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Preparation and validation of nanofibers loaded with silver sulfadiazine from zein/poly (Ɛ -caprolactone)/poly (ethylene oxide) for topical dosage forms to improve release behaviour

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ABSTRACT: The present study involved the preparation of Zein/Poly (Ɛ-caprolactone)/Poly (ethylene oxide) (Zein/PCL/PEO) nanofiber loaded with silver sulfadiazine (SSD) using the electrospinning process. These Nanofibers were intended for topical medication delivery applications to increase the drug delivery rate and minimise application times. In the present study, silver sulfadiazine was initially introduced into (Zein/PCL/PEO) nanofiber. The characterisation of nanofiber mat involved using Attenuated Total reflective Infrared Spectroscopy (FTIR) to assess the chemical interaction between SSD and the polymer matrix. The Scanning Electron Microscopy (SEM) technique was employed to study the surface morphology of the nanofibers. To improve the solubility, effective drug release, and efficient drug loading of SSD, composite nanofiber carriers consisting of (Zein/PCL/PEO) were electrospun by the identification of best formula using Design Expert® software, X-ray diffraction analysis (XRD) was used to identify the crystalline state of the pure SSD, (Zein/PCL/PEO) polymers and SSD loaded (Zein/PCL/PEO) nanofibers selected adsorbent. The scanning electron microscopy (SEM) photos demonstrated the successful production of composite nanofibers that exhibited a consistent and smooth surface morphology. The nanofibers' diameter decreased upon introducing SSD and the findings of many experimental outcomes have consistently indicated that composite nanofibers consisting of (Zein/PCL/PEO) loaded with SSD exhibit significant promise for topical medication delivery applications.

KEYWORDS: drug delivery systems; silver sulfadiazine; Poly (Ɛ-caprolactone); nanofiber matrix; Poly (ethylene oxide).

1. INTRODUCTION

Silver sulfadiazine (SSD) is a topical antimicrobial agent insoluble in water and in a nonionised state. It is produced through the chemical interaction between sulfadiazine and silver nitrate, forming a complex silver salt [1]. Silver sulfadiazine is widespread in applying localised therapy for burn wounds that have become infected [2]. Silver sulfadiazine results in the sustained release of silver ions over an extended period, in contrast to other silver salts, such as silver nitrate, which exhibit a rapid and simultaneous release of significant quantities of silver ions [3]. Therefore, the use of SSDs reduces the necessity for frequent application. The practicality and feasibility of regular application for patients may only sometimes be attainable, rendering silver sulfadiazine SSD an appealing and advantageous agent. Due to these factors, SSD demonstrates greater efficacy than other silver salts [4].

The lack of water solubility exhibited by SSD presents a significant obstacle, prompting researchers to concentrate on improving its bioavailability by enhancing its solubility. To achieve this objective, SSD was synthesised into various forms such as nanoparticles, nanorods, nanosuspensions, or incorporated into different polymeric carriers by formulation techniques including film, hydrogel, composite and fibre-based drug delivery systems [3,5].

The application of nanofibers in drug delivery systems is predicated on the concept that the extensive surface area of the nanofibrous carrier enhances the pace at which the medication dissolves. In contrast to the available dosage form such as hydrogels, noisome, liposomes, micelles and others the nanosized fibres

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produce very developmental solutions in case of toxicity caused by other forms or the reduced loading capacity and efficacy [6].

Poly (Ɛ-caprolactone) (PCL) and Poly (ethylene oxide) (PEO) exhibit considerable potential as biopolymers in the field of medication delivery. Poly (ethylene oxide) is a polymer with high solubility in aqueous environments [5]. This is attributed to its hydrophilic nature, facilitating rapid interaction with body fluids and subsequent dissolution. Poly (ethylene oxide) is commonly employed in polymer matrices to augment the bioavailability and solubility of different kinds of pharmaceutical combinations and formulas due to its notable water solubility and distinctive attributes in the realm of drug delivery [1,7–9].

The ability of PCL to interact with various medications allows for consistent dispersion of drugs inside the polymer matrix. Additionally, the slow rate of PCL breakdown makes it a desirable choice for extended drug delivery systems [1,9]. Zein is a naturally occurring polymer derived from maise. The polymer in question possesses biodegradable and biocompatible properties. Zein has been extensively utilised in biomedical applications because of its varied characteristics of being biocompatible and biodegradable [10].

The utilisation of electrospinning for the production of nonwoven fabric dates back to the initial patent for electrospinning. However, it has gained significant popularity in the 21st century. Subsequently, a cohort of scholars has investigated the electrospinning technique, focusing on diverse polymer materials [3].

This study employed the electrospinning technique to fabricate nanofiber mats composed of zein, which were further enhanced with the inclusion of an antibacterial agent, SSD. Effectively implement SSD on electrospinning. Silver sulfadiazine has been utilised as a wound care system, typically in hydrogel or composite materials [11]. However, to our knowledge, there has been no prior investigation into the loading of SSD onto electrospun nanofiber mats. One advantage of utilising the combination of this medication with a natural, biocompatible, and biodegradable polymer is that it allows for a greater occupation of the SSD on a broader surface area [5]. The findings of this study will have practical implications for using SSD-loaded wound dressings in industrial-scale settings [12].

2. RESULTS and DISCUSSION

2.1. Loading efficiency results statistical analysis

The nanofibers were removed from aluminium foil papers, gathered, and placed in a tight, sealed glass container. The sample was examined in a UV spectrophotometer (Shimadzu-Japan) at 271 nm, and the concentration from each run was applied to Equation 1 to determine the loading efficiency [5]. All the reading results of loading efficacy ranged from 26.9 % (run 8) to 98.31 % (run 7), shown in Fig. 1. The effect of variables on loading efficiency of 8 runs. The results demonstrated the observed fluctuations in loading efficiency across each experimental trial, which were contingent upon the concentration of the polymers employed. Specifically, an increase in Zein concentration and a decrease inPCL corresponded with a higher loading efficiency.

