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Antibacterial Non-woven Nanofibers of Curcumin Acrylate Oligomers

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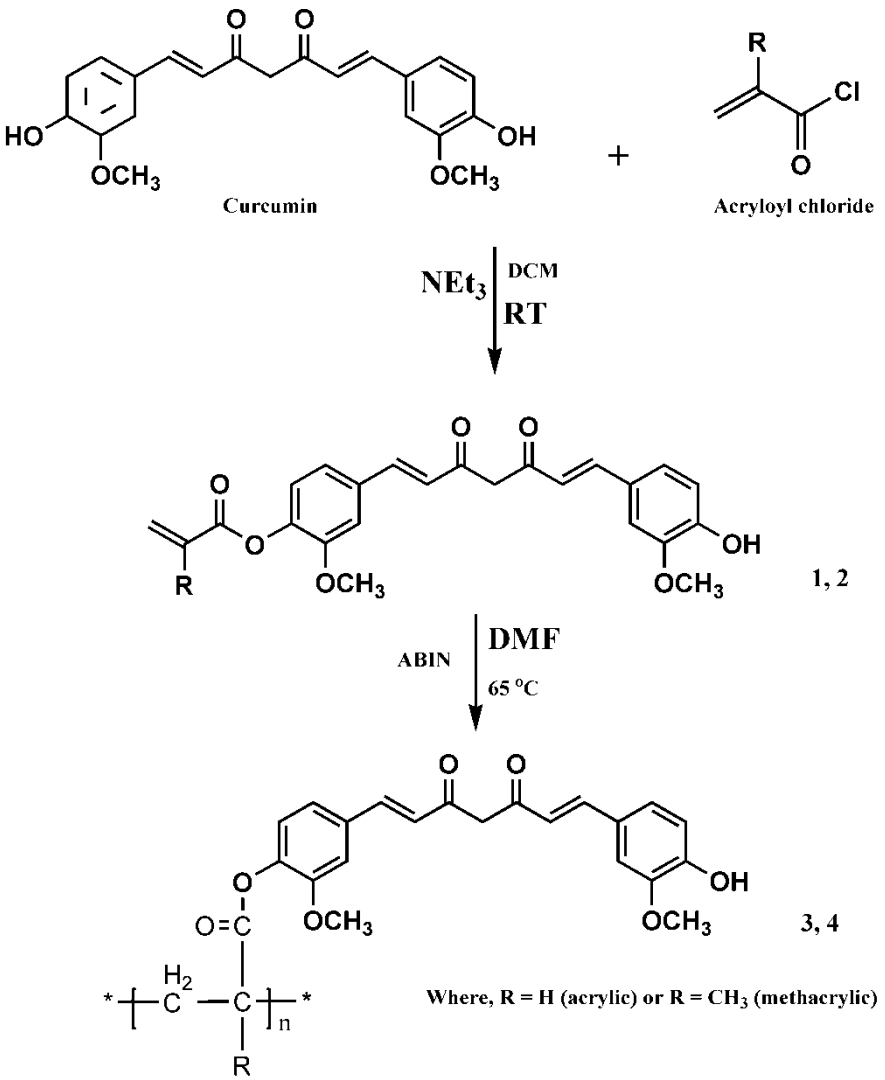
Two new (meth)acrylate monomers, namely, 4-((1E, 6E)-7-(4'-hydroxy-3-methoxyphenyl)-3, 5-dioxohepta-1, 6-dienyl)-2-methoxyphenyl acrylate, (curcumin monoacrylate), (CmA) and 4-((1E, 6E)-7-(4'-hydroxy-3-methoxyphenyl)-3, 5-dioxohepta-1, 6-dienyl)-2-methoxyphenyl methacrylate, (curcumin monomethacrylate), (CmMA) are synthesized by reacting (1E,6E)-1,7-bis(4-hydroxy-3-methoxyphenyl)hepta-1,6-diene-3,5-dione, (curcumin) with acryloyl and methacryloyl chloride respectively. And the respective derivatives are polymerized by free radical polymerization using an initiator, 2, 2-azobisisobutyrontrile (AIBN) to obtain oligomer of curcumin monoacrylate, (OCM) and oligomer of curcumin monomethacrylate (OCMA). The oligomers are characterized by FTIR, ^{1}H NMR spectroscopy and UV-vis. The molecular weights of the oligomers are determined by GPC which ranged between 2000-5500 Da. The melting temperature (T_m) and degradation temperature of the respective oligomers are evaluated by thermal analysis. The melting temperature of oligomers ranged from 195-197°C. Antibacterial studies are evaluated against *staphylococcus aureus,* where the minimum inhibitory concentration (MIC) of OCA1 is 27 mg mL^{-1}. The blends of Individual oligomers with poly (lactic acid) are electrospun to attain the respective non-woven nanofiber mats. Nanofibers are formed with the diameter ranging from 400-750 nm and the nanofiber mats are porous. The nanofiber mats being antibacterial and highly porous, they may have potential application as wound dressing material for tissue regeneration.

