±0.009   | 5.97±0.004 | 1.12±0.01     | 1.17±0.02 |
| 3.      | Pupa (cm)   | 2.77±0.008   | 2.88±0.009 | 1.32±0.11     | 1.56±0.10 |
| 4.      | Cocoon (cm) | 4.15±0.012   | 5.19±0.04  | 2.09±0.07     | 2.31±0.06 |
| 5.      | Adult (cm)  | 3.36±0.050   | 04.18±0.05 | 0.69±0.08     | 0.88±0.03 |

According to Sharma and Kalita (2020), the need for cocoon synthesis causes the protein concentration in hemolymph to gradually increase from the third to the fifth instar. The fifth instar had the highest concentration of carbohydrates (4.4 mg/ml). Due to its polyphagous nature and ability to adapt to a variety of climatic zones diets rich in carbohydrates facilitate this adaptation. Longvah *et al.* (2011) highlighted the nutritional potential of *S. ricini* raised indoors on castor leaves. A high protein and carbohydrate composition, particularly during larval stages, is highlighted by the current biochemical data. Prepupae had the highest ash level (3.5%), which is a measure of total mineral concentration, whereas fifth instar larvae had the lowest ash content (1.69%). These results align with those from Mishra *et al.*, 2003, which emphasize the pupal stage as a phase rich in minerals and support its use in dietary supplementation. Prepupae had a higher crude fibre content (2.38%) than fifth instar larvae (1.97%), which is consistent with typical nutritional models where growing tissues collect more structural components. Higher crude fibre in growing insect larvae comes from chitin in their developing cuticles. As larvae grow and shed their skin, they build more structural walls (Shantibala *et al.*, 2014). According to the findings, the fifth instar stage nutritional advantage makes it suitable for macronutrient extraction. In northeastern India, the prepupae and pupae of eri silkworms are prized as a tasty dietary item in several culinary preparations (Gokulakrishnaa *et al.*, 2025).

Vast majority of people in the developing nation suffer from malnutrition, and the primary cause of this condition is undeniably an inadequate diet. Furthermore, the conventional protein sources derived from plants and animals are insufficient to meet the increasing need for food in the millennia (Jafarzadeh *et al.*, 2024). Hence, in order to combat protein deficiency disorders and malnutrition, it becomes imperative to look for non-traditional protein sources (Malila *et al.*, 2024). Because of its high nutritional content as index by the biomolecular data *S. ricini* may be a viable source of protein in this situation to close the gap and supply nourishment at the grassroots level, both at the family and community levels. According to Huang *et al.* (2024), silkworms generate biocompatible and biodegradable proteinaceous fibres. Traditionally, textile materials with exceptional strength and ductility have been made from lightweight, glossy silk fibres. Therefore, silk is considered a potential bio-based fibre in the context of sustainable development goals (Yazawa *et al.*, 2022). For commercial purposes, some wild silkworm variants, like Eri silkworms, have been partially domesticated. After *Bombyx mori* and Tussah, Eri silkworms are the third most widely grown silkworms worldwide (Zhou and Wang, 2022). The mechanical characteristics of silkworm cocoons have received a lot of attention lately (Li *et al.*, 2022). Eri Silk is better suitable for items like shawls, blankets, and upholstery that

