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EDITED BY

Zeki Candan,
Biomaterials and Nanotechnology
Research Group | BioNanoTeam, Turkey

REVIEWED BY

Deng-Guang Yu,
University of Shanghai for Science and
Technology, China
Helinando Pequeno De Oliveira,
Federal University of São Francisco
Valley, Brazil

*CORRESPONDENCE

Tahir Farooq,
tahirfarooqfsd@gmail.com,
tfarooqfsd@gucf.edu.pk

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Development of polymeric nanofibers blended with extract of neem (*Azadirachta indica*), for potential biomedical applications

Arruje Hameed¹, Touseef Ur Rehman², Zulfiqar Ahmad Rehan³,
Razia Noreen¹, Sarosh Iqbal², Shaheera Batool⁴,
Muhammad Abdul Qayyum⁵, Toheed Ahmed^{2,6} and
Tahir Farooq^{2*}

¹Department of Biochemistry, Government College University Faisalabad, Faisalabad, Pakistan,

²Department of Applied Chemistry, Government College University Faisalabad, Faisalabad, Pakistan,

³Department of Materials, School of Engineering and Technology, National Textile University,

Faisalabad, Pakistan, ⁴Department of Biochemistry, CMH Institute of Medical Sciences Multan, Multan,

Pakistan, ⁵Department of Chemistry, Division of Science and Technology, University of Education,

Lahore, Pakistan, ⁶Department of Chemistry, Riphah International University, Faisalabad, Pakistan

In recent years, electrospinning has emerged as a promising technique for the preparation of nanofibers with unique properties like flexibility, high porosity and high surface area. In the context of nanodelivery systems, polymer-based nanofibers have become promising carriers of drugs and bioactive compounds ensuring their sustained release and targeted delivery. In this study, neem extract-loaded nanofibers were developed as sustained delivery systems using the electrospinning method. The chitosan, alginate and polyethylene oxide were used as the polymeric matrix for loading of aqueous extract of neem leaves. The prepared nanofibers NF1, NF2 and NF3 carrying 2%, 4% and 6% extract respectively were characterized using SEM, FTIR, XRD and TGA. Further, the as-prepared nanocomposites exhibited a high degree of swelling and dual-phase release of phytoconstituents. Moreover, the developed controlled delivery systems were tested for antifungal and antioxidant potential. Importantly, the bioactivities of the prepared nanofibers could be improved further by using organic extracts which are generally enriched with phytoconstituents. Herein, we selected biodegradable and mucoadhesive biopolymers and an aqueous extract of neem for the development of controlled-delivery nanofibers by electrospinning through a sustainable and cleaner production process. Thus, the prepared biocompatible nanofibrous systems with biphasic release profile could be employed for biomedical applications including wound dressing, soft tissue scaffolds and as transdermal carriers.

KEYWORDS

electrospinning, nanofibers, sustain release, nanocarriers, biopolymers, cleaner production, biphasic release, medicated nanofibers

Introduction

Plants have established their worth as an endless repository of promising bioactive molecules with a broad spectrum of therapeutic potential. Bioactive phytoconstituents have facilitated the synthesis of numerous modern drugs including antitumor, anti-HIV, anti-HCV, antivirals and anti-inflammatory etc. A major portion of the global population primarily relies on plant-based traditional medicines for all sorts of ailments (Choudhari et al., 2020; Mani et al., 2020). Over the past decades, medicinal chemists have shown significant interest to isolate the bioactive molecules from the routinely used and wild varieties of plants (Yao et al., 2017). Neem (*Azadirachta indica*), a member of the Meliaceae family, has been declared as the tree of the 21st century by the United Nations owing to its broad spectrum of medicinal and pharmacological properties (Upadhyay and Vigyan, 2014). This wonder plant is frequently available in the Indian subcontinent and is termed as a living pharmacy or village dispensary due to its unique and diverse pharmacological activities. It carries tannins, alkaloids, coumarins, terpenoids, and flavonoids etc as bioactive phytoconstituents. Each part of the plant has proven neuroprotective, hepatoprotective, anticancer, antibiotic, anti-inflammatory and antioxidant activities etc (Prakash et al., 2022).