Key words: curcumin acrylates, polymer synthesis, nanofibers, thermal properties, antibacterial.

Introduction

Curcumin (CUR) which constitutes 90% of turmeric (diferuloylmethane) is extensively used as a spice, food preservative and colouring material in South East Asia. In addition, it is being used as a house-hold remedy for various diseases, like biliary disorders, anorexia, cough, diabetic wounds, hepatic disorders, rheumatism and sinusitis. For the past few decades, extensive research has been done on curcumin to establish the biological and pharmacological actions, which posses a wide spectrum of biological properties such as antioxidant, anti-inflammatory, antibacterial, antifungal anti-parasitic anticancer anticoagulant, anti-protozoal, antiviral, anti-fibrotic, anti-venom, antiulcer, hypo-tensive and hypo-cholesteremic properties[1-12]. However poor water solubility of CUR has limited its application. Hence, research is under progress to enhance its water solubility. Generally, phenolic groups of CUR are being modified to enhance the solubility. Studies on CUR and or modified CUR entrapped in polymer matrix used for wound dressing materials showed an initial burst with sustained release[13]. Encapsulation of CUR in various polymeric materials for drug delivery applications have been reported[14-18]. Various biocompatible polymers are being designed and fabricated in the form of gels, films and nanofibers with and without drugs to encounter wound healing by regeneration of tissue[19]. Antimicrobial agents are being used to meet the problems associated with the contamination of microorganism in various areas (biomaterials, water purification systems, food materials, sanitation, etc)[20-22]. As reported, it is evident that most of the antimicrobial agents are more stable and active when conjugated to polymers[20]. The conjugation of antimicrobial agent is done by two methods, 1) conjugation of antimicrobial agent to the polymerizable functional groups of monomer, for instance; 4-amino-N-(5-methyl-3-isoxazolyl)benzenesulpfonamide was

conjugated to acrylate and methacrylate and the respective monmer derivatives were polymerized by free radical polymerization using benzoyl peroxide as a initiator [23]. Similarly, monomer derivative, N-[4-sulfamido-N-(5-methyl-3-isoxazolyl)-phenyl]maleimide was polymerized by free radical polymerization[23]. Two novel organotin monomers such as, (N-tri-n-butyltin)maleimide (N-TBTM) and m-acryloylamino-(tri-n-butyltinbenzoate) (m-AATBTB) were copolymerizedation with styrene in bulk at 65 °C using azobisisobutyronitrile as the free radical initiator to attain the respective antibacterial polymers[24]. 2) Antimicrobial agent conjugated to pre-formed polymer for example; 2-benzimidazolecarbamoyl was conjugated to poly (ethylene-*co*-vinyl alcohol (EVOH – CBZ) and ampicillin conjugated to poly (styrene-*co*-maleic anhydride) (PS-MA)[25-26]. In either case the antimicrobial activity is enhanced and the activity depends on the kind and concentration of the drug used. Nevertheless, there is always a need for new material with improved property for tissue regeneration. Poly (acrylic acid) derivatives were proven to be biocompatible polymers[27-29], and showed many applications in medicine[30-31]. As curcumin being antimicrobial, we anticipated designing a new bioactive curcumin conjugated acrylic polymers, that may be used as antibacterial agent to treat wounds. Therefore, the objectives of our studies are, 1) to synthesize CmA and CmMA and polymerize by free radical polymerization 2) characterize and determine the molecular weights of various polymers 3) study thermal and antibacterial properties of polymers and 4) fabricate the polymers in the form of non-woven nanofiber mats and evaluate the morphology of the nanofibers.



