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Green Synthesis Approach for Renewable Textile Coating and Their Mechanical and Thermal Properties

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GREEN, new and renewable smart coating was developed for furniture textile fabrics. Facile and single step method was used for synthesis of green coating based on mandarin peel and chitosan. As, the mandarin peel as fruit waste material was dried, grinded and directly dispersed in chitosan solution producing new green coating composite and then coated on textile fabrics. The mass loadings of green mandarin peel powder was varied on 20-70 wt% and optimized. Thermal stability of coated textile fabrics was enhanced and char yield was improved compared to uncoated one. The charring effect of mandarin peel powder coated samples was significantly enhanced anticipating good flame retardancy effect. The Maximum break loading of the coated textile fabrics was improved achieved 35% improvement compared to uncoated sample reflecting reinforcement of textile fabrics. The interaction between the renewable coating and textile was evaluated. The morphology of uncoated and coated textile fabrics was studied using microscopic technique. Additionally, based on thermal properties of mandarin peel powder it could be promising flame retardant for textile fabrics. This study open new avenues for finishing textile fabrics with enhanced thermal, flame retardancy and mechanical properties with cost-effective and renewable green and effective coating.

Keywords: Green material, Textile coating, Thermal stability, Reinforced textile fabrics.

Introduction

The extensive use of textile and textile based materials in various applications including industrial applications are increasing regularly. This is due to their interesting properties which require rapid development in their functions to be adapted to these applications [1-4]. Therefore, there are various treatments have been carried out to improve textile functions such as thermal stability, hydrophobic character, tensile strength, UV shielding, flame retardants and antibacterial properties [5-10]. Although, interesting results were obtained, however, these treatments required the use of various cost and toxic chemicals and solvents; this is in addition to prolonged time for preparation process and several steps for textiles treatments [11]. Therefore, the trend for using environmentally friendly and cost-effective materials for textile treatment is very appreciated and considered from manufactures and consumers point of view as it will avoid the use of cost and toxic materials. We and others have recently developed various cost-effective textile coating using green chemistry and promising results

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were achieved [3,12-15]. On the other hand, the poor thermal stability of textile fabrics could be one of the drawbacks for their use in some industrial applications, hence, researches for enhancing thermal stability for textile fabrics are crucial and demanded [11,16-18]. This is in conjunction to reinforcement of textile fabrics for standing for high tensile strength for industrial and domestic applications [19]. Therefore, in this report, for the first time green textile coating was developed from mandarin peel powder. As, mandarin peel was washed, dried, grinded and directly dispersed in chitosan solution forming effective and smart textile coating. Then, furniture textile was coated with developed green coatings. The morphological, thermal and mechanical properties of the developed coated and uncoated textile fabrics were studied

Experimental Section

Materials

Furniture textile fabrics of the following composition polyester/microfilament/fibran/wool 35/25/25/15% respectively, were bought from Al Mahalla Co., Algharbia, Egypt. Fresh mandarin was bought from Egyptian market and peel was obtained. Chitosan was purchased from Loba Chemie Pvt. Ltd. 107, Wodehouse Road, Mumbai 400005. India. Deionized (DI) water was used for washing coating paste preparation.

Synthesis of Green Mandarin Peel Powder

Mandarin peel was removed from mandarin and washed with DI water and cutted in small pieces. Then, dried in sun for seven days, afterwards, grinded and fine powder was obtained.

Synthesis of chitosan- Green mandarin peel powder (CH-GMPP)

In a glass beaker containing 2 wt.% of chitosan solution prepared by dissolving chitosan in 1 vol% acetic acid DI water solution. Then, different mass loadings of GMPP were dispersed individually (20, 30,50 and 70 wt.% based on final coating mass). This is followed by vigorous magnetic stirring for 30 min for uniform dispersion of GMPP in chitosan solution. The corresponding produced coatings were denoted as CH-GMPP20, CH-GMPP30, CH-GMPP50 and CH-GMPP70.

Treatment of Textile coatings composite (F- CH-GMPP)

In a glass beakers contains different coatings dispersions individually (CH-GMPP20, CH-GMPP30, CH-GMPP50 and CH-GMPP70 as indicated in Table 1) 20 cm x 20 cm of furniture textile fabrics were immersed in the different coatings dispersions individually and squeezed. Then the fabrics dried and cured at 120 ^{o}C in oven. Finally different textile coating composites were obtained as depicted in Table 1.