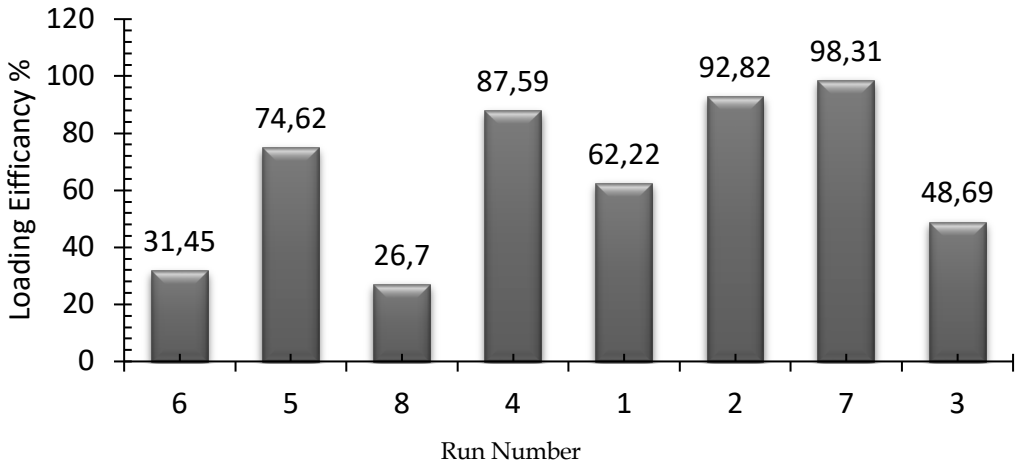

Figure 1. Effect of variables on loading efficiency of 8 runs that shows different loading efficiency in each run according to different polymer concentrations. Run number 7 shows the best loading efficiency value among the other runs.

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2.2. Fibres diameter results statistical analysis

The average diameter of nanofibers produced through electrospinning techniques was analysed using scanning electron microscopy (SEM) with an FE Axia chem SEM. Results obtained from the SEM analysis demonstrated a diverse distribution of fibre diameters, ranging from 310 nm in run 7 to 1780 nm in run 8. The lack of genuine nanofibers production in Run 8 can be attributed to the significantly low concentration of PCL, as mentioned by Barbak *et al*. and Ullah S, Hashmi M. [3,13]. The findings about the diameter of nanofibres are shown in Figure 2. Where an increase in zein concentration and a decrease in PCL leads to a reduction in nanofiber diameter, providing the best results.

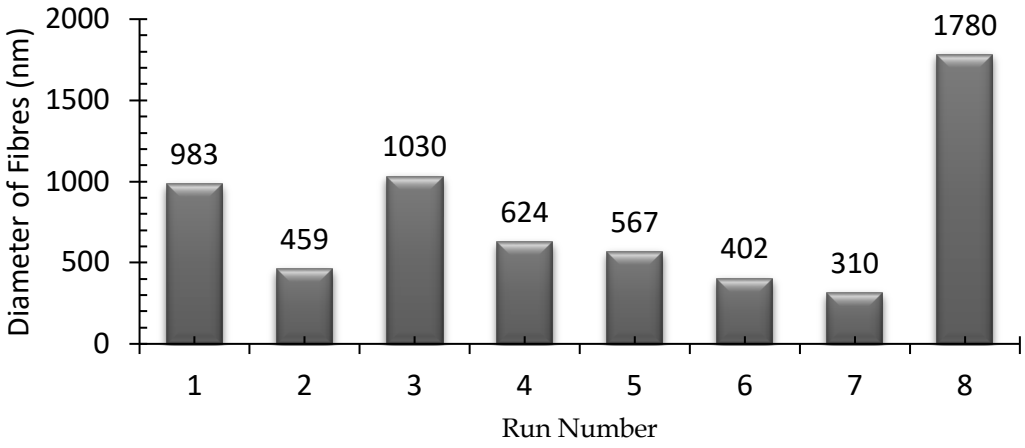

Figure 2. Effect of polymers with different concentrations on nanofiber diameter. Increasing the Zein concentration reduces fibre diameter and generation of uniform nanofibres in run 7.

2.3. SEM nanofiber size identification

The morphology of nanofibers is influenced by many device-related elements, such as flow rate, voltage, and distance, as well as ambient-related factors, including temperature and humidity. Solution-related factors also play a role in shaping the morphology of nanofibers. The creation of spotted structure can be seen in the increase of PCL concentration, as shown in run 8. The perfect fibre diameter can be seen in run 7. The images for runs 8 and 7 and the resultant fibre diameter are listed in Figure 3 A and Figure 3 B.

