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Grafting of prepared chitosan–poly(propylene) imines dendrimer hybrid as a biopolymer onto cotton and its antimicrobial property

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ABSTRACT

Cotton was successfully treated by chitosan––dendrimer PPI hybrid (CS–PPI) using pad-dry-cure method. Scanning electron microscope (SEM), Fourier transform infra red (FTIR) and weight gain analysis clearly confirmed that CS–PPI was grafted on cotton through the formation of new chemical bonds. Due to the presence of CS–PPI on the surface of cotton, the weight gain of cotton was ~6% increased, and consequently the antimicrobial activity of the treated fabrics under optimum conditions was raised. As a worthy phenomenon, the treated cotton with CS–PPI in a concentration of 20% on the weight of the fabric was shown 100% of bacterial reduction.

Introduction

Q2 Although, water absorbency, dyeing ability, stability, air permeability, biodegradability, and no static electricity in cotton makes that as a good candidate in textile industry, high holding moisture of cotton makes that susceptible to microbial attack [1,2]. Microbial enzymes can readily hydrolyze the polymer linkages of cotton, and especially attack to the additives of textiles. This attack causes to discoloration and damage of the textile's functional properties such as elasticity and tensile strength [3].

Nowadays, the rising demand of humans for comfortable, clean, and hygienic textile goods with the protected property of the body against fungus and bacteria is an essential requirement for the production of antimicrobial textiles [4–6]. For the achievement of these ideal purposes in textile industry, the following points should be considered for choosing the antimicrobial agents: no adverse effect on the color, compatible with human skin, lack of environmental problems and high operation speed against microorganisms and stability resistant to repeated washing. It is well known that chitosan is one of the best candidates in this scope [7].

Chitosan is a bio-polymer with many distinctive features such as bio-degradability, non-toxicity, cationic nature, and antimicrobial activity [8–10], and has various applications in textile dyeing and finishing processes. Unfortunately, bonding between textile and chitosan in alkaline conditions is weak and provides the loss antimicrobial activity and the poor durability of textile. This problem creates some disadvantages in widespread applications of chitosan [5,7,11]. To overcome these problems, two methods are generally applied for using of chitosan on textiles; the first includes the treatment of glyoxal, glutaraldehyde or citric acid as the cross linking agents between chitosan and textiles. These agents increase the durability of chitosan on textile [12,5,13]. In the second procedure; several modifications on chitosan structure is carried out. The modification includes the grafting of attractive multifunctional macromolecules such as sugars, cyclodextrin, crown ether and dendrimer with chitosan. This grafting provides the stronger linkages between chitosan and textiles and enhances the durability and the efficiency of chitosan properties on textiles such as antimicrobial, guest-molecule carriers and chelating [14–16].

Dendrimers, as the mono-disperse building blocks and acceptable bio-compatible materials, are perfect guest-molecule carriers [17,18] and have been recently used for the modification of chitosan in medicine, biology and dye removal applications [19–21].

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To our knowledge, no report has been presented on the grafting of CS–PPI on cotton fabric. So, in this study, CS–PPI was applied on cotton fabric according to the pad-dry-cure method for the first time. The effects of the operational parameters such as pH, time processing, CS–PPI and CA concentrations on the grafting process were evaluated by RSM technique. FTIR and SEM analysis were used to confirm the formation of new chemical bonds between CS–PPI and cotton fabric. The antimicrobial properties of treated fabrics were examined by *Escherichia coli* (*E. coli*) and *Staphylococcus aureus* (*S. aureus*) microorganisms. In addition, based on the finding of this study, some attempts were done to propose a grafting mechanism for this process.

Experimental

Materials and equipments

Plane cotton fabrics with weft/cm: 36 and warp/cm: 32 (density: 150 g/m^2) were utilized in this study. Chitosan was received by Kitotak Co. (degree of deacytilation (DD): 85%, M_W: 1000 kDa, Iran). Nonionic detergent (Lotensol, Hansa) was used to scouring fabrics. All other chemicals were used in their laboratory-grade (analytical reagents, Merck).

SEM graphs were prepared using the AIS-2100 scanning electron microscope (Seron Technology Co). All the samples were coated with gold before SEM testing. FTIR spectra were recorded on a Nicolet Nexus 670 instrument using KBr pellets under standard operating conditions. The measurements were performed at 20 °C and a relative humidity of 65%.

