RESEARCH PAPER

Fabrication and Characterization of Graphene and Linezolid Composite Loaded Scaffolds for Awesome Drug Delivery at Site of Burn Wounds

Rajesh Kumar[1], Ajay Kumar[2], Sandip Patil[3], Shashi Kiran Misra[4*]

[1]Research Scholar, Department of School of Pharmaceutical Sciences, CSJMU Kanpur.
Email: phd202300001870@csjmu.ac.in

[2]Associate Professor, Department of School of Pharmaceutical Sciences, CSJMU Kanpur

[3]Sandip Patil

[4*]Shashi Kiran Misra (Corresponding Author). Email: shashikmishra@csjmu.ac.in

Abstract

Because of PVA (CAS No. 9002-89-5) introduction and possible uses in a variety of fields, different polymers with multifunctional qualities are attractive. PVA and other synthetic polymers are highly esteemed as biodegradable, useful materials with biocompatibility properties. PVA has been considered a promising material for a variety of applications for over fifty years. This article presents a set of experiments, 10% w/v Polyvinyl Alcohol (Industrial grade) was found to be adequate for formation of smooth, defect free, and regular fibers. It also discusses the many methods used to characterize the polymer. The production of smooth, nano-range, mesh-like structures with distinct pockets within their structure was enthusiastically recognized by scanning electron microscopy (SEM). X-ray diffraction (XRD) and Fourier transform infrared spectroscopy (FTIR) confirmed the PVA scaffolds' polymer production and improved thermal behavior. This review presents PVA nanofiber preparations, optimizations, characterizations, and applications. Due to the polymer blend's somewhat improved permeability, the nanofibers' high swelling ability and hydrophilicity were attained. This lowers the crucial level for the creation of a nanofibrous scaffold, which is used to grapheme-linezolid composite drug delivery for stop fungal infections and an awesome treatment in burn wounds. Concluded by announcing improved nanofibers and putting out more persuasive dressing materials for a common burn wound infection regimen. Recent applications of grapheme-linezolid composite drug delivery for PVA in biomaterials have also been highlighted in the paper.

Keywords: PVA, Fabrication, Characterization, Optimization of Fabrication, Graphene.

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Introduction

Hermann and Haehnel produced polyvinyl alcohol (PVA) for the first time in 1924 by hydrolyzing polyvinyl acetate in ethanol using potassium hydroxide (Dennis et al. 2023). Commercial production of it typically involves a continuous process using polyvinyl acetate (Islam et al. 2020). The groups of acetate are hydrolyzed by ester exchange with methanol when aqueous sodium hydroxide or anhydrous sodium methylate are present (Dhuguru et al. 2025). The degree of hydrolysis and polymerization determine its physical properties and particular functional applications. There are two types of polyvinyl alcohol: fully hydrolyzed and partially hydrolyzed (Ma et al. 2024). PVA that has been partially hydrolyzed is used in foods. Polyvinyl alcohol is a translucent, white or cream-colored granular powder that has no flavor or odor. It dissolves in water (Liu et al. 2022). During the early part of the 20th century, PVA, a synthetic polymer, was used all over the world. Lacquers, resins, surgical threads, and food packaging materials that come into regular touch with food are just a few of the final products that have been made using it in the commercial, industrial, medical, and food sectors (Choudhury et al. 2022). PVA is an extensively used thermoplastic polymer that is safe for living things, nontoxic, and harmless. PVA is a biodegradable polymer, and because its carbon atoms have hydroxyl groups, hydrolysis aids in its biodegradation. Moreover, it has a hydrophilic nature and dissolves in water. Rates and the environment most polymers, including PVA, can degrade under a variety of circumstances.

These settings include composting in aerobic habitats, under soil coverings, in liquid environments, and even in anaerobic conditions. H-atoms connected between the hydroxyl group and possibly hydrogen atoms make up PVAs' crystalline structure. The addition of additives may alter the crystallinity of PVA. PVA possesses a glass transition temperature of 85 °C, and the melting point is 230 °C. After dissolving PVA in water at 80–90°C for 30 minutes while stirring continuously, the mixture is poured onto glass, from which films ranging in thickness from 10 to 30 mm can be removed (Willenberg et al. 2020). The films were kept at 50°C overnight to completely dry them out after the water in the solution evaporated. Following the casting process, the films were stored in a dehydrated environment by Silica gel (Surendhiran et al.2022).