Scheme 1. Synthesis of 1) CmA (R=H), 2) CmMA (R=CH_3) 3), OCA (R=H), 4) OCMA (R=CH_3)

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Results and discussion

Monomers of CmA (1) and CmMA (2) were synthesized by reacting curcumin with acryloyl chloride and methacryloyl chloride respectively. The pure monomers were separated by column chromatography to attain the respective products. As a result, the obtained yield of CmA (1) was 40% and CmMA (2) was 33%. The structures of these monomers were confirmed by UV-vis, FTIR, ^{1}H, ^{13}C NMR and mass spectrometer. The wave length (λ_{max}) of curcumin was 423 nm but the wavelength of CmA and CmMA shifted to lower value (413 nm) due to the formation of ester bond between curcumin and acrylic/methacrylic group.

The characteristic absorption bands for CmA and CmMA due to the presence of -OH, -C=C,-COO, appeared at around 3450 cm^{-1} (OH), 2936 cm^{-1} (H-C=C in alkenes), 2895 cm^{-1} (CH_3-C=C), 1747 cm^{-1} (O=C-O). 1633 cm^{-1} (α, β-unsaturated carbonyl group), 1526, and 1456 cm^{-1} (H-C=C in aromatic). A peak at 1747 cm^{-1} indicated the formation of ester bond due to the reaction between phenolic group of curcumin and acryloyl/methacryloyl chloride (Figure **1S**, supplementary data).

Proton NMR spectra of CmA (A) showed the characteristic signals, which appeared at 7.9 δ (s, phenolic group), 7.76 δ (d, β-hydrogen in α, β- unsaturated C=O group), 7.11-6.41 δ (aromatic hydrogens), 6.16 δ (=CH) (*cis* to carbonyl in acrylic group), 5.9 δ (=CH) (*trans* to carbonyl in acrylic group), 5.75 δ (s, methylene group), 3.87 δ (s, methoxy groups) and 1.78 (t, 1H in acrylic group). ^{13}C NMR spectra of CmA showed the characteristic signals at 184-181 δ (α, β-unsaturated C=O group), 164 δ (C=O in ester), 151, 148, 139, 134, 127, 123, 121, 111, 101, 56 (CH_2), 56.01 (OCH_3), which conformed the synthesis of CmA (A). Similarly, synthesis of CmMA (B) was confirmed by ^{1}H NMR and ^{13}C but, in CmMA (B) the characteristic signal of methyl appeared at 1.98 δ. Figure **2S** shows the ^{1}H NMR of CmA and CmMA (supplementary data).

CmA and CmMA were polymerized by free radical polymerization using AIBN as an initiator. The initiator concentration was varied to attain different molecular weights of OCMA1, OCMA2, OCA1 and OCA2. The obtained oligomers (OCA and OCMA) were characterized by UV-vis, FTIR, ^{1}H NMR. The FT-IR spectra for OCA and OCMA showed the characteristic absorption bands which appeared at around 3540 cm^{-1} (-OH), 2960 cm^{-1}, (H-C=C in alkanes), 1757 cm^{-1} (O=C-O) and 1635 cm^{-1} (α, β-unsaturated carbonyl group), 1526 cm^{-1} and 1462 cm^{-1} (H-C=C in aromatic) (Figure **3S**, supplementary data).

The ^{1}HNMR spectra of oligomers as well as the signals assignment were shown in Figure **1**. As a result of polymerization, all the peaks in the spectra were broad. Importantly, the signals of acrylic group (-HC=CH_2) at 6.16, and 5.95 δ were shifted to 1.3 δ due to conversion of double bond to single bond, which indicated that the polymerization was successful.