Owing to the best safety profiles, plant-based biologically active compounds have become attractive choices for the safer and risk-free treatment of both communicable and non-communicable diseases. However, their therapeutic effects depend upon the bioavailability in the human body which is often encumbered by issues related to their physiochemical properties and structural complexity. They show pH sensitive structural instability, poor adsorption and undesirable off-target interactions. Over the last decade, the exceptional advancements in nanotechnology have helped the developments of various nano-delivery systems like nanosuspensions, nanoemulsions, nanoparticles and nanoliposomes etc which improved the efficacy and bioavailability of drugs and bioactive compounds (Shakeri and Sahebkar, 2016; Ahmad et al., 2020; Manickam et al., 2021). Further, the improvement of bioavailability and controlled delivery of bioactive compounds depends upon the size, shape and internal structures of nanoderived assemblies. The nanoformulations enable the natural compounds to withstand effects of pH, enzymes and temperature, ensuring their structural integrity and target-specific controlled release within the biological systems (Shikov et al., 2008; Puglia et al., 2019; McClements, 2020).

In recent years, the electrospinning has emerged as a promising technique for the preparation of nanofibers with unique properties like flexibility, high porosity, high surface area and aspect ratio. The electrospun nanofibers have shown potential applications in various scientific domains including energy (Sha et al., 2022; Zhu et al., 2022), environment (Kang et al., 2022; Lv et al., 2022), drug delivery (Kang et al., 2020; Li

et al., 2022), sensors (Du et al., 2022; Zhang et al., 2022), functional textiles and medicated products (Khandaker et al., 2022; Wu et al., 2022) etc. In the context of nano-delivery systems, the polymer-based nanofibers have emerged as promising carriers for natural molecules, drugs and nanomaterials with wide applications in bioremediation, electrical and biomedical applications etc (Chen et al., 2020; Marinho et al., 2021; Sameen et al., 2022). Accordingly, a number of synthetic and natural polymers have been used to prepare nanofibers as nanocarriers of drugs, nanoparticles and biomolecules etc. However, their applications as plant extract products are still very limited, which has a potential broad market (Liu et al., 2022b). The electrospinning is fast-moving the coaxial (Ning et al., 2021), tri-axial (Zhao et al., 2021), side-by-side (Wang et al., 2022), and even tri-fluid side-by-side (Liu et al., 2022b) processes for creating complex nanostructures. However, the simplest single-fluid blending processes is still the mainstream, which holds great promise for large scale production, and always acts as a pioneer to expand new applications of electrospun nanofibers. Economic production of commercial products could be made possible by devising new methodologies with minimal energy consumption. The selection of polymer and optimization of various parameters helps to prepare nanofibers with desired physio-morphological properties. The chemical nature of the polymeric material significantly influence the loading capacity, initial burst and sustained release of the bioactive molecules. They could further stimulate the migration, cell adhesion and proliferation of loaded materials. Chitosan (CS) is a polycationic biopolymer showing a broad spectrum of applications in biomedical and pharmaceutical field. It displays strong antifungal and antibacterial potential due to its polycationic nature. Further, its biodegradable, biocompatible, mucoadhesive and nontoxic nature has made it an attractive choice for the development of nanocarriers (Silva et al., 2021). However, the electrospinning of CS is extremely difficult due to its low solubility and highly viscous nature. Alginate is also a biocompatible and biodegradable biopolymer with mucoadhesive and anti-infectious potential, an ideal candidate for delivery of bioactive agents in living systems. The electrospinning capacity of alginate is also limited due to its polyelectrolytic nature (Taemeh et al., 2020). Therefore, nonspinnable polymers are blended with some co-spinning agents to improve their mechanical strength and electrospinnability. PEO is a biodegradable biopolymer approved for internal use in pharmaceutical products, cosmetics, food and products of personal care. Hence, it is suggested as a suitable co-spinning agent for nonspinnable polymers like chitosan and alginate (Grothe et al., 2016; Grimmelsmann et al., 2017; Dodero et al., 2020).

Keeping in view, the unprecedented therapeutic potential of *A. indica* and advancements in electrospinning technology, we envisioned to develop biopolymer-based nanofibers loaded with

neem extract as eco-friendly and controlled releasing nanocarrier.

Materials and methods

Sodium alginate and chitosan 75% (deacetylated) were purchased from Sigma-Aldrich while all other chemicals were of analytical grade and received from local vender. The leaves of *A. indica* (AI) were arranged from botanical gardens of Agriculture University, Faisalabad.

Preparation of alginate/chitosan/PEO/AI solution

At first, 1.5% w/v sodium alginate solution was prepared using distilled water following 1% chitosan solution in 0.2% v/v acetic acid. For matrix preparation, the aforesaid solutions were mixed in 3:1 ratio. Then, 2%, 4% and 6% (w/v) *A. indica* leave extract solution were added in alginate/chitosan solution to prepare three precursor solutions for electrospinning. Then 1 ml of 1% PEO solution was added to each solution just before the electrospinning.

