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Preparation And Characterization of Polyvinyl Alcohol Nanofiber Loaded With Mafenide For Sustain Release

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Abstract This paper delves into the intricate process of preparing and characterizing Polyvinyl alcohol (PVA) nanofibers loaded with Mafenide to achieve sustained release functionality. The synthesis involves the careful integration of Mafenide, a pharmaceutical agent known for its antimicrobial properties, into PVA nanofibers. This combination holds promise for controlled drug delivery applications. The preparation begins with the electrospinning technique, a method widely employed for creating nanofibrous structures. During this process, the Mafenide is incorporated into the PVA matrix, forming a composite material. The choice of Polyvinyl alcohol as the base material is strategic, given its biocompatibility and excellent film-forming properties. The characterization phase involves a comprehensive analysis of the resulting nanofibers. Techniques such as scanning electron microscopy (SEM), Fourier-transform infrared spectroscopy (FTIR). are employed to examine the morphology and chemical composition of the nanofibrous system. These analyses provide insights into the structural integrity and the successful incorporation of Mafenide. The study focuses on the sustained release aspect, aiming to understand how the loaded Mafenide interacts within the PVA nanofibers over time. This sustained release mechanism is crucial for pharmaceutical applications, offering prolonged therapeutic effects and minimizing the need for frequent administration. The potential benefits of this research lie in the development of an efficient drug delivery system.

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Keywords: *Mafenide, polyvinyl alcohol, Nanofiber, electrospiner, sustained release*.

1. INTRODUCTION

The escalating demand for advanced drug delivery systems has spurred research into innovative materials and techniques to optimize therapeutic outcomes [1]. This paper introduces a novel approach to meet this demand through the preparation and characterization of Polyvinyl alcohol (PVA) nanofibers loaded with Mafenide, a potent antimicrobial agent [2]. The integration of Mafenide into PVA nanofibers is achieved via the electrospinning technique, a process renowned for producing intricate nanofibrous structures with high surface area [3].

Polyvinyl alcohol is selected as the base material due to its biocompatibility and exceptional film-forming characteristics, making it an ideal matrix for drug delivery applications [4]. Mafenide, known for its antimicrobial properties, holds great promise for medical treatments, especially in wound healing scenarios [5]. The synthesis process is meticulously designed to ensure the effective incorporation of Mafenide into the PVA nanofibrous matrix, aiming for a controlled and sustained release of the pharmaceutical agent [6].

This paper aims to explore the preparation and characterization of the resulting composite material, shedding light on its morphological and chemical attributes. Advanced techniques such as scanning electron microscopy (SEM) and Fourier-transform infrared spectroscopy (FTIR) will be employed to analyze the structural integrity and chemical composition of the PVA nanofibers loaded with Mafenide.

By delving into this innovative drug delivery system, the research aspires to contribute to the evolving landscape of medical treatments. The anticipated sustained release properties hold the potential to enhance therapeutic efficacy, particularly in applications where prolonged drug release is advantageous. This investigation represents a significant step toward developing more efficient and targeted drug delivery platforms, fostering advancements in the field of medical sciences and patient care.

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2. OBJECTIVES

The objective of this study was to fabricate nanofibrous films containing polyvinyl alcohol (PVA) loaded with mafenide by electrospinning, to investigate their sustain release effect, to evaluate the effect of incorporating different concentrations of mafenide acetate on their release activity, and to evaluate their ability to prevent microbial penetration, with an aim to assess their applicability in burn care.

3. MATERIALS AND METHODS

Mafenide was procured from ChemShuttle, China. Polyvinyl alcohol (PVA) (degree of hydrolysis 98-100%, average molecular weight 60000–125000 kDa) was procured from SD Fine Chemical, Mumbai, India. Buffer solution pH 7 (phosphate) was procured from Fisher Scientific Loughborough, United Kingdom

3.1 Preparation of Nanofibers

A metallic needle fixed 15 cm from a stable steel surface wrapped in aluminium foil was used to fill a 5-mL syringe with the polymer solution. Via an electrode attached to the needle, a voltage of 19 kV was given to the polymer solution. Additionally, the collector was grounded. One millilitre per hour was chosen as the solution's feed rate [7].