need bulk and comfort because of its lower bursting strength. The beginning length of the silk fibres for *S. ricini* and *B. mori* in the current study was 15 cm, whereas their respective bursting lengths were 28.4 cm and 39 cm. The *Bombyx mori* silkworm is the source of mulberry silk, which regularly has a longer bursting length than Eri silk. This is mainly explained by Mulberry Silk's finer, more consistent filament structure, which increases tensile cohesion and stress resistance (Kumar, 2021). On the other hand, because of their irregular and loosely packed fibre structure, Eri Silk fibres have a smaller bursting length despite being coarser and having a greater denier count (Palaniappan *et al.*, 2024). This rougher texture is a result of Eri silkworms' natural spinning behaviour, which lowers the fiber's mechanical resistance even if it helps create warmer, more breathable fabrics. In the present study *S. ricini* reared on castor leaves had a life cycle of 47–55 days. Oviposition lasted two to three days, egg incubation lasted six to seven days, and the larval stage lasted ten to twenty-four days. The eggs' morphological characteristics included a creamy or milky white colour. When the eggs hatched, it changed from bluish or purple to green and yellow when the larvae reached their fourth and fifth instars. The *S. ricini* cocoons were white in colour and thinner than those of other silkworms. The larvae were larger and wider, with black dots between the thorns on the thoracic region, and they underwent four moulting stages. The male moth was smaller than the female moth. Additionally, the female moth had a sturdy abdomen with a blunt end, whereas the male moth had a thin, slender abdomen. The female life cycle was prolonged until it laid eggs, whereas the male life cycle was finished after mating. The larvae demonstrated rapid developmental transitions through five instars, supported by detailed morphometric measurements. Notably, the larvae exhibited high feeding efficiency from the third to the fifth instar, correlating with significant growth in both length and girth. The appearance of thorn-like projections and color changes throughout the larval stages indicates active physiological metamorphosis, possibly influenced by host plant chemistry. These findings align with previous reports (Vaishali *et al.*, 2019; Sarmah, 2015) that suggest superior growth traits and silk productivity when reared on castor especially in spring.

Additionally, the emergence pattern of adult moths, with a nearly equal sex ratio and distinctive morphological differences, emphasizes the species' suitability for controlled breeding. An insect species is perfect for captive breeding if it has a balanced sex ratio and distinct morphological distinctions between males and females. These characteristics make it simple for managers to sort breeding partners, maintain steady population numbers, and genetic integrity without the need for complicated testing (Sandrock *et al.*, 2025). The principal and most nutrient-dense host plant for the Eri silkworm is the castor plant. Larval weight increase is accelerated by a high crude protein concentration. Young silkworms require moisture for easy feeding, and leaves are better suited for this property. According to research, worms fed castor have higher survival rates and produce cocoons with better silk ratios and larger shell weights (Thamizhselvi *et al.*, 2021). The results of the current study contribute to the expanding corpus of research on the benefits of breeding castor is Eri silk worms. The fifth instar larvae in the current study had the largest larval size in terms of length and breadth. The values for diet-1 were Length ( $3.92 \pm 0.11$ ) and breadth ( $1.06 \pm 0.02$ ). In diet-2 it was length ( $3.42 \pm 0.27$ ) and width ( $0.84 \pm 0.37$ ). The length and width measurements in the control

group were  $5.97 \pm 0.004$  and  $1.17 \pm 0.02$ , respectively. The difference between the artificial diet's and the control leaf's nutritional makeup could be the cause of the disparity in larval weight. The weight of the larvae increased gradually from the first to the fourth instar and sharply during the fifth instar. Since the fifth instar consume excess food hence the growth rate is at their highest. The current findings are similar to those of Chen *et al.* (1992). According to Fukuda *et al.* (1960), Eri silkworms raised on artificial diet grew nearly identically to those raised on fresh castor leaves. Raised on castor leaves throughout the entire larval period resulted in a significantly reduced overall larval duration (21.5 days), as demonstrated by the larval duration research (highest in diet2,  $8.6 \pm 0.51$ ). Reduced duration lowers labor costs and the leaf-to-cocoon ratio. It decreases disease risks and quickens crop turnover. Finally, it limits accumulation of litter and waste gas and facilities freeing up infrastructure for subsequent batches (Dubey *et al.*, 2021). In the current study, it was shown that the artificial diet groups—especially Diet 02—had considerably longer larval durations than the control group. As metabolic needs rise in later instars, the duration lengthening is especially apparent. The diets frequently lack the ideal moisture content, specific physical texture, or secondary plant metabolites, depending on how they are formulated. A crucial metric for evaluating the Eri silkworms' ability to survive on various diets was larval natality. According to Gokulkrishna *et al.* (2023), in order to guarantee the best possible larvae survival and development, artificial diets must mimic the biochemical environment of natural host leaves. Adding green gram powder to Diet 02 may have improved the protein content, but its amount didn't seem to be enough to improve larval performance over Diet 01, which employed a larger percentage of castor leaf powder. Particularly in the later instar stages, Diet 01 produced superior larval growth compared to Diet 02. These results are in line with research by Chen *et al.* (1992), which found that artificial meals could promote adequate larval development.