PVA solutions with concentrations ranging from 2% to 14% (w/w) were created by dissolving the weighed amount of powder in distilled water at 90 °C and stirring gradually for two hours in order to determine the solution properties of PVA. A variety of solution characteristics, including density, surface tension, and rheology profile, were examined in specially generated solutions. Up to a concentration of 13% (w/w), it is discovered that the density increases linearly with the mass concentration of the polymer in solution. Because of the system's high viscosity and the possibility of air bubble entrapment, the readings were inaccurate at concentrations higher than 13% (w/w). The PVA macromolecules are mostly found on the surface at lower concentrations, where they act as a surfactant to reduce surface tension (Rather et al. 2023). When the macromolecules reach a certain concentration, say 5% (w/w), the surface is completely coated, making it impossible to add more. As a result, more molecules localize in the bulk solution, where they start to rearrange and link to take on different configurations because of their intermolecular affinity. The latter's formation also results in the water's exclusion and surface placement. Crucially, as the number of polymer molecules in solution increases, so do the number of internal structures that are accessible and the amount of water that is compressed (Zhang et al. 2025).

Additionally, they showed that as the temperature rises, the surface tension decreases because of the increased surface area. Last but not least, changing the polymer's concentration in the solution causes the molecules to move and reorganize; the higher the concentration, the less surface area the dissolved molecules occupy. Since the viscosity of each PVA solution is independent of the shear rate, it is possible to assume that these solutions behave Newtonianically. PVA is characterized using a variety of characterisation techniques. Some of them are highly advanced. With the help of some available material, an overview of these methods was carried out (Pavlenko et al. 2022).

Significant causes of morbidity and mortality include severe sepsis syndrome, inflammatory response syndrome, and improvement in burn patients. According to Clara et al. (2024), the production of antimicrobials in the burn victims may therefore offer some promise for further research. Prior to the development of potent topical antibacterial chemotherapeutic drugs, heat-induced burn wounds were the most common site of infection, resulting in morbidity and, in the case of invasive procedures, near death for burn patients (Clayton et al. 2021). According to a review of the literature, structure-oriented, therapeutically functional, and therapeutically active 3D nanofibers can mimic the natural cell niche and show an endless array of applications in tissue engineering, cell growth, and cell proliferation due to their unique surface area and robust mechanical support (Kaka et al. 2025). Because different bioactive composites may be uploaded into electrospun scaffold nanofiber structures, they are better suited for usage as scaffolds and matrices for topical dressings. Another feature of such a formulation is the localized effective field of the medication working on the infection (Rajput et al. 2023). In order to prevent drug interactions with healthy host tissue, it has a strong retention of continuous confinement and prevents drug escalation into adjacent areas (Sahoo et al., 2025). Because of their intrinsic qualities, which include excellent adherence, biocompatibility, and elegance across the skin surface, polymers (10% w/v polyvinyl alcohol) have been used to produce nanofibrous scaffolds (Öztürk et al., 2024). Because of their different permeability characteristics, the current study investigates the use of a specific fraction of both polymers for regulated drug release from the nanofibrous scaffold (Abboud et al. 2025). lectrospun scaffolds nanofiber constructions are more capable for usage as scaffolds and matrices for topical dressings since it is possible to upload several bioactive composites into them. The localized effective arena of the medicine operating against the infection is another feature of such a preparation (Rajput et al. 2023). It firmly maintains a consistent confinement and prevents

drug escalation into nearby regions, preventing medication interactions with healthy host tissue (Sahoo et al. 2025). For the production of nanofibrous scaffolds, polymers (10% w/v polyvinyl alcohol) have been used because to their intrinsic qualities, which include efficient adhesion, biocompatibility, and classiness over the skin surface (Öztürk et al. 2024).

