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Ultrasound Mediated Modification and Characterization of Chitosan

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Chemical modification of chitosan under sono-chemical conditions is carried out using citric acid as the crosslinking agent. The resultant cross-linked products are characterized by scanning electron microscopy, Fourier transform infrared spectroscopy and differential scanning calorimetric. It has been observed that the morphology and thermal stability of the cross-linked modified chitosan synthesized was dependent on the reaction temperature at which modification was done.

Keywords: Chitosan, Sono-chemical, Chitosan, Cross-linking.

INTRODUCTION

Chitosan is the 2nd most abundant natural polysaccharide in universe after the cellulose. Chitosan, a positively charged biopolymer, is prepared by the hydrolysis of the polysaccharide chitin, which is found in the exoskeleton of crustacean shrimp, crab, lobster and other shellfish [1]. Chitosan is a biodegradable, biocompatible, antimicrobial and non-toxic polysccharide composed of 1-4 linked D-glucosamine deacetylated unit and N-acetyl-D-glucosamine acetylated unit.

The deacetylated chitin derivative chitosan is more useful and bioactive polymer. After deacetylation, chitosan is soluble in acidic solution of pH below 6.5 and becomes the only polysacchride that have property to hold the high density of positive charges [2-7]. The molecular weight of chitosan is 50-2000 KDa [8]. Chitosan is used as an excipient in pharmaceuticals as support material for tissue engineering, food, medical and biomedical fields in drug delivery system. The increase in the thickness of chitosan membrane decreases the rate of release of drug when used in drug delivery system [9]. The advantages of chitosan has minimum side effects and prolong the efficacy of the drug. Chitosan having low toxicity good biocompatibility has proved to be a good pharmaceutical excipient in both conventional and noval applications [10]. The solution of gelatin and chitosan were mixed at different mass ratio indicate the significant interaction between the two solutions. Furthermore the formation of multi-complex of two biopolymers are due to strong interaction between gelatin and chitosan [11].

Chitosan has excellent physical, chemical and biological properties. Cellulose and chitosan are widely used in biotechnology, cosmetic, waste water treatment, food packages, pharmaceutical and drug carrier *etc*. Recently, cellulose and chitosan were combined together to prepare cellulose-chitosan components which increase the mechanical strength of both biopolymers and their antibacterial properties [12].

Chemically modified chitosan improves the aqueous solubility as compared to the native chitosan and it has been widely used as a drug carrier [13,14]. Chemical crosslinking agent such as glutraldehyde, formaldehyde, terephtheloyl chloride, ephichlorohydrin *etc*. are used to control the drug release from diffusion controlled polymeric drug delivery matrices [15]. Chitosan has been used in the drug delivery system in the form of tablets, gels micro and nano-particles [16].

The aim of the present study is to chemically modify the native and characterize the modified cross-linked chitosan for its application in controlled drug release.

EXPERIMENTAL

Chitosan is obtained from Fluka, Mumbai. Acetic acid is purchased from Merck, Mumbai and citric acid is purchased from Himedia, Mumbai. All chemicals are used as received. All solutions are prepared in distilled water. Transducer Digital Sonifier Model 450 (Branson Ultrasonics Corporation, USA) is used for generating the ultrasound with a maximum power input of 400 W and a frequency of 20 kHz.

Modification of chitosan: The modification of chitosan was carried out under ultrasonication. For this, a 3 % chitosan solution was prepared in acetic acid. After that small amount of citric acid solution (1 % aqueous solution of citric acid)

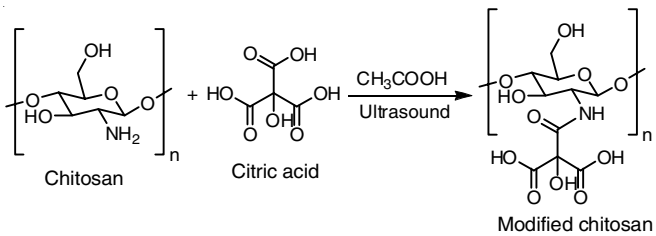
was added to the chitosan solution. Then, the ultrasonication of the mixture was carried out at two different temperature (*viz*. 40 °C and 70 °C) until the cross-linking was observed.