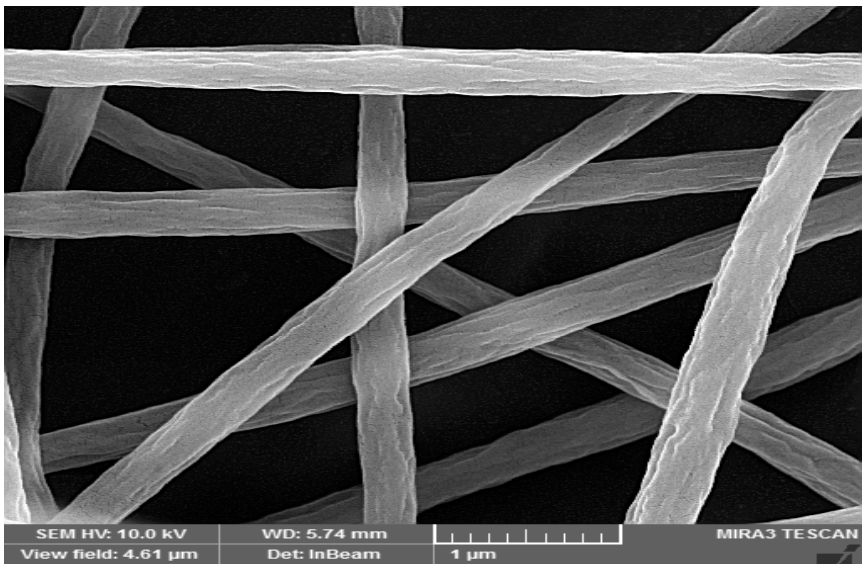

Figure 3A. Nanofiber SEM images with nanofiber diameter of Run 7 where is PEO 0.175 g, PCL 0.05 g and Zein 1.25 g, Nanofiber size around 310 nm.

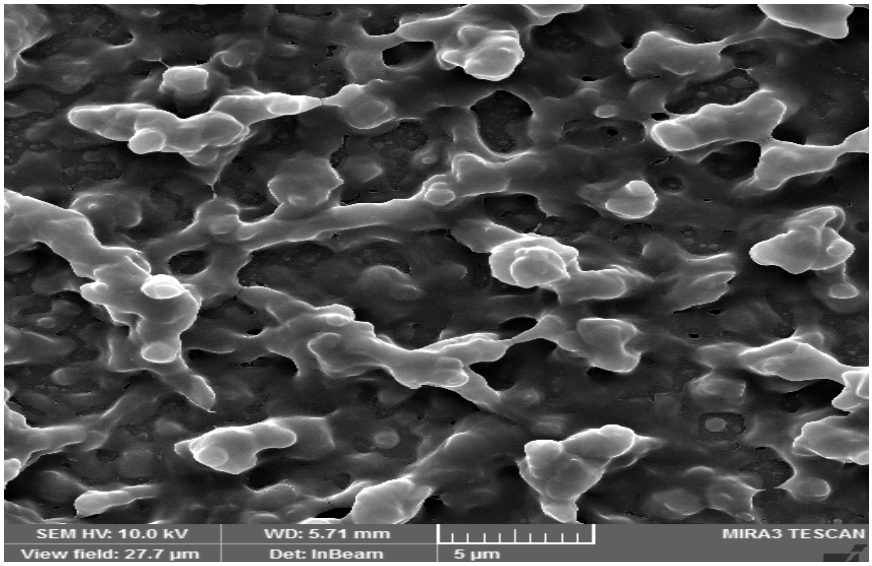

Figure 3B. Nanofiber SEM images with nanofiber diameter of Run 8 where PEO 0.175 g, PCL 0.2 g, and Zein 0.75 g, where is spotted, are formulated.

2.4. The effect of polymer variations on nanofiber properties and loading efficiency results

The impact of polymer composition concentration on the nanofiber diameter and loading efficiency by the statistical analysis of Design-Expert® software determined that the variations in polymer concentrations in each formula result in different impacts [5,13]. The increase of Zein polymer concentration results in lower nanofiber size and very good loading efficiency; the impact of PCL has a negative effect on both fibre diameter and loading efficiency, which is reduced in the optimum formula of nanofiber. PEO) has a determined impact on loading efficiency with neglectable low favourable effects on fibre diameter. As a result, the concentration of Zein was at its maximum peak, PCL at minimum concentration and PEO was introduced at the maximum concentration to get the best-optimized formula, as shown in Figure 4.

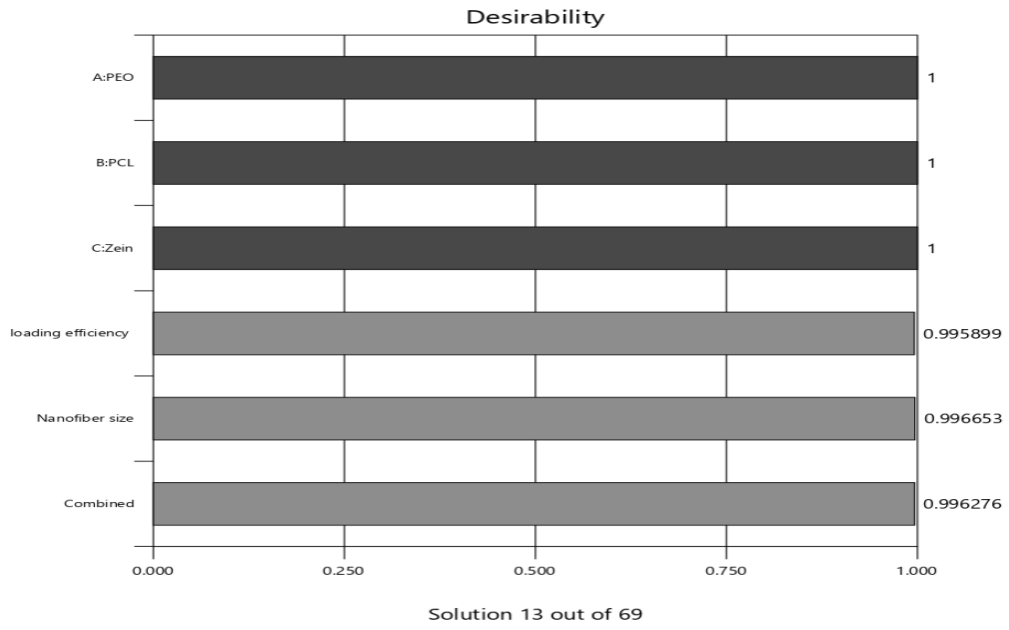

Figure 4: The desirability of the factors and the corresponding responses. The chosen formula exhibits the highest possible level of attractiveness.