1. Materials and Methods

1.1 Chemicals

Polyvinyl Alcohol (PVA), industrial grade (CAS No. 9002-89-5), was the main polymer utilized in this study. It was selected because of its superior biocompatibility, film-forming capability, and mechanical stability, which make it perfect for use in pharmaceutical and biomedical applications. To make sure there were no ionic impurities that would affect the stability of the medication or the solubility of polymers, deionized (DI) water was used as the solvent medium. Acetone was used to disinfect glassware and equipment before experiments in order to preserve laboratory cleanliness and a contamination-free experimental environment. Additionally, to guarantee complete drying and removal of any leftover contaminants from laboratory instruments, simple cleaning supplies like tissue paper and test tube brushes were utilized.

1.2 Glassware

- Measuring cylinder, Vials, Spatula, Butter paper, Magnetic bead, Industrial-grade Polyvinyl Alcohol (PVA) (CAS No. 9002-89-5) was used as the main polymer in the study because it is biocompatible and simple to electrospin. To provide a contaminant-free environment during the dissolution of polymers and the creation of nanofibers, deionized (DI) water was used as the solvent medium. To preserve experimental sterility, acetone was used to clean lab equipment and glassware. For regular laboratory maintenance, extra cleaning supplies including tissue paper and test tube brushes were utilized.
- For material handling and preparation, a variety of lab tools were used, such as spatulas for exact solid material weighing and mixing, vials for storing solutions, and measuring cylinders for precise solvent measurement. A magnetic bead allowed for consistent stirring during polymer dissolution using a magnetic stirrer, while butter paper served as a platform for sample drying and transfer.

1.3 Equipment

- Weighing balance (Max: 220 g, Min: 10 mg, Accuracy: 0.1 mg), Magnetic stirrer, Dryer, Electrospinning apparatus, 5 ml disposable syringe, Aluminum foil, Electro-Spine software system
- Polyvinyl Alcohol (PVA) (industrial grade, CAS No. 9002-89-5) was the main polymer used in this work. It was chosen because of its superior mechanical strength, film-forming capabilities, and biocompatibility, which made it appropriate for the production of nanofibers. To guarantee that contamination-free polymer solutions were prepared, deionized (DI) water was utilized as the solvent medium. Standard cleaning supplies like tissue paper and test tube brushes were utilized for laboratory upkeep, while acetone was used to clean glassware and experimental equipment in order to preserve sterility and prevent cross-contamination.
- Additional supplies included measuring cylinders for precise volumetric measurements, butter paper for sample drying and transfer, vials for storing samples, and spatulas for working with powdered ingredients. To ensure consistent stirring during the solution preparation process, a magnetic bead was employed.
- A high-precision weighing balance (Max: 220 g, Min: 10 mg, Accuracy: 0.1 mg) was used in the experiment to weigh the medication and polymer components precisely. PVA was uniformly dissolved in DI water with the aid of a magnetic stirrer. Prior to further processing, a hot air dryer was used to dry the produced solutions.
- An electrospinning device with aluminum foil collectors and a 5 mL disposable syringe was used to create the nanofibers. Electro-Spine software, which allowed for real-time monitoring and optimization of electrospinning parameters like voltage, flow rate, and collection distance, was used to control the device.

2. Preparation of polyvinyl alcohol polymer Solution

Originally, polyvinyl alcohol polymer was dissolved efficiently on the deionized water through wet chemical

route. To put it briefly, a uniform dispersion of polyvinyl alcohol polymer in deionized water was mixed and stirred for a long time.

2.1 Calculation

To prepare a 10% w/v solution:

For the calculation of PVA quantity, use the following formula:

$$\textit{Percentage of solution} = \frac{\textit{Quantity of solute}}{\textit{Quantity of solvent}} \times 100$$

Or, $10 = \frac{\text{Quantity of solute}}{5\text{ml}} \times 100$

Or, $\text{Quantity of solute} = \frac{5 \times 10}{100}$

Quantity of solute = 0.5 gm

Thus, **0.5 grams of PVA** is dissolved in **5 ml of DI water**.

2.2 Procedure

All glassware was cleaned thoroughly with water and further rinsed with acetone to remove residues and speed up drying. Equipment was dried using a hot air dryer to ensure a contaminant-free environment essential for electrospinning. 0.5 grams of PVA was weighed accurately using a precision balance and transferred to a clean, dry vial. A magnetic bead was added to the vial. The vial was placed on a magnetic stirrer set at 500 RPM at room temperature. 5 ml of DI water was added slowly to the vial to ensure even dispersion and to avoid sticking to the sides. The solution was stirred continuously for 2–4 hours (or overnight) to achieve a clear, homogeneous solution suitable for electrospinning.