According to Barid *et al.* (2025), early instars of larvae fed an artificial diet including castor leaf powder had higher protein content. Additionally, high shell ratio, female wingspan, and egg fertility were reported, along with decreased larval mortality ( $4.23 \pm 0.58\%$ ). This current study's findings about artificial feeds' ease of preparation and storage point to their practical viability for mass rearing. This is consistent with the industrial importance of continuous rearing systems, particularly when host plant seasonal unavailability becomes a constraint. The year-round larval rearing of silkworms is severely limited by the seasonal availability of host plants, which causes nutritional stress (Harisha *et al.*, 2025). Due to temporal mismatches and the fact that castor is an annual crop with low leaf production and high pest occurrence during dry winter spells, breeders must rely on other permanent host plants (Jigyasu, *et al.*, 2025). During severe winters or dry summers, deficiencies in fresh, high-quality foliage immediately lower cocoon yield, interfere with genetic selection processes, and raise larval mortality. In addition to ensuring precise nutritional control, preventing pesticide poisoning risks, and reducing labor-intensive feeding and leaf-harvesting requirements. Using an artificial diet in silkworm breeding ensures year-round production independent of seasonal mulberry leaf shortages (Yin *et al.*, 2023). Further, artificial diets simplify the feeding process, reduce labour expenses, and save time on picking and chopping leaves for delicate chawki (early age) rearing.

## CONCLUSION

In summary, the observations made across various life stages—egg, larva, pupa, and adult—underscore the robust adaptability and disease resistance of *S. ricini*, particularly when reared on castor leaves. The entire larval period of 21.5 days is a significant advantage in sericulture. The experimental rearing of the larvae under laboratory conditions confirmed that the growth and development of the silkworm are closely aligned with the nutritional quality and timely availability of the host plant. Additional research on diet composition and its impact on various attributes of Eri silkworm will yield useful insights for mass multiplication and use.