A JEOL JSM-6610 lv scanning electron microscope (SEM) is used to perform textural characterization of native chitosan and modified chitosan. For SEM studies, the samples are mounted on metal stubs using double-sided adhesive tape and submitted to a JOEL gold sputtering coater for 6 min to make them conducting before analysis. Different magnification are applied to each sample in order to estimate the morphology. Fourier transformation infrared spectra (FT-IR) of native and modified chitosan are recorded with a Bruker Tensor-27 spectrophotometer between 4000 and 400 cm^{-1}. The samples are thoroughly grounded with dry KBr and tablets are prepared by compression under vacuum. Differential scanning calorimetric analysis for native and modified chitosan is performed using Mettler Toledo 851D system. Accurately weighted samples are placed into platinum cups and sealed. The temperature range used from 20 to 240 °C under nitrogen atmosphere at a heating rate of 20 °C/min.

Rheological studies for native and modified chitosan are measured using Modular Compact Rheometer MCR-102 system. The rheology study of chitosan and modified chitosan solution reported in present work to determine the viscoelastic material function G′G″ and temperature [17-22].

RESULTS AND DISCUSSION

Sonochemical modification of chitosan: Modification of chitosan by surface grafting is an efficient technique to produce chitosan with enhanced physico-chemical properties and biocompatibility. Citric acid is considered as potential molecule for the modification of chitosan. Surface grafting with citric acid leads to enhanced hydrogen bonding and balanced hydrophilicity of the biomaterials. Citric acid modified chitosan is used as nucleation catalyst and for the removal of heavy metals *etc*. Chemical modification of chitosan under ultrasonicator, using 0.1 mol acetic acid and 1 % citric acid (CA) solution was prepared in deionized water. Then, both the solutions were mixed and the mixture was sonicated for 4 h at temperatures *viz*. 40 and 70 °C to get the modified chitosan. The schematic representation is shown in **Scheme-I**. It is evident that the citric acid molecules attack on the $–NH_2$ group of the chitosan and led to grafting of citric acid on the chitosan moiety. The modification was authenticated by using some advanced analytical techniques like FT-IR spectroscopy, SEM, DSC *etc*. The modification of chitosan can be verifiedby comparing the FT-IR spectrum of pure chitosan and citric acid treated chitosan. Further, the thermal properties can be accessed by using differential scanning calorimeter (DSC) studies.



Scheme-I: Chemical modification of chitosan under ultrasonication

FT-IR analysis: FT-IR spectra of pure and chitosan modified at different temperatures presented in Fig. 1. The spectrum of pure chitosan (CH) shows an O-H stretching band at 3464 cm^{-1} The C-N stretching band appears at 1384 cm^{-1} and peak at 1068 cm^{-1} is due to C-O vibrations.

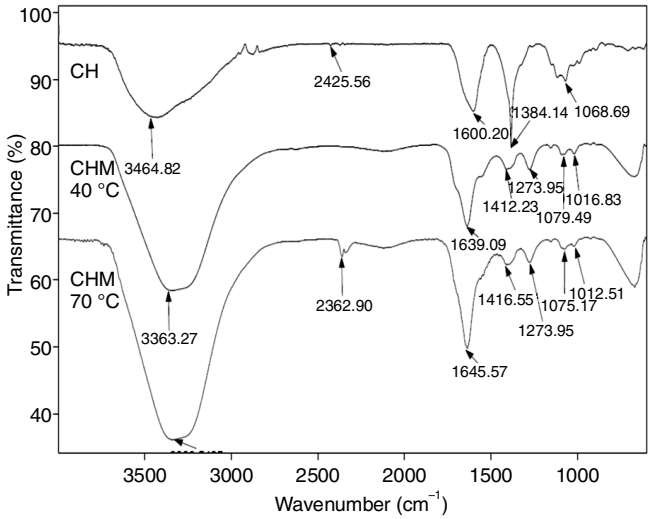


Fig. 1. FTIR spectra of native and modified chitosan. CH: native chitosan, CHM: modified at 40 °C, CHM: modified at 70 °C