3. Electrospinning Fabrication of polyvinyl alcohol polymer nanofibers

3.1 Syringe Preparation

- A 5 ml disposable syringe was filled with the prepared solution.
- A modified needle (tip cut for jet formation) was attached.
- Tissue paper was used for surface cleaning.

3.2 Software Setup

- **E-SPINE** software was launched.
- Parameters like flow rate, syringe diameter, and volume were input as follows:

Parameter Value

S. No.	Parameters	Value
1.	Flow Rate	1 ml/hour
2.	Syringe Diameter	12.40 mm
3.	Volume Filled	4 ml

3.3 Assembly and Adjustments

1. The syringe was fixed on a single-channel station.
2. Aluminium foil (30 × 15 cm) was taped onto the drum collector.
3. The needle-to-collector distance was measured using a scale.
4. High voltage (HV) connection was made to the needle.
5. Electrospinning process was initiated by powering on and commanding the software.

3.4 Operation Parameters

Parameter	Setting
Drum Speed	300 RPM
High Voltage	14 KV
Fan	OFF
UV Light	OFF
Light	ON
Chamber Temperature	33°C
Humidity	24% RH
Syringe Temperature	0°C

3.5 Y-Scan Settings

Parameter	Setting
Scan Distance	5 cm
Scan Time	1 hour
Scan Speed	Medium

- The electrospinning was carried out while monitoring jet formation.
- Frequent cleaning of the needle with tissue paper was performed (with HV turned OFF) to prevent clogging.

Furthermore, taking into account the aforementioned process parameters, the produced dispersion was subjected to the

electrospinning procedure. When the voltage was increased, the pendant drop was drawn into a conical shape called a Taylor Cone by the repulsive electric force. Once the electrical force overpowers the surface tension, a liquid jet forms from the syringe and travels in nanoseconds to the bra's collector as fine fibers (Gupta et al. 2025).

Figure: 10% PVA Nanofibers sheet on the aluminium foil.

Characterization

Fourier Transform Infrared (FTIR) Spectroscopy

FTIR spectroscopic studies to evaluate the materials' local chemical and compositional characteristics. Wave numbers ranging from 4000 to 500 cm−1 were used to record measurements on the distinct physical mixture, PVA and deionized water (DI) formulation nanofibers.

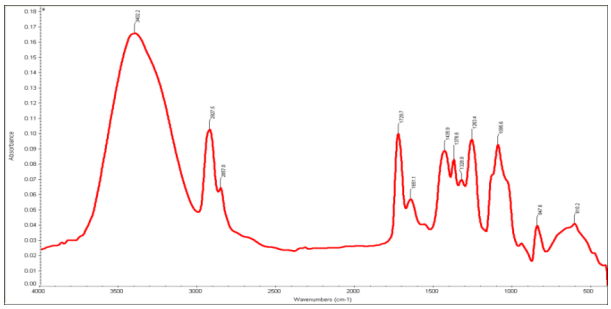


Fig.1 FTIR (Fourier Transform Infrared) spectrum

This spectrum is Fourier Transform Infrared (FTIR), with wavenumbers (cm^{-1}) on the X-axis and absorbance on the Y-axis. The spectrum's peaks are caused by different chemical bond vibrational modes in the sample.

Table.1 Different chemical bond vibrational modes in the sample.

S.N.	Peak (cm^{-1})	Observations
1	~3402	**O–H stretching**, indicating the presence of hydroxyl (-OH) groups.Common in polymers, water, and alcohol-based compounds.
2	~2927& 2857	**C–H stretching vibrations** from alkanes. Suggests the presence of polymeric backbones or organic molecules.
3	~1729	**C=O (carbonyl) stretching**, found in esters, carboxylic acids, ketones, and aldehydes. Indicates a polymer with ester groups or a drug/polymer interaction.
4	~1651	**C=C stretching (alkene or aromatic rings)** or **amide I (protein-related)** bonds.
5	1450-1370	**C–H bending** in alkanes or **aromatic C=C stretching**
6	1263-1069	**C–O stretching** (esters, ethers, or polysaccharides). This may be due to the polymer backbone or chemical modifications.
7	~847 and ~610	These are fingerprint region peaks, often associated with **out-of-plane bending vibrations** in aromatic or complex structures.

