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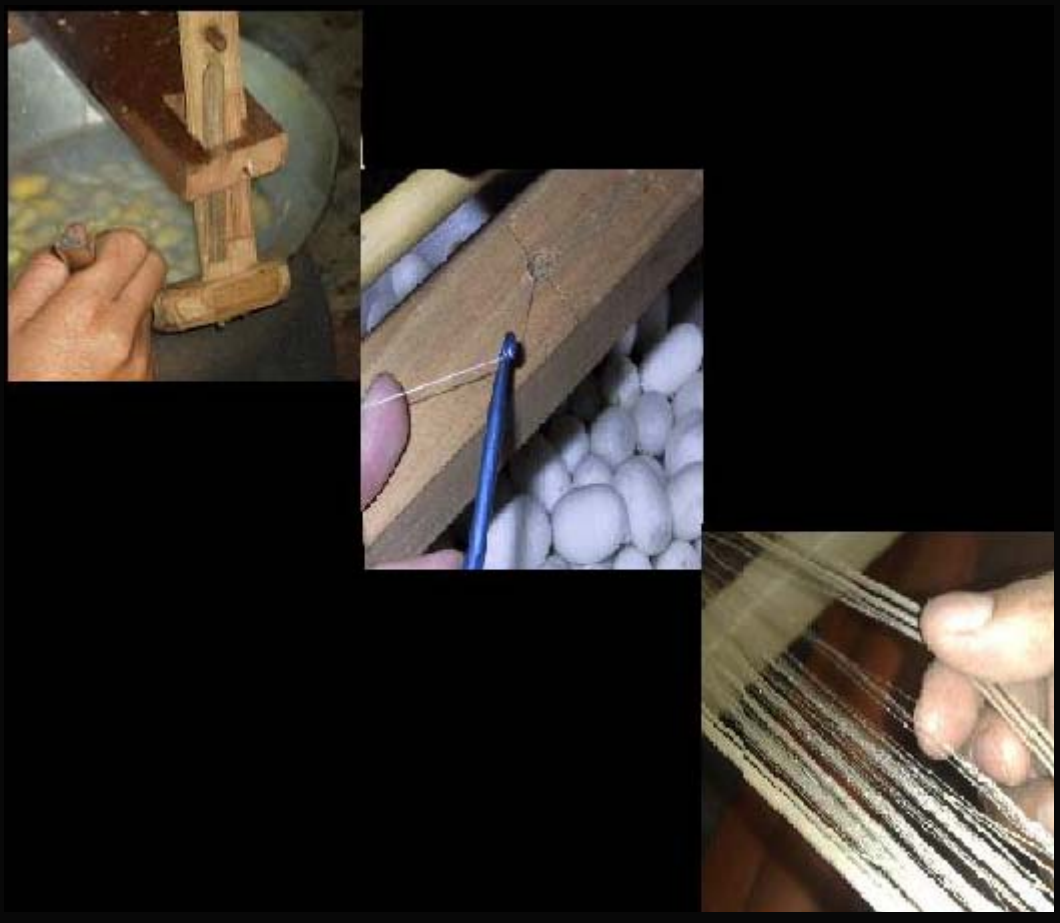

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Abstract: *Energy consumption for cooking and reeling operation in a domestic reeling unit of 6-basin was calculated. It is found that on an average 1000 kg firewood is required for production of 60 kg raw silk in conventional energy management. A new modified energy management process with solar water heating system and a mini-steam boiler yields a saving of 54% firewood consumption compared to conventional process.*

