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Comparative studies of Eri Silkworm (*Philosamia Cynthia Ricini*) reared on artificial diet and natural castor leaves (*Ricinus communis Linn*)

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ABSTRACT

Eri-silkworms (Philosamia cynthia ricini) were reared on castor leaves (its natural host plant) from 1st to 5th instars and artificial diet up to second instar then shifted to castor leaves. The larval duration was extended by one day in diet batch. The cocoon yield increased by 13% in diet feed batches compared to the leaf fed batches. Flimsy cocoon percent was higher in Castor leaves chawki reared Eri silkworm. The Stable cocoons crops percent was higher in artificial diet Eri chawki when compared to the Castor leaves reared chawki.

Keywords— *Artificial Diet, Eri silkworm, Castor leaves, Cocoon*

1. INTRODUCTION

Sericulture refers to mass rearing of silkworm for producing silk. India is unique in producing all commercial varieties of silk *i.e*, mulberry and non-mulberry (Tasar, Muga and Eri). The Eri silk is non-mulberry silk and the sates of Asam, Nagaland, Meghalaya and Manipur contribute to 98% of countries Eri silk production. Other states practicing in small scale are Arunachal Pradesh, Uttar Pradesh, Bihar, Odisha, West Bengal, Andhra Pradesh and Tamil Nadu.

Eri silkworm rearing is one of the important parts in the livelihood of North- East farmers. The primary food plants of Eri silkworm is castor oil plant (*Ricinus communis*).

The quality and quantity of the silk depend on the quality of the feed and maintenance of the rearing conditions like temperature and humidity. Nutritional management of castor leaves is very difficult unlike others crops and it varies from season to season.

The growth and development of silkworm larvae and subsequently cocoon production are greatly influenced by Castor leaves quality. The Eri silkworm should be fed abundantly with good quality castors leave for successful cocoon crops and high-quality silk. The castor leaves must be fresh enough to meet the preference of Eri silkworm; it must be fed 3-4 times a day. But such kind of rearing system has faced some problems.

(a) High land cost and maintenance cost of Castor leaves garden for tender leaves for chawki and mature leaves for late age silkworm rearing.
(b) Rearing houses and farmer's habitation
(c) Intensive labour
(d) Not available quality leaves every time.
(e) Crop loss and poor-quality cocoons

So, the rearing of Eri silkworm with artificial diet will solve all the above problems. Farmers who rear silkworm can purchase artificial diet directly from the manufacturer. Alternatively, the farmers can purchase 2nd stage larvae from artificial diet reared chawki center. The worms grown on artificial diet up to 2nd stage provides higher yield and better quality. The present work investigates the Eri chawki rearing with artificial diet which can be a potential replacement of castor leaves for chawki Eri rearing. After the chawki stage, the Eri silkworms can be shifted to castors leaves for late-age rearing.

2. MATERIAL AND METHODOLOGY

2.1 Identification and preparation of artificial diet for Eri silkworm:

2.1.1 Drying of castors leave: The good quality castor leaves were selected for production of castor leaf powder. Before drying proximate analysis of the leaf powder was performed. Drying process were carried out by sun drying. The 50 kg of leaves were

dried in sun dry and processed for artificial diet production. Castor leaves were collected and fragmented into small pieces. The leaves were kept for sun drying and powdered by mixer grinder.

2.1.2 Proximately analysis: The moisture percentage, ash content, Carbon, Nitrogen, cellulose and protein analysis of castor leaves powder was done as per the ASTM standards**.**

2.1.3 Formulation of artificial diet: The silkworms consume the castor leaf based on the following factors:

(a) Attracting factor
(b) Biting factor
(c) Swallowing factor

We have formulated artificial diet based by incorporating the above factors in our diet. In addition to this, the nutritional value of the diet is matched with that of the Castor leaves. Four different combinations of the artificial diet were formulated and it was examined for the feed response percentage. Based on the feed response, we performed the chawki rearing of Eri silkworm and continued up to cocoons stage.

2.1.4 Hydration of artificial diet: The artificial diet is in the form of dehydrated powder in order to increase the shelf-life of the product. This can be hydrated just before feeding the silk worms. The Artificial diet hydration process was performed in a pressure cooker through a normal cooking process by adding appropriate amount of water. Different trials were conducted to check the solidification of hydrated artificial diet.