2.5. Determination of optimal silver sulfadiazine electrospun nanofiber

The Design-Expert® software provides numerical optimisation techniques that utilise the desirability function, as determined by the software, to design the optimal nanofibers loaded with SSD. The objective was to achieve the desired responses, such as the highest entrapment efficiency and the lowest nanofiber diameter. Consequently, the data conducted statistical analysis to propose multiple equations, where the desirability of achieving the ideal goal varied due to altering the concentrations of each polymer [14]. The 69 proposed solutions offer an optimal formula for achieving high entrapment efficiency and low fibre diameter. The recommended formulas were arranged in ascending order from formula 1 to formula 69, according to their desirability rankings and the best-ranked formula was selected (formula number 13) with the highest desirability rate of 99.6 % and yielded superior outcomes in terms of loading efficiency (98.016 %) and nanofiber diameter (314.92 nm).

2.5.1. In vitro dissolution studies

The nanofiber formulation demonstrated biphasic release kinetics in the drug release profile, which can be attributed to the favourable composition of Zein, PCL, and PEO in the fibre matrix. The SSD exhibited an initial release rate of around 15 %, which may be attributed to the presence of particles stuck to the surface of the nanofiber and the rapid dissolution of the PEO polymer [5]. The subsequent release of SSDs exhibited a continuous release profile, with approximately 61 % of the total release occurring within 10 h. Subsequently, the controlled release of SSD was conducted for 24 h, resulting in an approximate release rate of 79 % [2,15]. This release rate demonstrated a decelerated pattern.

Topically applied commercial SSD creams are utilised on specific areas of the skin, with a recommended frequency of two to four applications per day. The regulation of medication release plays a crucial role in enhancing the therapeutic efficacy of treatment and optimising patient comfort by minimising the frequency of administrations [1,16]. The quantity of medication collected from the composite PCL/PEO/Zein in SSD nanofiber exhibited a progressive rise as time elapsed. Approximately 79 % of the medication was released from the nanofiber formulation after a duration of 24 h, as shown in Fig. 5. In burn-treatment applications, it is often desirable for drug carriers to possess the ability to undergo both rapid and progressive degradation to understand the mechanisms underlying the release of the SSD drug from composite nanofibers, various kinetics models such as Zero-Order, First-Order, Higuchi, and Korsmeyer-Peppas were employed to analyse the drug release profile. The regression coefficients (R2) corresponding to several kinetic models are shown in Table 1. The Korsmeyer-Peppas model yielded a result indicating a regression coefficient R2 of 0.9956. The drug release phenomenon was measured using Equation 2. The exponent n characterises the drug release mechanism, and k denotes the constant rate of drug release.

Table 1. The models of drug release kinetics for PCL\PEO\Zein-SSD loaded nanofibers with regression coefficient R^2.

Release kinetics models	R^2
Zero-order	0.9753
First order	0.9172
Higuchi	0.9745
Krosmeyer-Peppas	0.9956

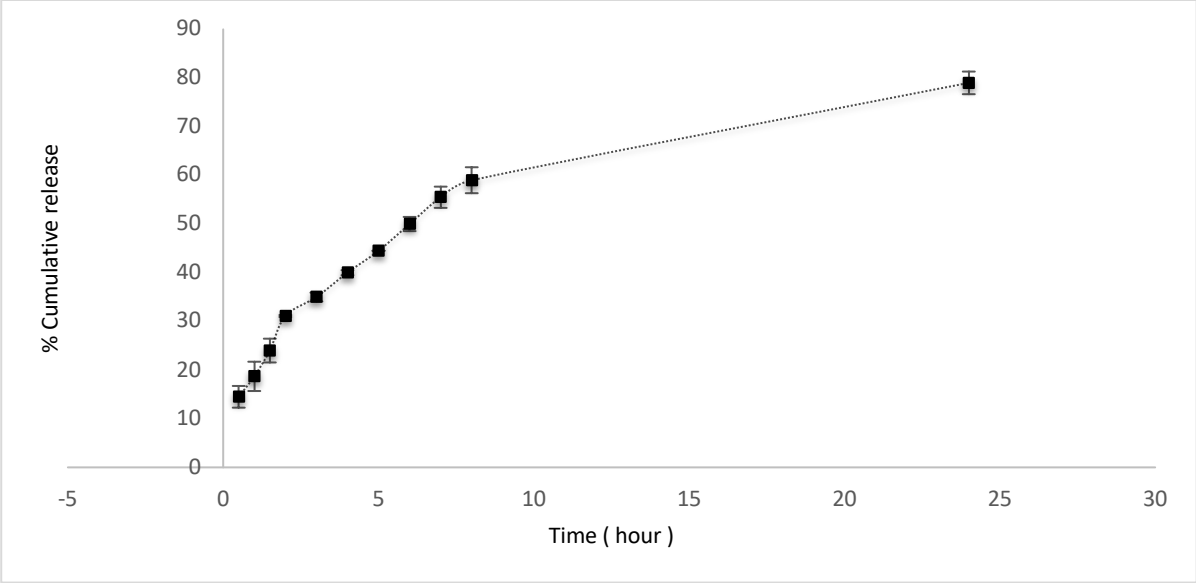

Figure 5: Cumulative release % of SSD from Zein\PCL\PEO nanofibers, squares show sample collection in different time areas starting from time zero to 24 hours showing different cumulative release concentration over the duration, providing precise feedback of how the drug released from the nanofibers.