Key words: *Silk reeling, Sericin, Firewood, Deforestation, Energy*

1.Introduction

Silk reeling industry is energy intensive in all stages of production like, cocoon drying, cooking, reeling and re-reeling. Being cottage industry located mostly in villages and towns, the industry depends on firewood and other different sources of agriculture residues for energy needs [1]. It is estimated that 1,45,000MT/year of fuel wood and 1,70,000MT/ year of other biomass consumed for production of raw silk in India as other commercial fuel sources (e.g. coal and LPG) [2] are not favoured due to limitation of price and environmental pollution. However, the level of energy consumption is high but energy efficiency is low at about 10% [2] with the use of fuel wood and biomass. The domestic machines, locally known as back reeling was evolved in Mysore, a southern city in India, sometime between 1925-1927 [3] and is being used prominently till today in Siddlaghatta cluster, Karnataka, India. As per the statistical information available with Central Silk Board [4] for the year 2004-05, India produced 14,620MT of mulberry raw silk on different reeling devices viz. filature/cottage basin (26,631 units), Charakha (28,014 units) and Multiend reeling (201 units). Thus more than 90% of raw silk produced in India is on domestic basin, cottage basin and charakha units. In a study, it is found that domestic reeling device consumed 1000 kg of firewood for production of 60 kg raw silk of 16/18 denier. In a model unit of 6-basin domestic reeling device of 5-ends, 5.5-6 kg of 16/18 denier raw silk produced in a day of 8 hours working by consuming 650 liter of water for cooking and reeling and fire wood consumption per day is 100 kg, ie gross energy consumption in Kilocalorie per day for 6 kg raw silk production is 1,38,600. In the gross energy consumption, it is measured theoretically that 1,18,080 Kilocalories of heat is consumed for cooking alone and 12,444 Kilocalorie heat is used to maintain the reeling temperature of water in reeling basins.

In a current study, the energy consumption of domestic filature reeling unit is evaluated and suitable modification has been suggested towards effective utilization of Solar Water Heating System (SWHS) along with 50kg mini-boiler, which generates steam by burning precious fossil energy. The suggested modification is expected to prevent deforestation.

2.Material and Methods

2.1 The Green Multivoltine silk cocoons used for production of raw silk in domestic 6-basin reeling unit under this study.

2.2. Conventional process of energy management in domestic raw silk reeling unit.

The domestic reeling unit consists of an assembly of three separate but functionally connected parts namely the cooking unit, the reeling bench and the reel assembly.

2.2.1.Cooking unit:

It is masonry structure of convenient height; one- cooking vessel to serve cooked cocoons to 2-reeling basins is mounted on a well-constructed oven and chimney for exhaust of waste gases from the oven. The cooking unit is usually located closely to reeling basin for easy supply of cooked cocoons. The cooking vessel contains 10 to 15 liters of water for cocoon boiling to soften sericin and draw continuous silk filament. In a model of unit of 6-basins with a production capacity of 6 kg/ 8 hours, three vessels are mounted on individual oven (one vessel/ 2 basins) and in a day of 8 hours, fresh water is filled in order to avoid turbidity of water. It is studied that 25 liters of water is required in cooking for production of 1 kg raw silk and 16.67 kg of firewood is burnt for production of 1 kg raw silk. In other words, 100 kg of wood (1,38,600 Kilocalorie heat energy) is consumed for production of 6 kg raw silk/6-basin/8 hours in a day. Part of the boiling water is also used to bring basin water to 45^{O}C for trouble free reeling.

2.2.2 Reeling bench:

Generally, each unit consists of four to six reeling basins. The tabletop is usually spacious and provides sufficient accommodation for keeping such necessary reeling equipment as water mug, waste collection frames or even small brushes, ladles etc. The reeling basin is fixed firmly in the table is made of copper sheet with a size of 45 X 25 X 7.5 cm to accommodate 7 to 10 liters of hot water. 70 liters hot water is consumed in reeling basin for production of 1 kg raw silk. Each basin is designed to reel 5-ends and jettebouts are provided to facilitate easy attachment of filaments. In some machines the jettebouts have been replaced by ordinary porcelain button thread guides mainly to simplify further and reduce its cost. Each basin has its independent croissure frame designed for application of tavellette croissure. For a model unit of 6-basins with 6 kg production capacity per day, 420 liters of water is required.

2.2.3 Reel frame:

This is an angle-iron frame fitted about one meter away from and parallel to the reel bench. The height of the bench is kept at 150 to 170 cm from the ground, enabling easy knotting and repair threads that break frequently in reeling. The reels are of standard size and pattern as prescribed for International standards. Each reel is served by a braking mechanism of simple design. To avoid gum spot in the skein, the burning charcoal from the oven is taken and spread on a tray, beneath reel to remove moisture from the raw silk during re-reeling process.

2.2.4 Raw silk production:

The multivoltine green cocoon procured locally was steam stifled, which is commonly practiced in the reeling cluster. With local reelers, the green cocoon after stifling was reeled on the 6-basin domestic reeling unit with conventional energy management process. In a day, 6-kg of raw silk was produced and reeling and energy-consumed details were noted down. Raw silk was tested for quality parameters.