Characterization

The SEM images were obtained using a scanning electron microscope (Quanta FEG-250, operating at a voltage of 15 kV). The FT-IR analysis for the samples was carried out using a spectrum two spectrophotometer (PerkinElmer), over the spectral range of 4000-450 cm^{-1}. Thermogravimetric (TGA) analysis was measured using TGA 50 (TA Shimudzu, Inc.) from room temperature to 550 ^{o}C under nitrogen. The maximum break loading (MBL) which reflects the tensile strength was tested using tensile testing machine model H1-5KT/S.

Results and Discussion

Green coating synthesis and textile fabrics coating

For the first time direct renewable coating from fresh mandarin peel was developed for textile fabrics. The fresh mandarin peel was washed, dried in sun and then grinded for fine powder. Then, dispersed directly in chitosan solution and stirred for uniform dispersion produced cost-effective and renewable coating composite as indicated in Figure 1. Afterwards, the coating dispersion was facilely coated on textile fabrics as depicted in Figure 1. The mass loadings was varied (Table 1) and 50wt% was found to be the optimum GMPP loading in terms of charring effect and tensile strength as will be discussed below. It is pertinent to note in this study, this developed green approach has double benefits; the first one in terms of textile treatments effect as cost-effective and renewable coating effective for enhancing textile fabrics tensile strength and thermal stability was developed. The second one was its positive environmental impact, as the mandarin peel was considered as fruit waste after using mandarin, so this process is environmentally friendly recycling of mandarin peel waste to be used for useful advanced applications.

TABLE 1. Composition of green textile coatings.

Sample code	Chitosan (CH) (wt.%)	Green Agent (GMPP) (wt.%)
F-0	0	0
F-CH-GMPP20	80	20
F-CH-GMPP30	70	30
F-CH-GMPP50	50	50
F-CH-GMPP70	30	70

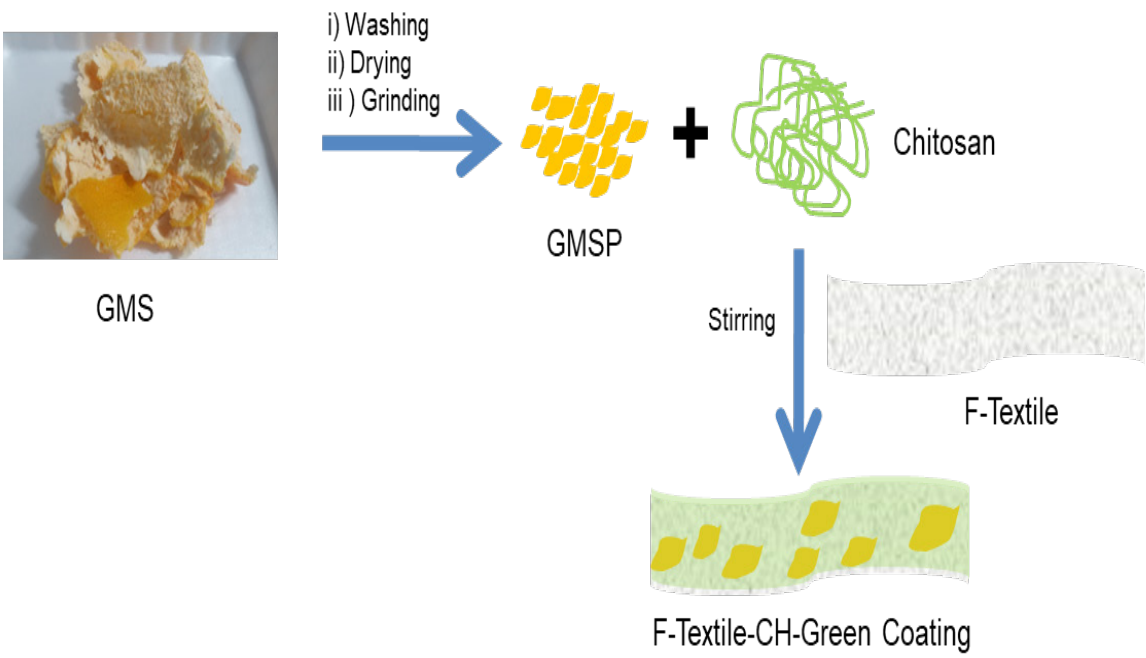

Fig. 1. Schematic diagram representing the synthesis of green mandarin peel powder based textile coating.