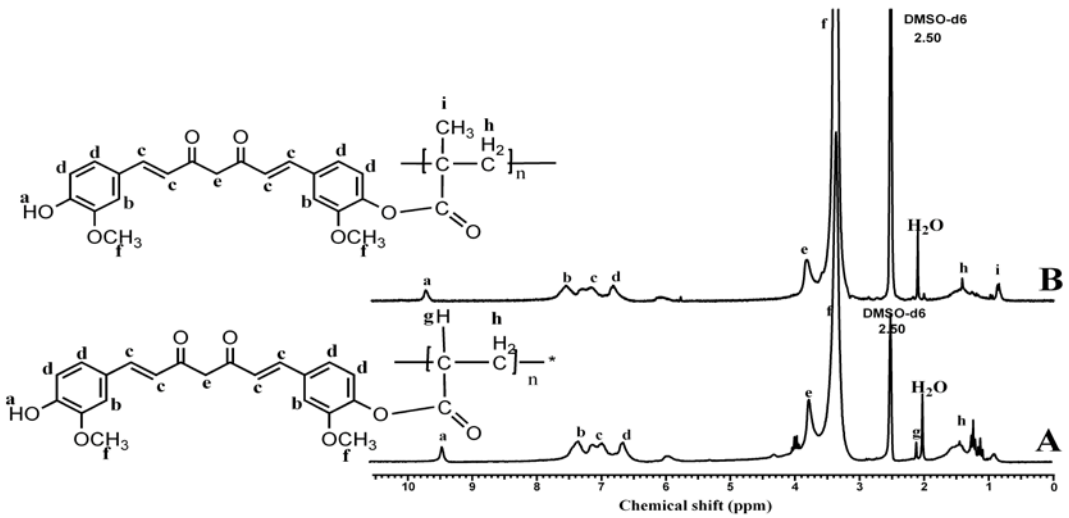

Figure 1. ^{1}H NMR spectra of A) OCA B) OCMA

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TABLE 1. Synthesis of oligomer and determination of molecular weight.

Oligomer	Monomer conc.in gm/lit	Initiator conc. in gm	Monomer : intiator	Yield%	Mw[a]	Mn[a]	PDI = (Mw/Mn)
OCMA1	0.150	0.0075	1 : 0.15	74	5400	2700	**2.0**
OCMA2	0.150	0.0035	1 : 0.09	40	2300	1200	**1.9**
OCA1	0.150	0.0075	1 : 0.15	65	4300	2400	**1.8**
OCA2	**0.150**	**0.0035**	**1 : 0.09**	**40**	**2000**	**1100**	**1.8**

'a' denotes molecular weight estimation using polystyrene standards.

Molecular weight distributions for oligomers were studied by GPC. Table **1** shows the average molecular weight (Mw^a), number average molecular weight (Mn^a), and polydispersity (PDI) for the respective oligomers. Low molecular weights were obtained, which ranged from 2,000 to 5,400 and the polydispersity index (PDI) was from 1.8 to 2. As shown in Table **1,** the yield of oligomers, OCMA1 and OCA1 was 74 % and 65 % respectively whereas; the yield for OCMA2 and OCA2 was 40 % each. We anticipated high molecular weight polymers with increase in initiator concentration; however oligomers of low molecular weight were obtained because of the antioxidant property of phenolic group. As reported earlier, the antioxidant property inhibits the free radical polymerization[32].

Thermal stability of OCA and OCMA were evaluated by heating the sample at a rate of 10°C min^{-1} under nitrogen atmosphere. Both OCMA1 and OCMA2 initiated the degradation at about 232°C though; there was a slight change in molecular weights. Maximum degradation was observed at about 430°C with the residue of 13-18% for OCMA1/OCMA2 (Table **2S,** supplementary data). The melting temperature (T_m) was studied by DSC. According to literature the CUR melting temperature was 183 °C, however the experimental value ranged from 179-184°C, indicating that the curcumin used was a mixture of CUR isomers. Oligomers, OCA1, OCA2, OCMA1 and OCMA2 showed melting transition temperatures (T_m) ranging from 195-197 °C. Increase in melting temperature is attributed to an increase in molecular weight (Figure **4S,** supplementary data**)**.

Powder X-ray diffraction analysis of CUR and oligomers is shown in Figure **2**. According to the reported literature[33], the distribution of 2θ values for CUR appeared at 8.9°, 12.26°, 14.54°, 17.24°, 23.33°, 24.60° and 25.52°. However, the CUR used in our studies too recorded the distribution of 2θ values at 9.1°, 14.6°, 17.5° and 23.5° suggesting that CUR is highly crystalline in nature. But, the oligomers did not record the crystalline peaks as CUR lost crystallinity on polymerization and became amorphous in nature.

