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A Study of The Effect of Temperature Variation on Cocoon Parameters of Muga Silkworm During the Drying Stage by Convection and Infrared Heating.

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ABSTRACT

Designing a system or device to dry Muga cocoons and kill pupa while maintaining the quality of the dried cocoon is a very challenging task, for producing good quality Muga silk. The proposed design includes a system for drying Muga cocoons at a controlled temperature. The paper explains the basic principle of the cocoon drying system that is designed for controlled drying of the Muga cocoon under the specified limits of heating. The dryer is designed mechanically with a steel enclosure, with insulated walls, for heating the inner space with a 1000-Watt convection heater and a 650-Watt Infrared heater. The mechanical performance of this dryer was tested for the effective drying of Muga cocoons using both the convection and IR heating methods. The temperature of the designed dryer was maintained at 70^0, 80^0, 90^0, and 100° C, as required, during the drying stage. Using this dryer, the moisture content of the Muga cocoons was brought to about 6-12% and was maintained at that level. Thus, this dryer was effective and efficient in maintaining a controlled environment for drying the cocoons, thus sustaining the required quality of the dried cocoon for producing quality Muga silk.

Keywords : Muga cocoon, Convection, Infrared, Temperature, Moisture content, Shell ratio, Pupae.

INTRODUCTION

Assam is the largest producer of Muga silk produced by Antheraea Assamensis silkworm in the world. Assam contributes a total of 95% of India's total Muga silk production. However, Muga silkworm cocoons produced by traditional sun-drying systems do not meet global market requirements and cocoon quality becomes very low after drying (Zafar *et al*. 2019). This method cannot control heat, cleanliness, and heating time. Therefore, cocoon quality deteriorates (U sub T *et al*. 2008). This method has a negative effect on the sericin layers of these cocoons and decreases the quality characteristics by exposing cocoons to ultraviolet and infrared rays, which in turn, increase the total reeling losses of cocoons. It was also indicated that the silk filament loses about 50% of its strength if exposed to ultraviolet rays for 6 hours. Several methods of artificial drying have been tried to kill the pupae, by spreading cocoons on perforated mats or in a wire box where they are exposed to steam or water for three hours. After that, the cocoons are subjected to drying. But the method most commonly used for pupae-killing and drying cocoons involves blowing hot air at 50° C to 102° C ± 2° C vertically through a grill on which the cocoons are placed in mesh bags (Hegazy

et al. 2006). Hot-air dryer in comparison with the traditional sun-drying method accelerates the drying of cocoons by killing the pupa inside it (Hendaw *et al*. 2017). Drying Muga cocoons involves killing the pupa inside it and preserving the cocoon for a longer period of time at normal temperature and humidity. When fresh cocoons are placed in the drying machine, water in the cocoon shell evaporates rapidly and heat enters the pupa through the shell. After the pupa is dead, generally 10 minutes later the pupa's body evaporates. Cocoon drying continues gradually and when the desired amount of water has evaporated, the speed of drying is reduced relative to the decrease of moisture until drying is completed. The drying temperature impacts the cocoon shell and its resultant raw silk yield. For example, if the temperature exceeds certain limits, sericin degenerates, and concurrently efficiency, reliability, and raw silk percentage decline. It is advisable to observe the following limits: For hot air drying 115° C ± 5° C is recommended in contact with the cocoon. For steam-heat drying 102° C ± 2° C is the preferred guideline (Safarov Jasur *et al*. 2018). While setting a higher finishing temperature increases drying efficiency, the melting point of sericin declines when the drying rate exceeds 50 percent. The finishing temperature should be reduced gradually from 60° C in hot air drying and 55° C in steam-heat drying (Mubashar Hussain *et al*. 2011). Sun-drying kills the pupa but it shows inferior reeling performance and raw silk quality compared to hot-water drying and oven method.

This paper describes the design of a Muga cocoon dryer using convection and Infra-Red heating methods under a controlled temperature. The study may lead to a major solution to the technological and physical challenges faced during the traditional methods of drying Muga cocoons. This work may provide a better alternative to conventional Muga cocoon drying, in order to improve the quality of the raw silk and the reeling performance.