2.1.5 Incubation of eggs: Comparison of Incubation of Eggs in traditional process followed by the farmers was compared with the standardized process to determine the hatchability percentage.

2.1.6 Rearing procedure: The rearing rooms and equipment were thoroughly disinfected with 1 % NaOCl solution, before rearing and strict hygiene was maintained throughout the rearing process

2.2 Procedure for artificial diet rearing up to II Moult

2.2.1 Materials required for artificial diet rearing: 70% alcohol, Cotton, Closed type plastic trays, Blue Polythene sheet, Newspaper, Plastic net, Scrapper. Before brushing the silkworm eggs, wash the hand with 70% alcohol as well as clean the outer surface of the supplied diet pack and rearing trays.

Proper care was taken to brush the larva in fully closed plastic tray with polythene sheet spread on it. The prepared diet scraped by using scrapper and fed to silkworm up to second instar. The hatched larvae were tapped down carefully on the feed. The temperature and humidity were maintained during the rearing process. The feed response percentage was calculated after 48 hours of brushing.

2.2.2 Feed response percentage of Eri silkworm reared on artificial diet and Castor leaves: Feed response percentage studied conducted both for artificial diet and castor leaf batches. After 48 hours of brushing, feed response percentage was calculated by following formula.

$$\text{Feed Response \%} = \frac{\text{Total number of larvae brushed – Unequal Larvae X 100}}{\text{Total number of larvae brushed}}$$

2.2.3 Larval stage: The larval weights were taken from each trial after first moult and second moult. The larval duration of Eri silkworm was studied by counting the days and hours from the time of brushing up to spinning. The larval duration was calculated by computing the time taken between moult out larvae and the time of entering into the next moult or spinning.

Five trials were conducted with artificial diet of chawki rearing along with control batch reared with castor leaves in traditional process. In artificial diet chawki rearing, temperature and humidity were maintained where as in tradition process it was not maintained in order to follow the conventional system.

2.2.4 Standard rearing house for Eri silkworm rearing and temperature and humidity for third to fifth stage: Eri silkworms are reared indoor. The working area 10 m x 5 m size rearing house having tin or thatch roofing with 1.5 m verandah all around were maintained which is recommended for 100 dfls (diseases free laying) commercial silkworm rearing per crop. It is important to maintain the rearing temperature and humidity properly.

2.2.5 Feeding time for artificial diet batches and leaves reared batches: 25 dfl (disease free layings) of Eri silkworm were reared on artificial diet up to second stage and shifted to castor leaves for rearing of late age and cocoons formation. Similarly, 25 dfls Eri silkworm reared on Castor leaves from First stage to Fifth stage. The feeding time is recorded for every trial.

2.3 Formation of cocoons

After the maturation of silkworm, the silkworms were transferred to the mountage for spinning. In the present study, the worms were allowed to spin on branches of leaves for 4-5 days. After the 5^{th} day, the cocoon characteristics were studied. The cocoons were harvested from 6^{th} days of spinning and effective rate of rearing percent, Cocoon weight, shell weight, Shell ratio and Flimsy cocoon percent were calculated.

2.3.1 Cocoon yield: Economic parameters analysis like cocoon weight, shell weight and SR % (Shell Ratio percentage) were recorded.

3. RESULTS AND DISCUSSION

3.1 Drying process

Drying of castor leaves took about 3- 6 days depending on the weather. The average dry leaves obtained from 50 kg raw leaf was 15.06 kg and the average powder obtained was 14.78 kg. The data is tabulated in Table 1.

Table 1: Drying process of Castor leaves

Trial No	Qty of raw leaves(kg)	Drying process	Duration of drying	Qty of dry leaves(kg)	Powdering process	Qty of powder (kg)
1	50	Sun dried	3 days	15.5	Pulverizer	14.9
2	50	Sun dried	5 days	14.7	Pulverizer	14.8
3	50	Sun dried	2 days	15	Pulverizer	14.9
4	50	Sun dried	6 days	14.5	Pulverizer	14.7
5	50	Sun dried	3 days	15.6	Pulverizer	14.6
Total	**250**			**75.3**		**73.9**
Avg	**50**			**15.06**		**14.78**

As it is sun drying, it takes long time for drying and the drying time varies from batch to batch.