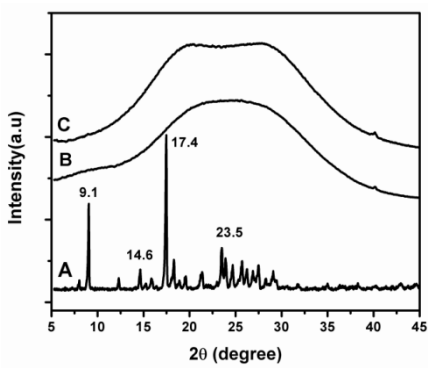

Figure 2. XRD analysis of A) CUR B) OCA C) OCMA

The antimicrobial activity of CUR and oligomer (OCA1) was tested against gram-positive bacteria, *Staphylococcus aureus* (Figure **3**). These bacteria are responsible for wound infection [34]. CUR is antibacterial and according to the reported literature, the minimum inhibitory concentration (MIC) ranged between 0.25 to 0.5 mg mL^{-1} [35]. However, the CUR used in our studies recorded the MIC of 2 mg mL^{-1}. The difference in MIC could be attributed to the purity of curcumin. To demonstrate the antibacterial activity of the oligomers,

one of the oligomer was selected, for example, OCA1. The respective 9, 18, and 27 mg mL^{-1} concentrations were used to determine the MIC. We observed that, 27 mg mL^{-1} of OCA1 recorded antibacterial inhibitory zone, whereas, 9 and 18 mg mL^{-1} did not inhibit bacterial growth. The MIC of oligomer was increased as compared to MIC of CUR because of derivatization of one of the phenolic group of CUR. Though the MIC of oligomer (27 mg mL^{-1}, 0.0063) was increased, the difference in the millimoles as compared to MIC of curcumin was less significant (2 mg mL^{-1}, 0.0052 mmoles), hence the antibacterial activity of curcumin acrylate oligomers is comparable with curcumin. As reported, the slight difference in the antibacterial activity for the oligomer is attributed to decrease in the number of phenolic groups, as they are the active antibacterial sites[36-37].

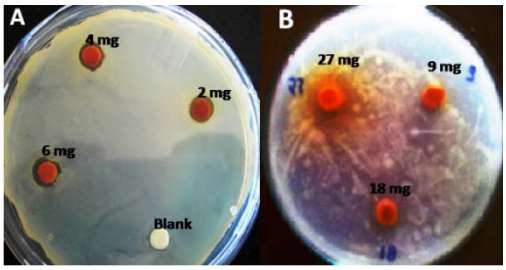

Figure 3. Antibacterial studies of A) curcumin and B) OCA1

We fabricated the oligomers in the form of non-woven nanofiber mats so as to enable their utility for tissue regeneration owing to antibacterial activity of the oligomer. Pure oligomers, OCA and OCMA were incapable to electrospun due to their low molecular weight. Therefore, we blended the respective oligomers with high molecular weight PLA. PLA of 8% concentration produced smooth and fine nanofibers. Hence, 8 % PLA was chosen to blend with 3% of the respective oligomers to fabricate non woven nanofiber mats.

Figure 4. Nanofiber mat of OCA1and PLA blend

Figure **4** shows non-woven nanofiber mat of OCA1 and PLA blend and Figure **5** shows the morphology of various OCA and OCMA. The diameter of these nanofibers varied from 400 -750 nm and the nanofiber mats were highly porous. As the designed nanofiber mats being porous and antibacterial, they may have potential application in tissue regeneration. The upcoming investigations would involve improvement of properties of the nanofiber mat by blending oligomers of curcumin acrylates with the suitable polymers and added bioactive agents.