Morphological and thermal stability properties of developed coated textile fabrics

The morphological properties of the uncoated and coated textile fabrics were evaluated using scanning electron microscope. Figure 2a represents the SEM image of uncoated furniture textile fabrics fibers which indicated smooth surface of fibers. Figure 2b shows the surface of textile fabrics coated with chitosan chains only which represent roughness on the fiber surface as indicated by arrows. However, Figure 2c shows the SEM image of F-CH-GMPP30 which reflects the coating of GMPP on the fiber surface and finally wrapped with CH chains. This was clearly indicated by decorating of GMPP sheets on textile fabrics fiber surface as depicted by arrows in F-CH-GMPP50 (Figure 2, d). It is also observed that, the coating of GMPP on the textile fabrics fiber surface was on the form of wrinkled sheets as seen in SEM images (Figure 2d).

On the other hand, Figure 3 shows the thermal analysis curves of uncoated and coated textile fabrics. Figure 3a represents the thermogram of uncoated textile fabrics which decomposed in two steps (Figure 3a). The first decomposition step was started at 280 °C which corresponds to the decomposition of cellulose chains of fibran and wool chains [20]. However, the second decomposition step was started at 391°C and attributed to the thermal decomposition of polyester and microfilament chains leaving char yield of 14.73 % (Figure 3a) [20]. The thermogram of F-CH-GMPP20 indicated lower temperature for the first and second decomposition steps of the textile composites and the main decomposition step was found to be at 388 °C. This lower thermal decomposition temperature could be attributed to the existence of organic chitosan chains (Figure 3b). However, the char yield was enhanced to 16.5%, compared to blank sample; this reflects the promising charring effect of GMPP. Figure 3c represents the thermogram of F-CH-GMPP30 which shows enhanced thermal stability of F-CH-GMPP30 compared to F-CH-GMPP20 and blank sample. As, its main decomposition step temperature was enhanced recording 396 °C. The thermal behavior of F-CH-GMPP50 and F-CH-GMPP70 was similar and behaved like to F-CH-GMPP30 showing enhanced thermal decomposition temperature of main step to 394 °C (Figure 3d,e). However, the charring effect was optimized in F-CH-GMPP50 achieved char residue of 18.4%. This indicated that 50wt% mas loading of GMPP was the optimum mass loading for achieving good thermal stability coating and excellent charring effect for textile fabrics chains. Thus, the GMPP could be promising flame retardant for textile fabrics.

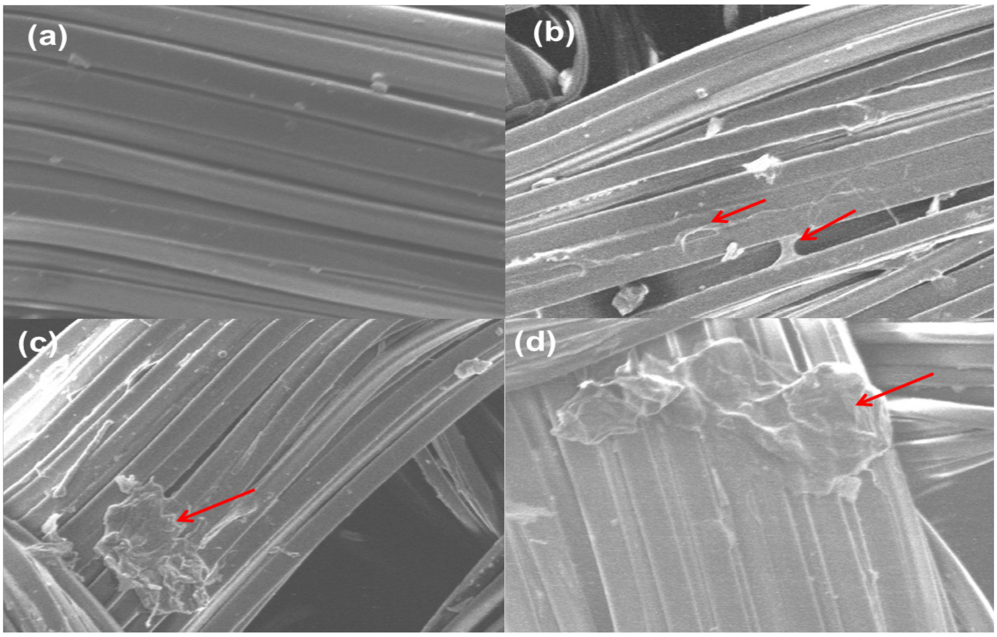

Fig. 2. SEM images of blank sample (a), F-CH (b) F-CH-GMPP 30 (c) F-CH-GMPP 50 (d).