3.2 Proximate analysis

Proximately analysis was performed before harvesting of castor leaves for powder formation. The data is tabulated in Table 2. The protein % was 16.22- 18.92, Cellulose % 35.11-38.40, Nitrogen % 4.45-4.72, Carbon % 42.10- 43.50 were recorded.

Table 2: Proximate analysis of castor leaves powder

Trial	Moisture	Ash	Carbon	Nitrogen	Cellulose	Protein
1	11.20%	5.60%	43.21%	4.70%	38.40%	17.23%
2	10.20%	5.50%	42.21%	4.45%	37.32%	18.92%
3	9.98%	5.20%	42.10%	4.62%	35.11%	18.67%
4	10.56%	5.72%	42.45%	4.55%	37.45%	19.76%
5	11.23%	5.67%	43.50%	4.72%	37.89%	16.22%
Avg	10.63%	5.54%	42.69%	4.61%	37.23%	18.16%

3.3 Formulation of artificial diet for Eri silkworm

The artificial diet were prepared by using castor powder, hydrolyzed protein, Carbohydrate etc., The diet was formulated and Bioassay study was conducted to evaluate the performance. The formulae are tabulated in Table 3.

Table 3: Artificial diet preparation for Eri silkworm rearing

Raw materials	Formula-1	Formula-2	Formula-3	Formula-4
Castor leaves powder	25%	25%	30%	35%
Hydrolyzed protein	25%	25%	30%	30%
Carbohydrate	2%	5%	7%	9%
Gelling agent	8%	8%	9%	10%
Attracting factors	0.10%	0.10%	0.10%	0.10%
Biting Factors	0.10%	0.10%	0.10%	0.10%
Salt mixture	4%	4%	5%	6%
Vitamin mixture	0.30%	0.40%	0.50%	0.60%
Sugar powder	5%	5%	5%	5%
Preservatives	0.02%	0.02%	0.02%	0.02%
Oil	1%	1.50%	2%	2.50%
Phytosterols	0.40%	0.50%	0.60%	0.70%
Galic acid	0.10%	0.10%	0.10%	0.10%
Sobric acid	0.10%	0.10%	0.10%	0.10%
Others herbal powder	29.00%	25.00%	10.00%	1.00%

Hung-sheng and Ji-fang C. (1979) improvement of diet composition and enlargement of the sources of diet material, introduce of new gelating agents for artificial diet of Eri silkworm. In present study agar- agar was used as a gelling agent.

3.4 Hydration process of artificial diet

After hydration, solid gel form with 70-80% moisture content. The total hydration time was 30 mins for all the batches. The data of hydration are tabulated in Table 4.

Table 4: Hydration and solidification study of artificial diet

Parameters	Trial 1	Trial 2	Trial 3	Trial 4	Trial 5
Addition of artificial diet and water	1:1	1:2	1:4	1:6	1:8
Hydration time	30 mins	30 mins	30 mins	30 mins	30 mins
Cooling time	1 hr	1 hr	1 hr	1 hr	1 hr
Solidification time	4 hrs	4 hrs	4 hrs	4 hrs	4 hrs
Grating of hydrated diet	No	No	Partially	Partially	Completely

Fig. 1: Castor leaves for Erisilkworm

Fig. 2: Artificial diet for Eri silkworm

3.5 Feed response percentage of Eri silkworm reared on artificial diet and Castor leaves

Lab trials of 500 numbers of Eri silkworm rearing conducted. Feed response percentage studied conducted both for artificial diet and castor leaf batches. After 48 hours of brushing, feed response percentage was calculated and tabulated in Table 5.