2.3 Quality parameters of raw silk & Testing.

The raw silk testing and classification i.e. grading is done as per the Standard method of raw silk testing and classification adopted by the International Silk Association [5].

2.3.1 Size: The object of size deviation test is to determine the degree of extreme variation within the test pieces of sizing skeins. It consists of Average size, Size deviation and Maximum deviation of size. The sizing skeins of 112.5 m circumference are made out of thread pieces taken from 40 skeins of 70 g each. To find the size i.e. the average denier of sample is measured by weighing in automatic electronic weighing balance. The size deviation, maximum deviation and minimum deviation are calculated either by statistically or with the electronic device attached to the balance.

2.3.2 Winding breaks: The object of this test is to determine the number of breaks occurring in the raw silk during certain period of winding and feasibility of the skeins for winding. The winding is done on a winding frame, which can be adjusted for its winding speed depending on approximate denier of the skein. 40 skeins of 70 g each are taken for winding test and number of breaks for a stipulated period is recorded for winding result.

2.3.3 Evenness variation I, II & III: Evenness variation, cleanness and Neatness tests are collectively done by Seriplane test instruments consisting of Seriplane winding machine, Seriplane inspection boards and illumination apparatus. Evenness variations are those defective portions of raw silk threads on an inspection board showing stripes caused by variation in the size of raw silk to such a degree as is easily noticeable by visual inspection. Evenness variation I, II & III are intensity of variations compared correspondingly to the standard photograph panels named as Vo, V1, & V2.

2.3.4 Cleanness: The object of this test is to determine the kind and the number of cleanness defects of raw silk. The cleanness defects are classified into three groups i.e. super major defects, major defects and minor defects based on visual inspection by comparing each class to standard photographs.

2.3.5 Neatness & low neatness: The object of this test is to determine the neatness percentage of raw silk. The imperfections or defects smaller than or does not fall under minor cleanness defects is determined by visual inspection comparing with standard photograph of neatness defects.

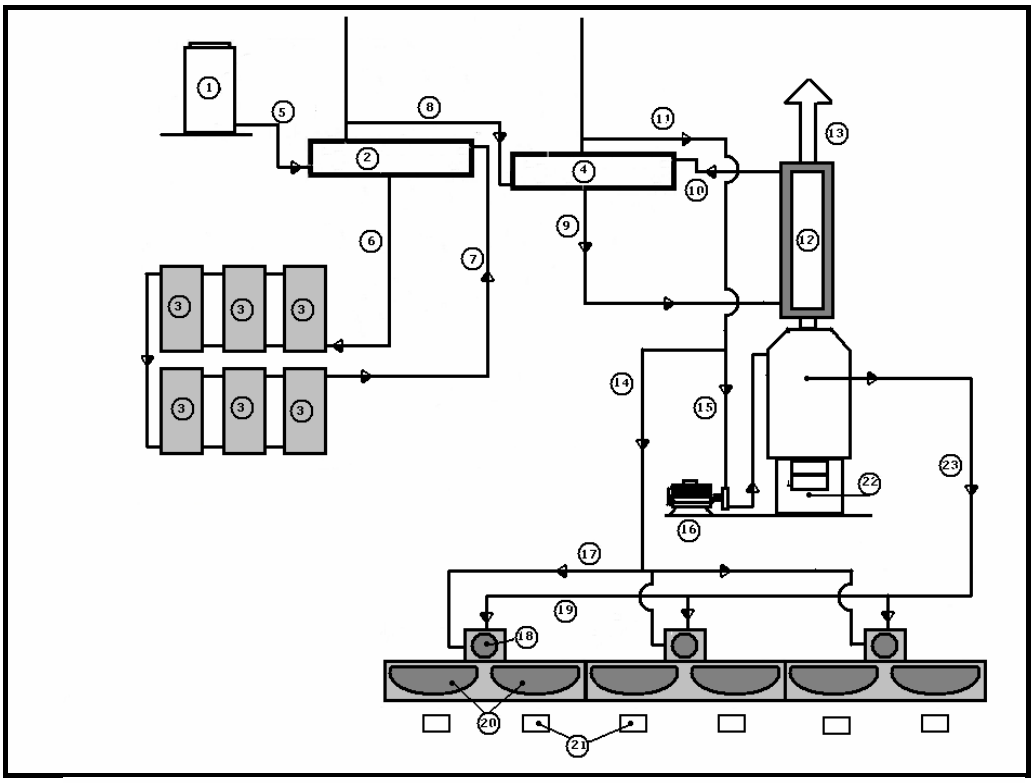
2.3.6 Tenacity and Elongation: The object of this test is to find load bearing capacity in terms of grams per denier and stretch ability in percentage of raw silk called as tenacity and elongation respectively. This test is called Serigraph test.