The PVA-deionized water system's FTIR pattern ought to display significant peaks for its own material content. Polyvinyl alcohol (PVA) is identified by the presence of O–H and C–H stretching vibrations. One could also observe the existence of oxygen-containing groups and the C=C bond. In this regard, FTIR spectroscopy should be essential for verifying the chemical makeup of the interaction between the polymer and deionized water as well as for identifying important groups that control important property attributes like the systems overall stability, solubility, and biodegradability.

Field Emission Scanning Electron Microscopy (FESEM)

The topography of the surface of the produced nonwoven electrospun nanofibers was examined using Field Emission Scanning Electron Microscopy. The samples were gold sputter-coated to enhance

conductivity for imaging. Average diameter of fibers and distribution of fibers were determined.

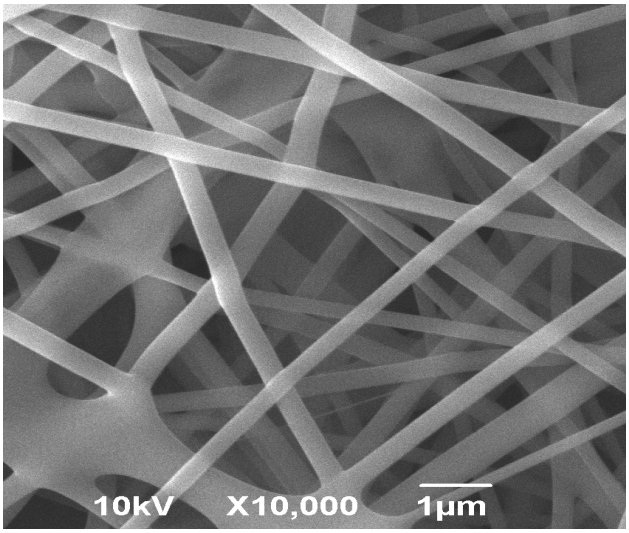


Fig.2 Scanning electron microscope (SEM), shows fibrous

This image, taken with a scanning electron microscope (SEM), shows a fibrous substance that may be electrospun polymer fibers or a nanofiber mesh. At 10,000x magnification, the image shows a complicated, interconnected network of thin filaments. Given that the scale bar shows a length of one micrometer (µm), the fibers' diameters are likely in the nanometer to sub-micrometer range. An accelerating voltage of 10 kV is required for SEM imaging. This kind of structure is typically found in nanotechnology and healthcare scaffolds.

Static water contact angle (WCA) was examined to explain the degree of hydrophilicity by sessile drop method with contact angle goniometer under video capture at room temperature. Using a microsyringe, 30 µL of deionized water was pipetted onto a dried electrospun nanofiber (2 cm^2) in a saturated water vapor atmosphere (Siddiqui et al. 2024). To avoid any fluctuations, WCA was estimated after 60 s of incubation. To get a good value, the average of three different contact angles was calculated.

Fig.3 Contact angle test, shows fibrous

XRD

The XRD spectrum provides information about the crystalline structure of the material. The Key Observations X-Axis (2Theta, Coupled Two Theta/Theta, λ = 1.54060 Å). This represents the diffraction angle (2θ) in degrees. Peaks are present at 44.731°, 64.998°, and 78.143°, indicating crystalline phases. Y-Axis (Counts) Represents intensity, which corresponds to the number of X-rays diffracted at a particular angle. The Peak Identification presence of sharp diffraction peaks suggests a crystalline structure. The peak positions at 44.731°, 64.998°, and 78.143° resemble characteristic reflections of metallic materials,

potentially face-centered cubic (FCC) structures like metallic gold (Au), silver (Ag), or nickel (Ni).

