

Properties of Osmanthus Fragrance-Loaded Chitosan–Sodium Tripolyphosphate Nanoparticles Delivered Through Cotton Fabrics

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ABSTRACT: Osmanthus fragrance-loaded chitosan nanoparticles (OF-NPs) were prepared via complex coacervation successfully. Then, the OF-NPs were applied in the cotton fabrics directly. The microstructures of OF-NPs were characterized by dynamic light scattering (DLS), transmission electron microscopy (TEM), Fourier transformation infrared spectroscopy (FTIR), and thermogravimetric analysis (TGA). The sustained property of the cotton fabrics treated with OF-NPs was investigated with scanning electron microscopy (SEM) and gas chromatography-mass spectrometry (GC-MS). The common OF was also treated on fabrics for the parallel comparison. TEM and DLS displayed that the spherical OF-NPs kept about 130

nm and dispersed evenly. FTIR confirmed that OF had been interacted with chitosan via the hydrogen bonds. TGA demonstrated that the thermal stability of OF-NPs had been improved in contrast to OF and the loading content of OF was as high as 12.05%. SEM and GC-MS displayed that the cotton fabrics treated by OF-NPs had an excellent washing resistance. Overall, nanoencapsulation with CS-TPP will provide an excellent method for releasing fragrance. © 2011 Wiley Periodicals, Inc. *J Appl Polym Sci* 123: 3748–3754, 2012

Key words: chitosan; nanoparticles; thermal properties; FTIR; compounding

INTRODUCTION

Currently, innovative textile applications have aroused the widespread interest, such as insect repellents,¹ long-lasting fragrance treatments,^{2,3} phase change materials,^{4,5} and antimicrobial medical textiles.^{6,7} The new textile products with high added-value can improve market competitiveness effectively. Especially, the aromatic textile favored by the vast number of consumers has become a very

promising potential product, for the therapeutic and health protection effect.

Arroma finishing of textiles has been carried out for a long time. Generally, fragrance compounds are directly added into the textiles. However, the active ingredients of the fragrance compounds often disappeared while stored or during service in short time.⁸ Therefore, only through an effective prolonged-release method can the fragrances be retained. From the industrial application viewpoint, microencapsulation techniques have been shown to be a promising technology for aroma finishing because of its high resistance to washings and stable releasing profile through the encapsulation of active substances. Rodrigues et al.⁹ prepared polyurethane/urea (PUU) microcapsules (a bimodal mean size of 1 and 10 μm .) loaded with a perfume via interfacial polymerization and applied on textile substrate at industrial scale. During the dry cleaning of the impregnated fabrics, the loss of limonene was 38% in the first cycle and up to 87% after five cleaning cycles. Monllor et al.¹⁰ reported that the impregnation of microcapsules into the cotton fabrics was better aroma than the bath exhaustion. However, the sustained release of fragrance in the finished cotton fabrics all depended on the use of adhesive agents in the above researches. Because the mean sizes of microcapsules

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are too big to penetrate into the holes of the cotton fabrics.

In the same time, the use of nanoparticles as prolonged-release systems has often been suggested. A kind of 200–260 nm spherical poly(*tert*-butyl acrylate) nanocapsule encapsulated perfumes was added to the softener fabric base. The release of perfume was about three to five times higher compared with the perfumed softener without nanocapsules after 3 days.¹¹ Nay more, a durable aroma finishing for PET fabric was carried out by adopting poly(vinyl acetate) (PVAc) nanoparticles containing lavender oil (LO) in core (244 nm of mean particle diameter). PET fabric treated with PVAc nanoparticles showed slower and more stable releasing profile and reached about 12 ppm of cumulative release after 16 days, which were under two thirds of that with MF microcapsules.¹² In all, the character of the nanoparticles that makes them particularly suitable for prolonged release is uniform dispersibility and smaller size. The release of fragrance can be retarded by diffusion through the wall and/or rupture of the nanoparticles.^{1,9} To get high loading content and effective prolonged-release performance, nanoparticles need to be tailored for smaller size.

Our previous work remarkably established that the fragrance can be encapsulated with polybutylcyanoacrylate via emulsion polymerization.¹³ In this article, sweet-scented osmanthus fragrance loaded the biopolymeric materials of chitosan–sodium tripolyphosphate (CS-TPP) was prepared via complex coacervation due to the delicate fruity-floral apricot aroma and pharmacological effects including neuroprotection¹⁴ and repellent.¹⁵ Then, this nanoparticle is applied in the aroma cotton fabrics. The microstructures of OF-NPs were characterized by dynamic light scattering (DLS), transmission electron microscopy (TEM), Fourier transformation infrared spectroscopy (FTIR), and thermogravimetric analysis (TGA). The sustained property of the cotton fabrics treated with OF-NPs was investigated with scanning electron microscopy (SEM) and gas chromatography-mass spectrometry (GC-MS).