Preparation of CS–PPI

Chitosan was dissolved in aqueous solution, containing acetic acid and water/methanol. Ethyl acrylate was added to the solution. After stirring at 50 °C for 10 days, the reaction mixture was quenched and then was precipitated in acetone which was saturated with $NaHCO_3$. The precipitate was collected by filtration, and then the filtrates dispersed in saturated H_2O with $NaHCO_3$. The resulting mixture was dialyzed against H_2O, and lyophilized to give *N*-carboxyethyl chitosan ethyl ester. For the preparation of *N*-carboxyethyl chitosan, the prepared ethyl ester was added to NaOH solution; the mixture was stirred for 2 h, dialyzed, and lyophilized as above. The precipitated powders were obtained in quantitative yield (95%).

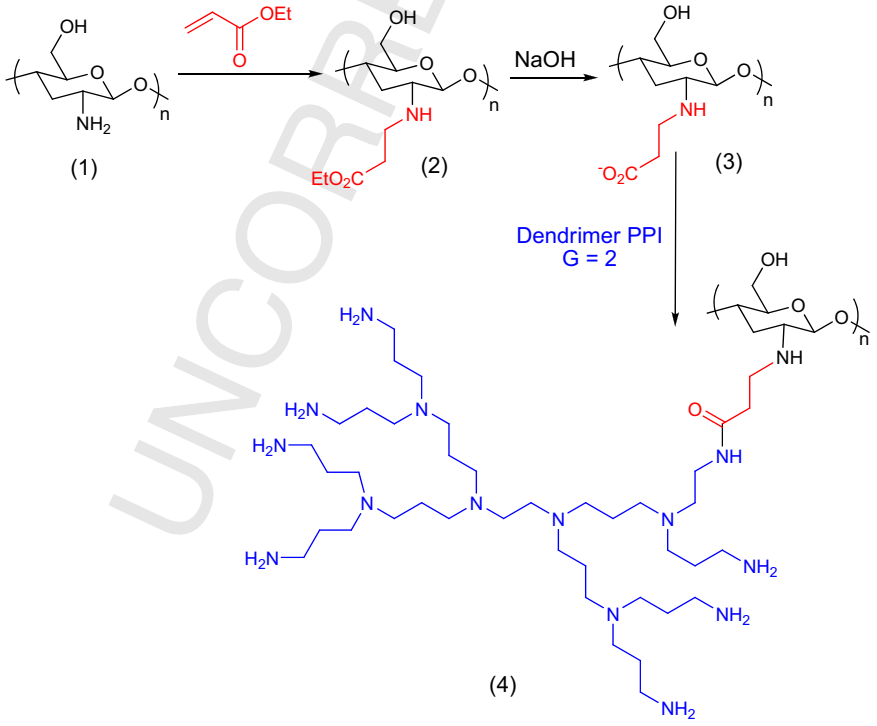
N-carboxyethylchitosan was dispersed in methanol, PPI ($G = 2$) was added to the prepared suspension and the mixture was stirred at room ambient. After three days, the mixture was evaporated to dryness, dispersed in NaOH solution at room temperature for 2 h, dialyzed, and lyophilized to give CS–PPI. The summarized preparation of CS–PPI is illustrated in Scheme 1 and was described in detail in our previous work [22].

CS–PPI grafting on fabric

The cotton fabric used in this work was desized, mercerized and washed. The fabrics washed using 2 g/L nonionic detergent (Lotensol, Hansa) for 30 min at 60 °C with L.R 40:1. Then, fabrics rinsed and dried. The grafting of CS–PPI as an antimicrobial agent in various concentrations (5–25% owf) on the washed fabrics was performed using CA (2.5–12.5% owf) as a cross-linking agent in different concentrations and sodium hydrogen phosphate (SHP) as a catalyst at a concentration of 10% (owf). This process was carried out in different time (6–30 h) and pH (4–12), and then fabrics dried at 70 °C for 5 min and cured at 110 °C for 3 min. Afterwards, fabrics weight gain was calculated from the difference in weight of the cotton fabric before and after the CS–PPI grafting reaction for three times and the average weight was reported.

RSM analyses

The effects of variables such as pH, time processing, CS–PPI and CA concentrations on finishing process were investigated by RSM



Scheme 1. The preparation of CS–PPI.