http://www.pjbs.org

PJBS

ISSN 1028-8880

Pakistan Journal of Biological Sciences

ANSInet
Asian Network for Scientific Information
308 Lasani Town, Sargodha Road, Faisalabad - Pakistan

Pakistan Journal of Biological Sciences 10 (16): 2732-2735, 2007
ISSN 1028-8880

Effects of Ultrasound Irradiation on Wet Wool Chlorination Treatment

Ramin Khajavi and Pedram Azari
Tehran South Branch, Islamic Azad University, Tehran, Iran

Abstract: In this study ultrasonic energy is applied for improving wet wool chlorination treatment one of the most well-established methods for reducing wool shrinking related to the felting. Sodium hypochlorite used for providing active chlorine in chlorination bath and samples chlorinated in the presence and absence of ultrasonic irradiation with equal processing parameters. The concentration of active chlorine during the treatment, shrinkage percentage, friction and some mechanical properties of treated samples determined and compared. Scanning Electron Microscope used for investigating the effects of different treatments on removal of wool scales. According to the results it was concluded that applying ultrasonic energy causes desirable mechanical and chemical effects in chlorination process. Cavitation phenomena causes more abrasion on wool surface especially on sharp places i.e., scales and the formation of hydrogen peroxide in ultrasonic bath managing the aggressive reaction of active chlorine on cuticle.

Key words: Ultrasonic energy, sonochemistry, wool, scale, cavitation, active chlorine

INTRODUCTION

The term wool refers to the fiber from the fleece of the sheep or lamb or hair of angora or Cashmere goat and may include the so-called specialty fibers from the hair of the camel, alpaca, llama and vicuna. The characteristic surface feature of a wool fiber is overlapping surface cells commonly called scales. As many as 700 scales may cover 1 cm of wool fiber. All scales, which make up the cuticle of the wool fiber, point toward the fiber tip (Hatch, 1993).

Scales act as a barrier for water and chemicals absorption and cause shrinking felting shrinking. Its removal is causing more absorption and shrink proofing but on the other hand may lead to catastrophic deterioration of mechanical properties. There are essentially three general approaches that have been used to shrink proof and or descale woolen textiles. These are pretreatment with oxidizing agents, reducing agents or solvents, treatment with oligomers or polymers and combinations of the first two. Approaches using oxidizing agents are the oldest method and are effective because the cuticle of wool fiber is softened or degraded by oxidation and among oxidation processes chlorination treatment is one of the most widely used (Vigo, 1994). Originally chlorination of wool was a preparatory treatment for increasing the absorption of dye in printing and it was not understood that it will decrease wool shrinkage at the same time. Chlorination of wool reduces the differential frictional effects by oxidizing and smoothing scales (Simpson and Crawshaw, 2002; Trotman, 1970).

Ultrasonic energy offers many potential advantages such as energy savings and reduced processing times, environmental improvements, process enhancement and lower overall processing costs. Ultrasound appears to be a very promising alternative technique to provide a far more efficient stirring/mixing mechanism for the immediate, border layer of liquid at the fiber's surface. Generally, sonication of liquid causes two primary effects, namely, cavitation and heating. When microscopic cavitation bubbles collapse at the surface of the solid substrate, they generate powerful shock waves that cause effective stirring/mixing of the adjusted layer of liquid (Blanchard *et al*., 2004). The common features of using ultrasound is: Cutting and sewing (Dermott, 2001), textile wet processing (Michielsen and Beckham, 2004; Vouters *et al*., 2004), elimination of polyester fiber oligomers (Cunko *et al*., 2001), preparation of non-woven fabric reinforced polyacrylonitrile (Hirata *et al*., 1992), low temperature dyeing of polyester (Bhatlacharya, 2000; Kamel *et al*., 2005), dyeing polyamide/lycra blend (Merdan *et al*., 2004), enzyme treatment of cotton fabric (Yachmenev *et al*., 1999), worn out process (Khajavi *et al*., 2007) and etc.

According to the literature survey, ultrasonic energy has been used in a wide variety of applications, including wet textile treatments which are intensive energy and water consuming process (Moholkar *et al*., 2002 and 2003a). In this study ultrasonic irradiation is used for improving the wet chlorination process of wool and its produced chemical and mechanical effects on wool fabric studied.

Corresponding Author: Ramin Khajavi, Tehran South Branch, Islamic Azad University, Tehran, Iran

MATERIALS AND METHODS

Experiments were done at Science and Research Campus of Islamic Azad University in 2006. Ultrasonic bath made by SA Iran (PARSONIC 2600s, 2.6 lit and 27 kHz). The effect of ultrasound energy on releasing rate of active chlorine recorded in different times. The amount of available chlorine in solution was estimated by titration with 0.1 M sodium thiosulphate (Trotman, 1970).