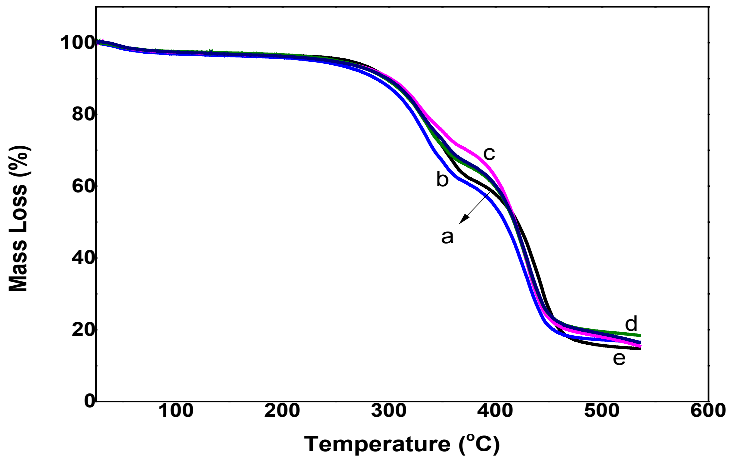

Fig. 3. TGA graphs blank furniture textile fabrics (a) F-CH-GMPP 20 (b), F-CH-GMPP 30(c), F-CH-GMPP 50 (d) and F-CH-GMPP 70(e).

Furthermore, the nature of interactions between the GMPP and textile were investigated using FT-IR as indicated in Figure 4. Figure 4a represents the characteristic absorption peaks of textile materials, however, the characteristic absorption peaks of GMPP were represented in Figure 4b which confirms the composition of GMPP; moisture, crude protein, crude fiber, crude fat, total ash, carbohydrate, ascorbic acid, carotenoids and polyphenol content [21]. Interestingly, FT-IR spectra of F-CH-GMPP20 and F-CH-GMPP70 were shown in Figure 4c,d which reflects the absorption peaks of both textile and GMPP with shifting in some peaks position indicating the formation of hydrogen bonding and superamolecular interactions between GMPP and FT. It is important to note that, the mandarin peel the rich with hydroxyl groups interacts with chitosan chains through hydrogen bonding as indicated by the schematic diagram (Figure 5).

Mechanical properties of developed coated textile fabrics

The maximum break loading (MBL) which reflect the tensile strength and elongation percent of coated textile fabrics were evaluated; this is in addition to the uncoated sample. The maximum break loading (MBL) values and elongation percent (EP) was measured for all samples and tabulated in Table 2. The MBL and EP of uncoated sample were found to be 535 N and 29% respectively. However, when renewable coating was used on the textile fabrics surface (F-CH-GMPP20) the MBL was enhanced to 717 N and EP was found to be 10% reflecting enhancement of tensile strength. When, further mass loadings incorporation of GMPP in coating almost same MBL and EP (718N and 9%) were recorded in F-CH-GMPP30 (Table 2). This enhancement in MBL was attributed the coating of GMPP in the forms wrinkled sheets (Figure 2d) reinforced textile fabrics fiber surface as indicated in microscopic morphology of F-CH-GMPP composite. This enhancement in MBL (tensile strength) was reached to optimum value in F-CH-GMPP50 achieved 719 N and EP was enhanced to 12.1. The MBL of F-CH-GMPP70 was found to be similar to F-CH-GMPP50 of 719 N, however, EP was little reduced (Table 2). This conclude that the F-CH-GMPP50(50wt% is optimum mass) is the best textile composite in terms of thermal stability, charring effect and MBL and further increase in GMPP mass is not economic (Table 1,2).