2.5.2. X-ray diffraction (XRD)

An X-ray diffraction (XRD) analysis was conducted to examine the crystalline structure of the electrospun nanofibers loaded with SSD [5]. The SSD exhibited distinct peaks at approximately 8.7° and 10°, corresponding to the crystallographic planes, respectively. The pure zein nanofibers exhibited a prominent peak at a 2θ value of 9.3°, as well as a broader peak at a 2θ value of 20°. The literature has also confirmed that pure zein powder displays the same pattern [13]. Data indicates that zein has maintained its structural integrity when transformed into nanofiber form.

The X-ray diffraction (XRD) pattern obtained from the PEO nanofibers exhibited distinct diffraction peaks at 2θ angles of 19° and 23.6°, which can be attributed to the presence of semicrystalline PEO. These peaks correspond to the (1 2 0) and (0 3 2) crystallographic planes, respectively, which are associated with the helical structure of the PEO crystal [5].

The semicrystalline PCL 2θ =21.2 and 2θ = 24.3 are associated with the (1 1 0) and (2 0 0) crystallographic planes of the PCL crystal [5].

Pattern of XRD for the Zein/PCL/PEO nanofibers loaded with SSD showed a microcrystalline characteristic, as evidenced by the prominent single peak that obtained at 10.1°. Albeit at a shifted position of 8° [5]. This pertains to the inclusion of PCL, which reduces the proportion of SSD within the formulation. Furthermore, the little peak at 2θ = 8.8° completely vanished, although the prominent peak at 2θ = 10° remained visible in the X-ray diffraction (XRD) pattern [5]. The observed low intensity indicates a decrease in crystallinity. Furthermore, the incorporation of a solid-state drive SSD into the nanofiber matrix resulted in a crystalline structure with decreased crystallinity, indicating that the electrospinning process contributed to the enhanced structural stability of the SSD [5].

The X-ray diffraction (XRD) analysis revealed that the structural stability of zein remained unaffected upon incorporating SSD. However, the XRD pattern of the nanofiber mats exhibited distinct peaks corresponding to the presence of SSD. Silver sulfadiazine in zein nanofibers was also confirmed, as shown in Figure 6 [5,13].

2.5.3. Fourier transform infrared analysis.

The FTIR spectrum was examined to identify the peaks at various bandwidth points of nanofibers loaded with SSD. In order to investigate the purity of polymers and loaded drug SSD, PCL, PEO and zein alone to define their presence in the formula and PCL, PEO, Zein loaded SSD nanofiber to declare their presence in the final product formula, beginning from asymmetric stretching of SO_2 that can be seen in the distinct peaks at 1231.6 cm^{-1} in the pure SSD.