Chlorination process (40 min in chlorine solution at 40°C) accomplished with two different active chlorine concentrations (0.1 and 0.2 g L^{-1}) and pH conditions (acidic with pH = 5 and neutral with pH = 7) both in the presence and absence of ultrasonic waves. The required amount of sodium hypochlorite (for reaching to 0.1 and 0.2 g L^{-1} active chlorine in solution) added periodically in four parts (time intervals = 10 min) starting at the beginning of chlorination process. At the end of each experiment the samples were treated with sodium metabisulfite (2% owf and 15 min at 45°C) to eliminate any residual chlorine.

Marking out method (BS 4931), Inclined plane and ASTM D 2256 (gauge length 500±5 mm and time 20±3 sec) methods were used for calculating the shrinkage percentage, measuring friction of fabric and determining some yarn mechanical properties orderly (Savile, 1999).

RESULTS AND DISCUSSION

It was expected that the rate of releasing active chlorine and consequently the amount of produced hypochlorous acid which causes falling of pH increases in ultrasonic bath. However according to the results (Table 1) it revealed that there is no significant difference between the values of active chlorine and pH in ultrasonic and conventional baths. It is due to the interaction of ultrasound with water which causes production of hydrogen peroxide, an important subsidiary substance which controls the amount of active chlorine. Water irradiation using ultrasound causes decomposition of the water molecules into extremely reactive radicals HO and H which in turn recombining and forming hydrogen peroxide and molecular hydrogen. This product makes the release rate slow according to reaction 1 (Ince *et al*., 2001; Moholkar *et al*., 2003a, b; Vajnhandl and Marechal, 2005). According to Table 1 data the presence of fabric in the ultrasonic bath cause increasing the rate of pH declining. As in the absence of entrapped air, textiles do not have any individual impact on the ultrasound wave; it is due to the consumption of hydrogen peroxide by wool (Datar *et al*., 1996a, b; Moholkar and Warmoeskerken, 2003b).

$$H_2O_2 + NaOCl \rightarrow NaCl + H_2O + O_2 \quad (1)$$

According to the shrinkage results of wool fabric in Table 2 it is seen that ultrasound facilitate the shrinkage of wool fabric during chlorination process. It is related to the intensification of water turbulent in ultrasonic bath and is useful for reducing subsequent shrinkages (Moholkar *et al*., 2003a; Warmoeskerken *et al*., 2002).

As it was expected according to friction results (Table 2) it is seen that the unprocessed sample have the highest amount of friction coefficient (highest value of tan θ = μ). Although the scale removal was performed better in presence of ultrasonic energy, samples showed higher friction coefficients in compare with corresponding samples due to more shrinkage during the process.

Table 1: Active chlorine and pH measurements in different times *

	Without ultrasonic energy				With ultrasonic energy			
	Without fabric in chlorination bath		With fabric in chlorination bath		Without fabric in chlorination bath		With fabric in chlorination bath	
Time (min)	Active chlorine conc. (g L^{-1})	pH	Active chlorine conc. (g L^{-1})	pH	Active chlorine conc. (g L^{-1})	pH	Active chlorine conc. (g L^{-1})	pH
0	4.26	9.43	4.26	9.20	4.26	9.45	4.26	9.23
8	4.26	9.39	3.55	9.18	3.90	9.42	3.55	9.26
16	3.90	9.37	3.55	9.11	3.90	9.36	3.55	9.02
24	3.90	9.33	3.40	9.06	3.90	9.35	3.40	9.01
32	3.90	9.33	3.20	8.99	3.90	9.33	3.20	8.96
40	3.90	9.30	3.20	8.93	3.55	9.24	2.84	8.91

*The concentration of active chlorine at the beginning was 4.26 g L^{-1}

Table 2: Shrinkage percent and angles of inclined plane θ for different chlorinated samples

	Without ultrasound waves				With ultrasound waves			
	Shrinkage mean (%)		tan θ = μ *		Shrinkage mean (%)		tan θ = μ *	
Active chlorine concentration (g L^{-1})	Neutral condition	Acidic condition	Neutral condition	Acidic condition	Neutral condition	Acidic condition	Neutral condition	Acidic condition
0.1	2.48	3.22	0.42	0.38	4.08	5.39	0.46	0.45
0.2	3.42	4.33	0.34	0.36	4.37	6.36	0.40	0.37