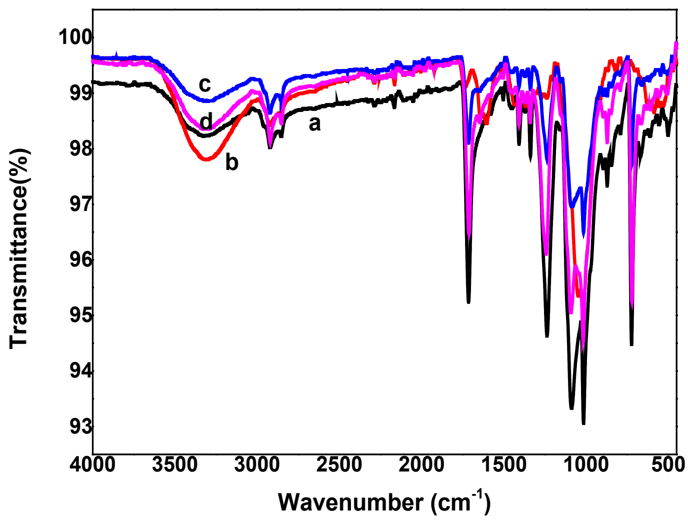

Fig. 4. FT-IR spectra of blank furniture textile fabrics (a) GMPP (b), F-CH-GMPP20(c), F-CH-GMPP70 (d) .

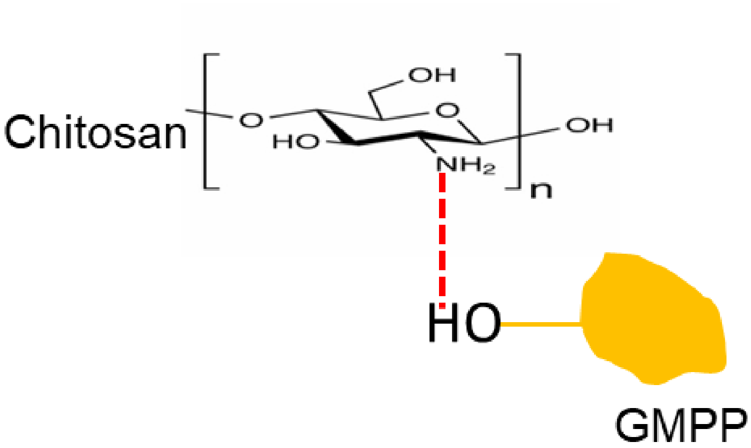

Fig. 5. Schematic diagram representing the interaction between GMPP and Chitosan chains

TABLE 2. Mechanical properties of untreated and treated textile with green coatings.

Sample code	Maximum break loading (N)	Elongation (%)
F-0	535 ± 4	29± 1.4
F-CH-GMPP20	717 ±36	10± 4
F-CH-GMPP30	718±18	9± 3.4
F-CH-GMPP50	719±30	12.1± 0.8
F-CH-GMPP70	719±44	7± 3.4

Conclusion

Smart, cost-effective and renewable textile fabrics coating was developed. Green coating was prepared from mandarin peel waste material through drying and grinding processes, then directly dispersed in chitosan solution. The mass loadings of mandarin peel powder was varied and 50 wt% was found to the optimum mass loading. The thermal stability and mechanical properties of developed coated textile fabrics were improved compared to the uncoated one. The green mandarin peel powder was found to be good thermal stability filler and has a promising charring effect for textile fabrics. The Maximum breaking loading of the coated textile fabrics was enhanced achieving 35% enhancement compared to uncoated one reflecting enhancement of tensile strength. Interestingly, the green mandarin peel powder was decorated on the textile fibers surface in the form wrinkled sheets reinforced them. Interestingly, mandarin peel powder could be is very good flame retardant material candidate for textile fabrics based on its promising charring effect.

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تصور تحضيرى اخضر لدهان منسوجات متجدد و خواصه الميكانكيه والحراريه

دهان جديد واخضر و متجدد لمنسوجات المفروشات تم تطويره

حيث تم استخدام طريقه سهله من خطوة واحده لتحضير الدهان من قشر اليوسفى والكيتوزان

حيث تم استخدام قشر اليوسفى بعد تجفيفه وطحنه و توزيعه داخل محلول كيتوزان كدهان اخضر و دهانه على المنسوجات

كتله قشر اليوسفى تم تغيره من ٢٠ الى ٧٠

الخواص الحراريه للمنسوجات المغطاه تم تحسينها بشكل كبير مقارنه بالغير مغطاه

قدره الغطاء على تكون غطاء اسود حامى تحسنت بشكل ملحوظ متنبءه بقدره الغطاء على مقاومه الحريق

قوة الشده للمنسوجات المغطاه تحسنت بنسبه ٣٥٪ مقارنه بالغير مغطاه

تفاعل الدهان المتجدد مع المنسوجات تم تقيمها كما تم تقييم الشكل السطحى للمنسوجات المغطاه والغير مغطاه باستخدام الميكروسكوب الالكترونى

بناءا على الخواص الحراريه تعتبر قشراليوسفى ماده مقاومه للحريق للمنسوجات