EXPERIMENTAL

Materials

Osmanthus fragrance was provided by Technico Flor in China. The fabric was the bleached 100% cotton plain weave (32 × 32 ends × picks/cm) with a specific weight of 136 ± 10 g/m² and a thickness of 1.40 mm. Chitosan (average molecular weight = 150,000) and sodium tyipolyphosphate (Na₅P₃O₁₀) as shell materials, castor oil polyoxyethylene ether (EL40) and fatty alcohol polyoxyethylene ether (AEO7) as emulsifiers, acetic acid as pH controller,

all purchased from Shanghai Chemical Reagent Ltd Corp in China. All the chemicals were reagent grade. Deionized water was applied for the whole processes.

Preparation of OF-NPs

A total of 150 mg of chitosan powder (CS) was ultrasonically (JY92-2D, China) dissolved in 40 mL distilled water containing 300 mg acetic acid at 800 W for 10 min. OF (400 mg) was blended with 160 mg AEO₇ and 160 mg EL40 under 500 rpm stirring for 5 min at 25°C, then the mixture was dispersed with 60 mL distilled water and 30 mg sodium tripolyphosphate (TPP). Emulsification for this mixture solution was performed with a high speed homogenizer (FA25, Germany) at 10,000 rpm for 10 min. At 25°C, 60 mL TPP solution was added dropwise to 40 mL CS solution under the moderate magnetic stirring of 500 rpm. Then, this reaction was kept for 2 h.

Impregnation of OF-NPs into cotton fabrics

15 g (10 cm × 10 cm) cotton fabrics were immersed in 450 g 0.4% OF emulsion and 450 g 0.4% OF-NP emulsion on a bed shaking (HYG-A constant temperature bed shaking, Taicang experiment equipment factory) at 300 rpm at 25°C for 2 h, respectively. The finished fabrics were dried at 40°C with the air current rate of 0.4 m/s for 1 h in the oven (moisture content: 0.01×10^3 kg/m³, Y802 Eight Baskets Oven, Huizhou electricity factory).

Durability testing

Specimens (50 g) were mixed with 1.5 L water at 40°C and 3 g 1993 AATCC standard detergents WOB, then laundered in a home washing machine (XQB42-777B Washing machine, Haier, China) for washing treatment. During each washing cycle, the perfumed cotton fabrics were washed with 1.5 L water at 40°C under standardized process for 10 min, drained and rinsed with 1.5 L water at 25°C for 5 min, and then, spun for 3 min. After 20 cycles, the sample was dried in the oven with the air current of 0.4 m/s at 50°C for 1 h.¹⁶

Transmission electron microscopy (TEM)

TEM analysis was used to investigate the morphology and the diameter of OF-NPs with H-600 electron microscope (Hitachi, Japan). TEM analysis was obtained by dropping one drop of aqueous solutions containing nanoparticles onto a carbon-coated copper grid and the sample was dried in air at room temperature without any further modifications before microscopy observation.

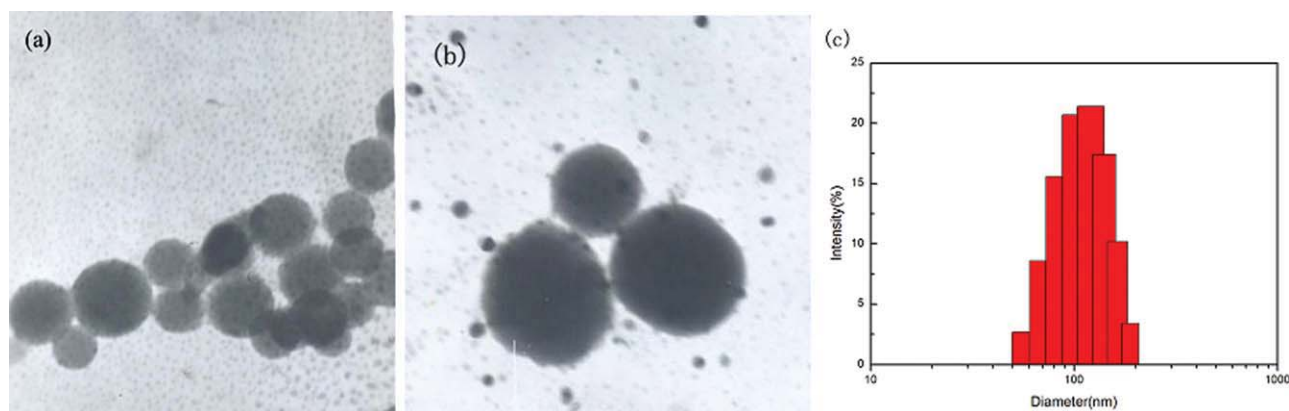


Figure 1 TEM of OF-NPs (a and b); DLS of OF-NPs (c). [Color figure can be viewed in the online issue, which is available at wileyonlinelibrary.com.]

