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The Importance Of Silkworm Pupa Solar Dehydrator In Silk Reeling Manufacturing Industries

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Abstract: ***The silk Industry one of the productive cottage sectors in India is developing rapidly and lucratively over the past years. Considering the industry as a whole, the entire process for silk fabric manufacturing is profitable. However, as far as individual sector is concerned, several constraints are involved. Furthermore, in conventional method the left over chrysalises (silkworm pupae) are dried in open area by sun-drying practice. This practice creates a significant health hazard to employees and neighboring communities. Another significant limitation is observed during waste pupae drying.***

In conventional method, after reeling process is completed, the left over silkworm pupae, a silk by-product are dried by open sun- drying method for one or two days. As the pupae are dried in open area, the inhabitants feel discomfort due to the extremely bad odor and the obnoxious gases released from the pupae.

Also, the open sun-drying system invites microbes, rodents, dogs, pigs, monkeys, crows, eagles and vultures for pupae feast. Moreover, the present method of drying provides poor and objectionable working conditions, including environmental problems, which is a significant health hazard to the employees and neighboring communities.

Keywords: silkworm pupa solar dehydrator, silk Reeling industry, Andhra Pradesh, pupae.

I. INTRODUCTION

In silk industry nothing goes waste, as every waste brings additional revenue as well as additional employment. Surprisingly, this value addition may even go up to 10% to 25% in various sectors of post cocoon with effective management and utilization of the waste. As far as silk reeling sector is concerned, silk and pupae wastes are the main by-products. Silkworm pupae are rich in vitamins such as B12 and D.

Large quantity of pupae that accumulate in reeling process could be utilized better to produce value aided by-product, by adopting improved technology / process. The oil that is extracted from dried pupae is very much used for soaps, animal biscuits, cosmetics, while cake is feed for fish and poultry.

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Figure 1: Live and dead chrysalises (pupae)

In fact, silkworm pupae are the delicious food for Chinese as well as for the tribal living in some parts of India, especially North-east India. Therefore, silkworms can produce the silk and as well as become food for the human beings, animals and birds.

Pupae and moths are used in preparation of medicines (vitamin- E), poultry food, oil extraction etc. Silk powder is said to be helpful in reducing cholesterol and blood pressure, while silk films are used as artificial blood vessels.

Silkworm pupae have been found to be a rich source of protein. They are a good source of animal protein in place of fish meal in animal feeds. There is a need to tap the potentiality of silkworm pupae for socio-economic development of rural and urban population.

Dead pupae are highly perishable. Value addition to silkworm pupae can be enhanced by finding suitable preservation methods and by conversion of silkworm pupae into convenient processed products for wider market acceptability in different regions. In India, approximately 40,000 MT of silkworm pupae is produced through sericulture, per annum. Conventional method of drying and disposal of silkworm pupae cause environmental pollution besides loss of nutrients in them.

Fats and oils collectively termed as lipids are in great demand for food and non-food. About 90% of this is used in production of soap and other surface-active compounds and the balance is used for other industrial purposes.

II. CONVENTIONAL METHOD OF SILKWORM PUPAE DRYING

During the reeling process, reelers will take enough care to extract maximum quantity of filament from the cocoons. And finally, a thin layer of silk shell called pealed is left with the dead pupa.

Figure 2: Pealed and pupae in reeling basins

Figure 3: Pupae with pealed after reeling Process

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These dead pupae along with the pealed are collected by some small scale entrepreneurs called pupae collectors, who later will dry the pupae for further sale. Before allowing the pupae to be dried, pupae collectors soak the pealed and the dead pupae in water containing caustic soda, and brush them to separate each other. Interestingly, both these pealed as well as dead pupae are the by-products, as the spun silk is drawn from pealed and oil is extracted through pupae.

At Dharmavaram of Anantapur district, Andhra Pradesh, pupae are dried in open air sun-drying for a period of 8 solar hours to 12 solar hours. Pupae soaked overnight in water and caustic soda, absorb a lot of water and will not dry in this short period. Its needs to dry the pupae at least for 14 solar hours to 16 solar hours, for obtaining required dried matter (30%). But, the pupae collectors continue their process of partial drying.