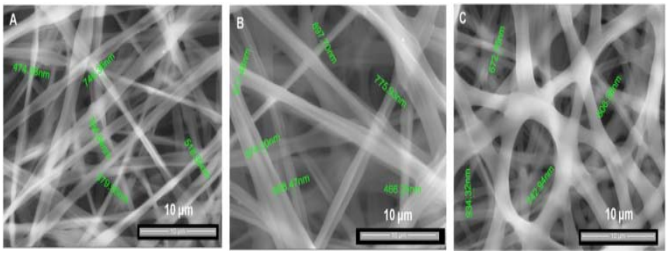

Figure 5. ESEM images for A) OCA1, B) OCMA1 and C) OCA2

Conclusions

Curcumin acrylic derivatives such as curcumin monoacrylate and curcumin monomethacrylate were prepared and polymerized by free radical polymerization, as a result the corresponding oligomers of curcumin monoacrylate and oligomer of curcumin monomethacrylate were obtained. These oligomers alone were unable to electrospun hence, they were blended with high molecular weight poly (lactic acid) to obtain non-woven nanofibers. The nanofiber mats were antibacterial and highly porous with large diameter. Therefore, these nanofiber mats may be potential material as wound dressing material. Further, the efficacy of the nanomaterial may be improved by blending and immobilizing bioactive agents. The studies in this direction are under progress.

Experimental

Measurements

Thin-layer chromatography (TLC) was performed on ALUGRAM SILG/UV_{254} (Macherey-Nagel, Germany) with detection by UV light. ^{1}H and ^{13}C NMR spectra were recorded on Bruker AV 200, in solvents, deuterated chloroform ($CDCl_3$) and dimethylsulfoxide (DMSO-d_6). Chemical shifts (δ) were given in ppm. Infrared spectra (KBr disks) were recorded with a Perkins Elmer spectrometer I, FTIR diffused reflectance (DRIFT) mode, USA. The wave numbers (ν) of recorded IR-signals were quoted in cm^{-1}. A mass spectrum was recorded using AB Scuex, MALDI-TOF, TOF-5800 U.S.A. The thermal properties of oligomers were determined by thermo gravimetric analysis (TGA) and differential scanning calorimetry (DSC). TGA data for a respective 5 mg sample was recorded under nitrogen atmosphere on a Perkin Elmer, TGA 7 analyzer at a scan rate of 10 °C min^{-1} from 50°C to 900°C (nitrogen flow rate 50 mL

min^{-1}). DSC data for the respective 5 mg sample was recorded on an instrument DSC-TA-Q10, in the temperature ranging from -90°C to 250 °C. A controlled heating and cooling rate was maintained at 5 °C min^{-1}. Experiments were performed under nitrogen atmosphere with a flow rate of 50 mL min^{-1}. Glass transition temperature (T_g) and melting temperature of polymer (T_m) were determined from the heating and cooling scans. UV-vis spectra were recorded using a UV 1601PC UV spectrophotometer, Shimadzu. Melting temperature of compound was determined using Melt-Temp, barnstead/Thermolyne 2555 kerperbaulenvard Dubuque/Iowa 52001, U.S.A. The powder samples were characterized using a philips 1830 X-ray diffractometer (Phillips, Amelo, The Netherlands). X-rays were generated by a CuKα source at a wavelength of 1.54Å. The samples were scanned in the 2θ region of 5-40°C to investigate the change in crystal structure before and after the formation of oligomers. Molecular weights of various oligomers were determined by gel permeation chromatography (GPC). The measurements were performed in tetrahydrofuran (THF) at 50 °C, using Waters 510 gel permeation chromatograph equipped with two Ultrastyragel columns (7 x 104 A pore size). The calibration curve was obtained with polystyrene standards.

Materials

Curcumin, (Loba Chemicals India), acrylic acid, methacrylic acid and poly (L-lactide) (Mw, 258,700 Da) (PLA) were procured from Aldrich-Sigma chemicals, Bangalore, India. Benzoyl chloride, hydroquinone, 2,2-azobisisobutyronitrile (AIBN), dimethylformamide (DMF), and dichloromethane (DCM) were purchased from Merk Chemicals, Mumbai, India. Acryloyl chloride and methacryloyl chloride were prepared according to the method reported by Stampel et al[38].