Dynamic light scattering (DLS)

The particle size and size distribution of OF-NPs were determined by Mastersizer 2000 (Malvern, England). Each sample was measured by a solid state He-Ne laser of 633.0 nm at 25°C with an angle detection of 90°.

Fourier transforms infrared spectroscopy (FTIR)

FTIR spectra were used to determine the composition of OF-NPs and the interaction between OF and CS-NPs. FTIR spectra were collected on a Vertex 70 FTIR (Bruker, Germany) in Transmittance mode Spectra between 4000 cm^{-1} and 500 cm^{-1} . CS-NPs and OF-NPs were separated by ultracentrifugation and then freeze dried into powder.

Thermo gravimetric analyzer (TGA)

TGA-Q5000IR (TA Instruments, USA) was used to measure thermal stability of OF-NPs and loading capacity of OF.¹⁷ This experiment was performed in the temperature from 25 to 550°C at a heating rate of 10°C/min under a constant nitrogen flow (20 mL/min). Powdered CS-NPs and OF-NPs were performed and other samples were carried out in the same weight.

Scanning electron microscopy (SEM)

SEM analysis was performed on a JSM 840A scanning electron microscope (JEOL, Japan). The surface morphology of untreated cotton fibers, OF-treated cotton fibers, OF-NPs treated cotton fibers was studied. The laundering durability of the treated fabrics was also evaluated as described as above. Each textile sample was coated with a thin layer of uttered gold before examination.

Gas chromatography-mass spectrometry (GC-MS)

The method of GC-MS can be applied to analyze volatile profile in textiles.¹⁸ A SPME fiber coated with poly-

dimethyl siloxane (PDMS, 100 μm) was used for the analysis, conditioned at 280°C for 30 min before use, commercially obtained from Supelco Company (Bellefonte, PA). For each SPME analysis, a procedure for the breakage of OF-NPs incorporated in the fabrics was developed. A treated fabric sample was cut into 5 cm \times 5 cm in a plastic bag and destructed by friction without damaging the plastic bag. Then, the fabric sample was cut into pieces and 1 g of sample was transferred into the vials and sealed with Teflon cover. After 2 min of equilibration between the sample and the headspace at 70°C, the fiber was exposed for 20 min to the headspace of the capped vial. The fiber was then withdrawn and introduced into the injection port of the GC for desorption of compounds at 220°C for 2 min in splitless mode. Analyses were performed in triplicate.

GC-MS analysis was carried out using a 6890N network gas chromatograph system fitted with a 5973 network mass selective detector (Agilent Technologies, USA) on a DB-5MS column (0.25 mm \times 60 m, film thickness 0.25 μm). The parameters for the analysis were as follows: carrier gas, helium at a flow rate of 1 mL/min; injection port temperature, 250°C; detector temperature, 250°C; initial oven temperature 60°C, increasing to 160°C at 5°C/min, then held at 160°C for 5 min; increased to 230°C at 2°C/min, then held at 230°C for 5 min; increased to 250°C at 10°C/min, then held at 250°C for 5 min. Ionization voltage, 70 eV. The tentative identification of volatile components was achieved by comparing with mass spectra in the Wiley7 n.l Database (Hewlett-Packard, Palo Alto, CA) and match > 95.

RESULTS AND DISCUSSIONS

The size distribution and morphology of OF-NPs

Figure 1 showed the micromorphology and size distribution of OF-NPs. OF-NPs with a well-defined spherical shape kept about 130 nm and dispersed evenly. DLS result displayed the size of OF-NPs was monodispersity and Polydispersity Index (PDI) was

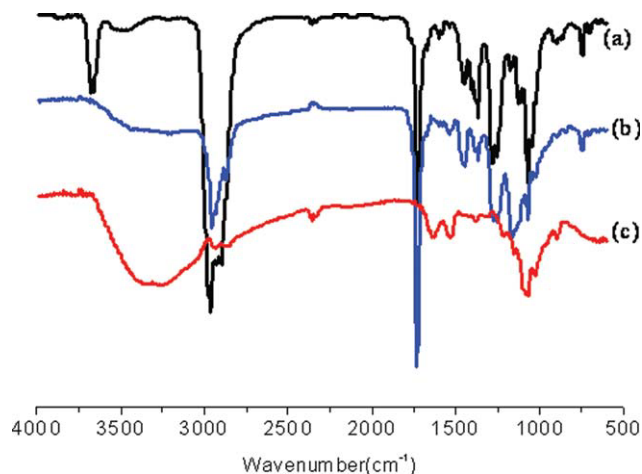


Figure 2 FTIR spectra of OF (a), OF-NPs (b), and CS-NPs (c). [Color figure can be viewed in the online issue, which is available at wileyonlinelibrary.com.]