Figure 4: Open-air sun-drying

These partially or semi dried pupae that is stored as a heap, releases obnoxious gases with unbearable odor, which causes discomfort to the inhabitants. This partially dried heap of pupae will be stored over a period of a month and will be sold to the oil extractors from Karnataka and West Bengal states for further processing.

III. DRAWBACKS IN CONVENTIONAL METHOD OF PUPAE DRYING

- ✓ Though open sun drying is relatively simple, it is dependent on the weather conditions and is susceptible to contamination.
- ✓ It requires at least 14 solar hours to 16 solar hours for removal of 70% of moisture from the pupae, as they possess lot of moisture.
- ✓ Moreover, the open sun-drying practice invites insects/ microorganisms, dogs, rodents, pigs, monkeys, crows, eagles and vultures for a pupae feast, which in turn causes reduction in production.
- ✓ Further, during rains the unprotected pupae will get damaged and will be perished.
- ✓ The obnoxious gases released from the pupae emit extremely foul smell, which causes inhabitants feel discomfort.
- ✓ Moreover, the present method of drying provides poor andobjectionable working conditions, including environm ental problems, which is a significant health hazard to employees and neighboring communities.
- ✓ Further, the pupae dried in open sun light are not clean; as the dust and stone particles are adhere to them. Hence, it is essential to find out a solution to overcome these obstacles.

Considering the disadvantages associated with conventional pupae drying, the Silkworm Pupae Solar Dehydrator (SPSD) was designed. The main idea is to dry the pupae in a closed solar cabinet with necessary gadgets that support the pupae dry faster and also rescue the pupae from insects, birds, animals and unfavorable climatic conditions. Therefore there will be no decline in the production. In addition, the solar dried pupae are protected against decaying and fungal attacks for a longer period.

IV. SILKWORM PUPAE SOLAR DEHYDRATOR - AN INNOVATION

The objective of this study was to conduct an experimental analysis to investigate the performance of the direct mode Silkworm Pupae Solar Dehydrator (SPSD) with forced convection to dry silkworm pupae under tropical weather conditions.

SPSD is developed with a flat-plate collector / absorber, covered with a transparent toughened glass. The properties of toughened glass include impact strength three to five times that of regular glass and has heatproof almost twice that of regular glass.

The SPSD cabinet is of 2.4384 m (8 feet) long and 1.2192 m (4 feet) width, with an aperture area of 2.9729 m^2 (32 sq. feet) and a loading capacity of 16 kg. A fan is provided to circulate the air in the solar cabinet. The SPSD cabinet temperature, moisture and pupae drying rate were examined in both fair and murky climatic conditions.

The cost-benefit analysis suggests that the revenue through SPSD dried pupae is 5.6 to 8.4 times that of the conventional open-air sun-drying method. Moreover, the payback period on the investment to manufacture the SPSD is around 10 months. Because of simple design and several advantages associated with SPSD, the proposed commercial application seems to be viable for silk reeling sector.

V. DEVELOPMENT OF SPSD – METHODOLOGY

The first attempt was made during January 2011 with a small laboratory model direct type Solar Pupae Drier (SPD) of 0.9144 m long, 0.6096 m breadth and 0.3048 m depth (3 feet long, 2 feet breadth and 1 foot depth) size. This drier was developed with locally available 1mm thick soft zinc sheet. The SPD cabinet was painted manually (by a 3" brush) in two layer coatings with black board paint. The cabinet was covered with a 6 mm regular transparent glass pane. A chimney was also provided for fumes to exit.

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Figure 5: Solar Pupae Drier (SPD) with glass pane and chimney

The color and texture of the wet and dried pupae are seen in these snapshots (Fig. 7.6). In SPD, 3 kg of wet pupae can be spread in a single layer comfortably for drying through solar radiation. It takes 9 solar hours to 10 solar hours to achieve the desired 30% died pupae.

Figure 6: Demonstration of solar pupae drier, during TUP

This model was demonstrated during Technology Up-gradation Programme (TUP) organized at Silk Conditioning and Testing House, Central Silk Technological Research Institute, Central Silk Board, Ministry of Textiles, Govt. of India, Dharmavaram, during February 2012.