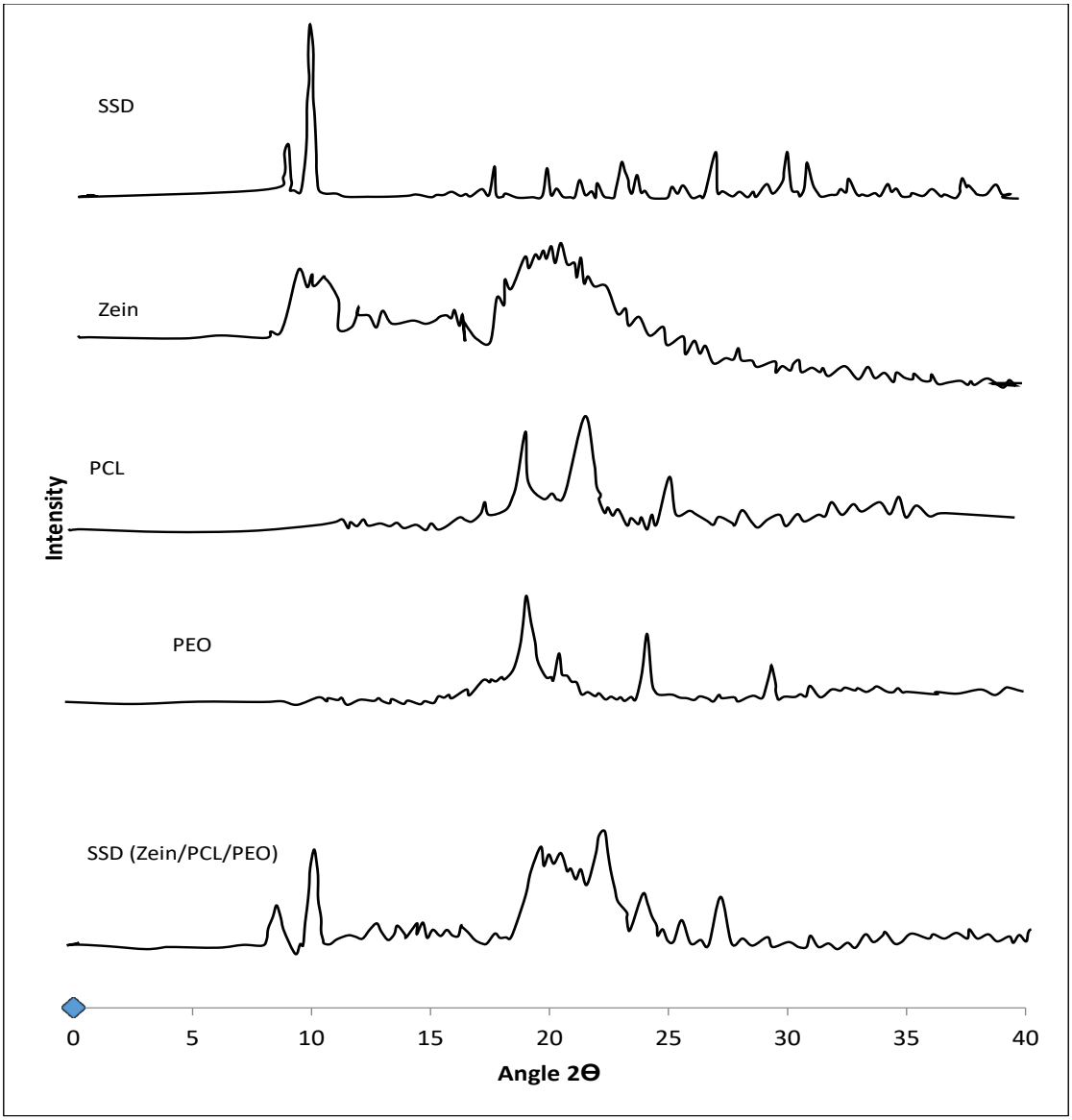

Figure 6. XRD Pattern of SSD, Zein, PEO, PCL and SSD loaded Zein/PEO/PCL nanofibers; the structural stability of zein remained unaffected upon the incorporation of SSD. The XRD pattern of the nanofiber mats exhibited distinct peaks corresponding to the presence of SSD.

In addition to this peak, the specimens containing SSD also exhibited peaks at 3341.52 cm^{-1} and 3391.07 cm^{-1}, which were attributed to the stretching band of the amine group (NH_2) [17]. The spectral band associated with the elongation of the N–H and O–H bonds within the amino acid constituents of the protein was seen within the wavenumber range of 2800 to 3500 $cm^{-1,}$ these resulted matching the results of Patel *Et al* [18].

An additional signal was detected at a wavenumber of 1650 cm^{-1}, indicating the stretching of the carbonyl (C=O) bonds within the amide groups associated with the peptide groups. The peak observed at a wavenumber of 1540 cm-1 was attributed to the angular deformational vibrations of the N-H bond. Additionally, the band observed at 1230 cm^{-1} was related to the C-N bond's axial deformational vibration [19].

The PCL was confirmed in all fibres by identifying distinctive peaks at 1732 cm^{-1}, corresponding to C-O stretching vibrations. Additionally, the presence of bands at 2866 and 2947 cm^{-1} which are related to CH stretching vibrations. Furthermore, bands at 1172 and 1240 cm^{-1}, corresponding to C-O-C vibrations, further support the identification of this polymer [18,19].

To detect the presence of zein polymer it can be distinguished by the presence of the amino acids that form their protein composition, the region between 2800 and 3500 cm^{-1} is associated with the vibrational stretching of the N-H and O-H bonds in the protein's amino acids. At a wavenumber of 1658 cm^{-1} that

presents the stretching of carbonyl (C=O) bonds inside the amide groups of the peptide moieties, namely the amide I region. The amide II band can be seen at a wavenumber of 1541 cm^{-1} that declare the angular deformation vibrations of the N-H bond. The axial deformation vibrations of the C-N bond can be seen at spectral peak observed at 1238 cm^{-1} [20].

The differential peaks of PEO can be noticed at 1462 cm^{-1} that include the vibrations of CH_2 groups, on the other hand peaks at 1354 cm^{-1} represents the wagging vibrations of CH_2 groups, another peak at 1296 cm^{-1} corresponds to vibrational twisting of CH_2 groups, lastly peaks at 840 cm^{-1} and 948 cm^{-1} that declare the vibrations of CH_2 groups. The triplet peaks at 1107 cm-1 indicate for the semicrystalline structure of PEO which represents C-O-C triplet peaks [21].

The Zein/PCL/PEO loaded with SSD exhibited distinct peaks at specific wavenumbers, including 752 $cm^{-1,}$ which can be attributed to the asymmetric stretching of SO_2. Additionally, peaks at 1539 cm-1 were observed, associated with the aromatic C=C stretching [5,13]. The presence of SSD in the PCL/PEO/Zein nanofibers did not significantly impact the peak at 1682 cm^{-1}, which is conjugated to NH_2 in the drug-free PCL/PEO\Zein nanofibers. The chemical binding of SSD to the polymer matrix and the overall symmetry of the SSD molecule remained largely unchanged within the electrospun nanofiber matrix. All the FTIR results are shown in Figure 7.

3. CONCLUSION

Applying electrospinning techniques yielded favourable results in producing SSD-loaded electrospun nanofibers, while the loading effectiveness was greater than 90 %. The electrospinning solution was prepared using a combination of biopolymers, namely PCL, PEO, and Zein, respectively. The biopolymers exhibited favourable electrospinnability and yielded homogeneous nanofibers with improved mechanical characteristics. By implementing this methodology, the release profile of silver sulphadiazine is enhanced by providing fast onset release and gradual release to reduce the number of applications.

4. MATERIALS AND METHODS

4.1. Materials

Silver sulphadiazine was supplied by Hayat pharmaceutical company, Iraq, as a gift sample. Zein polymer was purchased from Sigma Aldrich, USA, Poly-Ɛ-caprolactone purchased from Merk-Shuchardt, Germany, Polyethylene oxide was purchased from BDH chemical Ltd, England.

4.2. Method

4.2.1. Preparation of nanofiber solution

A solution was prepared by dissolving three synthetic biopolymers, PCL, PEO, and zein, then SSD was added to the mixture. Each polymer was individually dissolved in distinct formulations with continuous agitation overnight using a magnetic stirrer at ambient temperature. The three polymers, namely PCL, PEO, and Zein, were combined [5,13].