3.2 Studies on Nanofiber Morphology

With using the aid of a scanning electron microscope (SEM), the surface morphology of the films was assessed [8]. The film samples were placed on aluminium stubs, sputter-coated with a thin coating of platinum using a sputter-coater (Polaron, England) in an argon environment, and then SEM observation was performed. Using Microstructure Measurement software, the average diameter of the electrospun nanofibers was determined from SEM images [8].

4. CHARACTERIZATION OF MAFENIDE

4.1 Chemical purity of mafenide using FTIR

In order to asses mafenide purity, FTIR has been conducted. The result of FTIR analyse result has revealed the major peaks of mafenide, reflecting the purity of mafenide used in the experiment. An FT-IR spectrophotometer (Shimadzu, Japan) was used to get the FTIR spectra of the pure mafenide chemical. The functional spectrum's peaks were noted. groupings that are displayed in the Fig 1 chart. The result was compatible with findings of the references [9], [10], and [11].

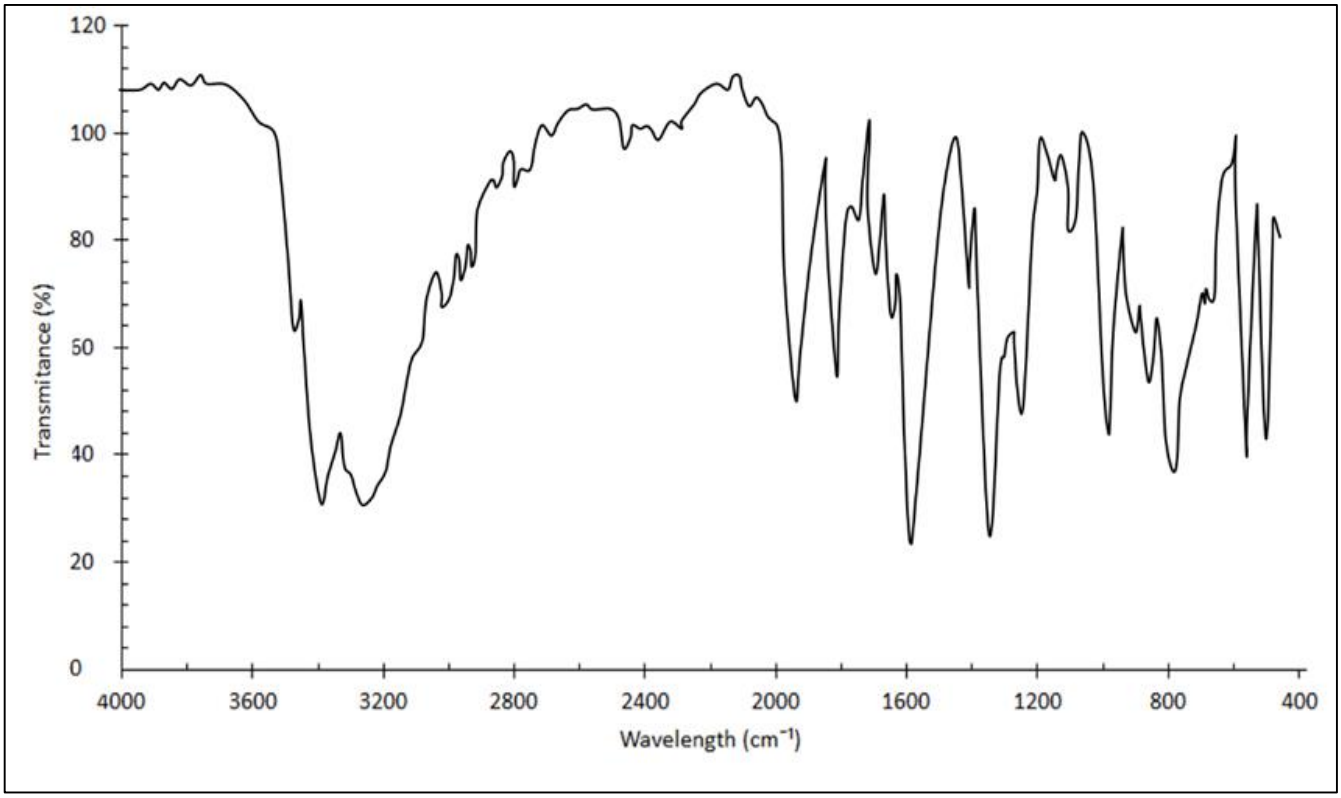

Figure 1 *The FT-IR spectrum of mafenide pure drug. The 10 mg mafenide was diluted with 10 mg KBr and fitted on the lens. The chart was drawn with a resolution of 2 cm-1. Measurements were taken in the range between 3500 and 400 cm-1 using FTIR spectrophotometer.*

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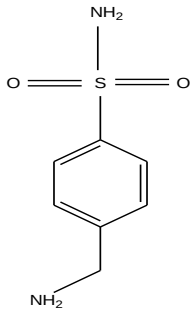
Table 1 *Characteristic FT-IR absorption bands of mafenide.*

Compound	Band ῡ cm^{-1}	Interpretation
Mafenide	3550 and 3000	Stretching vibration of N-H of sulfonamide
	1542, 1519	N-H bending
	1413	C-H stretching vibration of amide
	1319	C-N stretching
	1143	sulphonamide group
	1090	N-H bending