Depicts a demonstration of SPD to Smt. M. Sathiyavathy, I.A.S., and Member Secretary of Central Silk Board, Bangalore, Sri K. S. Menon, Joint Director, CSB, Bangalore, Sri D. Jayramappa, Joint Director, Department of Sericulture, and Anantapuram. Multi-end reelers from various places of Andhra Pradesh. They have inquired the possibilities of adopting such solar pupae driers in MRM and ARM units. The Member Secretary, CSB has advised to investigate the possibilities of drying vanya silkworms through the SPD. With this inspiration, a second attempt was made to develop 16 kg capacity SPD.

VI. CONSTRUCTIONAL DETAILS OF SILKWORM PUPAE SOLAR DEHYDRATOR (SPSD)

SPSD is developed to accommodate 16 kg pupae in 4 solar absorber trays spread in single layer (4 kg in each tray) inside the drying cabinet.

The drying cabinet of the SPSD is developed with

- ✓ Pupae Trays with solar absorbers.
- ✓ Toughened transparent solar glass panes.
- ✓ A 1-phase, 230 V, 80 W, 2550 rpm fan.
- ✓ Control panel.
- ✓ A chimney,
- ✓ A Mild Steel Cold Rolled (M.S.C.R.) frame and
- ✓ Supporting legs.
- ✓ Humidity cum Temperature Indicator was used to measure the cabinet temperature and relative humidity at different instants

Figure 7: Silkworm Pupae Solar Dehydrator (SPSD)

The entire drying chamber/cabinet is un-partitioned to accommodate the four individual pupae trays and for easy air movement in it. The constructional and operation details of individual parts of SPSD are discussed below.

PUPAE TRAYS

The SPSD system holds four trays made with iron angular frames of 1.2192 m x 0.6096 m (4 feet x 2 feet) and 1” depth size each. These are meant for loading and unloading the wet and dried pupae before and after drying processes, respectively. Four aluminum sheets of 1.2192 m x 0.6096 m (4 feet x 2 feet) size, with 1 mm thickness each are placed in these four iron trays (Fig.7.8).The aluminum sheets are meant for absorbing solar radiation as well as for spreading the pupae on them for drying.

The iron trays, aluminum solar absorbers and all other parts are coated with matt-black epoxy hybrid powder with 60 microns thickness. This powder coating process contains de-greasing → water rinse → de-rusting → water rinse → phospating → water rinse → passivation → epoxy hybrid powder spraying (at +99 kV) → curing → oven melting at 130°C to 180°C for 10 minutes for thermo setting. The thickness of the powder coating can be between 60 to 80 microns and optimal control is 60 microns. More microns may be essential at corners (called Faraday Effect). The manufacturers generally charge Rs.12.00 per sq. feet (0.092903 m^2) for this epoxy powder coating.

Figure 8: A tray with solar absorber (aluminum sheet)

The dull black or matt black coating enhances the temperature within the dehydrator. Due to the heat stored in the absorbers during day hours, the drying process will be extended for some more period even after sun set. Handles are also provided to these four individual trays, to pull-in and pull-out them on the iron L-angular channels provided in a structure.

SOLAR TOUGHENED GLASS PANES

Figure 9: Toughened solar glass with rubber beadings

Four toughened transparent solar glass panes of 4 mm thickness with glass beadings are fixed on the M.S.C.R. frame. The glass panes arrest the radiation developed within the cabinet, and do not allow weather conditions to influence the pupae as no air or rain enters the drying cabinet (Fig.7.9).

FAN

A 1-phase, 230 V, 80 W, 2550 rpm fan of size 172 x 172 x 155 mm (6”), 1020 g in weight (model REC 27255 A2) instrument cooling fan is arranged in a box on one of the sides of the SPSD cabinet to depart out the moisture vapors along with the obnoxious gases through the chimney. The atmospheric air is drawn from a circular opening provided below the fan box (cannot be seen in the figure) and is passed into the cabinet through a 1.5” diameter pipe. (Fig.7.10)

Figure 10: Fan - inside the box

The fan can be operated automatically with the help of a timer provided in the control panel. If continuous air circulation is provided with the help of this fan, temperature of the drying cabinet will come down. On the other hand, if fan is not operated, the moisture and obnoxious gases released from the pupae will not be let out. Therefore, on either case the SPSD system will not function effectively. Hence, if the fan operates (on / off) in regular intervals, for example, 5 minutes to 8 minutes On-time and 15 minutes to 20 Minutes Off-time, then the system can function effectively.