Zein was precisely quantified (1g/5 ml) and subsequently dissolved in 100 % ethanol and distilled water (DW) (50 ml) with mild agitation for one hour to guarantee thorough dissolution. Following this, it was incorporated into the polymeric solution at a proportion of 37.5 % (37.5ml) of the overall polymers utilised. Poly (ethylene oxide) was dissolved in a mixture of acetonitrile and acetic acid (3:1) and then added to a mixture of PCL in chloroform and ethanol in a ratio of 7:3 (13). Subsequently, the solution obtained was subjected to stirring for an additional hour and combined with the zein solution, preparing it for incorporation into the SSD mixture. This modified solution is considered appropriate for utilisation in the electrospinning process [13].

The determination of polymer concentration in the solution preparation was conducted using Design-Expert® software (version 13) by employing a multi-factorial design. The experimental design comprised of a total of 24 runs, separated into three blocks, with each block consisting of 8 runs. This design was replicated three times to assure the optimal quality of the resulting nanofibers. The primary objective of this study was to investigate the influence of various conditions on the development of fibres. The outcomes of this analysis, which encompass the measurements of fibre diameter and loading efficiency, are shown in Table 2 of the Design-Expert® Software.

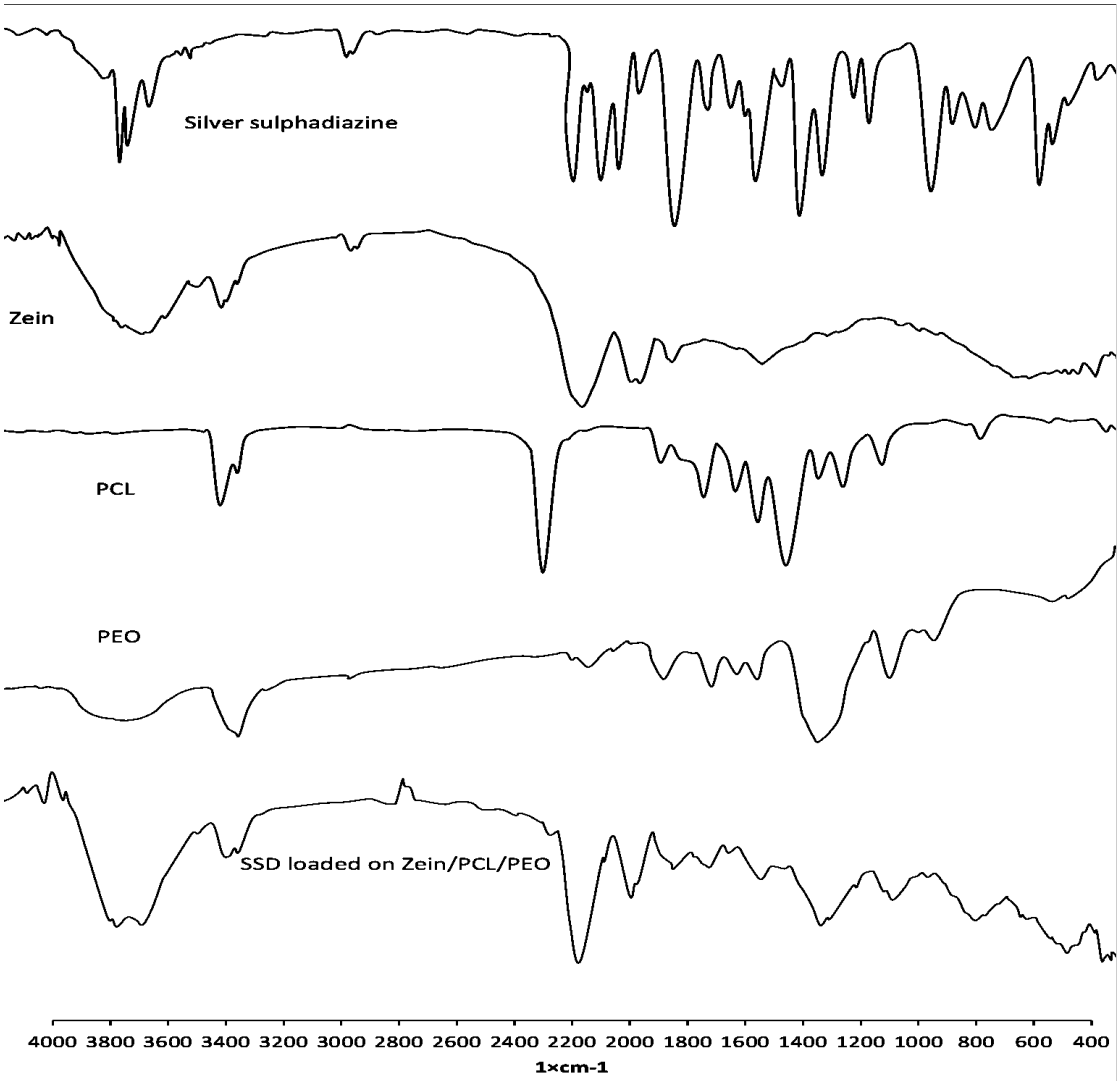

Figure 7. The FT-IR spectrum of SSD loaded on PCL/PEO/Zein. With the spectrums of SSD, PEO, zein and PCL.

Table 2. Different suggested formula by Design-Expert® software. The concentration of SSD used was 5% of the polymer total blend in grams.