Electrospinning process

Ten mL of the each precursor solution was loaded into a syringe with the needle diameter of 0.45 mm for the preparation of nanofibers using electrospinning apparatus (Elmarco, nanospider). The precursor solution was electrospun and the nanofibers were collected at a grounded drum collector 12 cm away from the tip of the needle. The solution flow rate, the applied voltage, the humidity, and the time for electrospinning were 1 ml/h, 15 kV, 40–50%, and about 10 h, respectively. The CS/ALG/PEO/AI composite nanofibers obtained from above mentioned 3 precursor solutions were dried at room temperature overnight and named as NF1, NF2 and NF3.

Characterization of prepared nanofibers

Scanning electron microscopy

The surface morphology of the prepared NF1, NF2, and NF3 composite nanofibers was examined by a scanning electron microscope (SEM) (SEM JSM-7000 F) operating at 10 kV-voltage. The prepared fibrous samples were coated with electrically conductive carbon. The SEM images were analyzed using 10,000 times optical magnification. Finally, the fiber size distribution was studied using Origin ver. 8.

Fourier-transform infrared spectroscopy

The PerkinElmer (spectrum 100) FT-IR spectrometer was used to study the functional group interactions between polymeric constituents and neem extract. The spectra were recorded from 400 to 4,000 cm^{-1} .

X-ray diffraction pattern

The crystalline nature of the prepared nanofibers was evaluated using the X-ray diffractometer (XRD) (Rigaku, SmartLab) operating with 40 mA current, 45 kV voltage and equipped with Cu-K α radiation source.

Thermogravimetric analyses

Thermal degradation behaviors of the prepared nanofibers were studied under a nitrogen atmosphere using (Thermo Scientific TGA), operating at 15°C/min from 25 to 350°C.

Measurement of antifungal activity

The prepared nanofibers were tested against the following fungal strains *Candida albicans*, *Aspergillus flavus*, *Microsporium canis* and *Fusarium solani* using agar diffusion and micro-dilution methods. The fungal cultures were prepared using Sabouraud's dextrose broth. A sterile stick was used to spread 100 μl of fungal strain on the surface of the agar plate. Then, 2 mm wells were prepared in each culture plate followed by the addition of drug (control), DMSO (negative control) and 10 μl of each nanofiber sample. Subsequently, the cultures were subjected to incubation at 37°C for 48 h. The measurement of clear zones around the nanofiber samples provided their respective antifungal activities. The experiment was performed in triplicate and the antifungal activities are given with mean \pm SD (Fonseca et al., 2021).