The FT-IR spectrum of citric acid modified chitosan (CA-CHM) at 40 °C exhibits, band at 1639 cm^{-1} due to stretching vibrations of the carbonyl group (C=O) group of amide. The band at 3363 cm^{-1} is due to O-H stretching vibrations. The C-O-C vibration band appears at 1079 cm^{-1} and the band at 1016 cm^{-1} is due to C-O bond vibrations. The FTIR spectrum of chitosan modified at 70 °C is also shown in Fig. 1. This is similar to the spectra of chitosan modified at 40 °C. The only difference is the slight shifting of the bands.

DSC analysis: DSC curves at pure chitosan and modified chitosan (at 40 and 70 °C) are presented in Fig. 2. It is clear that initial loss of water molecules occurs near 85 °C, after that the second weight loss is near 145 °C, which may be attributed to the loss of amine group. In citric acid modified chitosan the peak shifting was observed. The shifting is due to the incorporation of citric acid molecules to the free amine group of the chitosan.

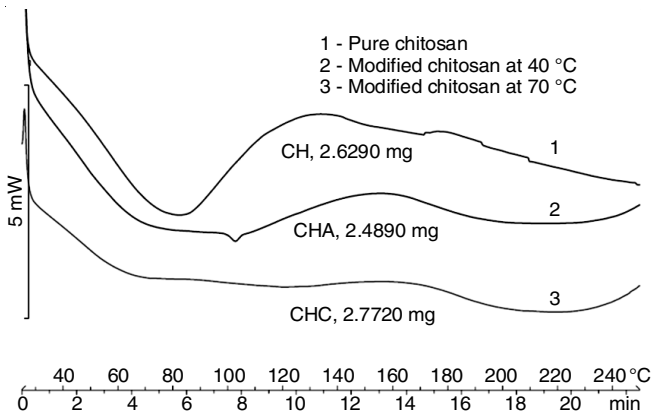


Fig. 2. DSC thermograms of native chitosan (CH:1) thermally modified chitosan (2,3) and chitosan modified by ultrasonication technique at heating rate of 10 °C per min