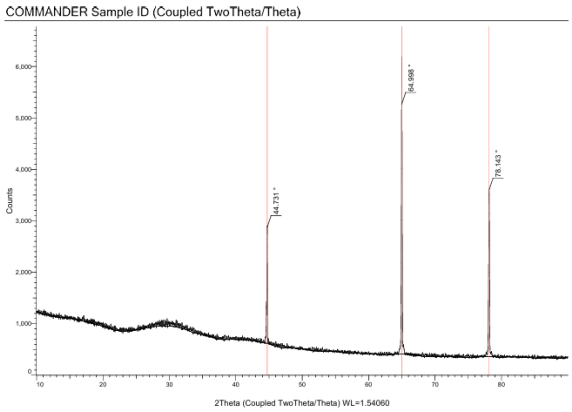


Fig.3 Phase determination of crystalline materials

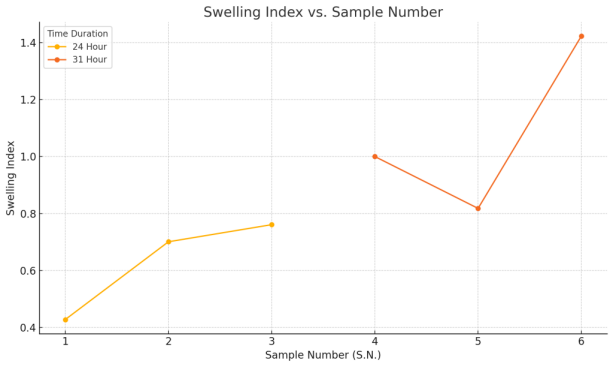
SWELLING INDEX

When using the gravimetric approach on skin with a pH of 7, the swelling index is considered a major tool for estimating the drug release behavior from the nanofibrous scaffold (Jung et al. 2025). Every nanofibrous scaffold (1 cm^2) that had been constructed was put in a Petri plate with 10 ml of medium and cultured for 24 hours at 37 °C. After using filter paper to peel off the media that was stuck to the scaffold surface, the wet weight was measured until it was constant. Three successive measurements of each nanofiber were used to calculate the average level of the swelling index. Table.2 swelling behavior of a material over time

S.N.	Time Durations (Hour)	Weight of dry (g)	Weight of wet (g)	Difference (g)	Swelling Index
1	24	0.0070	0.0100	0.003	0.428
2	24	0.0067	o.o114	0.0047	0.701
3	24	0.0067	0.0118	0.0051	0.761
4	31	0.0033	0.0066	0.0033	1
5	31	0.0033	0.0060	0.0027	0.8181
6	31	0.0045	0.0109	0.0064	1.4223

Swelling Index = (Weight Wet − Weight Dry) / Weight Dry

Table 2 displays the experimental findings for figuring out a material's swelling characteristics over time, or how much liquid it absorbs and increases in weight. Two duplicates are taken for the results at different time periods (measured in hours) to guarantee consistency. Weight Dry is the sample's initial dry weight, while Weight Wet is the sample's weight after soaking. The Swelling Index is then computed using the formula, which measures the liquid absorption as the difference between Weight Wet and Weight Dry.



Dry and wet weight measurements of samples taken after various times (24 and 31 hours) as well as their corresponding swelling indices make up the information supplied. Samples 1 through 3 have dry weights ranging from 0.0067 to 0.0070 g and wet weights ranging from 0.0100 to 0.0118 g throughout a 24-hour period. Swelling indices range from 0.428 to 0.761 due to weight differences that take into consideration the moisture absorbed, which range from 0.003 g to 0.0051 g. In this series, Sample 3 has the greatest swelling index. The wet weights during the 31-hour period (samples 4–6) vary from 0.0060 g to 0.0109 g, but the dry weights are somewhat lower, ranging from 0.0033 g to 0.0045 g. Among the weight gain variations, sample 6 had the largest water absorption (0.0064 g), which corresponded to the highest swelling index (1.4223) overall. The rise from lower to higher indices throughout the course of the 31-hour period as opposed to the 24-hour duration suggests that a longer duration enhances swelling ability.

