PREPARATION OF NATURAL SILK WASTE SOLUTIONS BY HIGH FREQUENCY HEATING

Iroda Nabieva[1], Bakhtiyar Sadriddinov[1], Makhfuza Khasanova[1], Khalima Alimova[1], Kaisa Klemola[2] & John Pearson[3]

[1]Tashkent Institute of Textile and Light Industry, Uzbekistan,
[2]Kuopio Academy of Design, Finland,
[3]University of Huddersfield, UK,
Tashkent Institute of Textile and Light Industry: Shohjahon 5, 700100 Tashkent, Uzbekistan; tel: 00 7 371 530606; fax: 00 7 371 533617; e-mail: niroda@bk.ru
Kuopio Academy of Design, PL98 Piispankatu 8, FIN-70101, Finland; tel: 00 358 17 308 111; fax: 00 358 17 308 222; e-mail: Kaisa.Klemola@designkuopio.fi
University of Huddersfield, Queensgate, Huddersfield HD1 3DH, UK; tel: 00 44 1484 472114; Fax: 00 44 1484 472826; e-mail: j.s.pearson@hud.ac.uk.

Abstract

Natural silk waste is an important by-product of the silk industry in Uzbekistan. Solutions to the problem of natural silk waste have been used to improve the properties of the locally produced polyacrylonitrile fibre. Nitron, and the effectiveness of this dissolution process, are very important to the textile industry in Uzbekistan. Previous methods used to dissolve natural silk waste have been time-consuming and relatively inefficient. This paper describes a new method for dissolving natural silk waste, using a high-frequency electromagnetic field.

Key words:

natural silk waste, high-frequency electromagnetic field, Nitron, polyacrylonitrile

Introduction

A major concern of the textile industry is the need to make the most efficient use of natural fibres, particularly in terms of recycling waste material from the textile processing sequence. This is of increasing importance in developing countries such as Uzbekistan, where the re-use of textile waste can contribute significantly to the national economy in terms of increasing production rates and minimising the adverse ecological effects of production.

Uzbekistan is a major producer and processor of raw silk, the major processing area being in Fergana-Namganam [1]. A significant amount of silk waste is produced, which is mainly processed in factories in Tashkent and Margilan. Silk waste itself arises from damaged cocoons or from cocoons which are difficult to unreel, together with waste fibre from the processes preparatory to spinning. Around 70% of silk waste can be processed in the same way as raw silk [2], but the remaining 30% is unsuitable for such processing. Izgorodin & Alimova [3] have used X-ray analysis to compare the properties of raw silk and silk waste, Kannan [4] has described the origin and properties of silk waste, while Reliovsky [5] has reviewed the uses made of silk waste and Mizzau [6,7] has analysed current and possible future market trends in the silk waste sector, stating that the world-wide production of silk and silk waste is decreasing.

Nitron acrylic fibre is also produced in Uzbekistan, and can be used in 100% form or in blends with cotton. This paper describes a new method for preparing a solution of the natural silk waste which cannot be processed by conventional methods. These solutions are produced for the modification of Nitron fibres in order to improve their textile properties, particularly moisture absorption and the anti-bacterial properties of products made from blends of Nitron with cotton (for instance, the specific electrical impedance of Nitron fibres is 3.9×10^9 ohm/g, while that of Nitron fibres which have been modified by the authors using a treatment with a solution of natural silk waste is 6.4×10^6 ohm/g). Such modification should also increase the range of dyes which can be applied to Nitron fibres and products. Indeed, Khamraev *et al* [8] have described the modification of Nitron fibres with silk waste, including a review of the dyeability of the modified fibres. Dyeability is of particular importance when developing products made from blends of Nitron with cotton. Overall, the ability to use the previously unsuitable silk waste produced in Uzbekistan for modifying Nitron fibres in order to develop commercially viable products will be beneficial to the Uzbekistan economy.

Natural silk waste

Raje & Rekha [9] have described the classification of silk waste and how silk fibroin may be separated from the waste, while Babadzhanov *et al* [10] have described methods for regenerating sericin and fibroin from silk waste using sodium thiocyanate in the presence of isopropyl alcohol (propan-2-ol). Raje *et al* [11] have described the extraction of fibroin from silk waste in the form of a powder using formic acid and calcium chloride or using lithium bromide, and have described possible uses for this powder. Much research into producing stable solutions of silk fibroin from silk waste has also been carried out at the Tashkent Institute of Textile and Light Industry (TITLI; [12]). Vaymarn [13] has considered neutral salt solutions as being the most effective solvents for producing synthetic fibroin yarns, but such solutions became unstable in a relatively short time. A solution of sodium rodanide (51.5%) with urea, dimethyl sulphoxide and ethylene diamine has been used to investigate the properties of regenerated fibroin [14].