CHIMNEY

Figure 11: Chimney and hood

A mild steel pipe of 1.5” diameter, 2.8956 m (9.5 feet) long, 1mm thickness is used as chimney and is provided on another side of SPSD cabinet (opposite side to the fan),

with the help of bolt and nuts. Chimney hood provided on the top of the chimney will not allow the rain to enter into the chimney. Warm moist air from the SPSD drying chamber exits to the atmosphere through the chimney, assisted by draft created in it.

MILD STEEL COLD ROLLED (M.S.C.R.) FRAME

A Mild Steel Cold Rolled (M.S.C.R.) square tube frame of 2.4384 m long, 1.2192 m breadth (8 feet long, 4 feet breadth) and

1.5 inches thickness is welded to another 1.5 inches thickness L-angular iron, to support the entire structure of the pupae trays, glass panes, fan, chimney and the supporting legs. Further, the necessary iron angular structure is also provided for accommodating the trays to slide and to fix the glass panes. This structure is welded / bolted / screwed to the M.S.C.R. frame.

SUPPORTING LEGS

All the four legs made up of 1.5" L-Angle iron angular are welded to the M.S.C.R. frame. They are in two different sizes (heights). The variation in heights from pupae loading side 0.6096 m (2 feet) to another side 0.4953 m (1.625 feet) is to provide a slant to the whole cabinet for better absorption of solar radiation and for easy flow of condensed water molecules along with the glass pane, inside the cabinet.

HUMIDITY CUM TEMPERATURE INDICATOR

Further, a precious and a sensitive Humidity cum Temperature Indicator with a sensor (Miltronics eMatiks make) and necessary probes was also used to examine the Humidity and Temperature of the SPSD, from time to time.

Figure 12: T & RH indicator and sensor

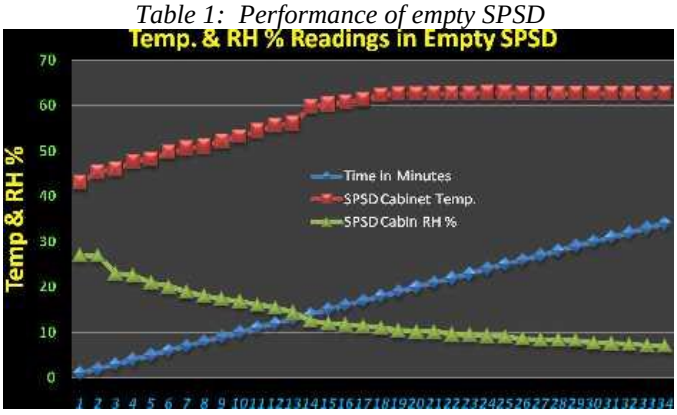
This indicator has digital interface. It has a relative humidity measuring range of 0 … 100% RH, with an accuracy of ± 1.5% and temperature measuring range of -40 … +85°C, with an accuracy of ± 0.3 °C. The power supply needed for this instrument is 3.5…50 V. d.c. and current consumption is less than 4 mA.

VII. PERFORMANCE OF SPSD

To examine the performance of empty SPSD cabinet, temperature and relative humidity readings were recorded while the average ambient temperature and relative humidity were 35°C and 43% respectively and the climate was fair. The fan was set in off position.