## REFERENCES

- AOAC International. (2019). Official Methods of Analysis of AOAC International (21st ed.). AOAC International, Gaithersburg, MD, USA.
- Chen, K., Yamamoto, T., & Lu, C. (1992). Studies on artificial diet rearing of the eri silkworm, *Samia ricini*. *Acta Sericologica Sinica*, 18, 45–52.
- Fukuda, T., Yoshitake, N., & Horie, Y. (1960). Studies on artificial diets for the eri silkworm (*Samia ricini*). *Journal of Sericultural Science of Japan*, 29, 21–28.
- Fukuda, T., Yoshitake, N., & Horie, Y. (1961). Further studies on mass rearing of eri silkworms using artificial diets. *Journal of Sericultural Science of Japan*, 30, 145–152.
- Gokulkrishna, M., Reddy, M. S., & Ramesh, B. (2023). Development and evaluation of a semi-synthetic artificial diet for eri silkworm (*Samia ricini* Donovan). *Indian Journal of Entomology*, 85(2), 456–463.
- Hedge, J. E., & Hofreiter, B. T. (1962). Determination of total carbohydrates by the Anthrone method. In R. L. Whistler & M. L. Wolfrom (Eds.), *Methods in Carbohydrate Chemistry* (Vol. 1, pp. 17–22). Academic Press.
- Lowry, O. H., Rosebrough, N. J., Farr, A. L., & Randall, R. J. (1951). Protein measurement with the Folin phenol reagent. *Journal of Biological Chemistry*, 193(1), 265–275.
- Sarmah, M. C. (2015). Eri silkworm (*Samia ricini*): Biology, host plants and prospects for sustainable sericulture. *Indian Silk*, 54(4), 22–27.
- Vaishali, R., Reddy, M. S., & Kumar, A. (2019). Comparative performance of eri silkworm (*Samia ricini*) on different host plants under tropical conditions. *Journal of Entomology and Zoology Studies*, 7(5), 1139–1144.
- Singh, K., Singh, B., & Kaur, K. (2025). Studies on biology of mulberry silkworm (*Bombyx Mori* L.) feeding on mulberry. *Journal of Krishi Vigyan*, 13(1), 180–184.
- Khan, F., Akter, M. R., Ibn Sayed, N., Mahjabin, S., Mofasser, A. Z. M., and Mia, R. (2026). Non-mulberry Silks: Diversity, Origins, and Production Techniques. In *Science and Technology of Silk: Volume I: Silk Production* (pp. 167–205). Cham: Springer Nature Switzerland.
- Das, Sahu and Singh (2020). Host plant diversity of non-mulberry silkworms: a review. *Journal of Pharmacognosy and Phytochemistry*.
- Boro, P., and Borah, S. D. (2020). Biodiversity of sericigenous insects in north-eastern region of India: A review. *Journal of Entomology and Zoology Studies*, 8(4), 269–275.
- Rajasri Mandali, R. M., & Narayanamma, V. L. (2015). Eri silk worm rearing on different castor genotypes and their economic analysis.
- Reddy, S. K., Carpenter, G., Bhardwaj, S., and Kaddatz, N. V. (2026). *The Rise of Jayanti Reddy: India's New Star in Luxury Fashion*. Kellogg School of Management.
- Mahesh, D. S., Chandrakumara, K., Keerthi, M. C., Kumar, K. P., and Neog, K. (2026). Standardization of rearing protocol for sustainable Eri Silk production in India: A focus on *Ricinus communis* and *Ailanthus grandis* through age-stage, two-sex life table approach. *Journal of Environmental Biology*, 47(1), 105–113.