Ghadiri M., et al [12], was found in the range, peaks at 1159, 1320 and 1540 cm-1 are assigned respectively to sulphonamide group, C–N stretching and N–H bending vibrations. The broad peaks at 3,000 to 3,550 cm-1 assigned to the N–H stretching band of mafenide.

4.2 Determination of mafenide melting point

The melting point of mafenide were measured using capillary tube method melting point apparatus (Stuart, Germany) was found to be 150 ℃, which was agreed with Dashi, et al [13], Yamazaki E., et al (2018) [14] and Manna R., et al, (2023) [15]who reported that mafenide melting point at 151 ℃ to 152 ℃ respectively where the changes in the melting point due to using different salts of mafenide by researchers. The result indicates the purity of the mafenide pure drug.

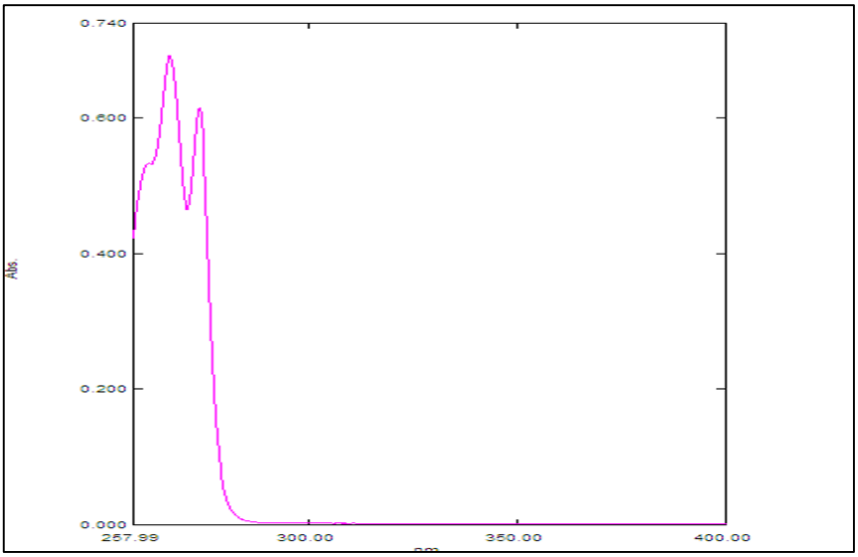


Figure 2 *The UV spectrum. The maximum wavelength (λ max) of mafenide in deionized water at pH of 5 is depicted. A quantity of a 0.25 µg.ml-1 of pure mafenide was dissolved in 10 ml prepared using deionized water followed by series of dilutions. The ultraviolet UV (Shimazu, Japan) absorbance of the prominent peak was measured. The experiment was replicated three times and the average value was calculated. (Shimazu, Japan).*

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4.3 Determination of mafenide λ max

A stock solution of mafenide, 50 µg.ml-1, in phosphate buffer, was analysed using a UV visible spectrophotometer (Shimadzu- Japan) in a wavelength ranging from 200 to 400 nm. The λ max of mafenide was absorbed in 265 nm as illustrated in Fig 3.2. This result was corresponded to the result of Rui Chen, et al. with modifications [16]. Using UV visible spectrophotometer, the absorbance was reported in the wavelength 265 nm.