Time in Minutes	SPSD Cabinet Temp. °C	SPSD Cabinet RH %	Time in Minutes	SPSD Cabinet Temp. °C	SPSD Cabinet RH %
1	43.00	27.00	18	62.19	11.00
2	45.39	26.90	19	62.59	10.39
3	46.00	23.00	20	62.59	10.19
4	47.65	22.59	21	62.69	10.19
5	48.15	21.00	22	62.69	9.59
6	49.69	20.09	23	62.69	9.50
7	50.59	19.00	24	**62.79**	9.29
8	51.00	18.00	25	**62.79**	9.09
9	52.19	17.39	26	62.69	8.59
10	53.19	16.89	27	62.69	8.39
11	54.39	16.09	28	62.69	8.39
12	55.59	15.39	29	62.69	8.29
13	56.00	14.39	30	62.69	7.69
14	59.75	12.50	31	62.69	7.59
15	60.29	12.00	32	62.69	7.39
16	60.79	11.79	33	62.69	7.19
17	61.25	11.39	34	62.69	**7.00**

Table 1: Performance of empty SPSD



X-axis Time in Minutes →

Figure 13: Temperature(°C) and Relative Humidity (%) in empty SPSD

Table suggests that at the above mentioned ambient values, the empty SPSD cabinet can generate a maximum temperature of 62.79°C and a minimum relative humidity (RH) of 7.0%. Fig. 6.16 illustrates how

the temperature values in empty SPSD cabinet are maintained constant for about 17 readings and the corresponding RH values are declining.

VIII. PERFORMANCE OF LOADED SPSD

To understand the performance, the SPSD was loaded with 16 kg wet pupae. The pupae were separated from the pelade, manually (i.e. the conventional methods like using soda, water and soaking were not followed for removal of the pelade).

SPSD cabinet with 4 trays is designed to accommodate 16 kg of wet pupae, 4 kg in each tray. It is practically noticed that in every

0.0929 m^2 (1 square feet) of tray area, 0.5 kg wet pupae can be spread in a single layer. The trays of SPSD are of 1.2192 m x 0.6096 m (4 feet x 2 feet) each, with an aperture area as well as drying area of 0.7432 m^2 (8 square feet). Therefore, the total pupae drying area is 2.9729 m^2 (32 square feet), in which 16 kg of wet pupae can be loaded for drying. The pupae drying time depends on solar radiation and air flow rate.

When 16 kg silkworm pupae are loaded, due to high moisture in the wet pupae the cabinet temperature of the SPSD has come down and corresponding RH% values were very high (Sl.No.1, Table 7.2). The loaded SPSD cabinet temperature (T°C) and corresponding relative humidity (RH%) values are recorded from time to time.

Sl. N0	Time a.m. or p.m.	SPSD Temp (T) °C	SPSD RH%	Fan On/ Off	Sl. No	Time a.m. or p.m.	SPSD Temp (T) °C	SPSD RH%	Fan On/ Off
Empty Cabinet Values						10.15	56.00	20.00	Off
1	10.30	40.30	90.59	Off	24	10.30	38.59	82.00	On
2	10.45	50.09	55.50	Off	25	10.45	49.50	63.69	Off
3	11.00	55.19	54.89	Off	26	11.00	47.00	62.59	On
4	11.15	57.00	49.89	Off	27	11.15	52.39	59.19	On
5	11.30	57.29	47.59	Off	28	11.30	53.59	50.00	Off
6	11.45	56.79	45.59	Off	29	11.45	52.29	50.69	On
7	12.00	57.00	44.29	Off	30	12.00	60.29	42.19	Off
8	12.15	54.00	40.29	On	31	12.15	61.79	36.69	On
9	12.30	56.50	46.89	Off	32	12.30	55.29	35.59	On
10	12.45	58.29	42.59	Off	33	12.45	51.89	39.79	On
11	1.00	58.00	45.39	Off	34	1.00	55.30	40.69	Off
12	1.15	56.39	38.69	On	35	1.15	51.50	41.39	On
13	1.30	49.00	49.39	On	36	1.30	44.69	44.69	On
14	1.45	54.59	44.00	Off	37	1.45	47.39	47.39	Off
15	2.00	56.00	44.00	Off	38	2.00	40.19	41.69	On
16	2.15	55.39	40.69	On	39	3.15	36.39	36.39	On
17	2.30	53.00	39.89	On	40	3.30	47.29	47.29	Off
18	2.45	53.89	41.89	Off	41	3.45	50.00	32.29	Off
19	3.00	53.19	44.69	Off	42	4.00	52.00	31.19	Off
20	3.15	51.19	43.39	On	43	4.15	53.00	30.09	Off
21	3.30	51.79	43.39	Off					
22	3.45	49.89	46.00	On					
23	4.00	40.09	53.89	Off					

Table 2: Performance of loaded SPSD

The average ambient temperature and RH% are 33°C and 32% Respectively. The climate was fair for first 5½ solar hours (Sl.No. 1 to 23, table 7.2). But for the next 5 solar hours (Sl.No. 24 to 43, table 7.2) the climate was cloudy.

