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Mini Review

A Review of Some Current Trends in Wool Research

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Abstract

The article explores some significant recent researches in wool. Attempt has been made to overcome the drawback associated with conventional protease enzyme treatment on wool. Wool fabric has been treated with protease enzyme obtained from novel isolated bacteria and commercial protease enzyme, and the results have been compared. A new method has been adopted for coloration of wool fabric through heat treatment under an inert atmosphere. It can not only give new color to the fabric but also minimize pollution, because it is water and dye free. The influence of various factors like temperature, time and different inert atmospheres(nitrogen,argon) used in the heat treatment on wool fabric color has been investigated. The bending stiffness, crease recovery angle, and tensile testing have been used to analyze the mechanical properties of wool fabric before and after heat treatment. The color fastness to soaping and light of wool fabric after inert atmosphere heat treatment were compared with that of traditional basic yellow dyed wool fabric.

Keywords: Wool; Coloration; Inert atmosphere; Proteas; Physical properties; *Bacillus*

Introduction

Enzymes are being increasingly being used in the textile industry. They are being used to develop cleaner processes and reduce the use of raw materials and the production of waste. The enzymatic processes are performed at much lower temperatures and use less water compared with classical methods [1]. Enzymes like amylase, laccase, pectinase, lipase, protease, catalase, and xylanase are used in different processing steps. Proteases constitute one of the most important groups of industrial enzymes, accounting for approximately 60% of the total enzyme market [2]. Proteases(peptidases or proteolytic enzymes) are degradative enzymes that catalyze the cleavage of peptide bonds in other proteins and are classified according to their structure or the properties of their active site. A variety of proteases are available, like, serine-, metallo-, carboxyl-, acidic-, neutral-, and alkaline proteases. Proteases are obtained from plants, animal organs, and microorganisms, with the majority obtained from bacteria and fungi. *Bacillus* species are the main producers of extracellular proteases, and industrial sectors frequently use *Bacillus subtilis* to produce various enzymes [3]. Proteases are widely used in leather processing, the detergent industry, food industries, bioremediation processes, the pharmaceutical industry, the textile industry, waste processing companies, the film industry and other sectors [4]. Wool is a natural fibre that has been used since time immemorial. It is largely used in the textile industry owing to its elasticity, hygroscopicity and thermal insulation, soft handle and reliable mechanical property [5-8]. But, because of the particular hydrophobic lipid layer on the surface of the wool fibre, it causes much difficulty for wool dyeing, which requires a great deal of fresh water and energy and is a negative influence in the textile industry [9-11]. Some physical and chemical methods try to modify the surface of the wool to solve this problem but this brings economical and ecological problems [12-15]. After dyeing the color fastness is an important parameter to evaluate the quality of wool fabric. To improve the color fastness is another big problem in the wool fabric dyeing process.

Comparative study on protease application using commercial and novel bacterial enzymes

In textiles, natural wool clothing has the tendency to shrink, and felting is unwelcome by customers. Washable wool is today's requirement. Wool's felting properties are due to its scale-like surface structure [16]. Wool fiber consists of three parts: the epidermis, cortex,and medulla layer. Wool fibers are highly resistant against enzymes compared with other protein fibers. The resistance comes from the disulfide (cysteine) bridges between the macromolecules. Disulfide bridges are reduced with reducing agents; wool keratin macromolecules are cleaved by trypsin and proteolytic enzymes such as papain as soon as they form polypeptides. The important point here is that enzymes work their way into wool fibers with large molecular structures and reveal the interior to the surface due to the shredding effects of the enzyme. The antifelting effect of fibers can be good rather than harmful. Protease treatments can modify the surface of wool and silk fibers to provide new and unique finishes [17]. Protease enzymes can be used to produce an antifeltingeffect, to remove the fiber ends protruding from the surfaces of woolen fabrics, to reduce pilling, and to increase brightness and smoothness. The combination of these effects in worsted wool causes weight loss to occur, and when using the selected pH, temperature, and process time, a reduction in enzyme concentration should be kept to a minimum. The dyeability of wool fabric treated with the enzyme is increased. The enzymes were observed to work at lower temperatures. They could also be made bio-clean.Over the last several decades, the textile industry has greatlyimproved in environmental, economic and product qualityaspects by using commercial enzyme preparations. Enzymeshave become an indispensable part of textile processing andare used in a wide variety of applications in the modern textileindustry [18]. Proteaseenzymes have been used to increase the end-use potential of coarse woolfibres [19]. It has been found