*The angle of inclined plane θ of raw sample = 0.6

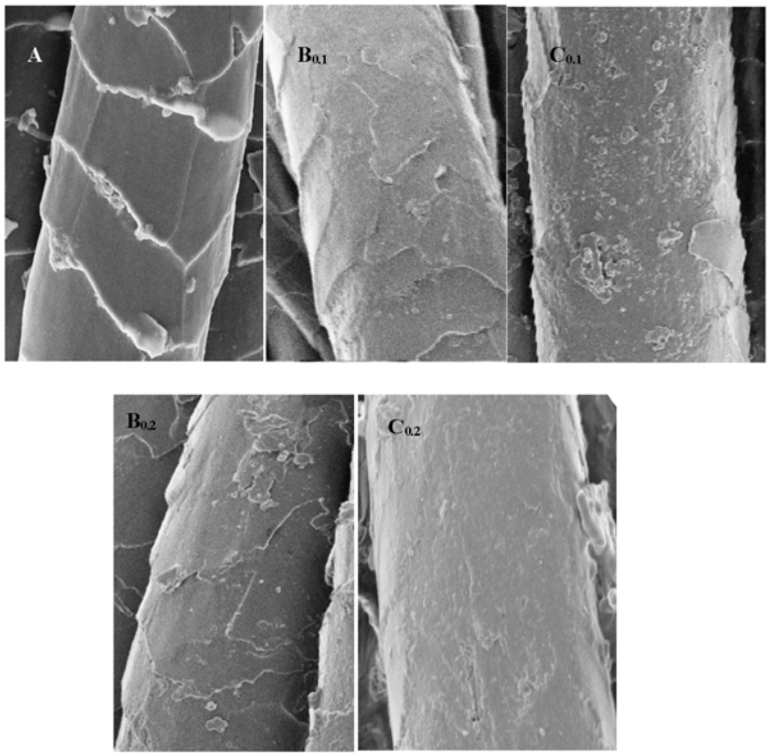

Fig. 1: SEM micrographs of different wool treated fibers, A) Raw sample, $B_{0.1}$ and $B_{0.2}$) Conventional treated, $C_{0.1}$ and $C_{0.2}$) ultrasonic irradiated samples, *Subscripts numbers are active chlorine concentrations (g L^{-1})

Table 3: Mechanical properties of different chlorinated samples

Mechanical property	Concentration of active chlorine (g L^{-1})	Without ultrasound waves		With ultrasound waves	
		Natural condition	Acidic condition	Natural condition	Acidic condition
Load (N)	0.1	10.10	10.20	10.60	10.75
(Raw sample =11.8)	0.2	10.20	10.34	10.50	10.70
Work of rupture (N.M)	0.1	0.38	0.39	0.39	0.39
(Raw sample = 0.40)	0.2	0.33	0.39	0.34	0.39

Chlorination process causes damages to cuticle layer of wool and hence deterioration of strength and work of rupture in general (Table 3) and there are many studies in this field to prevent of sever damages (Lenting *et al*., 2006). But according to the results in Table 3, the declination of mechanical properties in ultrasonic bath is less than conventional bath. The work of rupture is almost equal for different samples due to a balance between tensile strain and tenacity.

SEM micrographs (Fig. 1) shows that descaling of wool is intensified in ultrasonic bath, besides the kind of descaling, which can be related to cavitation phenomena and enormous shear forces are generated on the bubbles collapse specially in liquid/solid interface. Shock waves produced on cavity implosion cause direct erosion on the soild's surface (Vajnhandl and Marechal, 2005). The scales of wools are like sharp tips on wool surface causing more collapsing of bubbles in these places and hence more abrasion. It means that in contrast to conventional bath that the effect of chlorination is equal for all places on wool fiber surface, in ultrasonic bath the effect of oxidation is intensified on the edge of scales and hence less damage to main body of wool fibers and deterioration of mechanical properties. Apparently the amount of descaling is equal for samples $B_{0.2}$ and $C_{0.1}$ in Fig. 1. It suggests that with using ultrasound the concentration of active chlorine can be reduced.

CONCLUSIONS

Ultrasound chlorination treatment like any other ultrasound-assisted wet textile process intensifies diffusion and convection of medium liquid in the inter-yarn and intra-yarn pores of the fabric and hereby improves the uniformity and efficiency of the process. According to the cavitation phenomena and more collapsing of cavitation bubbles at the edge of scales, damages to the body of wool fibers can be more controlled and removing of scales can be attained with less concentration of chemicals. Applying of ultrasound in wet chlorination process causes formation of some useful chemicals such as peroxide hydrogen which is useful for controlling the concentration of active chlorine and removing the residual chlorine at the end of process.

REFERENCES

Bhatlacharya, S.D., 2000. Low temperature dyeing of polyester. Man-Made Textile in India, 43: 479-482.