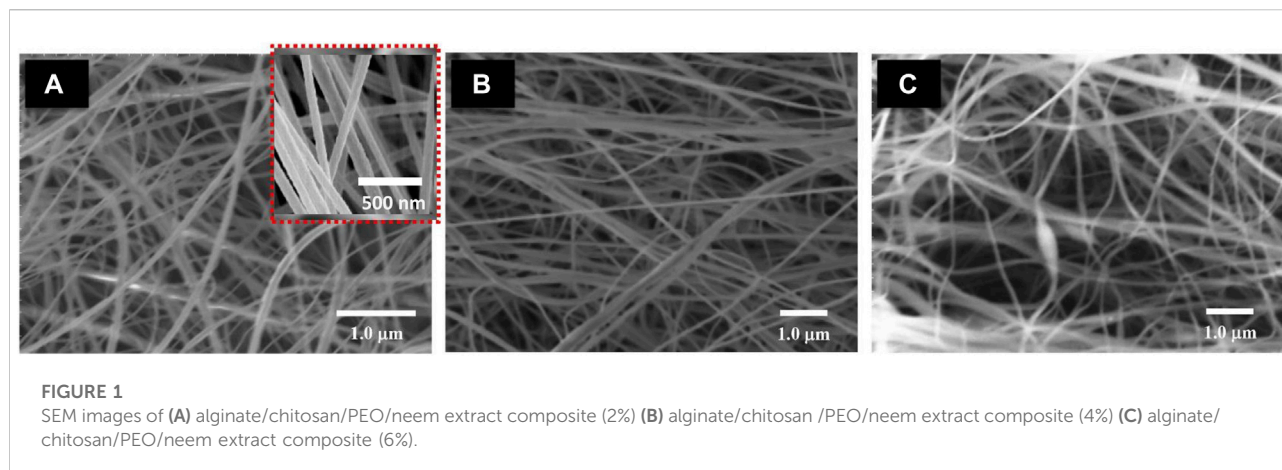
Measurement of antioxidant activity

The antioxidant capacity of prepared nanofibers was analyzed employing the DPPH assay (Bagheri et al., 2022). Samples of different concentrations from each fiber were prepared using methanol. After that, 1 ml of 50 μg per ml DPPH was mixed with 1 ml of each sample for half an hr. The ascorbic acid was used as an equivalent standard, 50 μg per ml DPPH as control and a subsequent change in absorbance of DPPH at 517 nm was measured using UV-visible spectrophotometer (CECIL CE 7200). The antioxidant activities of prepared nanofibers were calculated as follows using a standard curve,

$$AA (\%) = \frac{A_{\text{control}} - A_{\text{sample}}}{A_{\text{control}}} \times 100$$

where, A_{control} (absorbance of standard), A_{sample} (absorbance of nanofiber sample)

The % disappearance of DPPH plotted as a function of sample concentration provided IC₅₀ values.



Releasing behavior of bioactive constituents

The prepared nanofibers NF1, NF2 and NF3 were dipped in 50 ml of acetate buffer with pH 5.5 at 37°C as a simulation of human skin (Sadri et al., 2015). The samples were stirred and incubated at room temperature. After specific time intervals, aliquots of each sample (1 ml) were taken and diluted to 5 ml with fresh buffer solution and the concentrations were measured spectrophotometrically.

Swelling and weight loss studies

For weight loss studies, prespecified weights of NF1, NF2 and NF3 were immersed in deionized water at $35 \pm 2^\circ\text{C}$ for specific time periods. The surface of the samples was dried with filter paper following the incubation period. The surface dried samples were kept at 50°C before calculating weight loss (Nista et al., 2015).

$$\text{Weight Loss (\%)} = \frac{W_a - W_b}{W_a} \times 100.$$

W_a = weight of the dried sample before water exposure.

W_b = weight of re-dried samples after water exposure.

The weight of the swollen samples (W_s) and the finally dried samples were used for the calculation of the swelling rate.

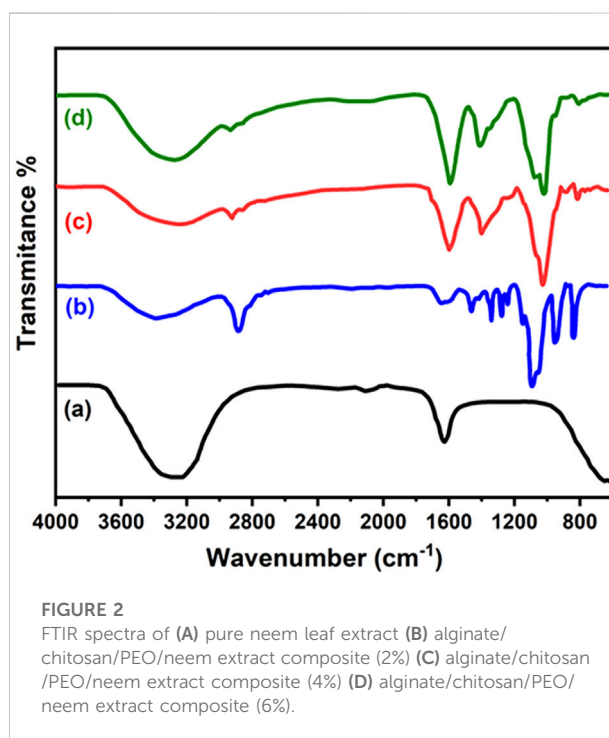
$$\text{Swelling ratio \%} = \frac{W_s - W_d}{W_d} \times 100.$$

W_s = swelling weight of samples after water exposure.

W_d or W_b = weight of re-dried samples after water exposure.

Results and discussion

The SEM was used to examine the morphologies of the as-prepared nanofibers (Figure 1). For alginate/chitosan/PEO/neem extract composite solutions with 2, 4 and 6% of neem extracts, nanofibers were produced from 4 to 6% solutions however, some



beads were observed in case of solution with 2% neem extract. Suggesting that the high concentration of neem extract improved the nanofiber formation. The increase of phytoconstituents increased the defect-free formation of nanofibers. The viscosity and solid contents of the precursor solution highly influence the electrospinning process. In this case, the presence of phytoconstituents controlled the threshold viscosity of precursors facilitating the electrospinning process. The SEM analyses revealed the average diameter of each of the electrospun nanofibrous compositions was 120 nm.