4. 4 Construction of mafenide calibration curve in deionized water

Calibration curve was constructed as shown in Fig 1. The absorbance to concentration ratio of mafenide in buffer solution has been used and listed in Table 2 [17]. The regression coefficient (R^2) was 0.9996 and the linear equation generated was y = 2.2663x + 0.0121. The calibration curve of mafenide solution in deionized water was constructed using UV-spectrophotometer at λ max 265 nm. A straight line was drowned between series of mafenide solution concentrations versus obtained absorbance in nm according to Beer law. The result was corresponding to the mafenide finding reported by Orachorn N., *et al.* (2021) [18], who reported standard solutions in a concentration range of 5 – 25 µg.ml^{-1} , where the regression coefficient was R^2 = 0.998 and drew the strait line, and Mahajan R., *et al.* (2022) [19] solubilize mafenide in deionized water and drew a straight line with 5 points and R^2 = 0.9995.

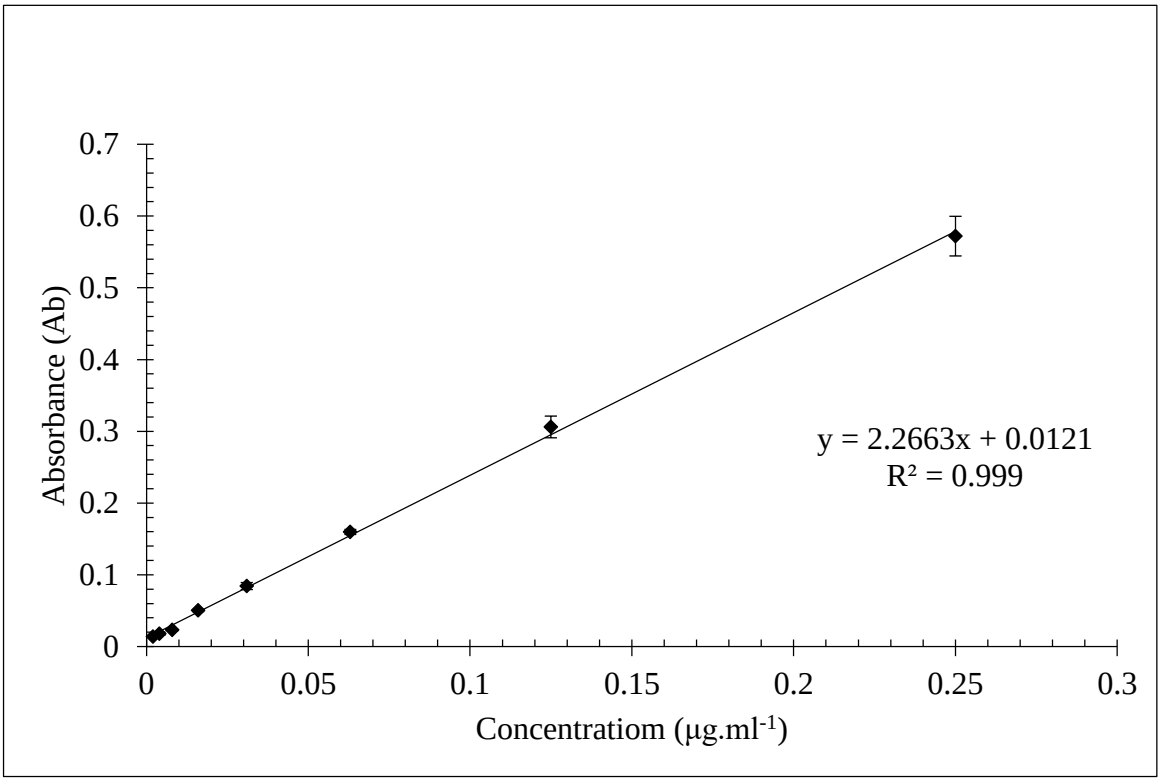

Figure 3 *Calibration curve of mafenide. stuck solution 50 ml at concentration range of 0.02 µg.ml-1 to 0.25 µg.ml-1 in deionized water. Then, serial of 8 concentrations were taken from prepared stuck solution, 2 ml of stuck solution withdrawn and diluted in 2 ml of deionized water and measured at 265 nm UV spectrophotometer (Shimazu, Japan).*

Table 3 The concentration of mafenide in deionized water to absorbance of UV spectrophotometer.

Concentration (µg.ml^{-1})	**Absorbance** ± SD
0.002	0.572 ± 0.027
0.004	0.306 ± 0.051
0.008	0.159 ± 0.035
0.016	0.084 ± 0.049
0.031	0.050 ± 0.01

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0.063	0.023 ± 0.001
0.125	0.018 ± 0.002
0.25	0.014 ± 0.001

The result was corresponding to the mafenide finding reported by Orachorn N., et al. (2021) [18], who reported standard solutions in a concentration range of 5 – 25 µg.l-1 , where the regression coefficient was R2 = 0.998 and drew the strait line, and Mahajan R., et al. (2022) [19] solubilise mafenide in deionized water and drew a straight line with 5 points and R2 = 0.9995.

5. DRUG DIFFUSION BEHAVIOUR

Sample that contained mafenide with PVA nanofiber was chosen for the drug release study because it had a uniform shape, good mechanical strength, and good swelling behaviour, as shown by the tests used to characterize it. The film crumbled after a cumulative release lasting three hours, as shown in Figure 4 and listed in Table 2. The polymer network becomes more compact whith polyvinyl alcohol (PVA), enabling regulated swelling during solvent ingress. The polymer composite's three-dimensional network influenced how quickly the medication was released from the matrix. Sample with polymer network traps the medication, gradually releasing after controlled swelling, resulting in a sustained release profile.

