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UTILIZATION OF SILK WASTE AND RECLAIMED SERICIN FOR MAKING PAPER LIKE NONWOVENS

SUMMARY

Silk is a natural protein fibre reeled from the cocoon of the silk worm *Bombyx mori*. During the process of reeling silk from cocoons, about 25 to 30 % of silk waste is generated. Some of the silk waste is being used to make floss, spun silk and noil silk but a huge quantity is exported without further processing. Value addition to silk waste can generate additional employment, increase the income of the reeler and bring in more foreign exchange. This paper describes a simple, bio-inspired method of utilizing silk waste to produce paper-like nonwovens. Natural binders have been employed including sericin, the gummy silk protein, which is normally discharged into textile wastewaters. The eco-friendly nonwovens were evaluated for appearance, bursting strength, tensile strength, tearing strength, air permeability, etc. They were found to be aesthetically appealing and possessing functional properties. Based on their properties some possible commercial applications have been suggested.

Silk is a natural textile fibre. It is reeled from the cocoon of the silkworm *Bombyx mori*. The cocoons consists of two proteins: fibroin the silk filament and sericin the glue that binds the filaments. India reels about 24000 MT of raw silk annually through rural based cottage industry (1). During reeling operations, defective cocoons, parts of normal cocoons which cannot be reeled are removed as waste. Silk waste accounts for 25 to 30 % of the raw silk produced (2). Silk waste is sold at a very nominal price (less than 2% of total returns) for conversion into floss, spun or noil silk (3&4). Also, a huge quantity of silk waste is exported without further processing / value addition as alternative methods to utilize the silk waste are not available.

Broadly, nonwovens are fibrous web structures in which the fibers are bonded together by mechanical entanglement, thermal fusing or chemical bonding. Silk nonwovens were previously developed from silk waste by needle punch process which mechanically interlocks the fibers in the web (5). This method requires huge investment in terms of mechanization. Silk nonwoven was also prepared by water stream entanglement which had a satisfactory liquid absorbency and softness suitable for medical supplies such as surgical gauzes (6). In Japan some laboratories have developed silk papers in different colors for making craft flowers and lamp shades (7). Sericulture industry should look at the utilization of silk fiber in total for innovative marketable products for modern society's application and appreciation (8). Applied research on product diversification followed by publicity and marketing strategies would enhance the returns of the silk reeling industry through value addition and employment generation.

In this paper, silk waste nonwovens are developed in a simple, eco-friendly manner using locally available binding materials, including sericin. Sericin constitutes 25% of raw silk and is removed by the degumming process and discarded into waste water (along with the chemicals used for extraction) to expose the bright and lustrous silk filament. The extracted sericin was reused to bind the fibroin together, just as in a cocoon, to form a nonwoven. As no huge machinery is required, this method offers a scope for employment generation and enhancing income through value addition. These nonwovens were evaluated for appearance and mechanical properties and found to be suitable for developing novel high end products.

EXPERIMENTAL

Web Formation

Reeling waste was dried and cleaned by removing extraneous matter. Sericin was extracted in hot water under high pressure without the use of chemicals. The extracted sericin was recovered (for use as a binder) by filtration followed by partial evaporation. The s fibres were dried and opened by hand (Fig 1). A known weight of fibres was spread out randomly in a predetermined area to form an even web. Both un-dyed and dyed silk wastes were used for this purpose. Dyeing was carried out using vegetable dyes namely turmeric and mulberry fruit extracts.

Fig. 1 Degummed silk waste.

Web Bonding

The fibers in the web were impregnated with different binders such as (i) sericin extracted from the waste silk, (ii) starch (tapioca) based binder, (iii) sap of the silver oak tree. The binders were used in their colorless form and also by adding natural coloring agents. After application the web was allowed to dry at room temperature for 24 hours. Some of the nonwovens are shown in Figure 2.

Fig. 2 Nonwovens from silk waste.

Testing

The nonwovens were subjectively evaluated for appearance (sheen) and texture (hand). They were tested for grammage (mass), thickness, air permeability, crease recovery, tear strength, bursting strength, tensile strength, and abrasion resistance based on BIS methods of evaluation for textiles. The percentage composition was calculated from the conditioned weight of fiber and that of the nonwoven (fiber plus binder weight). For comparison, a handmade paper was also tested for all parameters similarly.