TABLE SUGGESTS THAT

- ✓ SPSD has taken 30 minutes time to regain its temperature after loading the wet pupae in it (Sl. Nos. 1 to 3).
- ✓ The weight of silkworm pupae (Chrysalises) is reduced from 16 kg to 4.8 kg, (which is 30% dry matter) in 10 solar hours in the mixed (fair and cloudy) climate conditions.
- ✓ The moisture content of the silkworm pupae is reduced by 11.2 kg H_2O, at the rate of 0.70 H_2O kg^{-1}, in this duration.
- ✓ And, the maximum temperature in loaded SPSD recorded is 61.79°C (Sl.No.31).
- ✓ The maximum and minimum RH values during wet pupae loading time and dry pupae unloading time are 90.59% (Sl.No.1) and 30.09 % (Sl.No.43), respectively.
- ✓ Due to heavy water molecules present in the silkworm pupae, the drying rate during first 5 solar hours to 6 solar hours is minimal. For example, after 5½ solar hours of drying operation (Sl.No.23), the dry rate was only 37%
- ✓ After 8½ solar hours (Sl. No. 38) of drying operation, the dry rate was increased to 64% and after 10 solar hours the pupae was dried up to 70% (Sl. No. 43 and Fig. 7.17).
- ✓ In contrast, for the same quantity of chrysalises and in similar climatic conditions, the open-sun drying practice is needed around 14 to 16 solar hours to achieve the required dry percentage. Hence, the drying time required by SPSD is 62.5% to 71.4% [(=100- ((16-10/16) * 100))] or [(=100-((14-10/14) * 100))] to the open-sun drying practice.
- ✓ Further, when the fan is switched "On", the SPSD cabinet temperature and humidity are reduced and during "Off" position these values are regained. When the fan is "On", the moisture vapors and obnoxious gases will escape through the chimney. In the entire 10 hours of drying operation, the fan runs for ~ 4 hours 30 minutes.

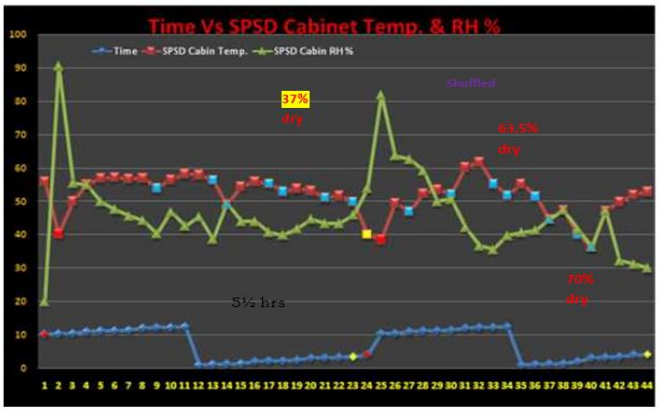


Figure 14: Temperature (°C) and Relative Humidity (%) in fully loaded SPSD (X-axis: Sl.No. and corresponding Time in minutes, Y-axis: T°C And RH %) ◆ Start Time ◆End Time

Graph in Fig. illustrates the cabinet T°C and RH% values at different timings, the pupae shuffled time and the dry percentages at different times etc. Further, it is also noticed that the pupae drying time will be reduced if they are shuffled upside down for every 3 hours. And, by touch it is observed that the dried pupae are oily and like puff-rice. Shown below in Fig. 7.18 is the picture of the dried pupae in SPSD. When 16 kg silk worm pupae was loaded in the SPSD (4 kg in each tray), it is observed that the pupae has lost 70% of moisture in them in 10 solar hours.