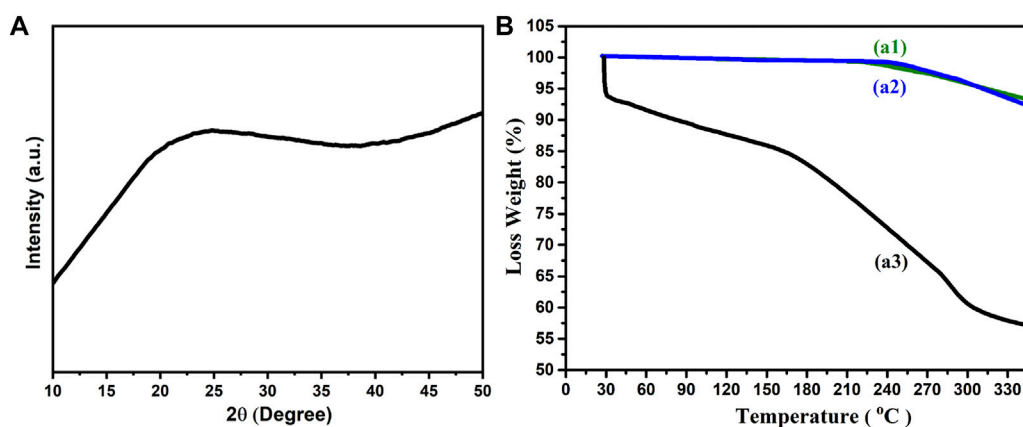


FIGURE 3

(A) XRD spectra of alginate/chitosan/PEO/neem extract composite (6%) (B) TGA spectra of (a1) alginate/chitosan/PEO/neem extract composite (2%) (b1) alginate/chitosan /PEO/neem extract composite (4%) (c1) alginate/chitosan/PEO/neem extract composite (6%).

The prepared nanofibers were analyzed by FTIR (Figure 2). The available spectra of the pure alginate, chitosan, PEO and neem extract were examined. In chitosan, the peaks due to O–H and N–H stretch were observed at 3,365 and 3,302 cm^{-1} while amide bond at 1,654 and 1,593 cm^{-1} . In case of alginate, O–H stretch was observed at 3,327 cm^{-1} while antisymmetric and symmetric carboxyl stretch at 1,603 cm^{-1} due to the and one at 1,413 cm^{-1} . In our case, the spectra of the fibers showed broader peaks at 1,416 cm^{-1} and 1,596 cm^{-1} indicating the overlapping of carboxylic groups from both polymers. This corresponds to anionic complexation of amine groups of chitosan and carboxylic groups of alginate (George and Abraham, 2006; Liu et al., 2012). This interaction cause changes in the absorption bands of interacting functionalities. As a result, the amine carboxylic peaks showed significant shift of acid near 1,621 cm^{-1} (Cruz, 2004), (Costa Jr and Mansur, 2008). The specific peak of $-\text{NH}_2$ group disappeared which is linked to the formation of NH_3^+ (Liu et al., 2012). Wang et al. also described such electrostatic interactions between amine and carboxyl groups and shifting of peaks (Wang et al., 2001). Further, the natural polyphenols in neem extract exhibit peaks due to O–H stretching at 3,414 cm^{-1} (Singh et al., 2010) and C–H bending vibration at 1,460 cm^{-1} . Moreover, C–H and C–OH stretching vibrations were appeared at 2,925 and 1,238 cm^{-1} respectively. These peaks are attributed to the presence of flavonoids and polyphenols. In aromatic ring C=C stretching vibrations were observed at 1,644 cm^{-1} . The carbonyl stretching vibration of carboxylic acid and C–H in CH_3 peaks were observed at 1,745 and 1,379 cm^{-1} (Elumalai and Velmurugan, 2015). The terpenoids in the neem extract exhibit C–O–C– linkage at 1,114 cm^{-1} (Ahmed et al., 2016). The peaks at 1,652 cm^{-1} and 1,744 cm^{-1} were attributed to amide stretching and C=O stretching respectively in FTIR spectrum of synthesized

composite. The binding of $-\text{COOMe}$ group of azadirachtin of neem with the NH_2 group of chitosan forms $-\text{NH}-\text{CO}$ and reduce free $-\text{NH}_2$ groups and shifting the peak at 3,425 cm^{-1} (Chakraborty et al., 2015). A single phase is developed due to the formation of the anionic complex in nanofibers.