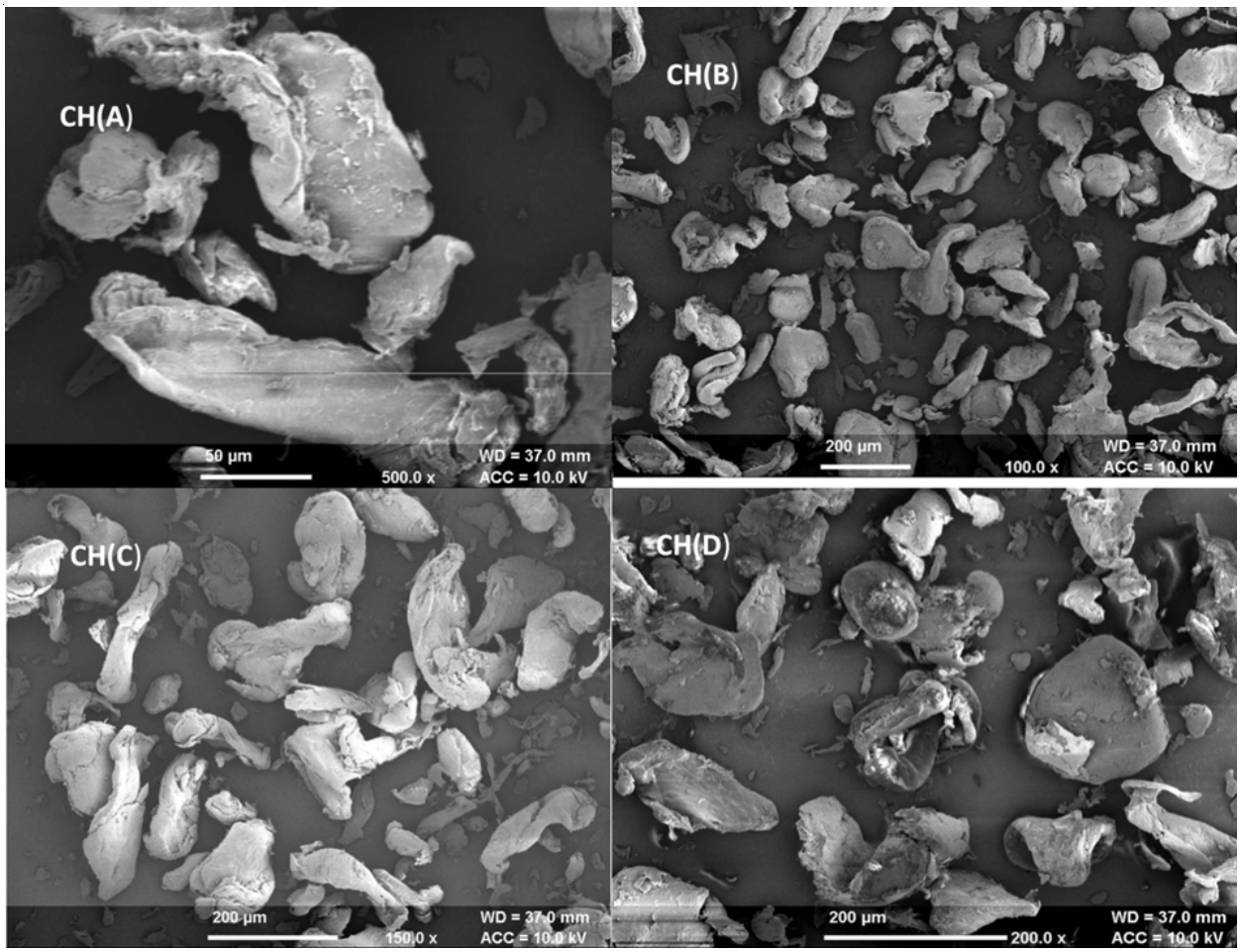


Fig. 3. SEM Images of native chitosan (CH) and modified chitosan (CHM)

SEM analysis: SEM images of pure chitosan, chitosan treated at 40 °C and chitosan treated at 70 °C are shown in Fig. 3. The SEM image of pure chitosan magnified 500 times exhibit the presence of chitosan flakes in bulk. SEM image of the chitosan modified at the 40 °C shows relatively smooth surface at a magnification of 2000. Similarly, the chitosan treated at 70 °C show further smoothness on the surface. This is due to the fact that grafting of chitosan with citric acid molecules leads to the binding of polymer chains with hydrogen bonds due to the presence of amine and hydroxyl sites in the chitosan chains and the presence of carboxylic group in the citric acid moiety. As a result of this, the polymer chains will