0.133. For this reason is that fragrance can be emulsified in the micelle with the emulsifiers and the homogenize treatment. CS can form the cationic polyelectrolyte with the protonated amino group on CS molecule in diluted acetic acid aqueous solution. So that fragrance can be encapsulated into NPs via the complex coacervation interactions between the positively charged protonated amino groups on CS and the negatively charged phosphate groups on TPP.^{19–21}

FTIR analysis

Figure 2 demonstrated the different chemical structures of OF, OF-NPs, and CS-NPs. OF was a compounded mixture mainly including alcohols, esters, and aldehydes (Table I). The obvious absorption peaks of OF appeared at 3674 cm^{-1} , 2900 cm^{-1} , 1730 cm^{-1} , and 1074 cm^{-1} , which represented —OH , $\text{—CH}_2\text{—}$, C—H , C=O , and C—O stretching, respectively. The wide absorption peak at 3379 cm^{-1} was in accordance to hydroxyl groups in CS-NPs. Nay more, the strong bonds at 1638 cm^{-1} and 1537 cm^{-1} in CS-NPs were ascribed to C—O stretching and N—H blending modes, respectively. However, for the OF-NPs, the absorption peak of 3379 cm^{-1} has shift to 3480 cm^{-1} , and the intensity of peak also obviously decreases. The appearance of this peak confirms that CS-NPs have interacted with OF via the hydrogen bonds.²² In addition, the peaks at 1601 cm^{-1} and 1537 cm^{-1} in OF-NPs were also well detected. They were indicative of interaction between tripolyphosphoric groups with amine groups on chitosan chain,²³ resulting in the formation of OF-NPs.

TGA analysis

Figure 3 showed the different TGA results among OF, CS-NPs, and OF-NPs. OF was decomposed

TABLE I
The Washing Durability Results of the Impregnated Cotton Fibres with OF-NPs and OF

Compounds	Loss ratio (%)		Change ratio (%)
	OF-NPs ^a	OF ^a	
Acetyl cedrene	23.31	40.4	17.09
beta-Citronellol	3.15	13.62	10.47
Diethyl phthalate	91.57	94.99	3.42
Dihydro-beta-ionone	93.43	93.88	0.45
Dihydro methyl jasmonate	29.87	97.44	67.57
Galaxolide	9.28	25.41	16.13
Gamma isomethyl ionone	82.79	91.36	8.57
Geraniol	75.15	74.97	−0.18
Hexyl cinnamic aldehyde	28	30	2
Hydroxy citronellal	95.39	96.55	1.16
β -Ionine	90.92	94.02	3.1
Iso E super	39	39.96	0.96
Limonene	16.56	UD	83.44
Longifolene	28.77	UD	71.23
Methyl anthranilate	33.35	84.09	50.74
Musk ketone	20.49	39.93	19.44
Neoisolongifolene-8-ol	34.72	UD	65.28
4- <i>tert</i> -Butylcyclohexyl acetate	94.77	UD	5.23
γ -Unsecalactone	45.42	UD	54.58

UD indicates the volatile was not detected after washing.

^a Calculation based on HS-SPME-GC-MS peak area.¹⁰

obviously. Only thermal decomposition of 50 to 160°C was observed for OF. For CS-NPs, there was two-stage weight loss, below 100°C due to the loss of moisture²⁴; the second weight loss appeared from 140 to 250°C , which could be associated with decomposition of the shell. When OF was encapsulated inside CS-NPs, the decomposition temperature was increased to 130°C . This demonstrated that the thermal stability was extremely improved. A three-stage weight loss was observed in OF-NPs. The first stage,

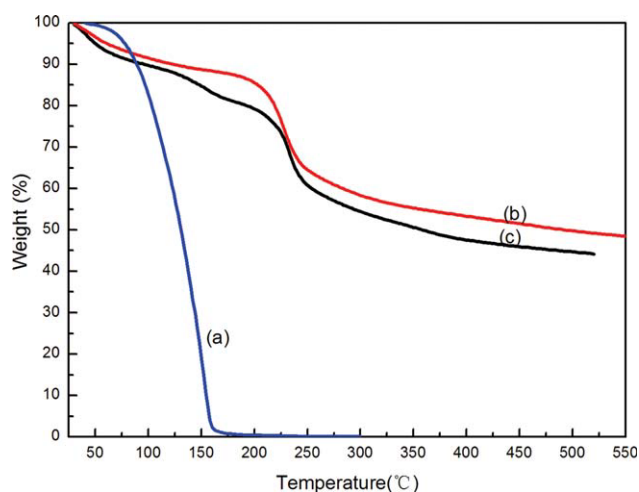


Figure 3 TGA curves of OF (a), CS-NPs (b), and OF-NPs (c). [Color figure can be viewed in the online issue, which is available at wileyonlinelibrary.com.]