The Figure 3A showed X-ray diffraction spectroscopy results revealing crystalline and amorphous nature of alginate/chitosan/PEO/neem extract composite (6%). The crystalline nature of chitosan has been validated by a peak at $2\theta = 20.3^\circ$ which is attributed to reflection plane of (200). The predominant amorphous nature is reflected by the broad region from 20.3 to 80°. The hydrogen bonding caused free-energy balance which gives chitosan a semi- crystalline in nature (Costa-Júnior et al., 2009).

Thermogravimetric curves of as-prepared nanofibers (chitosan, alginate, PEO and neem extract) are shown in Figure 3B. The TGA thermogram of alginate/chitosan/PEO/neem extract composite showed 2 region of weight loss; between 360 and 415°C is related to the PEO while refers to the alginate $\sim 160^\circ\text{C}$ (Caykara et al., 2005). The peaks in range 359–391°C and 225–250°C reflects PEO and alginate degradation respectively. The degradation temperature of chitosan is influenced by its degree of acetylation and crystallinity (Wang et al., 2020). The maximum degradation of chitosan and appeared at 270°C which is less than the cited work (Nam et al., 2010). This variance is possibly due to the incorporation of neem extract and PEO, which changes the crystallinity of the as-prepared nanocomposite. The decomposition of pure chitosan membrane exhibited one exothermic peak at 307°C. The decomposition peak moves to 217°C in case of CS/PEO indicating the influence of additives on composite stability. Accordingly, we have observed different onset of weight loss for each composite due to the addition of

TABLE 1 Antifungal activities of prepared nanofibers.

Name of fungus	Observation	NF1	NF2	NF-3	Std. Drug mic $\mu\text{g/ml}$	% Inhibition
<i>Candida albicans</i>	% Inhibition	17	28	33	Miconazole	100
	Result	+	+	+		
<i>Aspergillus flavus</i>	% Inhibition	09	17	24	Amphotericin B	28.40
	Result	+	+	+		
<i>Microsporum canis</i>	% Inhibition	14	27	32	Miconazole	97.8
	Result	+	+	+		
<i>Fusarium solani</i>	% Inhibition	21	32	39	Miconazole	81.30
	Result	+	+	+		
<i>Candida glabrata</i>	% Inhibition	0	0	0	Miconazole	68.8
	Result	-	-	-		

neem extract. The alginate/chitosan/PEO/neem extract (6%) composite was thermally more stable than composites with (2 and 4%) extract. The complexation-mediated reorganization of polymeric chains influenced thermal degradation shifting it to a lower temperature region (Fuzlin et al., 2020).

The *A. indica* displays a broad spectrum of therapeutics due to a rich source of bioactive constituents. The azadirachtin is the most important phytochemical while quercetin, salannin, nimbidol, nimbin and nimbolin etc are varyingly concentrated in different parts of neem. These bioactive constituents activate antioxidant enzyme for antioxidant activities, rupture cell wall for antibacterial properties and modulate cellular pathways for chemopreventive effects. The antibacterial and antifungal activities were shown by the quercetin, β -sitosterol and other polyphenols purified from leaves samples (Rahmani et al., 2018; Saleem et al., 2018). The aqueous extracts of leaves of *A. indica* are already known for their strong antifungal potential (Leontopoulos et al., 2017). In our case, the prepared nanofibers were found effective against, *C. albicans*, *A. flavus*, *M. canis* and *F. solani*. The prepared nanofibers exhibited extract concentration-dependent antifungal activities (Table 1).

