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Diversified post-harvest treatment of eri cocoon and its effect on spun yarn

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Abstract

Eri silk worm is known to be reared indoor in different part of the world with diverse expectation of silk, food and biomaterial. It possesses a very unique characteristics than other silk found in India. The cocoon is open mounted and have discontinuous filaments as moth emerges from its own and thus can be spun only rather than reeled. Before spinning into yarn, the cocoon was treated with alkaline solution made with traditional formulation of different plant ash to make alkaline solutions. The alkaline solutions of 10ml each is used to degummed the sericin from 400 cocoon but it's after effect on fibre and yarn quality is yet to be assess. Hence, pre and post treatment of eri cocoon before spinning was undertaken and found that cocoon treated with alkaline solution of plaintain ash and black gram plant ash extracts is found more appropriate method of degumming than chemically treated cocoon with sodium-bicarbonate.

Keywords: Silkworm, tensile strength, eri silkworm, yarn, protein fibre, post-harvest, sericulture

Introduction

Sericulture forms a unique form of agriculture in Northeastern states, particularly in Assam, as this zone is predominant and popular for agroforestry. The region enjoys a unique distinction of being the place in the country that produces all the variety of natural silk viz. mulberry, tasar, muga, oak tasar and eri silk.

Eri silk worm is known to be reared indoor in different part of the world with diverse expectation of silk, food and biomaterial. The tribal population of Assam and Northeastern region primarily rear eri silkworm for food as eri silkworm pupae is considered as a food of delicacy among tribal community and cocoon is a secondary by-product (Meth and Gogoi, 2016)^[7]. Rearing of eri silk worm is almost a prerogative of tribal people and inherited from one generation to other as culture. However, it was believed that sericulture is a poor's man job and a leisure time activity and is a secondary source of income for clothing and food (Neog K, 2019)^[5].

The woolly silk is also popularly known as 'fabric of peace' as the process involve does not kill the moth and thus commonly termed as 'Ahisha Silk'. Eri silk is also known as 'endi' or 'errandi' and is multivoltine, polyphagous sericeous insect under non-mulberry sector, spun silk cocoons. The ericulture is carried out throughout the year in tribal rural villages of the region due to year-round availability of either castor leaf (Ricinus Communis) (primary food plants), Kesseru leaf (Heteropanax fragrans) (secondary food plants) and tapioca leaf (Manihot esculenta) (tertiary food plants) and hence farmer can rear 6-7 crops annually. At present per kg cost of cocoon ranges from Rs. 800-850/- per kg and eri pupae cost Rs 360-400/per kg

Eri silk constitute nearly 66 % of total non-mulberry silk

production of 7157 MT of silk production in India during 2019-20. Hence, eri silkworm rearing not only a means of employment but also creates income generation avenues for a wider section of rural mass as it provides food as well as fabric. Keeping this in mind, a project named ARYA (attracting and retaining youth in agriculture) under ICAR (Indian council of Agriculture Research), ATARI Zone VI and AAU (Assam Agricultural University) was also introduced through KVK (Krishi Vigyan Kendra) in tribal population of Kokrajhar district of Assam where scientific method of rearing was introduced with traditional amalgamation of rearing for higher cocoon yield and quality spun yarn.

Eri silkworm cocoon consist of two main natural proteins biopolymer filaments consist of fibroin (fibre) and sericin (gum). It possesses a very unique characteristics than other silk found in India. The cocoon is open mounted and have discontinuous filaments as moth emerges from its own. Due to discontinuous filament, it can only be spin like cotton rather than reeled. The process of producing single yarn by twisting the discontinuous filament is called spinning. Different traditional methods of post-harvest treatment of harvested cocoon were applied to remove the sericin (gum) and to soften the fibroin (fibre) before spinning into yarn without considering its effect on spun yarn. Thus, recognizing the eri silk production and lack of exposure on eri cocoon spinning the present study highlight the different post-harvest treatment of cocoon before spinning, innovative techniques and effect of various treatment in fibre quality in terms of tensile strength were undertaken.

Methodology

The methodology section outlines the plan and method of the research study. This includes selection of cocoon, postharvest processing and treatments, testing of tensile strength, data and analytical framework which are as follows:

Selection of Cocoon

Cocoon are of varied quality and thus clean, dry and uniform quality cocoon was selected before degumming.