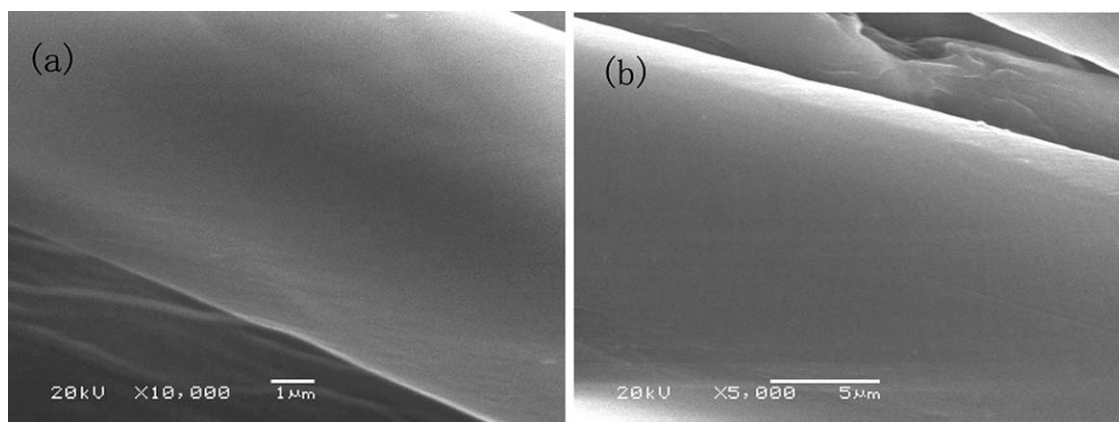


Figure 4 SEM images of untreated cotton fibers.

an initial weight loss below 100°C was observed because of the moisture loss. The second stage, ranging from 130 to 230°C, before the decomposition of the shell, resulted in a 6.32 wt % weight loss gap for OF was absorbed on the particle surface and hence was also leading to weight loss. The third stage, located around 250°C, represented a 5.73 wt % weight loss gap due to OF molecules encapsulated into CS-NPs. Thus, the loading content of OF was as high as 12.05%. Nay more, the encapsulation of OF

in CS can slow down the release of fragrance under the high temperature and increase the aroma retaining time.

SEM analysis

Figure 4 displayed the surface appearances of the untreated cotton fibers. The untreated cotton fibers exhibited uniform neat plain structure and its surface was smooth. Figure 5 demonstrated the