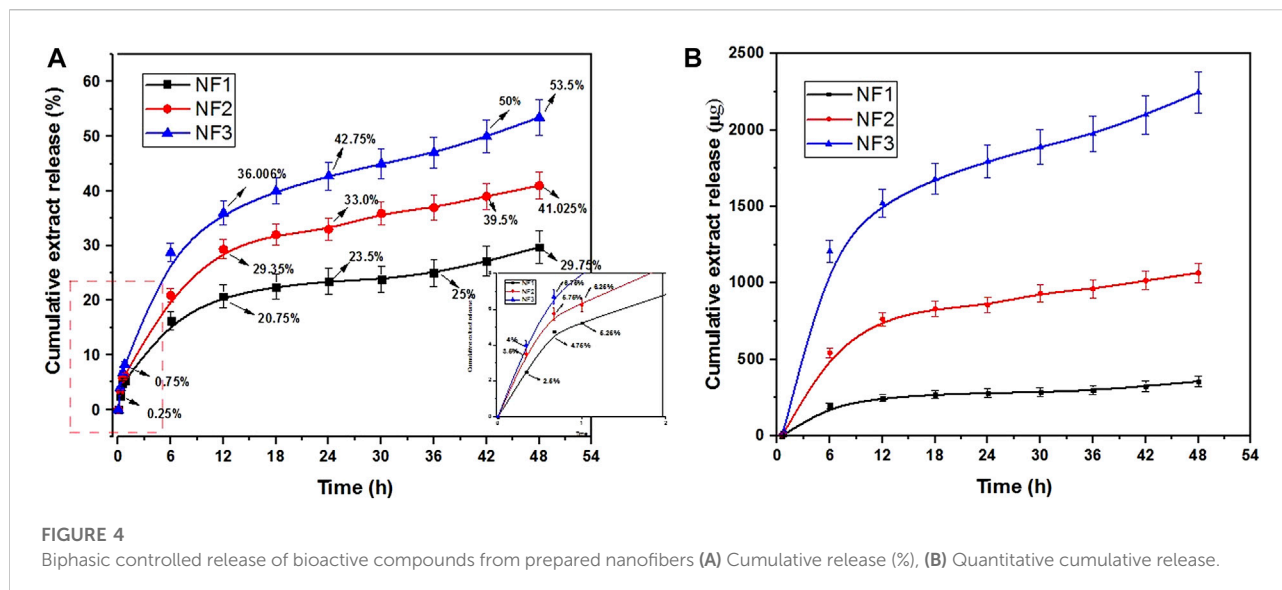
Reactive oxygen species (ROS) disrupt metabolic pathways and cellular signaling and delays wound healing and regeneration process. Therefore, controlled ROS generation using phytochemical-based antioxidants is a key for an accelerated wound healing. The phytochemicals especially the polyphenols quench ROS through redox reactions or they activate antioxidant enzymes (Engwa, 2018). Leave samples of *A. indica* were found to carry azadirachtin, nimbanene, nimbin and other polyphenolic flavonoids like β -sitosterol and quercetin (Sarah et al., 2019). The aqueous extract of *A. indica* leaves mainly carries azadirachtin and nimbin which are responsible for their high antioxidant potential (Airaodion et al., 2019).

TABLE 2 The antioxidant activities of prepared nanofibers.

Code	DPPH activity	
	(%) Inhibition at 1 mg/ml	IC ₅₀ (μg)
NF1	11.2 \pm 0.01	-
NF2	17.40 \pm 0.03	-
NF3	60.03 \pm 0.02	3.25 \pm 0.45

Another study revealed the concentration-dependent antioxidant potential of azadirachtin and nimbolide. Both of the compounds were found to upregulate enzymatic antioxidant and prevented DNA oxidation (Iman et al., 2021). Other few such studies also explored the antioxidant properties of leave, flowers, fruit and bark extracts etc. In our case, the prepared nanofibers loaded with aqueous extract exhibited concentration-dependent ROS scavenging properties (Table 2).

In our case, the prepared nanofibers loaded with leave's aqueous extract exhibited antioxidant and antifungal potential. As the literature suggests, the aqueous extracts of *A. indica* leaves exhibit anti-inflammatory (Modi et al., 2021), hepatoprotective (Sani et al., 2020), antibacterial (Hikaambo et al., 2022), wound healing (Ugoeze et al., 2021), Antidiabetic (Dholi et al., 2011; Hikaambo et al., 2022), etc. Further, the organic extracts of neem leaves have been reported to show anticancer (Kashif et al., 2019), virucidal activity (Baidya et al., 2021), antimalarial activity (Udeinya et al., 2008; Akin-Osanaiya et al., 2013; Afolabi et al., 2021) and neuroprotective effects (Sandhir et al., 2021). It has always been challenging to control the initial release of hydrophilic molecules from delivery systems. The medicated nanofibers release the loaded active ingredients upon encountering water or release media. Typically, the release



profile could be pulsatile showing a fast release (Bhusnure et al., 2021) or a sustained release showing a time-dependent controlled release (Abasalta et al., 2022). A fast release is desired when a quick drug action is required under conditions like heart attack, fever or pain. Whereas sustained release is preferred when administration frequency needs to be reduced in some cases. However, new electrospinning approaches like side-by-side electrospinning, electrospaying and coaxial electrospinning or their combine forms are adopted to achieve more sophisticated profiles like a biphasic or dual-phase release for special therapeutic applications (Lv et al., 2021; Liu et al., 2022a). However, these multiple-fluid electrospinning processes are not easy for large-scale productions.