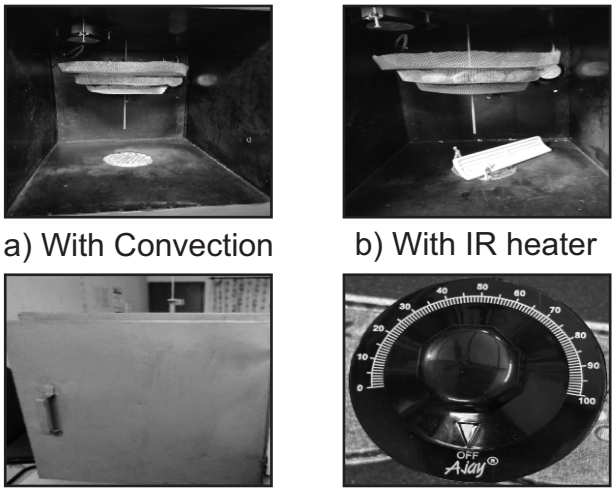
MATERIALS AND METHODS

The Muga cocoon samples were collected from different regions of Assam and were used for experimentation. A mechanical dryer was designed, fabricated, and used for stifling Muga cocoons. The studied drying system consised of a drying chamber enclosed with three stacks made of netted steel. The mechanical dryer consised of five main parts: the drying frame, a drying rack, a heating source with a temperature control unit (Energy regulator), and an air-cooling system (processor fan), as shown in Figure 1. The drying frame was constructed using a plain sheet with dimensions of 50 cm X 50 cm X 50 cm as shown in Figure 1. The three sides of the dryer were covered with 5 cm thick steel sheets and insulated with fiberglass to reduce heat loss. The fourth side was the door of the dryer with a thickness of 2.5cm and it was also insulated to avoid heat loss. The main dryer frame was attached with two heating sources (Convection and Infrared) alternately. A 1000 W Convection heater and a 650 W Infrared heater were used as heating sources alternately inside the drying chamber and the performance of both was observed. An industrial thermometer in the range of 0-110˚C was installed on the back side of the drying frame to continuously monitor the temperature. The drying rack

consisted of three netted racks made of steel. A 10-inch diameter rack was attached in between a 12-inch and 8.5-inch diameter rack. The racks were stacked together such that the higher diameter rack was installed at the top and the lower diameter rack was installed at the bottom to avoid the Muga cocoon from falling down while shuffling as shown in the Figure 2. A 6 mm steel shaft was attached with screws and nuts at the center of the three racks to continuously shuffle the Muga cocoons during the drying process. A 0-100 scale (1000 Watts) energy regulator was used to control the temperature of the heating sources. The air-cooling system consisted of two processor fans (50/60Hz, 0.08A) installed inside the heating chamber. One fan was installed at the top and another was installed at the back side of the dryer so that air would be circulated uniformly for each drying rack inside the drying chamber. This air-cooling system helped the temperature of the drying chamber to cool down slowly and to circulate the air around the drying racks.

Experimental Procedure

Freshly harvested Muga cocoons were collected from different parts of the state of Assam and were used in this investigation. A batch of 10 cocoons was taken to conduct the experiment each time. The study was performed at four different levels of temperatures, *viz*., 70˚, 80˚, 90˚, and 100˚ C, and the moisture content of dried cocoons was studied manually for these different levels of temperature. The dryer was heated up to each temperature level for a certain time period until the cocoons got dried to the expected level. The cocoons were placed in medium and small trays for drying them using both convection and IR heating methods separately. In the convection heating method, the energy regulator was adjusted initially at 30 scales and then increased by 5 scales every 5 minutes. In both the convection and IR heating methods, the temperature was monitored every 5 minutes using the Industrial Thermometer. The heat treatment was stopped as soon as the temperature reached its desired level and the two processor fans inside the dryer were switched on immediately for uniform circulation of air. When the dryer would reach its cooling temperature of approximately 50˚C the door would be opened and the dried cocoons would be collected from the trays. For each treatment, the collected cocoons were weighed using a digital balance after and before drying to calculate different cocoon parameters.



a) With Convection b) With IR heater

c) Drying frame d) Energy regulator

Figure 1: Images of the designed drying system

The moisture content of the dried Muga cocoons could be calculated using the formula:

%Moisture content = [(w - d)/d] X 100

where *w* = initial weight of the cocoon and *d* = dried weight of the cocoon.