2.3.7 Cohesion: The object of this test is to determine the degree of agglutination of cocoon filaments forming the thread. Test value is counted in strokes on a cohesion tester.

2.4 Modified process of energy management in domestic raw silk reeling unit.

To use energy efficiently in combination of renewable solar and fossil energy, a new process model is evolved. The schematic line diagram of modified energy management process addressing the energy needs of same domestic reeling unit of 6-basin capacity for cooking and reeling hot water is shown in **Figure 1.**

Study is involved by using smaller type of firewood Mini-boiler of 50 kg capacity which is fully insulated along with Solar Water Heating System (SWHS)-6 solar collectors of 2 m^2 each and Heat Recovery Unit (HRU).



1. Over heat tank
2. Insulated solar tank
3. Solar Panels
4. IInd insulated tank
5. Cold water supply
6. Water supply to solar panels
7. Hot solar water
8. Hot solar water to IInd tank
9. Solar hot water supply
10. Hot water from HRU
11. Hot water supply
12. Heat Recovery Unit (HRU)
13. Chimeny
14. Hot water supply to cooking
15. Pre-heated water to boiler
16. Water pump
17. Hot water supply to cooking
18. Cooking vessel
19. Steam supply to cooking unit
19. Steam supply
20. Reeling basins
21. Reelers sitting benchs
22. Fire box
23. Steam supply

Figure-1: Schematic diagram of modified energy management in domestic raw silk reeling unit

As shown in the schematic diagram at **Figure-1**, the overhead tank supplies cold water to 500 LPD water tank and by gravitational circulation of water through Solar collectors, water gets heated around 65°C to 85°C in full day sunshine in insulated solar tank (500LDP). The incidence of solar radiation on each solar Panel is 4-6 Kw/m^2/day [6]. More number of panels may also be added for better performance of the system. The hot water in solar tank is drawn to additional 2nd insulated tank of 500 LPD at morning or afternoon before start of reeling in order to avoid mixing of cold water in 1st 500 LPD solar tank during water consumption for reeling. 500 LPD insulated additional tank is connected to inlet and outlet point of a Heat Recovery Unit (HRU) [Developed by Tata Energy Research Institute - Teri] for further heating through HRU. The HRU is chimney like attachment; mounted on the 50 kg capacity Mini-boiler's chimney and it is fully insulated to avoid heat loss that takes place by natural cooling. The HRU works to recover energy that is being escaped through the mini-boiler chimney while burning firewood in the boiler. The fire wood burning processes involves that around 55% is utilized for generating steam in the mini-boiler and remaining 45% of energy derived gets lost by

emitting gases into the atmosphere viz. carbon dioxide, carbon monoxide etc.[7] HRU helps to recover the energy that is being wasted otherwise. Such recovered energy helps further heating of the water drawn in the additional insulated tank as shown in the line diagram and this hot water used for 6-reeling basins and as pre-heated water for boiler and cooking vessels.

Same cocoon used in conventional method is subjected for reeling in same domestic reeling unit to produce 6 kg raw silk by using new modified energy management process. The steam generated by 50-kg boiler connected to cooking vessels was used for cocoon cooking followed by reeling on 6-basin domestic reeling unit for production of raw silk. The reeling details and energy consumption details were noted down for comparison with conventional method. Raw silk was tested for quality parameters.

3. Results

Raw silk produced in conventional energy management process was tested for raw silk quality parameters, and is tabulated at **Table-1.**

S.No	Parameters	Test results
1	Average size	18.1
2	Winding breaks/10 skeins/hr	70
3	Standard size deviation	1.21
4	Max-size deviation	1.8
5	Evenness variation	
	I	8
	II	8
	III	0
6	Cleanness %	76
7	Average neatness %	87
8	Low neatness %	85
9	Tenacity (g/d)	3.69
10	Elongation	18.8
11	Cohesion (Strokes)	46

Table-1: Test results of raw silk produced on conventional energy management process.