Table5: Feed response percentage of Eri silkworm reared on castor **leaves and artificial diet with formula 1 and 2**

Formula: 1			Formula: 2	
Trial	Artificial Diet batch	Leaves batch	Artificial Diet batch	Leaves batch
1	69	100	78	100
2	72	100	85	100
3	71	100	79	100
4	69	100	78	100
5	70	100	76	100
Average	70.2	100	79.2	100

Table 6: Feed response percentage of Eri silkworm reared on castor leaves and artificial diet with formula 3 and 4

Formula: 3			Formula: 4	
Trial	Artificial Diet batch	Leaves batch	Artificial Diet batch	Leaves batch
1	99.7	100	80	100
2	99.8	100	82	100
3	99.8	100	83	100
4	99.6	100	85	100
5	99.7	100	83	100
Average	99.72	100	82.6	100

3.6 Incubation stage

In standardized process, the incubation temperature was 24-25◦C and humidity was 75-80% where as in traditional process the temperature was 20-30◦C and humidity was 52-65%

Table 7: Temperature and humidity during Incubation of both Traditional and Standardized process

Days of Incubation	Standardized condition			Traditional process		
	Temp (°C)	Humidity (%)	Observation	Temp (°C)	Humidity (%)	Observation
Day-1	24-25	75-80	Yellow colored Egg	20-23	60-65	Egg colour is yellow
Day-2	24-25	75-80	Yellow colored Egg	20-22	60-62	Egg colour is yellow
Day-3	24-25	75-80	Yellow colored Egg	25-30	55-60	Egg colour is yellow
Day-4	24-25	75-80	Yellow colored Egg	25-30	50-55	Egg colour is yellow
Day-5	24-25	75-80	Yellow colored Egg	22-25	60-65	Egg colour is yellow
Day-6	24-25	75-80	Yellow colored Egg	20-23	52-54	Egg colour is yellow
Day-7	24-25	75-80	Yellow colored Egg	20-22	60-65	Egg colour is yellow
Day-8	24-25	75-80	Yellow colored Egg	26-32	50-55	Egg colour is yellow

Day-9	24-25	75-80	Eggs turned to blackish	25-30	60-65	Egg colour is yellow
Day-10	24-25	75-80	Eggs turned to blackish	20-23	55-60	Egg colour is yellow
Day-11	24-25	75-80	**Hatched silkworm 85%**	20-25	55-60	Eggs turned to blackish
Day-12	24-25	75-80	Hatched silkworm 15%	25-30	45-55	Eggs turned to blackish
Day-13				22-28	60-65	Hatched silkworm 40%
Day-14				25-30	55-60	Hatched silkworm 30%
Day-15				22-24	55-60	Hatched silkworm 20%
Day-16				25-30	60-65	Hatched silkworm 10%

It was observed that in traditional process, egg colour turned to blackish on the 11th days of incubation where as in standardized process it turned on 9th day of incubation. In traditional process hatching took 4 days (40% in Day-13, 30% in Day-14, 20% in Day-15 and 10% in Day-16). But in standardized process maximum hatching (85%) completed on Day-11 and 15% hatched on Day-12. Therefore, it is concluded that temperature and humidity are the vital role for proper incubation and hatching of Eri silkworm.

Larval stage: (First stage to Fifth stage)

Effect of Temperature and Humidity in Chawki Stage

The success of Chawki rearing mainly depends on the maintenance of Temperature and Humidity along with other factors like nutrition and Hygiene. The temperature and humidity were recorded for chawki rearing which is tabulated in Table 8

Table 8: Temperature and humidity during chawki stage of both Traditional and Standardized process

Days of Larva	Standardized condition		Observation	Traditional Process		Observation
	Temp (°C)	**Humidity (%)**		**Temp (°C)**	**Humidity (%)**	
1st stage Day-1	28-29	70-75	Worms are healthy	20-23	55-60	Worms are healthy
1stStage Day-2	28-29	70-75	No un equal larvae	20-22	60-65	Unequal percentage observed 12 %
1st Stage Day-3	28-29	70-75		23-25	50-60	
1st Stage Day-4	28-29	70-75	Worms are healthy and **100% worms** settled for moult at 10 am	25-28	50-60	**70% worms** settled for moult in morning 10 am and **30% settled** for mounts in evening 7 pm
2nd Stage Day-1	28-29	70-75	Feeding of artificial diet	20-24	60-65	Feeding of leaves
2nd Stage Day-2	28-29	70-75		20-23	50-55	
2nd Stage Day-3	28-29	70-75	Worms are healthy and settled for 2nd moult in morning 11.30 am	20-23	50-55	**70% worms** settled for moult in morning 11.30 am and **30% settled** for mounts in evening 8 pm
3rd stage	25-26	65-70	Fed Eri leaves	25-26	65-70	Fed Eri Leaves