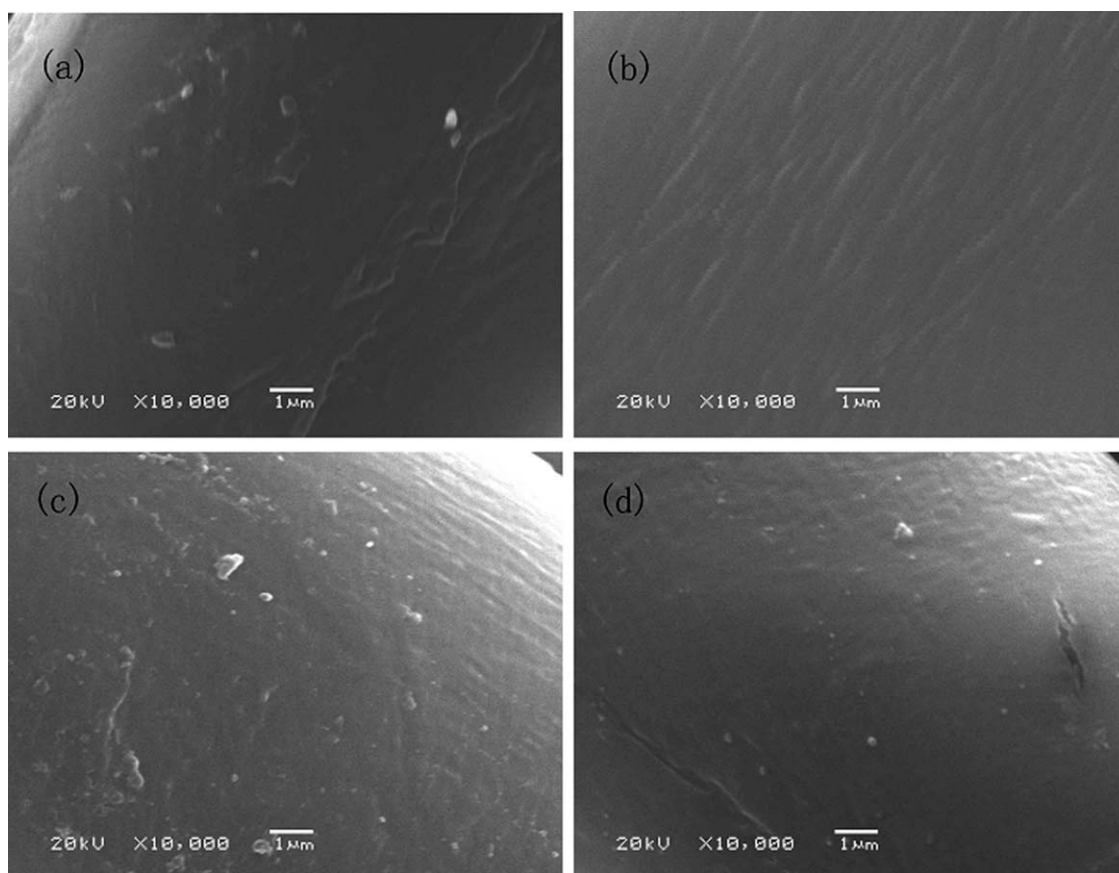
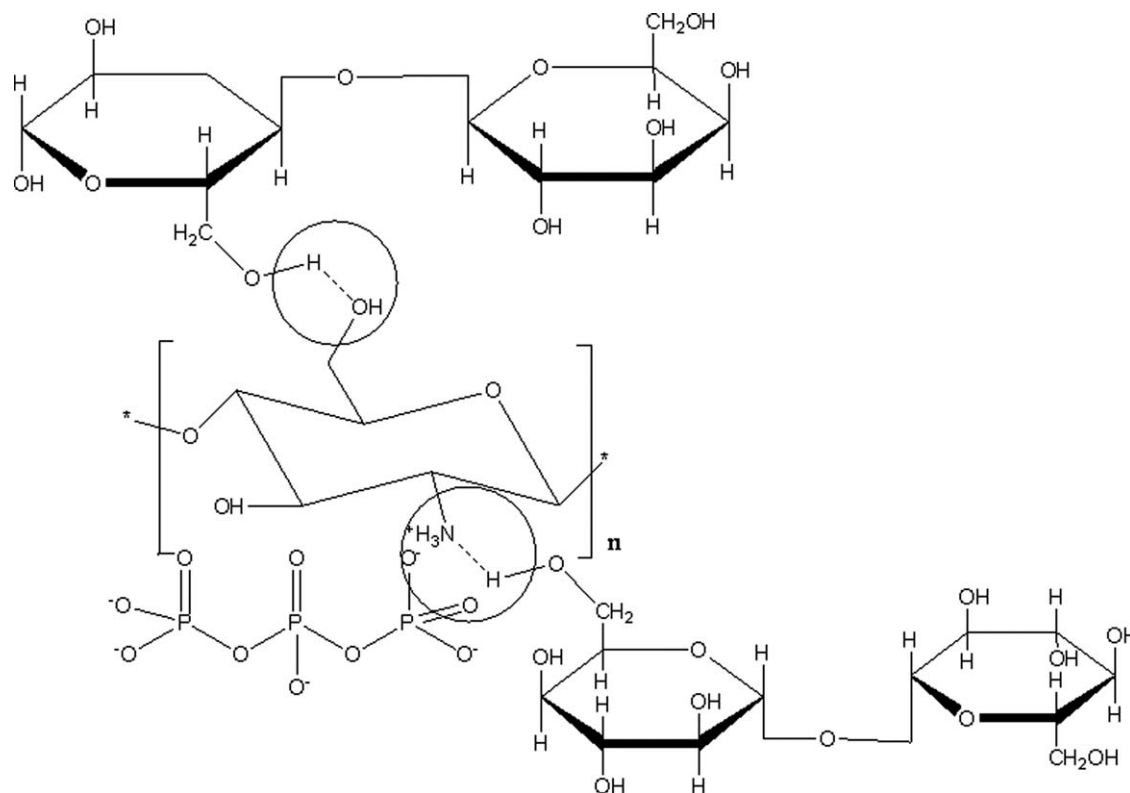


Figure 5 SEM images of OF (a and b) and OF-NPs treated cotton fibers (c and d) (a and c—without washing; b and d—washing 20 cycles).