Post-harvest processing and treatments of cocoons

Before spinning of eri cocoon into spun yarn, cocoon was undergone some pre and post treatment operation.

Pre-treatment

Eri cocoon were pre-treated with commercially available non-ionic liquid detergent to soften the cocoon. 400 numbers of cocoon were soaked for 12 hours in 1% solution of non- ionic liquid detergent called easy before degumming or post treatment.

Post- treatment of cocoon

a. Degumming

b. Traditional method

400 numbers of cocoon were loosely tied in cotton cloth having M: L (Material: Liquor) is 1:20 and boiled in 10ml of different alkali solution for 45 minutes at 90 degrees centigrade. After boiling the individual cocoon were washed in cold water and dried in sun for after use. The degummed cocoon was wet again in glass of cold water before spinning the yarn.

 T_1 - Cooking with alkaline solution made with Paddy straw ash extract.

 T_2 - Cooking with alkaline solution made with black gram dal plant ash extract.

T₃- Cooking with alkaline solution made with Mustard plant ash extract.

T₄- Cooking with alkaline solution made with banana plant ash extract.

Improved method

Eri cocoon are loosely tied in a porous polyester net (bolting) cloth and bundles of 400 cocoon (about 1kg) are immerged in alkaline solution of 10g soap and 4g soda water per litre of water for 45 minutes. The cocoon was then washed in cold water and again re-boiled in water for another 20 minutes. After proper washing the cocoon are directly dried without disturbing the fibre layer and utilised for spinning in spinning machine. Before spinning the cake are wet again in plain water.

 $T_{5}-Cooking \mbox{ with alkaline solution of sodium bicarbonate /cooking soda}$

Spinning

Spinning is carried out in 3-in-1 solar cum electric cum manual spinning machine. The spinner holds the cocoon cake in the left hand, draft and then feed the strands with right hand to the spindle attached in the spinning machine. The speed of spinning can be adjusted accordingly with the skill of spinner.

Testing

The count of yarn, breaking load, tensile strength, breaking elongation, spinning efficiency percentage and tenacity of spun yarn treated with diversified alkaline treatment process were tested at IJIRA, Kolkata and calculated.

Degumming loss %

Based on the initial weight of the cocoon shell, the degumming loss % was calculated.

Degumming loss.
$$\% = \{(W1-W2)/W1\} \times 100$$
 (1)

Where,

W1 is the initial weight of the material and W2 is the material weight after degumming.

Count of Yarn

Yarn count is a numerical value which express coarseness and fineness of a yarn. Yarn count is measured as weight of yarn per unit length or length per unit weight.

Breaking load

Load which causes fracture in a tensile, compression, or torsion test.

Tensile strength

Tensile strength means the maximum stress that a material can withstand while being stretched or pulled before breaking. It is the rate of elongation and load of the force applied which can be used to calculate the material properties. Tensile strength is measured in units of force per cross sectional area. The ultimate tensile strength of a material can be found by dividing the force required to break a material by its original cross-sectional area. In international system, the units of Tensile strength are Pascal (Pa).

Breaking elongation

Elongation at break is called breaking elongation or fracture strain. Measurement of elongation in yarn is important because it is a measure of material's ductility i.e., the ability to deform without breaking. It is the ratio between changed length and initial length after breakage of the spun yarn. Breaking strength and elongation are two prime quality attributes of spun yarn. To calculate the breaking elongation, subtract the original length from the final length to obtain the change in length. Divide the change in length by the original length and multiply by 100% to obtain the total percent elongation. The sample elongation is expressed in percentage.

Spinning efficiency percentage

The ability of a material to perform its task is called efficiency. In other words, it is the ratio of the output to the input of a spinning machine. Spinning efficiency is represented as percentage and is calculated by true spin divided by total spin rate.

Tenacity

Tenacity means strength of a fibre or yarn. It is calculated by breaking force divided by linear density of the yarn. The unit is cN/Tex.

Data and analytical framework

For accessing the efficacy of the data collected, a

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comparative study was be carried out and plotted in tabular or graphical forms. Secondary data were collected from secondary sources to supplement and strengthen the research data.