Std	Run	Factor 1 A: ZEIN (g/5ml)	Factor 2 B: PCL (g/5ml)	Factor 3 C: PEO (g/5ml)
7	1	0.75	0.2	0.175
5	2	0.75	0.05	0.175
8	3	1.25	0.2	0.175
4	4	1.25	0.2	0.1
1	5	0.75	0.05	0.1
2	6	1.25	0.05	0.1
6	7	1.25	0.05	0.175
3	8	0.75	0.2	0.175

4.2.2. Preparations of nanofibers by electrospinning

Before starting the electrospinning process [14,24], the electrospinning device is composed of a syringe pump (New Era pump system, USA); the other part of the device is collected and designed locally, had been set on several factors to control the whole process. Depending on preliminary studies, the flow rate of solution was set on 1 $ml.hr^{-1}$, the Spinarate to collector distance was kept at 15 cm, the temperature of device chamber was controlled at 20-25 °C, the relative humidity was measured at 25-30 %, electrical voltage applied by power supply was reserved at 15 Kv and the ground collector wrapped with aluminium foil, the

mixture was loaded with 18 G needle syringe of 3ml volume for each run of the electrospinning prosses [5,13].

4.2.3. Electrospunded nanofibers characterisation

Nanofiber diameter identification

The surface morphology of the nanofibers was analysed using a scanning electron microscope (SEM) instrument [13] (the FE Axia chem SEM, thermos fisher Holand). The SEM was operated at a voltage of 10 kV and a working distance of 5.71 mm. A minute quantity of nanofibers was manufactured and subsequently subjected to a gold (Au) coating process using a sputter-coating machine. The diameters of the fibres were determined by utilising the picture J software, which was applied to 24 distinct fibre sections extracted from a (SEM) picture. The average diameter was determined using the recorded measurements and an estimation of the standard deviation [13].

Drug loading efficiency identification

The drug loading efficiency of nanoparticles is the ratio between how much drug is actually in the nanoparticles and how much drug was used to make them. This can be measured using UV-visible spectrophotometry (Shimadzu, Japan) with the absorbance peak at 285 nm wavelength for SSD. A 5 mg sample of SSD-loaded nanofiber was excluded and weighed. The 5 mg sample was put into 5 ml of chloroform, acetonitrile, ethanol and acetic acid cosolvent and then mixed for 24 h to get the sample to dissolve again [5].

The following day, it was changed, and the absorbance of SSD was recorded. The experiment was repeated three times. Equation 1 was used to figure out the drug loading efficiency:

$$\text{Drug loading Efficiency} = \frac{Aact}{Aint} \times 100 \quad \text{E.q. 1}$$

In Equation 1, the A act is the amount of real drug loading, and A int is the initial (theoretical) drug loading into the nanoparticles. The drug loading efficiency was calculated by looking at three nanofiber patches and writing down the average number [5].

In vitro drug release studies

To determine the mechanisms underlying the release of the SSD drug from composite nanofibers, various kinetics models such as Zero-Order, First-Order, Higuchi, and Korsmeyer-Peppas were employed to analyse the drug release profile.

The 5 mg sample was put into 5 ml of chloroform, acetonitrile, ethanol and acetic acid cosolvent and then mixed for 24 h to get the sample to dissolve again. Then, a sample was collected in order of half hour for 8 hours, then 24 hours and measured using UV-visible spectrophotometry (Shimadzu, Japan) with the absorbance peak at 285 nm wavelength for SSD [5].

The Korsmeyer-Peppas model yielded a result indicating a regression coefficient R^2 of 0.9956. The drug release phenomenon is mathematically represented by the Equation 2:

$$\frac{Mt}{M\infty} = ktn \quad \text{E.q. 2}$$

The variable Mt/M∞ represents the quantity of drug released at a specific time (t). In contrast, M∞ represents the entire quantity of drug released up to time ∞ (i.e., the total amount of drug present in the formulation). The exponent n characterises the drug release mechanism, and k denotes the constant drug release rate [12].

SEM analysis

The surface morphology of the nanofibers was analysed for all 8 runs using a scanning electron microscope (SEM) instrument [13] (FE Axia chem SEM, thermos fisher Holand). The SEM was operated at a voltage of 10 kV and a working distance of 5.71mm. A minute quantity of nanofibers was manufactured and subsequently subjected to a gold (Au) coating process using a sputter-coating machine. The diameters of the fibres were determined by utilising the picture J software, which was applied to 24 distinct fibre sections extracted from a scanning electron microscopy SSD picture. The average diameter was determined using the recorded measurements and an estimation of the standard deviation [5,13].

Fourier Transforms Infrared Spectroscopy (FTIR)

A specimen of the nanofiber was applied onto a petri dish, obtained, and afterwards analysed using FTIR with the aid of an FTIR spectrophotometer (Bruker-Optic162, Germany). The 10 mg SSD loaded on PCL/PEO/Zein was diluted with 10 mg KBr and fitted on the lens. The chart was drawn with a resolution of 2 cm^{-1}. Measurements were taken in the range between 3500 and 400 cm-1 using FTIR spectrophotometer. To ensure the accurate delivery of the specified formula without any potential interactions [5,13].

X-ray diffraction analysis of silver sulfadiazine nanofiber aerosol

Powder X-ray diffraction (DX2700BH, China) was used to evaluate the crystalline state of the pure SSD, Zein, PCL, PEO polymers and SSD loaded Zein/PCL/PEO nanofibers selected adsorbent. The target metals Cu, filter Kα, 30 kV, and 20 mA. The scan was over a 2θ range of 0-40° at 1.5406 Å wavelength [5,13].

4.3. Statistical analysis

The study involved the analysis of eight different formulas and their corresponding experimental results. These formulas were examined using statistical analysis through the Design-Expert® software. The objective was to determine the impact of each polymer on the experimental outcomes, specifically the increase in loading efficiency and the decrease in nanofiber diameter. Statistical analysis such as the assessment of factor relationships, the use of Pareto charts, the application of half normal plots, the implementation of three-dimensional surface plots, and the examination of factor interactions [14].

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