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Figure 15: Pupae dried in SPSD

From one of the trays, the silkworm pupae were collected to observe the weight and dry percentage at 3 different instants i.e. at 5½ solar hours, 8½ solar hours and 10 solar hours of drying operation (Sl. Nos. 23, 38 and 43, Table 7.2 respectively). The values are given below.

Weight of the Wet Pupae, W_1 = 4 kg

INSTANT 1: (at 5 ½ solar hours)

Weight of the Dried Pupae, W_2 =2.52 kg

Dry Percentage, D%

= $(W_1 - W_2 / W_1) * 100$

=37%

INSTANT 2: (at 8 ½ solar hours)

Weight of the Dried Pupae, W_2 = 1.46 kg

Dry Percentage, D% = $(W_1 - W_2 / W_1) * 100$

= $(4 – 1.46 / 4) * 100$

= 63.5%

INSTANT 3: (at 10 solar hours)

Weight of the Dried Pupae, W_2 = 1.20 kg

Dry percentage, D% = $(W_1-W_2/W_1)100$

= $(41.20/4)*100$

= 70%

- W_1 is the initial weight of the wet pupae in kg
- W_2 is the final weight of the dried pupae in kg.

Further, experiments that were conducted at Dharmavaram of Andhra Pradesh state during cloudy weather conditions suggest that the SPSD needs 11 solar hours to 12 solar hours to remove the required 70% moisture. It was observed that the drying duration with the SPSD in both summer and winter seasons is satisfactory, when compared with the conventional method of silkworm pupae drying. Further, the pupae in SPSD were clean, odour free and fully protected from insects, birds, animals and dust. It is further perceived by hand feel that the lipid (oil and fat) content of the dried silkworm pupae in the SPSD was not affected.

Figure 16: Conventional open-air sun-drying

In addition, wet pupae were also dried through conventional open-air sun-drying (Fig.7.19), with the same aperture area (of single SPSD tray), ambient temperature, and RH% and in free air circulation. By hand touch it is noticed that the pupae that were dried in open sun took around 14 solar hours to reach desired dry percentage. The final weight of the dried pupae was unaccountable as the pupae were attacked by ants, microbes, and it was difficult to protect them from crows and monkeys. Further, the dust that was accumulated in the pupae also influenced the weight and quality.

It can be noticed from Fig. that the color and texture of the pupae that dried in SPSD are superior when compared with the pupae dried through open-air sun-drying.

IX. ECONOMICS FOR MRM UNITS

Generally, a 10-basin Multi-end Reeling Machine (MRM) Unit with 100 kg cocoons consumption per day produces about 12.5 kg of raw silk and 50 kg to 68 kg of wet pupae with pealed (a thin layer of silk filament that cannot be removed during reeling process). After removal of pelade, about 48.5 kg to 66.5 kg of wet pupae can be obtained.

Every day huge quantity of silkworm pupae is generated through 10-basin, 20-basin or 30-basin reeling units. By selling these pupae, the reeling entrepreneurs are obtaining only Rs.10,000.00 to Rs.15,000.00 per annum as a token amount. But, if the reeling entrepreneurs adopt the SPSD, they can obtain Rs.15.00 to Rs.18.00 through every kg of dried pupae from the oil extractors. Hence, reelers can obtain better revenue from the oil extractors than from the local pupae collectors.

Table 7.3 suggests that the SPSD is another earning source for 10-basin MRM reeling entrepreneurs, as solar dried pupae can generate revenue of ~Rs.84,000.00 per annum. Similarly for 30 basins, the revenue would be ~Rs.2,52,000.00 per annum. Therefore, if reeling entrepreneurs adopt SPSD for their reeling units, they can obtain better revenues from the pupae oil extractors, which would be 5.6 to 8.4 times than their present earnings.

The fan has to be operated for 4½ hours to 5 hours in a 10 hour drying operation. Therefore, a fan of 80 W capacity consumes 360 Wh to 400 Wh per day. Hence, for 300 solar hours (for 30 days, with 10 solar hours / day) power consumption would be 10,800 Wh (or 10.8 units) to 12,000 Wh (or 12 units), which is not taken into consideration while discussing the economics.

