STUDIES IN THE USE OF SOLAR ENERGY IN PREPARATION OF COTTON AND SILK FABRICS

by
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To Kamlesh Gupta ....

My inspiration
My strength
My weakness
My mother

Certificate

This is to certify that the thesis entitled *"Studies in the Use of Solar Energy in Preparation of Cotton and Silk Fabrics"* being submitted by Mr. Sanjay Gupta to the Indian Institute of Technology, Delhi for the award of the degree of Doctor of Philosophy is a record of bonafide research work carried out by him under my guidance and supervision.

To the best of my knowledge this thesis has reached the required standard. The material presented in this thesis, in part or full has not been submitted to any other University or any other Institute for the award of degree or diploma.

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S. Gupta

(Sanjay Gupta)

ABSTRACT

Textile processing involves a highly energy intensive set of processes consuming 60-80% of the total energy consumed by the textile industry. The preparatory processes i.e., desizing, scouring and bleaching account for nearly 20-25% of this share. The low grade heat required for these processes is produced using high grade fuels like coal and oil leading to high wastages, as conversion efficiencies are only 2-4%. Search is on for an alternate source of energy to provide this low grade heat, which will not only result in more efficient utilization of energy but will also save the precious high grade fuels.

Such a source is available in the form of solar thermal energy. Flat plate collectors, solar hot boxes and simple concentrators available today, commercially, have the potential to provide the low grade heat needed for textile wet processing. During the last decade few attempts have been made to tap this perennial source of energy for use in textile industry.

In the field of preparatory processes also, recent advances have made possible the combining of two or more processes. These single stage or two stage preparatory processes are flexible in terms of chemical concentrations, treatment time and temperatures. This means the fabric is not damaged even under adverse treatment conditions. The preparatory treatment for silk is called degumming whereby sericin is removed from the fibroin. A large number of degumming agents are being used all over the world, and the treatment conditions are almost similar. 1-2 hours at 95°C, depending on the grade of silk.

This thesis is an attempt to integrate the two technologies, to device solar thermal systems suitable for single and/or two stage preparatory processes for cotton and for degumming of silk; to study the performance of solar systems and the properties of the fabrics processed in them with respect to conventionally prepared fabrics; and to optimise the treatment conditions.

A solar *hot-box* type collector with double glazing and a booster mirror, termed *solar oven* was used for the experiments. The hot-box of the oven has been used for storing the samples padded in a chemical formulation meant to give combined Desizing and Scouring. Fabrics padded in the liquor were sealed inside a transparent, Polypropylene

bag and stored in the oven for 3 hours.

Two sets of fabric were tested. One during the winter period when the oven temperature was less than 100°C and second during the summers when the temperature was higher. Fabrics were tested for absorbency, strength loss and whiteness. All properties were comparable to that of the conventionally prepared one when the temperatures were less than 100°C. Temperatures above 100°C affected the whiteness adversely.

A pad-batch process was used for single stage desizing, scouring and bleaching of cotton fabrics in the solar oven. A self emulsifiable solvent based scouring agent was used along with H_2O_2 for this purpose. An attempt was made to analyse the solar oven for heat transfer coefficients which were used along with other variables to develop the performance equation of the oven. Performance equation was used to predict fabric temperature.

A regression analysis was carried out to determine the relationship between the process variables i.e., time, temperature of treatment and bleaching agent concentration. The results were used to optimise the treatment conditions.

Temperature of the solar oven varies with the incoming solar radiation. Hence it is not possible to measure the kinetics of peroxide consumption. However, it is instructive to determine the average rate on days when the temperature in the oven varies the least. Therefore, average rate of decomposition of peroxide has also been calculated.

A conventional kier was modified and integrated with a *solar hot water system*. The resultant machine was called as *solar kier*.Elements of fluid mechanics and heat transfer were used to design the storage tank and heat exchanger for the solar system. Number of collectors required to supply the desired energy were calculated for all the months in a year and the maximum number were taken. The system passed through several developmental stages during which the heat exchanger and kier vessel were modified.

Some 28 batches were processed in the kier using the self emulsifiable solvent based scouring agent and hydrogen peroxide. Samples were tested for strength loss, absorbency and whiteness; and optimum treatment conditions worked out. Eleven batches were then processed under the optimised treatment conditions.

Cost of the process as compared to conventional 3-stage process and low temperature single stage process have been worked out. The fabric processed in the solar kier shows lower processing cost.

The 20 kg solar kier was scaled up to a capacity of 100-125 kg. Heat exchanger length and number of solar collectors required were calculated as before.

The system was set up in a local processing unit (East India Cotton Mills, Faridabad, India) and semi-commercial trials were taken on various qualities of fabric and thread. The kier was found to be suitable for processing of yarns, threads and fabrics as well.

In the solar kier, although conventional thermal energy was completely replaced by solar thermal energy, electrical energy was still used to drive two pumps. For silk degumming a *thermosiphon* system was envisaged that works independent of any form of conventional energy.

A recipe based on carbonate - bicarbonate buffer was used to degum Mushirdabad silk. To estimate weight loss a calibration curve was prepared by making standard samples and staining them with a direct dye. K/S values were plotted against the weight loss to give the calibration curve. Also estimated were the strength (in warp and weft direction) whiteness and yellowness indices. The properties of these samples were compared with the samples prepared using commercial degumming agents like Marsaille soap, Japanese soap and an Italian product called Sapojet seta.

It was found that when solar insolation is weak(like in winters) a booster mirror is required to provide the necessary temperatures in the degumming vessel. Degumming is inadequate below 90°C. Treatment time of 2-3 h is sufficient to achieve satisfactory results.

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