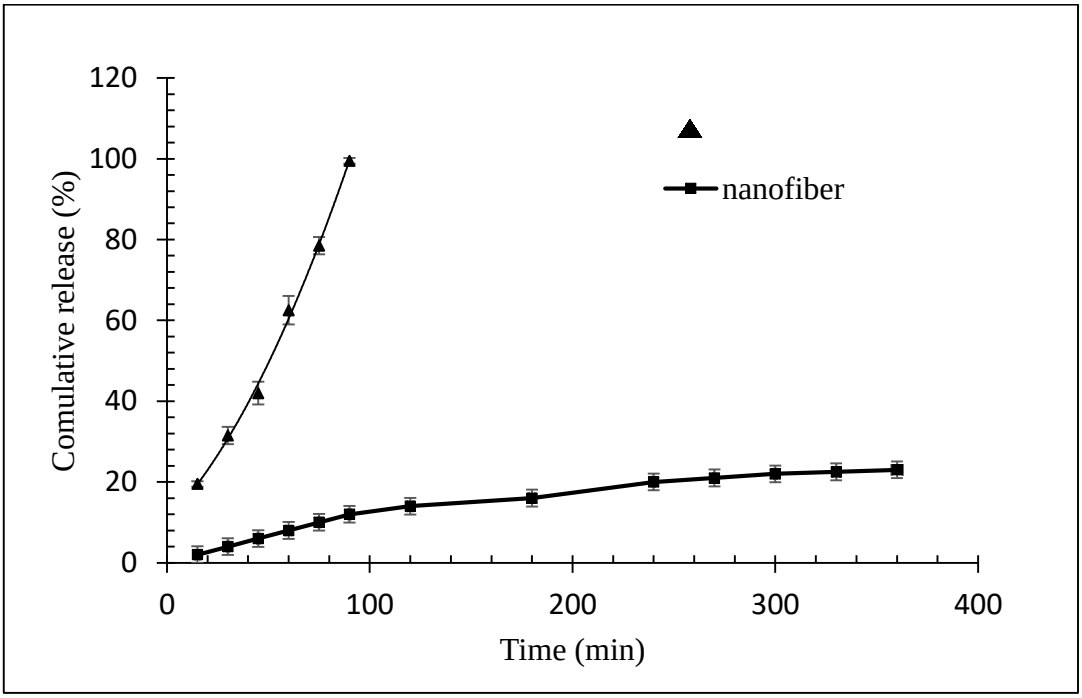

Figure 4: *The cumulative release (%) study of mafenide loaded nanofiber and mafenide drug (Blank). The nanofiber putted in 150 ml phosphate buffer pH 5 at 37 ± 0.5 °C and 5 ml of sample was withdrawn every 15 min for 360 minute and analysed spectrophotometrically at 265 nm. data are mean ± SD of three independent experiments.*

Table 2. *Cumulative drug release (%) of the Nanofibre-loaded mafenide and Free mafenide.*

Time (min)	Cumulative release (%)	
	Nanofibre-loaded mafenide	Free mafenide
15	2	20
30	4	30
45	6	40
60	8	60
75	10	80
90	12	100
120	14	
180	16	

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240	20
270	21
300	22
330	22.5
360	23

6. RESULTS

The morphological analysis of the film compositions showed that pure PVA made nanofibers that were smooth and uniform, with a mean diameter of 1064 nm. The diameter of these nanofibers dropped to 418 nm and 102 nm, respectively, when 20% and 40% mafenide were added. All film samples containing mafenide acetate released more than half of their medication within 30 minutes, according to in vitro release studies. The release rate of films containing 40% drugs was faster than that of films carrying 20% drugs. The findings also demonstrated that the release rate of chitosan/PVA blend nanofibers was lower than that of pure PVA nanofibers. This is likely due to chitosan's reduced solubility at pH 7.4 in comparison to PVA. A higher medium transmittance represents a decreased rate of microbial growth. Mohammadreza A., et al. (2015) founded same result using PVA with mafenide acetate [3]

7. DISCUSSION

The final nanofiber formula was successfully prepared using electrospinning technique. The used polymers were biocompatible with the model drug mafenide. The melting point of mafenide were measured using capillary tube method melting point apparatus was found to be 150 ℃ [21]. The result of FTIR analyse result has revealed the major peaks of mafenide, reflecting the purity of mafenide used in the experiment [22]. Calibration curve of