- Vijay, S., and Susikaran, S. (2023). Evaluation of different spacing for growth and yield contributing characters of tree type mulberry.
- Kumara, R. R. (2023). Breeding in host plants of Eri silkworm for rearing suitability. 24–43.
- Duarah, P. (2017). *Effect of Structural Design On The Performance of Eri-Union Fabrics* (Doctoral dissertation, Assam Agricultural University Jorhat).
- Thanga, M., Susikaran, S., Chozhan, K., Venkatachalam, S. R., and Geetha, B. (2021). Research impact on different host plants of eri silkworm *Samia ricini* Donovan (Lepidoptera: Saturniidae). *Pharma Innovation*, 10(11), 322–325.
- Pradhan, P. P., Sahoo, S., Hazarika, J., Rahman, T., and Kashyap, P. (2022). Practice of entomophagy in North-East India: A review. *The Pharma Innovation Journal*, 11(10S), 462–468.
- Ahmed, S. A., Sarkar, C. R., Sarmah, M. C., Ahmed, M., and Singh, N. I. (2015). Rearing performance and reproductive biology of eri silkworm, *Samia ricini* (Donovan) feeding on *Ailanthus* species and other promising food plants.
- Deori, M., Devi, D., Devi, R., and Sarma, K. (2026). Consumer Preferences and Market Prospects of Edible Silkworms in Dhemaji District, Assam. *HEXAPODA*, 1–6.
- Ray, M., and Gangopadhyay, D. (2021). Effect of maturation stage and sex on proximate, fatty acid and mineral composition of eri silkworm (*Samia ricini*) from India. *Journal of Food Composition and Analysis*, 100, 103898.
- Borah, M. P., Kalita, B. B., and Phukan, A. R. (2019). Physio-mechanical properties of Eri silk and its union fabrics. *Int. J. Chem. Stud*, 7(1), 2398–2401.
- Boruah, S. (2018). *Evaluation Of Twill Weave Fabrics Made Of Blended Eri-Modal And Eri-Acrylic Yarns Suitable For Different Dress Designs* (Doctoral dissertation, ASSAM AGRICULTURAL UNIVERSITY JORHAT).
- Mishra, N., Hazarika, N. C., Narain, K., and Mahanta, J. (2003). Nutritive value of non-mulberry and mulberry silkworm pupae and consumption pattern in Assam, India. *Nutrition Research*, 23(10), 1303–1311.
- Samami, R., Seidavi, A., Eila, N., Moarefi, M., Ziaja, D. J., Lis, J. A., ... and Cappai, M. G. (2019). Production performance and economic traits of silkworms (*Bombyx mori* L., 1758) fed with mulberry tree leaves (*Morus alba*, var. Ichinose) significantly differ according to hybrid line.
- Deuri, J., Barua, P. K., Sarmah, M. C., & Ahmed, S. A. (2017). Biochemical attributes of castor and tapioca leaves, the promising food plants of eri silkworm (*Samia ricini* Donovan). *International Journal of Ecology and Ecosolution*, 4(1), 1–4.
- Gokulakrishnaa, R. K., Selvamuthukumaran, T., & Kothandaraman, S. (2025). Eri Silkworm Pupae Meal As A Fish Meal Replacement In Japanese Quail Starter DIET. *Journal of Animal and Plant Sciences*, 35(1), 273–284.