Scheme 1 Function mechanism between cellulose and OF-NPs.

influence of the laundering cycles on the microcosmic structures of the fabrics treated with OF and OF-NPs, respectively. Only a few of the irregular emulsified fragrance clusters were aggregated on the surface of the cotton fabrics treated with OF due to the absence of the interaction groups between CS and OF [Fig. 5(a)].²⁵ After washing 20 cycles, small or no residual aroma chemicals remained on the fiber surfaces showing the limited retention of trace amounts of aroma chemicals [Fig. 5(b)]. Whereas, there were a lot of nanoparticles dispersed on the surface of the cotton fabrics treated with OF-NPs as shown in Figure 5(c). Although the treatment decreased the number of nanoparticles on the cotton fabrics, there were still a little bit of nanoparticles dispersed on the surface of the cotton, which was attributed to the chemical structure and framework structure of the cotton fabrics. Holes (50–200 nm) on the surface of the cotton fibers²⁶ could make the nanoparticles penetrate into themselves depending on the osmotic pressures. Besides, cotton was a natural fiber consisting of cellulose with 1,4-D-glucosepyranose as its repeating units.²⁷ The hydroxyl groups of cellulose could facilitate the absorption of OF-NPs onto the cotton fibers (Scheme 1).²⁸ The strength of O—H—N was 29 kJ mol and the energy of O—H—O was 21 kJ mol, they were stronger than a van der Waals force but weaker than covalent or ionic bonds.²⁹ Additionally, the H-bond networks were sensitive to humidity level because water molecules could diffuse into the surface and disrupt the

network.³⁰ So washing will reduce the number of the nanoparticles.

GC-MS analysis

The evaluation of the fragrance concentration was based on the determination of the components in the headspace of the finished cotton fabrics. The slow release property can be reflected via GC-MS comparison between the cotton fabrics finished by OF-NPs and OF. Table I demonstrated that the comparison between the loss ratio of main components in the gas phase of the fragrance release from the cotton fabrics treated by OF-NPs and OF after washing. Whatever OF-NPs or OF, there was a decrease of fragrance in the textiles after washing treatment.

The washing resistance of the cotton fabrics treated by OF was poor because the complete loss of limonene, longifolene, neoisolongifolene-8-ol, γ -unsecalactone, and 4-*tert*-butylcyclohexyl acetate; and the contents of methyl anthranilate and dihydro methyl jasmonate were reduced by 84.09% and 97.44%, respectively. Whereas, every fragrant ingredient in OF can be detected for the cotton fabrics treated with OF-NPs; methyl anthranilate was kept around 66.5% of the initial amount and dihydro methyl jasmonate above 70% of the initial content. It was appeared that the cotton fabrics treated with OF-NPs had an excellent washing resistance. However, geraniol and iso E super did not show marked differences when compared with the corresponding OF. OF was a

kind of compounded mixture, so not every ingredient could be encapsulated into the nanoparticles due to different solubility. Besides, the different volatility in every fragrant compound listed by Poucher³¹ would lead to the fragrance loss during the washing treatment. Geraniol was a small, light molecule that evaporated quickly. The contribution of it in a mixture to the total profile could be only from 30 min to 2 h. Therefore, it tended to fade out as time passed away when it was exposed to outer space from the shell. While iso E super fell into the base note. Lifespan of base note could last up to weeks and it retained over 60% after 20 launderings.

CONCLUSIONS

Osmanthus fragrance-loaded chitosan nanoparticles (OF-NPs) was successfully prepared via complex coacervation. Then, the OF-NPs were applied in the cotton fabrics directly. The spherical OF-NPs kept about 130 nm and dispersed evenly (PDI: 0.133). FTIR confirmed that OF had been interacted with chitosan via the hydrogen bonds. TGA demonstrated that the thermal stability of OF-NPs had been improved in contrast to OF and the loading content of OF was as high as 12.05%. SEM displayed that the cotton fabrics treated by OF-NPs had an excellent washing resistance. This was attributed to the hydroxyl group interaction between the cotton fabrics and the OF-NPs. However, the fragrance of the treated cotton fabrics with OF-NPs could not be kept for a long time because of the limited interaction. GC-MS showed that the washing resistance of the cotton fabrics treated by OF was poor because were lost completely limonene, longifolene, neoisolongifolene-8-ol, γ -unsecalactone, and 4-*tert*-butylcyclohexyl acetate; and the content of methyl anthranilate and dihydro methyl jasmonate were reduced to 84.09% and 97.44%, respectively. Whereas, every fragrant ingredient in OF can be detected for the cotton fabrics treated with OF-NPs. It was appeared that the cotton fabrics treated with OF-NPs has an excellent washing resistance. Overall, nanoencapsulation with CS-TPP will provide an excellent method for releasing fragrance.