RESULTS AND DISCUSSION

Table - 1 : Composition and subjective analysis of nonwovens and handmade paper

#	Nonwovens/ Handmade paper	Percentage composition		Sheen		Tactile property	
		Silk	Binder	Silky	Dull	Cloth-like	Paper-like
1	Silk-Sericin nonwoven	81	19	v			v
2	Silk-Starch nonwoven	74	26	v		v	
3	Silk-Silver oak sap nonwoven	70	30	v			v
4	Handmade paper	-	-		v		v

The nonwovens consist of 81 to 74% silk waste and 19 to 26 % binder, which is in the range of the natural fibroin/sericin ratio in the cocoon. The ratings of appearance and hand show that the nonwovens are silky in appearance and mostly paper-like to the touch. Whereas the handmade paper evaluated was judged dull in appearance.

Table 2 : Mechanical parameters of nonwovens and handmade paper

#	Mechanical Parameter	Testing equipment	Silk-Sericin nonwoven	Silk-Starch nonwoven	Silk-Silver Oak sap nonwoven	Hand made paper	SE ±	CD 95%
1	Grammage (g/m^2)	Electronic balance	123	127	140	209	1.48	4.45
2	Thickness (mm)	Micrometer	0.81	0.79	0.95	0.65	0.05	0.16
3	Density (g/cm^3)	Calculated	0.996	1.003	1.330	1.350	-	-
4	Tear strength (N)	Elmendorf tester	15.06	15.06	12.55	1.30	0.36	1.09
5	Bursting strength (kPa)	Mullen type	1168.2	639.0	964.3	486.1	68.47	206.39
6	Tensile strength (N) (Strip test)	UTM	62.66	128.62	84.30	50.10	6.79	20.48
7	Abrasion resistance (% loss in grammage)	Martindale tester	2.16	4.09	3.57	0.51	-	-
8	Crease recovery angle (degree)	CRA tester	80	110	85	25	3.48	10.48
9	Air permeability (m^3/m^2/min)	at 10mm pressure drop	2.65	23.31	1.00	0.20	1.70	5.12

The calculated density of the nonwovens was in the range 1.00 to 1.33 g/cm^3 and that of the handmade paper was 1.35 g/cm^3. The tear strength of the nonwovens is significantly higher than that of the handmade paper evaluated. Similarly, the bursting strength of the nonwovens is at least 30% higher. The higher strength is attributed to the high intrinsic tenacity of silk fibers (34gf/tex) and the longer fiber length and their random alignment. The tensile strength of the nonwovens and handmade paper are not significantly higher, except in the case of the starch based nonwoven. It may be inferred that the binder type and quantity also influence the strength parameters of the nonwovens. The nonwovens are thus lighter yet stronger than the handmade paper. They offer better abrasion resistance. This implies that any friction or rubbing action on the surface of the nonwovens is likely to affect them less severely than the paper. Air permeability and therefore porosity varies widely between the nonwovens and it may be influenced by the type of binder used. Air permeability is an essential factor for applications as in wall paper (so that the glue dries up completely after pasting), protective covering, certain packaging, filtration, etc. The capacity to recover from creasing is significantly higher in the nonwovens than handmade paper. This suggests that the nonwovens provide a clean, wrinkle free area and find applications where a clear surface is preferred such as in the case of envelopes, file covers, gift carry bags, etc.

Geometric, strength parameters and functional properties of the nonwovens are quite different from that of the handmade paper evaluated, although they have a paper-like feel. The silk waste nonwovens have a silky appearance, adequate strength and functional properties.

CONCLUSIONS

Nonwovens were developed from silk waste by a simple, women-friendly method. The silk protein, sericin was used as a natural binder in their preparation. The nonwovens may be used for making exclusive cards, lamp shades, wall hangings, specialty file cover and handicrafts. They may be coated, calendared and finished to impart additional characteristics like water resistance and fire resistance, for a wider application as in decorative silk panels for table tops, doors, partitions, veneer blinds and molded fancy products. Nonwovens are fast becoming the preferred substrate for wallpaper (9) and those made from waste silk will have aesthetic advantage, besides being eco-friendly.

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