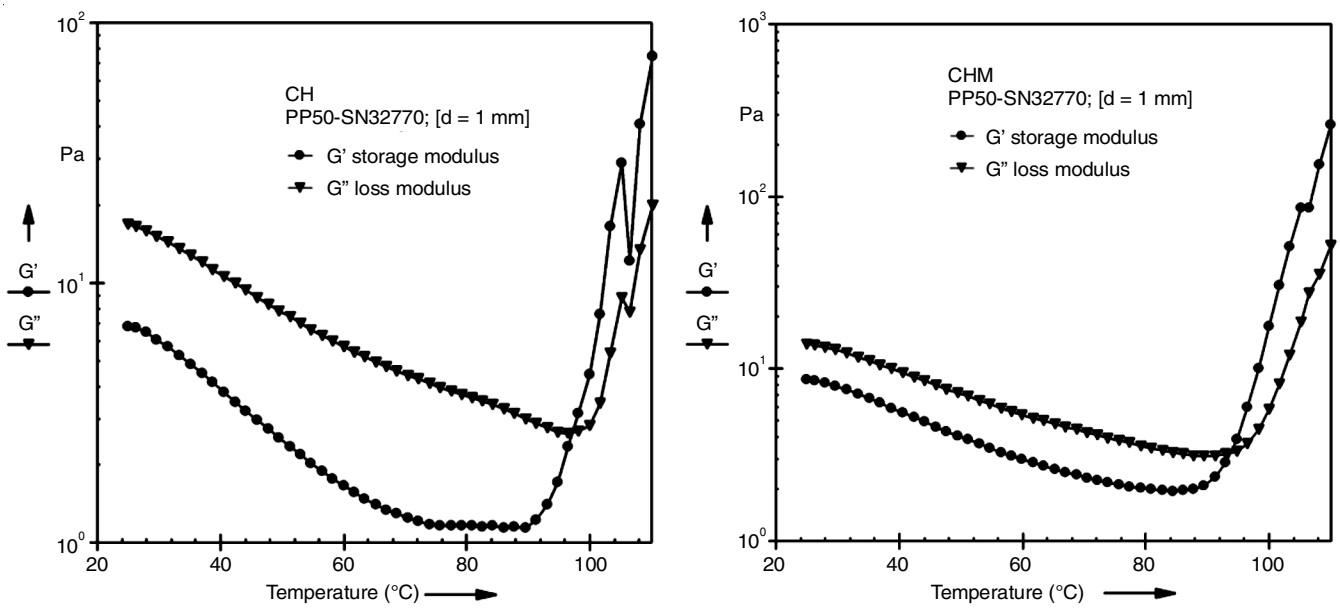


Fig. 4. Viscoelastic behaviour of chitosan and modified chitosan

flip on each other which leads to surface smoothness. On the other hand the unmodified chitosan appeared as flakes due to the absence of hydrogen bonding. Further, the treatment at 70 °C leads to more grafting of the citric acid molecules on polymeric chains; which is not the case when chitosan was treated at 40 °C. So, the surface appeared to be more smooth when chitosan was treated with citric acid at 70 °C.

Rheological studies: The rheological properties of chitosan (CH) and modified chitosan (CHM) have been studied. The viscoelastic material functions G2, G3 and temperature of chitosan and modified chitosan solutions showed significant change. Initially the Fig. 4 show the similarly trend lines in both chitosan and modified chitosan but in modified chitosan at 85 °C has more stability than unmodified chitosan and also more storage modulus (G″). Modified chitosan are highly suitable for sustain/controlled released formulation as compared to non crosslinked chitosan.

Conclusion

In conclusion, the chitosan has been successfully modified with citric acid at two different temperatures. The various characterization techniques show that citric acid has been grafted to the chitosan backbone. The modified chitosan exhibit high stability and better hydrophilicity.