It was observed that, the artificial diet batch, (where temperature and humidity were maintained), there were no unequal larvae but in leaves reared batch (followed the traditional process), the unequal larvae percentage was about 12%

3.7 Studies on larval growth of Eri silkworm on diet and castor leaves:

The first instar larval weight (10 numbers) of leaves fed batches were 0.011 to 0.124 g where as in diet fed batches it was 0.123-0.0134 g. The second instar average larval weight of diet fed 0.0265 g and in leaves fed batch it was 0.224 g (Table 9)

Table 9: Larval weight of First and second instar silkworm reared on artificial diet and leaves

Trial	Artificial Diet batch	Leaves batch	Artificial Diet batch	Leaves batch
	Larval weight First moult (g)		**Second moult (g)**	
1	0.0134	0.0123	0.0234	**0.0213**
2	0.0123	0.0112	0.0256	**0.0214**
3	0.0133	0.0124	0.0276	**0.0231**
4	0.0134	0.011	0.0283	**0.0232**
5	0.0142	0.0123	0.0277	**0.0234**
Average	**0.01332**	**0.01184**	**0.02652**	**0.02248**

Mangammal, P.; Devi, G. S. (2012) reported that the larval mortality was minimum in Eri silkworms reared on artificial diet up to first instar followed by artificial diet up to second but in present study there were no difference of larval mortality between diet batches and leaves batches. It may depend on the composition of artificial diet.

3.8 Total larval duration of Eri silkworm reared on diet and castor leaves

It was observed the larval duration was one day more in diet fed batches than leave fed batches.

Table 10: Larval duration of silkworm reared on artificial diet and leaves

Instar	Artificial Diet batch		Leaves batch	
	Feeding (Days)	Moulting (Days)	Feeding (Days)	Moulting (Days)
I -Instar	3.5	1	3	**1**
II-Instar	3.0	1	2.5	**1**
III -Instar	3	1	3	**1**
IV-Instar	3	1	3	**1**
V -Instar	6	0	6	**0**
Total	**18.5**	**4**	**17.5**	**4**

Fig. 3: First instar Eri silkworm reared on leaf

Fig. 4: First instar Eri silkworm reared on diet

Fig. 5: Second instar Eri silkworm reared on leaf

Fig. 6: Second instar Eri silkworm reared on diet

Fig. 7: Fifth instar Eri silkworm reared on leaf

Fig. 8: Fifth instar Eri silkworm reared on diet

3.9 Standard rearing house for Eri silkworm rearing and temperature and humidity for third to fifth stage

Following are the room temperature and humidity maintained druing third to fifth instar.

Table 11: Rearing house temperature and humidity from Third to Fifth sate and cocooning stage

Sl No	Stages	Temperature	Humidity
1	Third Stage	25-26	65-70%
2	Fourth Stage	25-26	60-65%
3	Fifth Stage	24-25	60-65%
4	Cocooning stage	24-25	50-60%

Feeding time for artificial diet batches and leaves reared batches

Table 12: Feeding times of artificial diet reared batches and leaves reared batches

Parameters	Artificial diet fed batches	Leaves fed batches
Chawki Stage		
First stage	1 time feeding	9 times feeding
Second instar	1 time feeding	7 times feeding
Total feeding	2 times feeding of diet	16 times feeding of leaves
Late stage		
Third instar	12 times feeding	12 times feeding
Fourth Instar	12 times feeding	12 times feeding
Fifth Instar	24 times feeding	24 times feeding
Total feeding	48 times feeding	

In artificial diet chawki rearing two feeding is required for first and second stage, where as in leaf chawki rearing 16 feeding is required for first and second stage. No of feeding in late age rearing are the same for both batches