The release profile greatly depends upon the hydrophobic or hydrophilic nature of the polymeric carriers. The loaded molecules are freed into the dissolution medium through a diffusion mechanism when the carrier matrix is water-insoluble (Yang et al., 2020; Jain et al., 2022). In our case, the blending of hydrophilic and hydrophobic polymers along with aqueous extract helped to control the initial release and managed a prolonged and sustained release of bioactive constituents (Figure 4). The prepared nanofibers exhibited a biphasic release pattern. A burst release was observed in the first half hr followed by a diffusion-controlled sustained release over a period of 48 h. A dual-phase or biphasic release controls the delivery of active ingredients in the most suited way in biological systems. In fact an initial pulsatile release provides quick relief followed by a sustained release for a prolonged therapeutic effect (Zhao and Cui, 2020). The maximum and the minimum release percentile at 48 h was exhibited by the sample NF3 and NF1 respectively. Presumably, the NF1 samples exhibited a slow release percentile owing to more percentage

TABLE 3 Weight loss (%) and swelling rate of prepared nanofibers.

	Time	4	8	12
Weight Loss%	NF ₁	33 ± 2	35 ± 2	36 ± 2
	NF ₂	35 ± 2	37 ± 2	41 ± 2
	NF ₃	40 ± 2	42 ± 2	45 ± 2
Swelling rate (%)	NF ₁	19 ± 1	22 ± 1	25 ± 1
	NF ₂	33 ± 1	38 ± 2	41 ± 2
	NF ₃	55 ± 2	60 ± 2	65 ± 2

of nano-net structure and low loading of extract. An initial burst release is desirous sometimes to deliver higher amounts of active ingredients to control infections at acute injury phase. Generally, higher burst release is observed due to the direct incorporation of active ingredients into electrospinning solution which cause over accumulation of bioactive molecules on the surface of nanofibers (Amiri et al., 2020). The slow and sustained release of the extract is attributed to the structural morphology and strong interactions of carboxylic and amide groups of NFs with bioactive molecules. The high surface area and small diameter provides a short diffusion pathway for the release of active constituents. Further, higher contents of the extract caused a higher degree of swelling of nanofibrous structures resulting in faster release of active molecules. Therefore, the NF3 sample exhibited a higher initial burst followed by a sustained release due to the higher loading of molecules. The higher swelling rate helps to maintain a higher content of moisture which keeps the wound surface wet and facilitates an accelerated healing process (Prakash et al., 2021). As described earlier, increased

swelling also favors the delivery of bioactive constituents for the recovery of wounds (Sasmal and Datta, 2019).

As expected, the swelling rate of samples increased with time owing to the hydrophilic nature of the polymeric matrix (Shekarforoush et al., 2018; Rodríguez-Rodríguez et al., 2020). In weight loss studies, the samples showed a steady weight loss due to the leaching of PEO and constituents of neem extract suggesting a stable complex of polycationic and polyanionic polymers (Table 3). The samples of NF3 showed relatively a bit higher weight loss at 24 h due to the leaching of more phytoconstituents. Therefore, higher swelling rate and sustain release of active molecules suggests the prepared nanofibers as potential candidates for the development of wound dressings and other medicated materials. Further, a single-fluid electrospinning approach has been disclosed for the preparation of medicated-nanofibers with sophisticated double-phase release profile.

Conclusion

The prepared biopolymer-based nanofibers loaded with neem leave extract exhibited antioxidant and antifungal properties. They also showed high swelling rate and sustained release of phytoconstituents. Further, a single-fluid electrospinning approach has been disclosed for the preparation of medicated-nanofibers with sophisticated double-phase release profile. Thus prepared nanofibers could be employed as wound dressing, soft tissue scaffolds and as transdermal carriers.

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Data availability statement

The original contributions presented in the study are included in the article/Supplementary Material, further inquiries can be directed to the corresponding author.

Author contributions

AH supervised the extraction and purification process, ZR and MAQ Supervised the electrospinning process, TA (interpreted Characterization studies, TR Data curation and analysis, RN, SI, and SB Proof reading and supervision of biological studies and TF overall supervision, conceptualization of idea, Manuscript write-up.

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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