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thatprotease-treated wool had a higher degree of whiteness,lower feltingtendency, and improved dyebility [20]. Mojsov(2017) treated the wool fabric with different concentrationsof protease enzyme and observed the effects on wool fabric [21]. The environmentallyfriendly enzymatic treatment has been studied for wool fibre and fabric withdifferent proteases and other enzymes [22]. Some researchers reported that enzyme pretreatment ondyed wool fabrics improved softness, handle, drape, pillingresistance, and change the colour [23-25]. Different proteolytic enzymes from *Bacillus* lentusand *Bacillus subtilis* in native and the soluble polymer Polyethyleneglycol (PEG)-modified forms were investigated andtheir influence on the modification of wool fibres werestudied, as a result Scanning Electron Microscope (SEM)images of wool fibres confirmed smoother and cleaner fibresurfaces without fibre damages using PEG-modified proteases [26]. Thefibre destruction is caused by the diffusion and the hydrolyticattack of the native proteases onto non-keratinous partsof the protein fibre [27-29] showed that the native proteases diffuse deep into thewool fibre and causing no significant modifications on theouter fibre surface. The higher rate of native enzyme diffusioninto the inner part of the fibre resulted in almost completedegradation of the fibre at longer incubation time(180 min) [30]. It has been reported that the isolation of wool degrading B. thuringiensisL11, partial characterization of extracellular proteases, kineticsof production and potential application of bacteria forfabric treatment, and studies of physicalproperties on woolfiberand -fabric have been showed promising results for thetextile industry [31]. It has been stated that the treatment ofwool fabric with Perizym-AFW improved shrink resistance,whiteness, pilling behavior, dye ability, and wash ability [32]. Research has demonstrated a moderateimprovement in shrinkage behaviour of wool by enzymaticpretreatment, and has achieved successful results [33]. The use of enzymes to improve white colour, shrinking behaviour, dyeing affinity, pilling behavior in the woollen sector isparticularly interesting [34,35].

It has been focused to isolate *Bacillus* sp. with a highprotease producing capacity from soils, to investigate theeffects of different partially purified enzymes and commercialprotease enzyme on the physical properties (weight loss, pilling, tear strength, and color) of woolen fabric, so thatthe effect of both enzymes will be compared [36]. Enzymes provide the desired effect on wool fabric without harming the material structure of the fabric. Hence, Proteinase-based treatments had a positive effect on fabrics and it is potential alternative to chemical treatments. The effects of protease from novel isolated *Bacillus subtilis* 168 E6-5 and commercial protease treatments of wool fabrics were compared and, *Bacillus* protease enzyme yieldedimprovements in the physical properties of wool fabric. It may be suitable for potential textile and other industrial applications.