A new method for producing solutions of natural silk waste using high-frequency heating

The current methods used by TITLI to dissolve silk waste take 6 to 8 hours [15], which limits the economic efficiency of the process. The new method described here is intended to be quicker and therefore more efficient than the existing processes, and aims at producing a more homogeneous solution more quickly by using a directional external electromagnetic field. As a result of applying this field, the dipole moment of the fibre-forming macromolecules causes them to vibrate in the field. The temperature of the material rises rapidly and uniformly, leading to a more rapid dissolution of the natural silk waste. In order to produce an electromagnetic field of appropriate strength, a High Frequency MSD-242 Unit was used with an electromagnetic frequency of 2,450 MHz.

A comparison of the standard method used for dissolution and the current method is shown in Table 1 below:

Table 1. A comparison of the standard and HF-field dissolving methods for natural silk waste

Type of natural silk waste	Standard dissolving method		HF field dissolving method	
	Dissolving time (h)	Type of solution	Dissolving time (m)	Type of solution
fuzz	6 – 8	Brown	25	Brown
Strip	6	Light brown	25 – 35	Light brown
Canvas	7	Brown	25 – 35	Brown
pelades	5	Indistinct, including undissolved material	-	-

The results shown in the table demonstrate that dissolution times for the new method are up to 20 times faster than when using the conventional method.

Modification of Nitron fibres using a solution of natural silk waste produced by the HF-field method

Nitron fibres were modified by treatment with an HF-field-produced solution of natural silk waste in both freshly-produced liquid and dried forms. Fibre modification was carried out using the technique developed at TITLI. Previously formed pills made from pressed fibre were treated at 70^{o}C in a modifying bath containing natural silk waste solution (dried fibres were treated at 90^{o}C) for 3 minutes. The pills were then re-pressed, dried at 100^{o}C, and thermo-fixed at 130-140^{o}C for 2 to 3 minutes.

Relationship between the natural silk waste content of Nitron fibres with their dyeability

Modified and unmodified Nitron fibres, both freshly-formed and dried, were dyed using direct dyes. The results (Table 2) showed that modified fibres take up more dye than unmodified fibres. The increase in dye uptake was shown to be directly related to the concentration of natural silk waste in the modifying bath.

Table 2. Effect of the method of preparing natural silk waste solutions on the dyeability of Nitron fibres modified with these solutions (NSW = natural silk waste solution)

Fibre samples	Intensity of dyed fibres (K/S)
Untreated fibre	3.79
Modified freshly-formed fibre (NSW dissolved in HF-field)	20.6
Modified freshly-formed fibre (NSW dissolved at 116 C)	23.7
Modified dried fibre (NSW dissolved in HF-field)	7.87
Modified dried fibre (NSW dissolved at 116^{o}C)	9.50

These results show that modifying Nitron fibres with a natural silk waste solution increases their dye uptake, and that the effect is most significant in freshly-formed Nitron fibres. This effect is due to the interaction between amino- and hydroxyl groups in the macromolecules of the natural silk waste at the elevated temperatures used in thermo-fixation. Natural silk waste solutions modify the surfaces of Nitron fibres, loosening the surface structure, and thus leading to an acceleration of the dye sorption process. This loosening of the surface structure can occur as a result of sorption of calcium chloride during previous processing (kiering), and also as a result of pores and interstices in the Nitron fibres becoming filled by fragments of fibroin. This is confirmed by the data shown in Table 3:

Table 3. Effect of modification of Nitron fibres with solutions of natural silk waste (NSW) on fibre structural properties

Structure indicators	Untreated fibres	Fibres modified by NSW solutions
Fibre density (kg/m^3)	0.0114	0.015
Specific surface area (m^2/g)	0.40	0.53
Total vacuum volume (cm^3/g)	0.13	0.14
Vacuum radius (A^o)	12.0	63.0

These results indicate that, as the temperature increases, the contribution of entropy increases, leading to an increase in dye-fibre affinity at high temperatures. Moreover, the unfixed components of the modifying bath move from both internal and external parts of the Nitron fibre structure during dyeing. This, in turn, leads to an increase in fibre porosity and an increase in the dye sorption capacity of Nitron fibres.

Conclusions

The dissolution process of natural silk waste in a high-frequency electromagnetic field was investigated. The dissolution time was significantly reduced. Nitron fibres modified by such solutions of natural silk waste showed an increase in dye uptake similar to that achieved by using standard dissolution methods. The new dissolution method is therefore seen to be a quicker and more efficient and cost-effective method for producing solutions of natural silk waste for subsequent modification Nitron fibres intended to be blended with cotton.

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