Methods

General procedure for Synthesis of CmA and CmMA

CUR (2 g, 0.0054 gmol) and triethylamine (TEA) (0.71 mL, 0.0051 gmol) were taken in a 100 mL round bottom flask and dissolved in DCM (30 mL). The reaction mixture was purged with nitrogen while stirring for 10 min at 0 °C. Under same conditions, acryloyl chloride (1 mL, 0.0054 gmol) dissolved in DCM (5 mL) was added drop wise. After addition, the reaction mixture was allowed to stir under nitrogen atmosphere for 24 h at room temperature. Later, DCM was evaporated under reduced pressure and the crude product was dissolved in ethyl acetate and washed with saturated aqueous solution of sodium bicarbonate. The organic layer was collected and dried using anhydrous sodium sulphate. The obtained product was concentrated under reduced pressure and purified by column chromatograph (eluent 2:1 pet ether/ethyl acetate) to obtain the pure CmA as a primary product and curcumin diacrylate as a secondary product. Similar procedure was followed for preparation of CmMA.

4-((1E, 6E)-7-(4'-hydroxy-3-methoxyphenyl)-3, 5-dioxohepta-1, 6-dienyl)-2-methoxyphenyl acrylate (CmA) (1)

Yield: 40%. mp: 126-133°C. ^{1}H NMR (200 MHz, $CDCl_3$, δ, ppm): 7.9 (s, 1H), 7.76 (d, 2H), 7.11, 6.98 (d, 2H), 6.87, 6.67 (d, 4H), 6.41(d, 2H), 6.26 (t, 1H), 6.16, 5.9(dd, 2H), 5.75 (s, 2H), 3.87 (s, 6H), 1.78. ^{13}C NMR (200 MHz, $CDCl_3$, δ, ppm): 184 (C-1, C=O), δ 182 (C-2, C=O), 164 (C-3, C=O), 151, 148, 139, 134, 127, 123, 121, 111, 101, 56 (CH_2), 56.01 (OCH_3). FT-IR (KBr, thin film, cm^{-1}): 3348 (-OH), 2925 (H-C=C), 1736 (O=C-O), 1633 (α, β- unsaturated C=O), 1523, 1466 (C=C aromatic). UV-vis (ethanol) λmax, nm: 413. MS MALDI TOP, m/z: Calcd for 422.14; found: 422.96 $[M+H]^+$.

4-((1E, 6E)-7-(4'-hydroxy-3-methoxyphenyl)-3, 5-dioxohepta-1, 6-dienyl)-2-methoxyphenyl methacrylate (CmMA) (2)

Yield: 33%; mp: 154-158°C. ^{1}H NMR (200 MHz, $CDCl_3$, δ, ppm): 7.9 (s, 1H), 7.68 (d, 2H), 7.21, 7.02 (d, 2H), 6.67, 6.58 (d, 4H), 6.41 (d, 2H), 6.06, 6.00 (dd, 2H), 5.85 (s, 2H), 3.87 (s, 6H), 1.98 (s 3H). ^{13}C NMR (200 MHz, $CDCl_3$, δ, ppm):184 (C-1, C=O), 183 (C-2, C=O), 165 (C-3, C=O), 151, 148, 139, 135, 124, 123, 115, 111, 101, 56 (CH_2), 51 (OCH_3), 18 (CH_3). FT-IR (KBr, thin film, cm^{-1}): 3382 (-OH), 2939 (H-C=C), 1737 (O=C-O), 1633 (α, β- unsaturated C=O), 1535, 1462 (C=C aromatic). UV-vis (ethanol) λmax, nm: 413. MS MALDI TOP, m/z: Calcd for 436.15; found: 436.996 $[M+H]^+$.

Synthesis of oligomers

Oligomer of curcumin monoacrylate, (OCA) (3) and oligomer of curcumin monomethacrylate, (OCMA) (4) were synthesized using the respective monomers, CmA (**1**) and CmMA (**2**). The protocol for synthesis of oligomers remains same for both. For example, A mixture of monomer **1**, (0.15 g, 0.0054 gmol) and initiator, AIBN (0.0075 g, $4x10^{-5}$ gmol) were taken in two necked round bottom flask and dissolved in DMF (2 mL). The mixture was purged with nitrogen for 30 min to remove oxygen from the reaction mixture. While maintaining the inert atmosphere, the reaction mixture was left in water bath at 65 ^{0}C. After 48 h, the reaction mixture was precipitated using a mixture of ethyl acetate and pet ether (1:1 ratio) to obtain OCA (**3**). Yield: 76% and OCMA (**4**), yield: 74%. The melting temperature of the oligomers ranged between 195-197°C.