Table-2 shows the energy consumed in 6-basin domestic reeling unit for production of 6 kg, 16/18-denier raw silk per day in conventional process. Similarly, the raw silk produced with new modified energy management process was tested for raw silk quality parameters and is tabulated at **Table-3.**

S.NO	Activity	Energy Consumption (In Kilocalorie)	Amount of firewood consumption (In kg)
1	Cocoon cooking	1,18,080	85.19
2	Hot water for reeling basin	12,444	8.99
3	Invisible loss	8,066.52	5.82
TOTAL		**1,38,590.52**	**100.00**

Table - 2: Energy consumption in conventional process

S.No	Parameters	Test results
1	Average size	17.8
2	Winding breaks/10 skeins/hr	75
3	Standard size deviation	1.07
4	Max-size deviation	1.6
5	Evenness variation	
	I	9
	II	7
	III	0
6	Cleanness %	74
7	Average neatness %	85
8	Low neatness %	87
9	Tenacity (g/d)	3.72
10	Elongation	19.2
11	Cohesion (Strokes)	49

Table-3: Test results of raw silk produced on modified energy management process.

Table-4 shows the energy managed and utilized in combination of solar water heating system, 50 kg mini-boiler and heat recovery unit for production of 6 kg raw silk in 6-basin domestic reeling unit.

S.NO	Activity	Energy Consumption (In Kilocalorie)	Amount of firewood consumption (In kg)
I	500 LPD Solar Water Heating system of 6 Solar Collectors (2m^2 each) at 80% efficiency	26,400	–––
II	Wood consumption of Mini-boiler of 50 kg capacity (Insulated)	63,756	46.00
III	Energy recovered by fully Insulated "Heat Recovery Unit" (HRU) at 70% efficiency	49,588	–––
	TOTAL	**1,39,744**	**46.00**

Table-4: Modified energy management process with solar water heating system.

4. Discussions

From the **Tables-1 & 3**, it is seen there is no significant variation in the quality of raw silk produced in both energy management process. From the **Table 2 & 4**, a comparison in terms of energy and firewood consumption between conventional process and modified energy management process is studied. In the conventional process 100 kg of firewood was burnt for cooking and reeling activity for production of 6 kg 16/18 denier raw silk in 6-basin domestic reeling unit and for similar production under modified energy

management process by using same reeling device, the amount of firewood was reduced to 46 kg, resulting a saving of 54 % in firewood consumption. Thus the new modified energy management process reduces the environmental pollution significantly thereby reduction in the emission of Carbon dioxide and other gases into the atmosphere, thereby helping to reduce global warming.

The economical benefit, which can be derived by promoting modified energy management process, is shown at **Table-5**. It is corroborated from the tabulated data that, the expenditure incurred in the new process, which includes installation of solar water heating system, heat recovery unit, mini-boiler and insulated cooking bench is Rs **1,17,000**/-. The saving of firewood due to the use of new energy management process per annum amounts to Rs. 48,600.00/-. Thus, the recovery period works out to be 2.41 years by considering the total investment in the new energy management process with respect to the amount saved in the consumption of firewood.

S.No	Components	Amount (In Rs)
1	Installation of solar water heating system of 500 LDP- evacuated vacuum tube type with additional solar tank of 500 LPD	70,000.00
2	Heat recovery unit	7,000.00
3	50 kg insulated Mini-boiler	40,000.00
	Total investment	**1,17,000.00**
4	In new energy efficient management process 54% fire wood is saved compare to 100 kg firewood consumed by conventional process for production of 6 kg raw silk per day. Amount saved per annum of 300 working days Rs.3/- per kg firewood.	48,600.00
Recovery period		**2.41years**

Table-5: Economical benefits of new energy efficient management process

India produces 16,000 MT of raw silk per annum by using conventional energy sources, estimated at 1,45,000 MT / year of fuel wood and 1,70,000 MT/year of other biomass. The new modified energy management process reduces around 54% in firewood consumption. The installation of Solar Water Heating System with Heat Recovery Unit for Mini-boiler in the domestic reeling machine silk reeling sector is advised to arrest deforestation and to protect our globe from environmental imbalance.

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