Blanchard, E.J., A.H. Lambert and V.G. Yachmenev, 2004. Use of ultrasonic energy for intensification of the bio-preparation of greige cotton. National Textile Centre Annual Report.

Cunko, R., M. Andrassy and E. Pazelj, 2001. Elimination of polyester fiber oligomers using ultrasound waves. Texsciance, 1: 62-64.

Datar, G.V., P. Bankslee and P.L. Grady, 1996a. Acoustical properties of fabrics in low-tensity ultrasound. Applied Acoustics, 47: 345-350.

Datar, G.V., P. Bankslee and P.L. Grady, 1996b. Acoustical properties of fabrics in high-tensity ultrasound. Applied Acoustics, 47: 345-350.

Dermott, M.C., 2001. Sonobond Ultrasonics Cutting and Sewing System. Westchester, USA.

Hatch, K.L., 1993. Textile Science. West Publishing Company, United State of America, pp: 141-143.

Hirata, S.H., K.M. Muto and H.H. Ohya, 1992. Preparation of non-woven fabric reinforced polyacrylonitrile. J. Chem. Eng. Japan, 25: 716-722.

Ince, N.H., G. Tezcanli, R.K. Belen and I.G. Apikyan, 2001. Ultrasound as a catalyzer of aqueous reaction systems: The state of the art and environmental applications. Applied Catalysis B: Environmental, 29: 167-176.

Kamel, M.M., R.M. El-Shishtawy, B.M. Yussef and H. Mashaly, 2005. Ultrasonic assisted dyeing III. Dyeing of wool with lac as a natural dye. Dyes and Pigments, 65: 103-110.

Khajavi, R., B. Novinrad and A. Kiumarsi, 2007. The effect of ultrasonic on the denim fabric worn out process. Pak. J. Biol. Sci., 10: 645-648.

Lenting, H.B.M., M. Schroeder, G.M. Guebitz, A. Cavaco-Paulo and J. Shen, 2006. New enzyme-based process direction to prevent wool shrinking without substantial tensile strength loss. Biotechnol. Lett., 28: 711-716.

Merdan, N., M. Akalin, D. Kocak and I. Usta, 2004. Effects of ultrasonic energy on dyeing of polyamide (micro fibre)/Lycrablends, Ultrasonics, 42: 165-168.

Michielsen, S. and H.W. Beckham, 2004. Fundamental investigation of ultrasonic effects in textile wet processing. Textile Centre Annual Report, pp: 173-182.

Moholkar, V.S., M. Huitema, S. Rekveld, M.M.C.G. Warmoeskerken, 2002. Characterization of an ultrasonic system using wavelet transforms. Chem. Eng. Sci., 57: 617-6290.

Moholkar, V.S.V.A. Nierstrasz and M.M.C.G. Warmoeskerken, 2003a. Intensification of mass transfer in wet textile processing by power ultrasound, AUTEX Res. J., 3: 129-138.

Moholkar, V.S. and M.M.C.G. Warmoeskerken, 2003b. Acoustical characteristics of textile materials. Textile Res. J., 73: 827-837.

Savile, B.P., 1999. Physical Testing of Textiles. Woodhead Publishing, pp: 174-175, 278-279.

Simpson, W.S. and G.H. Crawshaw, 2002. Wool Science and Technology. Woodhead Publishing, pp: 60-85 and 219-224.

Trotman, E.R., 1970. Dyeing and Chemical Technology of Textile Fibers, Charles Griffin and Co. Ltd., pp: 187-188 and 260-300.

Vajnhandl, S. and A.M.L. Marechal, 2005. Ultrasound in textile dyeing and the decolouration/mineralization of textile dyes. Dyes and Pigments, 65: 89-101.

Vigo, T.L., 1994. Textile Processing and Properties: Preparation, Dyeing, Finishing and Performance. 2nd Edn., Elsevier Science, Netherland, pp: 266-268.

Vouters, M.P., P. Rumeau and Tierce S. Costes, 2004. Ultrasounds: An industrial solution to optimize costs, environmental requests and quality for textile finishing. Ultrasonis Sonochemistry, 11: 33-38.

Warmoeskerken, M.M.C.G., P. Vandervlist, V.S. Moholkar and V.A. Nierstrasz, 2002. Laundary process intensification by ultrasound. Colloids and Surfaces A: Physicochemical Engineering Aspects, 210: 277-85.

Yachmenev, V.G., E.J. Blanchard and A.H. Lmbert, 1999. Study of the influence of ultrasound on enzymatic treatment of cotton fabric. Textile Chemist Colorist American Dyestuff Rep., 1: 47-51.