Influence of inert atmosphere for the heat treatment coloration of wool fabric

Heat treatment is a novel environment friendly method for dyeing due to it being water- and dye free [37]. Pioneers have tried to use heat treatment for dyeing cellulose materials, such as wood, to increase the color homogeneity and avoid chemical dye [38-40] The mechanism of dyeing is attributed to the degradation and oxidation of the hemicelluloses and elluloses [41,42]. In the chemical fiber field, the carbon fiber precursor Polyacrylonitrile (PAN) is a typical example of color change after heat treatment; the color of PAN fiber changes from white to brown after the oxidation process, and then to black after heat treatment under high temperature for carbonization.Some researchers also used wool for heat treatment. InMichlik's research, wool yarns were heated to 120-180ºC in the air; the color changed to yellow, but themechanical properties were reduced significantly [43]. In a previous study on wool fiber heat treated under nitrogen, the color changed to yellow successfully and, due to the protection of nitrogen, the mechanical properties did not decrease much compared to fiber heated under air. In this article, heat treatment was used to color the wool fabric under two inert atmospheres (nitrogen and argon) [44]. This novel method will not use any chemical or synthetic dyes and does not need any water during the treatment process. The color strength (K/S) of wool fabric could be controlled by heating time, heat temperature and heat atmosphere. The bending stiffness, crease recovery angle, mechanical properties and color fastness were investigated. The results show that the fabric could be colored yellow successfully through the heat treatment method. By controlling the temperature and time, the color of the treated wool fabric can be adjusted from light yellow to brownish yellow. The fabric has reliable mechanical properties and good color fastness, and therefore shows a great potential for use in the textile industry in water-deficient areas.

This work has demonstrated that heat treatment under an inert atmosphere could color the wool fabric to yellow successfully. By controlling the temperature and time, the color of the treated wool fabric can beadjusted from light yellow to brownish yellow. By comparing the heat treatment under nitrogen and argon in the same conditions, the fabric obtained under nitrogen showed a deeper color [45]. The bending stiffness and crease recovery angle performance were improved and positively correlated with the heat treatment temperature and time. The fabric treated under argon was softer and more elastic compared to the fabric treated under nitrogen. The contact angle of the wool fabric after the treatment would decrease first and then increase with the increasing temperature. In addition, the tensile strength of the wool fabric decreased with increasing heat treatment temperature and time under both nitrogen and argon atmospheres. The TSR of the treated wool fabric was generally higher than 80% that of the untreated fabric, which is a reliable strength for use in textile field. The breaking elongation also decreased. Finally, the fabric also showed a good color fastness to soaping. The heat treatment method for coloring wool fabric is an environment friendly dyeing method that does not need any chemical and synthetic dyes. The mechanical properties and color fastness of the fabric are reliable and could be used in the textile industry. The method does not need water during any part of the process, which could make it possible to color wool fabric in a water-deficient area. In conclusion, the heat treatment method for color wool fabric has a great potential for future textile fields.

Conclusion

Wool fabric has been treated with protease enzyme obtained from novel isolated bacteria and commercial protease enzyme, and the findings have been compared. The tear strength, pilling changes in delta E values, whiteness values, yellowness values of wool have been controlled. The findings reveal that the treatment with *Bacillus Subtilis* 168 E6-5 protease enzyme yielded improvements in the physical properties of wool fabric as against enzyme commercially available. The findings on the influence of inert atmosphere for the heat treatment coloration of wool fabric reveal that the K/S value of wool fabric treated with a nitrogen and argon atmosphere increased with the increasing temperature and time. Under the same heat treatment conditions, the maximum K/S value of fabric heat treated under nitrogen was higher than that under argon. The bending stiffness and crease recovery angle performance were improved and positively correlated with the heat treatment temperature and time. The samples treated under the same conditions under nitrogen showed higher bending stiffness and a lower crease recovery angle than under argon. The contact angle of the wool fabric after the treatment would decrease first and then increase with the increasing temperature.

The tensile strength of the wool fabric would decrease with increasing temperature and time of the heat treatment in both nitrogen and argon, and the tensile strength of the wool fabric after treatment was higher than 80% of the original tensile strength, although the breaking elongation decreased. The color fastness to soaping and light of wool fabric after inert atmosphere heat treatment were better than for the traditional basic yellow dyed wool fabric. Therefore, the use of inert atmosphere heat treatment to endow wool fabric color is a potential research direction.

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