Results and Discussions Selection of Cocoon

Life cycle of eri silkworm passes with 4th stage viz., egg, larvae, pupae and adult moth and takes 6 weeks in summer and 12 weeks in winter to complete its life cycle. During larvae stage it passes through 1st instar, 2nd instar, 3rd instar, 4th instar and 5th instar. Towards the end of the 5th stage eri silkworm stop eating and become matured larvae and start spinning cocoon. Properly reared worms, when ripe spin good quality cocoon even in unsuitable condition. Moreover, selection of matured larvae subjected to mounting is also important as over ripe larvae hurriedly spin cocoon at any place and thus form flat, irregular, stained cocoon, doubled cocoon or defective cocoon. On the other hand, if the worms are mounted before maturity, they spoil the cocoonage by defecating above it and move here and there in search of food. However, providing quality mountages or cocoonage facilitate quality cocoon production (Anuja B et al., 2022)^[1]. The process of cocoon spinning takes place with 3rd -4th days in multivoltine and 4th -5th days in bivoltine silkworm. The selection of quality cocoon should be assessed based on cocoon weight, shell weight, and silk ratio (Sarmah et al. 2013)^[9]. Harvested cocoons are kept for sun dry for 12 hours after extraction of larvae and preserved carefully to protect from fungal infection and other predators (Sakthivel 2019)^[8]. Two silk fibers (brin) extruded through the spinneret of the eri silkworm after joining the gum sericin to form a single fibrous stand (bave) during cocoon formation (Biswal et al., 2022)^[2]. The presence of sericin over fiber make it harder for further processing.

Post-harvest processing and treatments of cocoons

The selected cocoon was treated under different alkaline solutions and shows variations in terms of yarn count, breaking load, tenacity and elongation as shown in Picture-1 and Table-1



Fig 1: Post harvest treatment of eri cocoon with a) sodium bi carbonate and b) alkaline solutions

Treatments	Count of Yarn	Breaking load (Kg)	Tenacity (g/denier)	Elong
ng with alkaline solution made Paddy straw ash extract	15.32 Nm (1/15 Nm)	0.4236	0.7167	

Table 1: Diversified post-harvest treatment and its effect on yarn properties

Treatments	Count of Yarn	Breaking load (Kg)	Tenacity (g/denier)	Elongation (%)	
T ₁₋ Cooking with alkaline solution made	15.32 Nm	0.4226	0.7167	21.74	
with Paddy straw ash extract.	(1/15 Nm)	0.4230	0.7107	21.74	
T ₂ - Cooking with alkaline solution made	16.12 Nm	0 4979	0.0178	22.00	
with black gram dal plant ash extract.	(1/16 Nm)	0.4070	0.9178	23.00	
T ₃ - Cooking with alkaline solution made	15.76 Nm	0.5200	0.8066	26.60	
with Mustard plant ash extract.	(1/16 Nm)	0.3299	0.8900	20.09	
T ₄ - Cooking with alkaline solution made	15.49 Nm	0.4240	0 7258	22.67	
with banana plant ash extract	(1/15 Nm)	0.4349	0.7558	22.07	
T ₅ -Cooking with alkaline solution of	14.28 Nm	0.5825	0 9799	22.08	
sodium bicarbonate /cooking soda	(1/14 Nm)	0.3835	0.8788	22.98	

The eri cocoon treated with alkaline solution of black gram dal, mustards ash solution and banana plant ash extract show higher yarn count of 16.12 Nm, 15.76 Nm and 15.49 Nm respectively followed by cocoon treated by paddy ash extract. However, cocoon treated with sodium bi carbonate shows least yarn count of 14.28 Nm.

The tenacity and elongation were found higher in cocoon treated with mustard plant ash and black gram dal as 0.91g/denier, 23.00% and 0.89g/denier and 26.69% respectively due to incomplete degumming. In this same context, Sreenivasa and Padaki, 2023 [10] states that raw (undegummed) eri shows higher elongation percentage of 17.8% than degummed cocoon treated with soap-soda sample (16.4%) due to presence of sericin. Breaking load is

also found higher and with least yarn count shows that sodium-bi-carbonate though help to remove sericin from fibroin but effects the fiber quality to withstand wear and tear.