mafenide stuck solution 50 ml at concentration range of 0.02 µg.ml-1 to 0.25 µg.ml-1 in deionized water showed that the regression coefficient (R2) is 0.999 [23]. Nanofiber of polyvinyl alcohol (PVA) and mafenide were developed in various ratios and characterised using FTIR analysis, mechanical studies, scanning electron microscope (SEM) analysis exhibit superior properties compared to model drug alone. Scanning electron microscope (SEM) analysis revealed that the film was uniform and the polymer has good miscibility. field emission scanning electron microscopy of the final formula of nanofiber on aluminium foil plait showing different nanofiber size. Nanofiber release study showed that mafenide loaded nanofiber with PVA has more releasing time that reached 360 min compared to model drug without polymers.

8. CONCLUSION

The final nanofiber formula was successfully prepared using the electrospinning technique. The used polymers was biocompatible with the model drug mafenide. Nanofiber of polyvinyl alcohol (PVA), and mafenide were developed in various ratios and characterized using FTIR analysis, mechanical studies, scanning electron microscope (SEM) analysis and swelling studies. Scanning electron microscope (SEM) analysis revealed that the films were continuous and uniform, and the polymer had good miscibility. FTIR analysis revealed a physical interaction among the polymers, indicating that the formulations would have good release efficiency. Overall, the final formula showed good potential as a nanofiber according to the Design-Expert® software [20], analysis to aid and accelerate wound healing. In conclusion, a final formula of nanofibers containing mafenide exhibits sustained release properties compared to model drug alone.

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Nil

AUTHORS CONTRIBUTIONS

All authors have contributed equally.

CONFLICT OF INTERESTS

The author declares that there are no conflicts of interest regarding the publication of the paper.

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