Fig. 9: Different stage of Eri silkworm larva

3.10 Formation of cocoons

Fig. 10: Eri cocoons formation

Fig. 11: Eri cocoon cleaning after 5th day

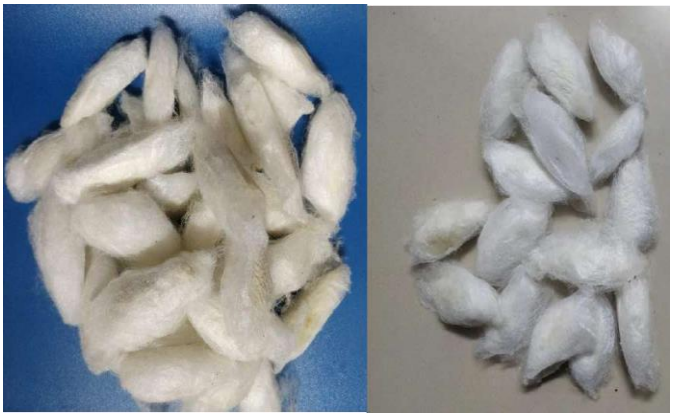

Fig. 12: Eri cocoons reared on artificial diet

Fig. 13: Eri cocoon reared on leaves

3.11 Cocoon yield:

Table 13: Cocoon yield and flimsy cocoons % of diet fed batch and leaf fed batch

Trial	Cocoon yield per 100 DFLs		Flimsy Cocoon %	
	Diet batch	Leaves batch	Diet batch	Leaves batch
1	65	52	2%	5%
2	62	51	4%	6%
3	65	50	4%	8%
4	63	49	3%	9%
5	60	50	4%	7%
Avg	**63**	**50.4**	**3%**	**7%**

It was observed that the cocoons yield is more in diet feed batches than leaf fed batches. Flimsy cocoons % is more in leaves chawki reared batches compared with diet fed chawki batches. Fukuda *et al* (1961) studied that the larval raising, cocoon fibres and eggs of the eri-silkworms reared on artificial food were the same as those in the case of the eri-silkworms reared on fresh leaves of castor-oil plant, natural food for this insect, or rather better. But in present study the cocoon yield was more in diet batches than leaves batches.

4. ECONOMIC PARAMETERS ANALYSIS LIKE COCOON WEIGHT, SHELL WEIGHT AND SR %

The observation of artificial diet and leaves reared batches indicated that, Effective rate of rearing percentage (ERR %) is more in artificial diet fed batch than leaves reared batches. All the post cocoon parameters like cocoon weight, shell weight and Shell ratio percentage are more in diet fed batches than leaves fed batches. Total yield of increased 13% in artificial diet batches than castor leaf batches.

Table 13: Cocoon weight, Shell weight and SR% of diet fed batch and leaf fed batch

Trial	Artificial Diet Batch				Leaves Batch			
	Cocoon weight	Shell weight	Shell ratio %	ERR%	Cocoon weight	Shell weight	Shell ratio %	ERR%
1	2.310	0.401	17.359	90	2.220	0.359	16.171	70
2	2.300	0.390	16.957	88	2.200	0.350	15.909	72
3	2.320	0.411	17.716	87	2.300	0.388	16.870	69
4	2.310	0.402	17.403	90	2.210	0.375	16.968	70
5	2.300	0.399	17.348	88	2.100	0.329	15.667	72
Average	2.3080	0.4006	17.356	89	2.2060	0.3602	16.3170	70.60

Jatuporn Tungjitwitayakul and Nujira Tatun (2017) studied the comparison between the larval and pupal weights . They reported that Eri-silkworms reared on the artificial diet had higher larval and pupal weights than those reared on cassava leaves, but the cocoon shell weight did not differ between the groups. But in present study cocoon weight increased in artificial diet rearing than castor leaves rearing.

5. CONCLUSION

- Artificial diet chawki rearing cost is significantly lesser than leaves chawki rearing cost.
- Artificial diet rearing is a labor-saving process. As the chawki silkworm shifted to leaves after 2nd stage therefore leaves consumption from third stage to fifth stages are the same in both batches
- Stable cocoon were obtained in artificial diet chawki batches with limited (1 to 3 %) flimsy cocoons whereas the conventional leaf reared batches had about (5-9%) flimsy cocoons. Cocoons yield was 13% higher in artificial diet chawki rearing than the leaves chawki rearing. The farmers earned additional income when reared artificial Eri silkworm in terms of yield, quality and saving the labor cost.

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