- Wongsorn, D., Chueakhokkrud, A., Pinwiset, J., & Saenmahayak, B. (2024). Evaluation of host plants' nutrition on life cycle, economic traits and nutrition value of eri silkworm (*Samia ricini* Donovan).
- Kakati, L. N. (2018). Production parameters and yarn realization in eri silkworm *Samia ricini* as influenced by alternative host plants. *Indian Journal of Entomology*, 80(1), 114-123.
- Mangammal, P., and Devi, G. S. (2012). Influence of artificial diet on larvae of eri silkworm, *Samia cynthia ricini* Boisduval.
- Bukhari, R. (2019). Rubia Bukhari, Kiran Pal Singh and Rashad Hussain Shah. *Journal of Pharmacognosy and Phytochemistry*, 8(4), 311-323.
- Sangannavar, P. A., Manjunatha, G. R., Ahmed, S. N., Moorthy, S. M., Halagundegowda, G. R., Mishra, R. K., and Sivaprasad, V. (2023). Prospects for promotion of eri culture in non-traditional areas of India-a review. *Journal of Experimental Zoology India*, 26(2), 1341.
- Ismayil, M. M. S., Kumar, N., Bankar, D. R., Chauhan, A. S., & Thomas, A. (2023). Novel approaches in plant protection.
- Liceaga, A. M., Aguilar-Toalá, J. E., Vallejo-Cordoba, B., González-Córdova, A. F., and Hernández-Mendoza, A. (2022). Insects as an alternative protein source. *Annual Review of Food Science and Technology*, 13(1), 19-34.
- Gautam, A., Gyawali, I., Poudel, S., Devkota, S., Acharya, R., Kandel, M., and Subedi, D. (2025). Insects as food and feed source: A comprehensive review on nutritional value, food safety concern, environmental benefits, economic potential, technological innovations, challenges, and future prospects. *Food Frontiers*, 6(6), 2591-2646.
- Montesano, D., Gallo, M., Blasi, F., and Cossignani, L. (2020). Biopeptides from vegetable proteins: new scientific evidences. *Current Opinion in Food Science*, 31, 31-37.
- Zhou, Y., Zhou, S., Duan, H., Wang, J., and Yan, W. (2022). Silkworm pupae: a functional food with health benefits for humans. *Foods*, 11(11), 1594.
- Longvah, T., Mangthya, K., & Ramulu, P. J. F. C. (2011). Nutrient composition and protein quality evaluation of eri silkworm (*Samia ricini*) prepupae and pupae. *Food chemistry*, 128(2), 400-403.
- Shantibala, T., Lokeshwari, R. K., & Debaraj, H. (2014). Nutritional and antinutritional composition of the five species of aquatic edible insects consumed in Manipur, India. *Journal of Insect Science*, 14(1), 14.
- Jafarzadeh, S., Nooshkam, M., Zargar, M., Garavand, F., Ghosh, S., Hadidi, M., & Forough, M. (2024). Green synthesis of nanomaterials for smart biopolymer packaging: challenges and outlooks. *Journal of Nanostructure in Chemistry*, 14(2), 113-136.
- Malila, Y., Owolabi, I. O., Chotanaphuti, T., Sakdibhornssup, N., Elliott, C. T., Visessanguan, W., ... & Petchkongkaew, A. (2024). Current challenges of alternative proteins as future foods. *npj Science of Food*, 8(1), 53.
- Hu, Z., Liang, Y., Fan, S., Niu, Q., Geng, J., Huang, Q., ... and Zhang, Y. (2024). Flexible Neural Interface From Non-Transient Silk Fibroin With Outstanding Conformality, Biocompatibility, and Bioelectric Conductivity. *Advanced Materials*, 36(46), 2410007.
- Yazawa, K., Tatebayashi, Y., and Kajiura, Z. (2022). Eri silkworm spins mechanically robust silk fibers regardless of reeling speed. *Journal of Experimental Biology*, 225(3), jeb243458.
- Li, M., Luo, J., Xiong, Y., and Wu, J. (2022). Anisotropic microstructure and performance characterization of wild silkworm cocoons for designing biomimetic protective materials. *Polymers*, 14(15), 3072.
- Kumar, H., Huang, S., Mei, G., and Garg, A. (2021). Influence of feedstock type and particle size on efficiency of biochar in improving tensile crack resistance and shear strength in lean clayey soil. *International Journal of Damage Mechanics*, 30(4), 646-661.
- Palaniappan, G., CB, S., Senthil Kumar, S., Kumar B, S., & E, D. (2024). Studies on thermal and moisture properties of novel Eri silk knitted structures. *Research Journal of Textile and Apparel*, 28(4), 839-856.
- Sandrock, C., Generalovic, T. N., Paul, K., Petersen, G. E. L., Sellem, E., Smith, M. B., ... and Obšteter, J. (2025). BugBook: Genetics of insects as food and feed. *Journal of Insects as Food and Feed*, 11(18), 397-455.
- Thamizhselvi, D., Supraja, S. V., and Priyadharshini, G. (2021). Help Farmers–Farm Era App. In *Recent Trends in Intensive Computing* (pp. 93-97). 1 Oliver's Yard, 55 City Road, London, EC1Y 1SP: SAGE Publications.
- Dubey, S., Gupta, H., Goyal, M. K., and Joshi, N. (2021). Evaluation of precipitation datasets available on Google earth engine over India. *International Journal of Climatology*, 41(10), 4844-4863.
- Barid, S. S. A. U. Q., Ramadhani, F. S., Purwanto, H., Saragih, H. T., Aldawood, A. S., and Nuringtyas, T. R. (2025). Artificial diet for the cultivation of eri silkworm (*Samia ricini* Drury 1773)(Lepidoptera: Saturniidae). *Communications in Science and Technology*, 10(2), 343-351.
- Harisha, R., Patidar, O. P., Antoo, S., and Neog, K. ERI HOST PLANTS BREEDING: CURRENT STATUS, CHALLENGES AND FUTURE PROSPECTS. (2025). *Silkworm Host Plant Breeding: Trends, Challenges and Future Strategies*, 132.
- Jigyasu, D. K., Patidar, O. P., Shabnam, A. A., and Kumar, A. (2025). Castor Plant in Ericulture: Opportunities and Challenges. *Ricinus Communis: A Climate Resilient Commercial Crop for Sustainable Environment*, 113-134.
- Maheswari, N. U., & Arulkavi, K. (2023). Natural Products in Biotic Materials of Silk. *Advances in Multidisciplinary Research and Development*, 140.

\*\*\*\*\*