Degumming Loss percentage

The degumming loss percentage of eri cocoon under different alkaline treatment are found higher in sample treated with Sodium bi carbonate and soap solution (13.4%) followed by cooking with alkaline solution of banana ash extract and black gram ash extract, 11.6 and 11.4% respectively as shown in Graph-1.



Particulars		T ₂	T 3	T 4	T5
Pre-treatment of cocoon (soaked for 12 hrs in non-ionic liquid detergent)		1%	1%	1%	1%
Post -treatment of cocoon					
Material is to liquor ratio	1:20	1:20	1:20	1:20	1:20
Temperature	90	90	90	90	90
Time, minute		45 min	45 min	45 min	45 min
Quantity of cocoon		400	400	400	400
pH of water		8.5-9.5	8.5-9.5	8.5-9.5	8.5-9.5
Alkaline doses		10 ml	10 ml	10 ml	10 ml
Degumming loss		11.4	10.2	11.6	13.4

Graph 1: Showing degumming loss percentage of eri cocoon during post-harvest treatments with alkaline solution.

The degumming loss of eri cocoon 13.5% is found with sample treated with soap and soda ash treatment of different doses and sericin loss percentage ranges with a minimum degumming loss of 12.50% and maximum of 14.50% (Dou H *et al.*, 2015)^[4]. Higher concentration of sodium bi carbonate with longer duration of boiling results complete degumming but effects fiber tenacity and elongation (Chattopadhyay *et al.*, 2016)^[3]

The result reveals that sample treated with alkaline solution of paddy straw extract (10.5%) as well as mustard plant ash extract (10.2) have minimal degumming loss. In this same

context, Sreenivasa and Padaki, 2023 ^[10] states that the sericin content of raw eri silk is in the range of 13-17% and weight loss % of eri silkworm during degumming is ranges from 8-15%. However, higher boiling temperature and high pressure also effect sericin removal.

Spinning efficiency

The time required to spun 400 numbers of eri cocoon to eri yarn with the help of *Takli* (drop spindle) and 3-in 1 solar cum electric cum pedal-operated eri spinning machine are as follows:

Particulars		T_2	T 3	T 4	T ₅
Time required with <i>takli</i> {in Hours (h)}		8	8	8	8
Post treated cocoon given for spinning (g)		70	70	70	70
Total yarn spun (g)	51	60	57	65	47
Waste cocoon %		13.3	17.3	06.6	32.8
Time required in spinning machine {in Hours (h)}		8	8	8	8
Post treated cocoon given for spinning (g)		150	150	150	150
Total yarn spun (g)		145	140	148	131
Waste cocoon %		03.3	06.6	01.3	12.6

Table 2: Quantity of yarn spun with takli and spinning machine from treated cocoons

The rearer especially Bodo women belongs to tribal community used *Takli/Takuri* (Sarmah *et al.*, 2013)^[9] as a hand tool for spinning yarn. It works on the drop spindle method and is a leisure time activity for old-aged tribal women.

The amount of yarn spun through drop spindle method i.e. with *Takli* within 8 hours is found more in cocoon treated with alkaline solution of banana ash extract (65 g) and ash extract of black gram dal (60 g) out of 70 g of degummed cocoons and thus waste cocoon percentage is minimum,

6.6%, 13.3 % respectively. Further, in this same context, it was also reported that 40-60 gm of eri yarn can be spun daily spending 8 hours/day (Joncy *et al.* 2020) ^[6]. Moreover, the spun yarn spun in spinning machine also show spinning efficiency in cocoon treated with plaintain ash extract solution and black gram ash extract solution used for degumming followed by cocoon treated with mustard plant ash extract. However, the spinning efficiency is directly proportional to fiber length. The longer the fiber length, the stronger the yarn will be as minimum twist per inch was given during spinning process. Moreover, fiber strength with higher elongation is also directly proportional to spun yarn strength (Chattopadyay D *et al.*, 2015) ^[3].

Conclusion

Traditional formulation of degumming is an appropriate method of degumming sericin from fibroin than chemical method of extraction as it causes less harm to fiber or spun yarn. Appropriate alkaline dose, boiling temperature, cooking condition plays a vital role in degumming. Good elongation, less breaking load, acceptable degumming loss, adequate spinning efficiency facilitate good tenacity and tensile strength to spun yarn and leads less yarn wastage during weaving.

Conflict of Interest

The author declares that there is no conflict of interest.

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