References

- Specos, M. M. M.; García, J. J.; Tornesello, J.; Marino, P.; Vecchia, M. D.; Tesoriero, M. V. D.; Hermida, L. G. T. *Roy Soc Trop Med H* 2010, 104, 653.
- Liu, H. Q.; Obendorf, S. K.; Leonard, M. J.; Young, T. J.; Incorvia, M. J. *J Surf Deterg* 2005, 8, 311.
- Li, S. Q.; Lewis, J. E.; Stewart, N. M.; Qian, L.; Boyter, H. *J Text Inst* 2008, 99, 177.
- Shin, Y.; Yoo, D.; Son, K. *J Appl Polym Sci* 2005, 96, 2005.
- Onder, E.; Sarier, N.; Cimen, E. *Thermochim Acta* 2008, 467, 63.
- Nischala, K.; Rao, T. N.; Hebalkar, N. *Colloid Surf B* 2011, 82, 203.
- Khalil-Abad, M. S.; Yazdanshenas, M. E. *J Colloid Interface Sci* 2010, 35, 293.
- Nelson, G. *Int J Pharm* 2002, 242, 55.
- Rodrigues, S. N.; Martins, I. M.; Fernandes, I. P.; Gomes, P. B.; Matak, V. G.; Barreiro, M. F.; Rodrigues, A. E. *Chem Eng J* 2009, 149, 463.
- Monllor, P.; Bonet, M. A.; Cases, F. *Eur Polym Mater* 2007, 43, 2481.
- Ouali, L.; monthoux, V.; Latreche, D.; Boonneville. U.S. Patent 7,279,542 (2007).
- Sohn, S. O.; Lee, S. M.; Kim, Y. M.; Yeum, J. H.; Choi, J. H.; Ghim, H. D. *Fiber Polym* 2007, 8, 163.
- Hu, J.; Xiao, Z. B.; Wang, M. X.; Ma, S. S.; Zhou, R. J.; Li, Z.; Dai, S. P. *J Funct Mater* 2010, 41, 186.
- Lee, H. H.; Lin, C. T.; Yang, L. L. *J Biomed Sci* 2007, 14, 819.
- Omura, H.; Honda, K.; Hayashi, N. *J Chem Ecol* 2000, 26, 655.
- Li, S.; Lewis, J. E.; Stewart, N. M.; Qian, L.; Boyter, H. *J Text Inst* 2008, 99, 177.
- Wang, P.; Zhu, Y. H.; Yang, X. L.; Chen, A. P. *Flavour Frag J* 2008, 23, 29.
- Zhu, H. O.; Lu, Z. G.; Cai, J. H.; Li, J. J.; Gao, L. R. *Polym Test* 2009, 28, 521.
- Janes, K. A.; Alonso, M. *J Appl Polym Sci* 2003, 88, 2769.
- Csaba, N.; Höggård, M. K.; Alonso, M. J. *Int J Pharm* 2009, 382, 205.
- Tang, E. S. K.; Huang, M.; Lim, L. Y. *Int J Pharm* 2003, 265, 103.
- Lu, Y. H.; Chen, Y. Y.; Lin, H.; Wang, C.; Yang, Z. D. *J Appl Polym Sci* 2010, 117, 3362.
- de Moura, M. R.; Aouada, F. A.; Avena-Bustillos, R. J.; McHugh, T. H.; Krochta, J. M.; Mattoso, L. H. C. *J Food Eng* 2009, 92, 448.
- Shown, I.; Murthy, C. N. *Appl Polym Sci* 2009, 111, 2056.
- Liu, H. Q.; Kay Obendorf, S. J.; Young, T. J.; Incorvia, M. *Appl Polym Sci* 2003, 91, 3557.
- Rous, M. A.; Ingolic, E.; Schuster, K. C. *Cellulose* 2006, 13, 411.
- Abhishek, S.; Samir, O. M.; Annadurai, V.; Urs, G. R.; Mahesh, S. S.; Somashekar, R. *Eur Polym Mater* 2005, 41, 2916.
- Ravindra, S.; Mohan, Y. M.; Reddy, N. N.; Raju, K. M. *Colloid Surf A* 2010, 367, 31.
- Emsley, J. *Chem Soc Rev* 1980, 9, 91.
- Parthasarathi, R.; Subramanian, V.; Sathyamurthy, N. *J Phys Chem A* 2006, 10, 3349.
- Poucher, W. A. *Poucher's Perfumes, Cosmetics and Soaps*; Athenæum Press: Great Britain, 1993.