Cocoon weight is the approximate measure

of the raw silk obtained from the dried reeled cocoons (Mahadevappa, D *et al*. 2000). In the present study, a sample of 10 cocoons was taken and this sample represents the entire quality of individual replicate. The individual weight of the cocoon was measured for 10 cocoons and an average of weight was considered as the approximate weight of the dried cocoon. The cocoon weight was measured in grams. The shell weight represents the total quantity of silk in a Muga cocoon. The average single shell weight was calculated from 10 shells used for the measurement of cocoon weight. The cocoon shell ratio represents the amount of silk present in a single cocoon and it is expressed as a percentage. It can be calculated as follows:

Cocoon shell ratio (%) = {(Weight of the cocoon shell)/ (Weight of the entire cocoon)} x 100

RESULTS AND DISCUSSIONS

3.1 Effect of temperature on moisture content, cocoon weight, shell weight, and shell ratio

The moisture content of the Muga cocoon was studied and compared at four different levels of temperature, *viz*., 70˚, 80˚, 90˚, and 100˚C for both Convection and IR. Cocoon moisture content was decreased with an increase in temperature for both the Convection and IR heating methods. The average moisture content, cocoon weight, shell weight, and shell ratio of the cocoon at different temperature levels are shown in Table 1. It was observed from Figure 2 that the moisture content of the Muga cocoon dried using the proposed drying system is optimal (6-12%) at 100˚C for both Convection and IR heating methods. However, Table 1 and Figure 2 represented that the IR heating method provides a more accurate moisture content compared to the Convection method as the moisture content was 10.8% at 100˚ C which was in the range of optimum value suitable for producing quality Muga silk and preserving the Muga cocoon for longer period of time [1]. Figure 3 represented that the cocoon weight gradually decreased as the temperature of the dryer increased. A maximum value of 1.14 gm at 70˚C and a minimum value of 0.56 gm at 100˚C was recorded using the Convection heating method. Similarly, a maximum value of 1.71 gm at 70˚C and a minimum value of 1.04 gm at 100˚C was recorded using the IR heating method for the proposed system design.

Table 1: Cocoon parameters with respect to temperature for convection and

Heating Method	Temp (^{0}C)	Average Cocoon weight (gm)	Average Shell weight (gm)	Average Shell Ratio (%)	Average Moisture content (%)
Convection	70	1.14	0.56	49.1	44.4
	80	0.75	0. 40	53.33	39.12
	90	0.63	0.39	62	20.73
	100	0.56	0.37	66	13.2
IR	70	1.71	0.85	49.7	29.37
	80	1.33	0.76	57.1	29.36
	90	1.15	0.725	63	15.5
	100	1.04	0.70	67.3	10.8

It was observed from Figure 5 that the average shell ratio varied approximately linearly with respect to temperature. Figure 4 and 5 represented that the shell weight and shell ratio obtained from the cocoon dried using the IR heating method gave a more accurate result. The maximum shell ratio obtained at 100˚C for convection and IR methods were 66 per cent and 67.3 per cent respectively. Whereas the minimum shell ratio obtained at 70˚C for the Convection and IR methods were 49.1 per cent and 49.7 per cent respectively. It was observed from the present study that the optimum levels of moisture content, cocoon weight, shell weight, and shell ratio were obtained at 100˚C for both Convection and IR heating methods