Quantity of wet pupae that generate /day kg	Wt. of the 70% dried pupae Kg.	Dried pupae price/kg Rs.	Revenue through dried pupae Per day Rs.	Revenue for 30 days Rs.	Revenue for 350 days Rs.
50	15	30.00	450.00	13,500.00	157,500.00

Table 3: Economics of SPSD for a 10-basin MRM Unit

The manufacturing cost of the SPSD depends on the capacity of the wet pupae to be dried. The manufacturing cost of the SPSD for drying one kg of wet pupae, with the described design factors and with locally available materials is ~Rs.1500.00. Hence, to develop a 50 kg capacity SPSD, it required to spend ~Rs.75,000.00 as one time investment. This cost includes the materials, fan, manufacturing, painting (powder coating) etc. As it may not be needed for the reelers to measure the temperature and humidity of the SPSD cabinet, it is not required to purchase Humidity cum Temperature Indicator that costs ~Rs.9,500.00.

When compared to the manufacturing cost of SPSD and the revenue through it (Table 7.3), the payback period would be ~10 months. Further, the developed 16 kg SPSD needs 2.9729 m^2 (32 sq. ft) area. Therefore, a 50 kg capacity SPSD needs ~9.2903 m^2 (~100 sq. fit) area.

Figure 17: Spikes in Bissu machine

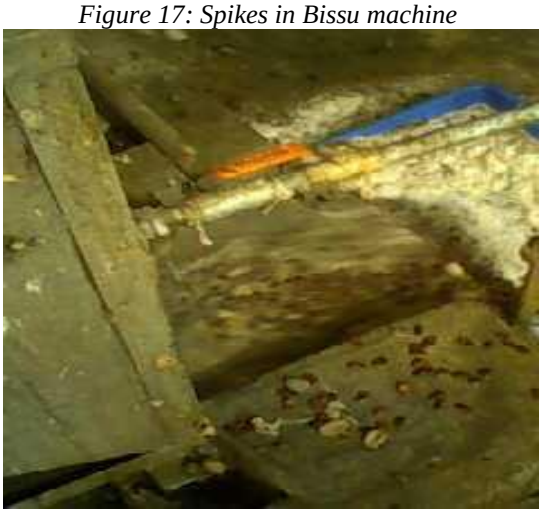

Figure 18: 7.20 Separation of pupae to pierce the pelade

Reelers can manage by their existing crew for pealed removal, loading and unloading of pupae. There is a pleade and pupae separating machine called "Bissu", which can be adopted by the MRM entrepreneurs.

In Andhra Pradesh, for instance, 5000 tons of cocoons are consumed per annum for production of raw silk. Through these cocoons, ~2250 tons of wet pupae and ~675 tons of dry pupae will be generated. Hence, the reelers in A.P. State can acquire additional revenue of ~Rs.1,08,00000.00 (= 675 * 1000 * 16) per annum, through pupae.

Due to its simplicity, faster drying rate and many other advantages, the proposed system is relatively inexpensive. Therefore, commercial application seems to be viable.

Silkworm Pupae are the by-product of the silk reeling industry, which can generate additional revenue for the reeling entrepreneurs with effective management and utilization. In some parts of India and China, the silkworm pupae are regarded as delicious food and are extensively used. In tropical countries, pupae are ruined throughout the drying retro due to enduringly high RH and unexpected rainfalls. Open-air sun-drying is an old-style drying method in these areas, foremost to inadequate product quality. In order to be vendible, the silkworm pupae have to encounter high quality standards. Else the price will weakens.

The silkworm pupae are having high nutritive and medical values and it may be essential to store them for longer periods. It is difficult to restore these values through conventional open-air sun drying system. If the pupae are dried through SPSD, they can be packed, stored and can be exported, as no fungus will be attacked due to removal of 70% moisture from the pupae.

Further, due to various advantages, if the silk reeling sector adopts the Silkworm Pupae Solar Dehydrator for drying the silkworm pupae (Chrysalises), it will not only be beneficial to the entrepreneurs but also eco-friendly.

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