Oligomer of curcumin monoacrylate, (OCA) (3)

Yield: 76%. ^{1}H NMR (200 MHz, $CDCl_3$, δ, ppm): 9.7 (s, phenolic -OH), 7.5, 6.3 (m, aromatic), 3.81 (s, OCH_3), 2.18 (m, CH-C=O), 1.39 (t, CH_2). UV-vis (ethanol) λmax, nm: 399. FT-IR (KBr, thin film, cm^{-1}): 3546 (-OH), 2941 (H-C=C), 2782 (CH_2), 1759 (O=C-O), 1634 (α, β- unsaturated C=O), 1598, and 1463 (C=C aromatic).

Oligomer of curcumin monomethacrylate, (OCMA) (4)

Yield: 74%. ^{1}H NMR (200 MHz, $CDCl_3$, δ, ppm): 9.72 (s, phenolic -OH), 7.58, 6.4 (m, aromatic), 3.87 (s, OCH_3), 1.38 (s, CH_2), 1.07 (s, CH_3). UV-vis (ethanol) λmax, nm: 406. FT-IR (KBr, thin film, cm^{-1}): 3540 (-OH), 2940 (H-C=C), 2839 (CH_2), 1754 (O=C-O), 1635 (α, β- unsaturated C=O), 1537, and 1464 (C=C aromatic).

Fabrication of nanofibers by electrospinning

Three percent of corresponding OCA, OCMA and 8% of PLA were dissolved in 1:1 ratio of DCM and DMF solvent mixture. The dissolved solution was electrospun to attain non-woven nanofiber mats. For example, a 2 mL syringe equipped with a blunt ended stainless steel hypodermic needle of pore diameter 0.8 mm was used as a nozzle. The syringe was filled with 2 mL of blend solution and it was mounted on to a syringe pump with a controller [Model 351, SAGE Instruments and Division of Orion Research Development] to control the flow rate of the solution. The syringe needle was connected to a high voltage generator [GAMMA High RR40-3.75/DDPM, voltage regulated DC power supply; Ormond Beach, USA] operated in positive DC mode. Aluminium plate set in a closed chamber was used as grounded collector for nanofibers. The electrospinning parameters such as voltage, distance between the syringe tip to the collector, and the flow rate were fixed to 15 kV, 15 cm and 0.75 mL h^{-1} respectively. The experiments were performed with these parameters because typically most of the polymers were electrospun to achieve nanofiber mats. As described above, all experiments were performed thrice under the identical conditions and at room temperature for reproducibility.

Antibacterial studies of OCA1

The antibacterial activity of curcumin, OCA1 and the nanofiber mat of OCA1 against *Staphylococcus aureus* (*S. aureus*, ATCC 25923) was demonstrated by disc diffusion method[39-40]. The disc diffusion method was performed in a nutrient agar plate using a modified Kirby Bauer technique. The bacterial suspension (100µL of 10^5-10^6 colony forming units (CFU)) was spread uniformly on the surface of a nutrient agar plate and various concentrations of OCA1 was prepared in dimethylsulfoxide (DMSO) and loaded in wells made on agar plates. In each well, 50 µL of the sample was loaded. Later, the agar plates of the samples were incubated for 24 h at 37°C to record zone of inhibition.

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Figure legends

Figure 1. ^{1}H NMR spectra of A) OCA B) OCMA.

Figure 2. XRD analysis of A) CUR B) OCA C) OCMA.

Figure 3. Antibacterial studies of A) curcumin and B) OCA1.

Figure 4. Nanofiber mat of OCA1 and PLA blend.

Figure 5. ESEM images for A) OCA1, B) OCMA1 and C) OCA2.

GRAPHICAL ABSTRACT

Antibacterial Non-Woven Nanofibers of Curcumin Acrylate Oligomers

Oligomers of curcumin acrylates were blended with polylactide and elctrospun to nanofiber mats, which were antibacterial and highly porous.