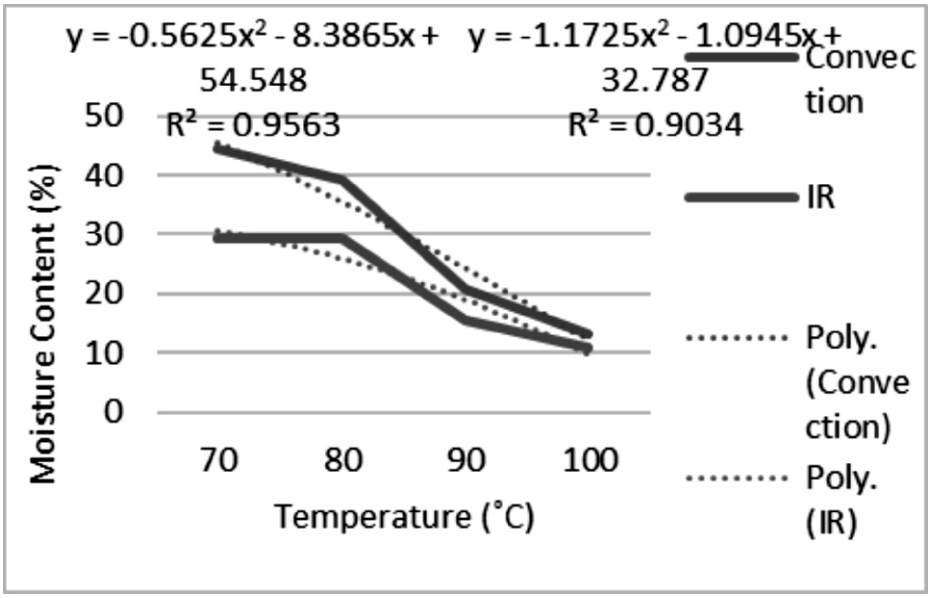


Figure 2: Temperature vs. Moisture content graph

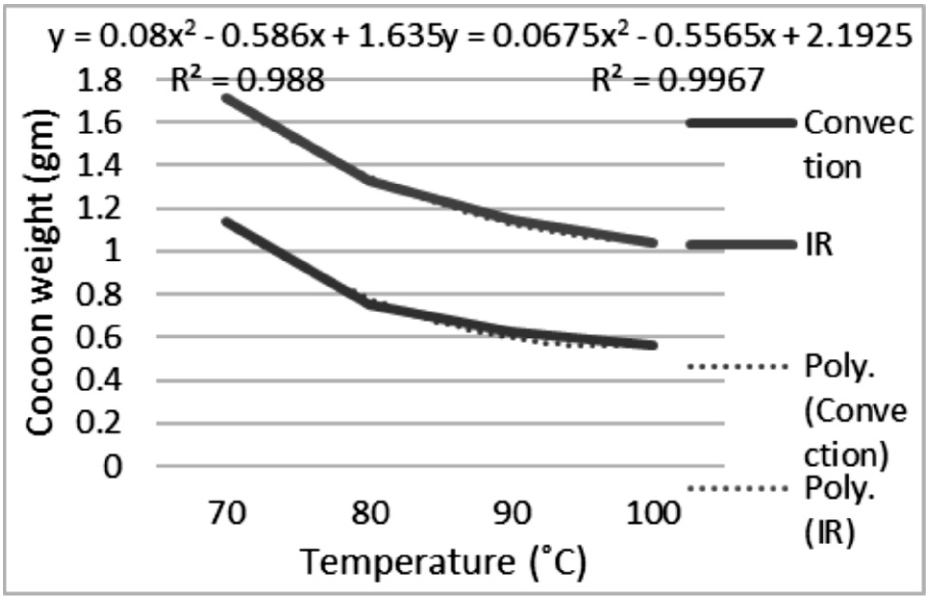


Figure 3: Temperature vs. Cocoon weight graph

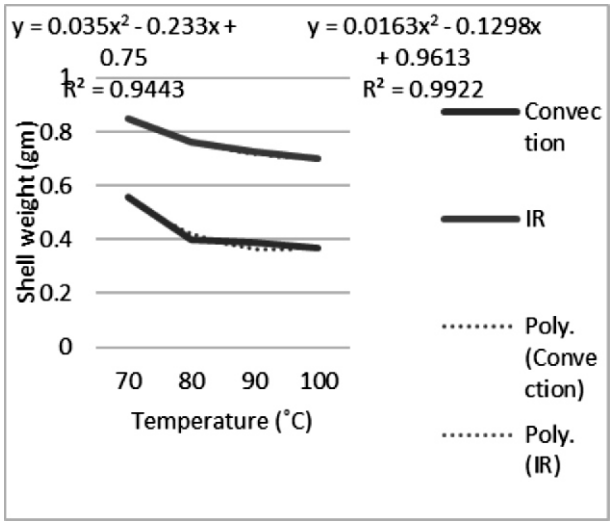


Figure 4: Temperature vs. Shell weight graph

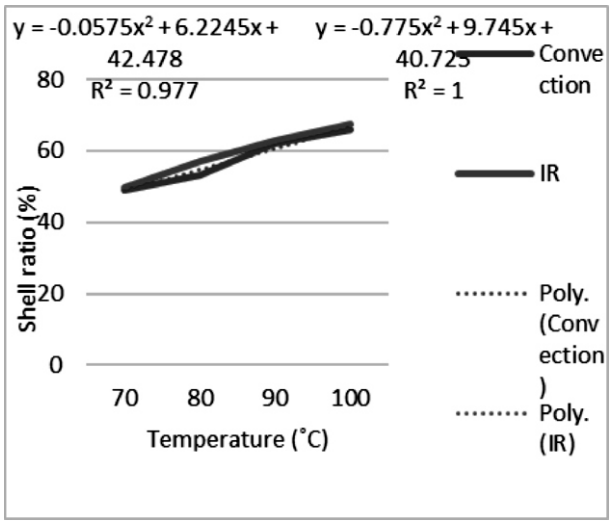


Figure 5: Temperature vs. Shell ratio graph

3.2 Effect of temperature on drying time

The effect of temperature on the time of drying Muga cocoon is shown in Table 2. It can be observed from Figure 6 that the drying time of the Muga cocoon increased approximately linearly with temperature. Figure 6 also implied that the IR heating method was a bit faster than the Convection heating method while drying the Muga cocoon.

Table 2: Effect of temperature on time

Heating Method	Temperature (^{0}C)	Time (mins)
Convection	70	15
	80	16
	90	17
	100	18
IR	70	12
	80	13
	90	14
	100	15

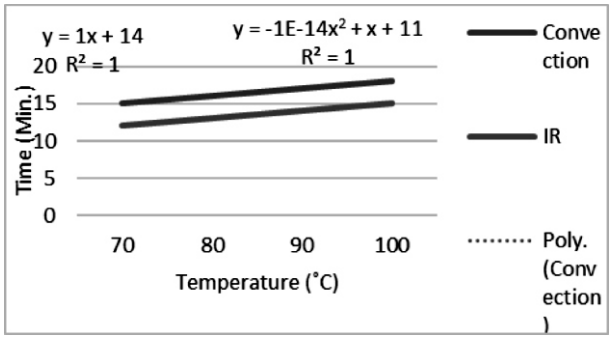


Fig. 6: Temperature vs time graph

CONCLUSION

The effect of temperature on different cocoon parameters can be seen from the results of the experiment conducted for the drying of Muga cocoons using the Convection and IR heating methods. It can be observed that when the temperature is increased for both methods the quality of the cocoon improves with regard to the moisture content, cocoon weight, shell weight, and shell ratio. The temperature of the designed dryer was maintained at 70˚, 80˚, 90˚, and 100˚C, as required, during the drying stage. Using this dryer moisture content of the cocoon was maintained at 6 - 12% at the temperature level of 100˚C. Therefore, the designed system would be an efficient and appropriate one for drying Muga cocoons in a controlled environment, to maintain the optimum values of different parameters such as cocoon weight, shell weight, and shell ratio. It can be concluded from the comparative study of Convection

and IR heating methods for the four different levels of temperature (70º, 80º, 90º and 100˚C) that both the methods would be efficient for drying Muga cocoons at a maximum temperature of 100˚C while maintaining the quality of the Cocoon for producing good quality Muga Silk. The study also implies that the designed dryer using the IR heating method is the more energy-efficient method as compared to the Convection at a low cost for drying Muga cocoon due to its less consumption of energy. Moreover, it provides a safe environment inside the drying chamber, as the heat generation of the IR heater is more localized. The performance of the IR heating method is also faster than the Convection heating method. Hence, the controlled IR heating method can be a better choice for drying Muga Cocoons, for maintaining a high quality of dried cocoons for Muga silk production.

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