REFERENCES

1. V.R. Sinha, A.K. Singla, S. Wadhawan, R. Kaushik, R. Kumria, K. Bansal and S. Dhawan, *Int. J. Pharm.*, **274**, 1 (2004); https://doi.org/10.1016/j.ijpharm.2003.12.026.
2. Y. Liu, X. Shen, H. Zhou, Y. Wang and L. Deng, *Appl. Surf. Sci.*, **370**, 270 (2016); https://doi.org/10.1016/j.apsusc.2016.02.124.
3. L. Qin, H. Dong, Z. Mu, Y. Zhang and G. Dong, *Carbohydr. Polym.*, **133**, 236 (2015); https://doi.org/10.1016/j.carbpol.2015.06.099.
4. X. Cheng, K. Ma, R. Li, X. Ren and T.S. Huang, *Appl. Surf. Sci.*, **309**, 138 (2014); https://doi.org/10.1016/j.apsusc.2014.04.206.
5. S. Tang, B. Tian, Y.J. Guo, Z.A. Zhu and Y.P. Guo, *Surf. Coat. Technol.*, **251**, 210 (2014); https://doi.org/10.1016/j.surfcoat.2014.04.028.
6. T.L. Yang and Y.C. Hsiao, *Biomaterials*, **66**, 29 (2015); https://doi.org/10.1016/j.biomaterials.2015.06.028.
7. Z. Li, H. Dou, Y. Fu and M. Qin, *Carbohydr. Polym.*, **132**, 430 (2015); https://doi.org/10.1016/j.carbpol.2015.06.062.
8. R. Riva, H. Ragelle, A. des Rieux, N. Duhem, C. Jérôme and V. Préat, eds.: R. Jayakumar, M. Prabaharan and R. Muzzarelli, Chitosan and Chitosan Derivatives in Drug Delivery and Tissue Engineering, In: Chitosan for Biomaterials II. Advances in Polymer Science, Springer, Berlin, Heidelberg, vol. 244, pp. 19-44 (2011);
9. S.A. Kumar, D. Vivek and A. Vandana, *J. Pharma. Scient. Innov.*, **1**, 11 (2012).
10. M.K. Singh, S.K. Prajapati, A. Mahor, N. Rajput and R. Singh, *Int. J. Pharm. Sci. Res.*, **2**, 2266 (2005); https://doi.org/10.13040/IJPSR.0975-8232.2(9).2266-77.
11. C. Qiao, X. Ma, J. Zhang and J. Yao, *Food Chem.*, **235**, 45 (2017); https://doi.org/10.1016/j.foodchem.2017.05.045.
12. Y. Zhou, M. Fan, X. Luo, L. Huang and L. Chen, *Carbohydr. Polym.*, **113**, 108 (2014); https://doi.org/10.1016/j.carbpol.2014.06.081.
13. A.B. Sieval, M. Thanou, A.F. Kotze, J.C. Verhoef, J. Brussee and H.E. Junginger, *Carbohydr. Polym.*, **36**, 157 (1998); https://doi.org/10.1016/S0144-8617(98)00009-5.
14. N.M. Alves and J.F. Mano, *Int. J. Biol. Macromol.*, **43**, 401 (2008); https://doi.org/10.1016/j.ijbiomac.2008.09.007.
15. K. Kumari and S. Virpal, *Asian J. Chem.*, **25**, 9817 (2013); https://doi.org/10.14233/ajchem.2013.15435.
16. T. Kiang, J. Wen, H.W. Lim and K.W. Leong, *Biomaterials*, **25**, 5293 (2004); https://doi.org/10.1016/j.biomaterials.2003.12.036.
17. C. KienzleSterzer, D. Rodriguez-Sanchez and C. Rha, *J. Appl. Polym. Sci.*, **27**, 4467 (1982); https://doi.org/10.1002/app.1982.070271133.
18. W. Wang and D. Xu, *Int. J. Biol. Macromol.*, **16**, 149 (1994); https://doi.org/10.1016/0141-8130(94)90042-6.
19. M. Mucha, *Macromol. Chem. Phys.*, **198**, 471 (1997); https://doi.org/10.1002/macp.1997.021980220.
20. J. Berger, M. Reist, J.M. Mayer, O. Felt and R. Gurny, *Eur. J. Pharm. Biopharm.*, **57**, 35 (2004); https://doi.org/10.1016/S0939-6411(03)00160-7.
21. J. Desbrieres, *Biomacromolecules*, **3**, 342 (2002); https://doi.org/10.1021/bm010151+.
22. A.V. Mironov, G.A. Vikhoreva, N.R. Kil'deeva and S.A. Uspenskii, *Polym. Sci. Ser. B*, **49**, 15 (2007); https://doi.org/10.1134/S1560090407010046.