Applications

PVA properties that have implications in advanced medical disciplines, hemodialysis, drug delivery systems, and implantable medical devices are bio-inertness and biocompatibility. PVA-based polymers are used as drug carriers in the biomedical and pharmaceutical industries as well as in tissue engineering research. Polyvinyl alcohol is used in tablet coating formulations for items like food supplement tablets to shield the active chemicals from oxygen, moisture, and other environmental factors while also masking their taste and odor. It facilitates swallowing and consumption and makes handling the finished product easier. Because of its consistency, polyvinyl alcohol coating agents can be applied to tablets, capsules, and other forms that film coatings can be applied to. By choosing products from each food category that had the highest percentage of moisture-sensitive ingredients, calculating the surface area of those ingredients, and assuming polyvinyl alcohol coated the entire surface area, maximum use levels of polyvinyl alcohol were determined for the finished foods. Numerous biomedical applications have made use of PVA hydrogels. PVA hydrogels are perfect candidates for biomaterials because of a few benefits. PVA hydrogels have the advantages of being bio-adhesive, non-toxic, and non-carcinogenic. PVA closely resembles genuine tissue and is readily absorbed by the body due to its high swelling ratio in water and rubbery, elastic nature. PVA gels have been used in medicine delivery, contact lens, and prosthetic heart lining applications. This substance had excellent bioadhesive qualities. PVA is used in a variety of applications, including lubrication, mechanical strength, load bearing capacity, and bone attachment. PVA is mostly used in ocular preparations and topical medications. It is used in emulsions as a stabilizer. PVA is used as a thickening ingredient in viscous materials, such as eyeglasses. Additionally, soft contact lenses use it. passage of oxygen via clean PVA sheets. The use of transdermal patches as a biomedical device is being investigated because of the benefits of PVA, such as its water solubility and biodegradability. Oral precision relief devices are one use for PVA cross-linked microspheres. It is used as a lubricant in transdermal patches, sustained release oral medications, and contact lens solutions. This polymer can be mixed with other natural and synthetic polymers because of its hydrophilic and processing qualities. Because of their biocompatibility, PVA composites, also known as hydrogels, have found extensive use in the medical field. They are a well-known polymer gel with a range of applications, such as wound treatment, medication administration, and organ replacement. PVA is a protective agent that tends to adsorb metal ions and generate complex products. It also has an excess of OH groups and forms water solutions.

Results and discussion

A 10% PVA polymer solution was successfully prepared and used for electrospinning to produce nanofibers. The process was completed under controlled laboratory conditions at BAI-LABS (Arazi-67, Naramau Banger, G.T. Road, Kanpur, Uttar Pradesh, 209217). Creation of the Fabrication and characterization of PVA scaffolds for awesome drug delivery at site of burn wounds facilitated direct physical adsorption and

noncovalent interaction with the aromatic hydrophobic drug. It would modify macromolecules with biologically active modules to transport into target tissue/cells invaded by burn wounds. The enhanced loading capacity is by the decreased steric hindrance impact of the loaded molecule throughout the composite creation process. The PVA scaffolds would not emit bioactivagent during its delivery route, preventing harmful effects on healthy tissue or cells, unlike liposomal drug carriers or micelles (Tian et al., 2025). Optimization of polyvinyl alcohol polymer concentration for the production of nanofibers following electrospinning, beaded, uneven, and nonuniform nanofibers appeared on the collector, accompanied by polymeric droplets of the polyvinyl alcohol polymer solution (8% w/v). In order to achieve regular beadles and a consistent nanofibrous scaffold, the concentration of polymers was increased to 10%w/v, which was thought to be polyvinyl alcohol polymer (Fig. 2).

Conclusion

In the present study, nanofibrous scaffolds of the polyvinyl alcohol polymer was joyfully created. An in-depth analysis of the PVA's characteristics and applications was necessary for a comprehensive evaluation. PVA displays the usual characteristics of a polymer solution. For the past 30 years, PVA, a synthetic polymer, has been utilized in a variety of industries, including medicine. Based on both clinical and nonclinical research, the polymer has been thoroughly studied. The literature suggests that PVA still has a lot of prospective applications in many fields of science and technology, despite the fact that it has been used extensively. Produced from the polymer to the extracellular matrix, S.N.6 nanofibers demonstrated rapid hydrophilicity, high swelling properties, and drug release control. These properties were predicated on new uses for bandages or dressing materials to treat burn wounds. At the first stage, nanofibers was advantageous for treating burn wounds; thereafter, the restricted and regulated drug release enhanced the nanofibrous scaffold's antibacterial efficacy indefinitely. Consequently, the nanofibrous scaffold would offer a way to construct dressing materials for the management of severe burn injuries.

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