RESEARCH PAPER

Characterization Of Pva/Collagen Bioscaffold Enriched With Xanthium Strumarum Leaf Extract

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ABSTRACT

Background: Polymeric scaffolds are widely used in tissue engineering due to their ability to mimic extracellular matrix architecture. Polyvinyl alcohol (PVA) provides mechanical stability, while collagen enhances biocompatibility; however, their combination lacks intrinsic bioactivity. Incorporation of plant-derived bioactive compounds may improve the biological and functional performance of such scaffolds. Xanthium strumarium is a medicinal plant known for its antimicrobial and anti-inflammatory properties.

Aim: To fabricate and characterize a PVA/Collagen bioscaffold enriched with Xanthium strumarium leaf extract and evaluate its physicochemical, mechanical, and biological properties for potential tissue engineering applications.

Materials and Methods: A composite bioscaffold was fabricated using 10% PVA and 1% collagen with methanolic Xanthium strumarium leaf extract and processed via freeze-drying. The scaffold was characterized using Fourier transform infrared spectroscopy (FTIR), X-ray diffraction (XRD), scanning electron microscopy (SEM), and energy-dispersive X-ray analysis (EDAX). Mechanical properties were evaluated through tensile strength testing and porosity assessment. Biological performance was assessed by cell viability assays and anti-inflammatory activity through measurement of TNF-α and IL-6 levels.

Results: FTIR and XRD analyses confirmed successful incorporation of the plant extract and modification of scaffold crystallinity. SEM revealed a highly porous and interconnected architecture, with EDAX confirming elemental composition. The extract-enriched scaffold demonstrated increased tensile strength and porosity compared to the control scaffold. High cell viability and significant reduction in pro-inflammatory cytokines were observed, indicating good biocompatibility and anti-inflammatory potential.

Conclusion: The PVA/Collagen bioscaffold enriched with Xanthium strumarium leaf extract exhibited favorable physicochemical, mechanical, and biological properties, highlighting its potential application in tissue engineering and wound healing...

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INTRODUCTION

Tissue engineering aims to restore, maintain, or enhance tissue function through the combined application of biomaterials, cells, and biologically active molecules. Among these components, scaffolds play a pivotal role by providing a three-dimensional framework that mimics the extracellular matrix (ECM), facilitates cell adhesion, proliferation, and differentiation, and supports nutrient diffusion and waste removal[1]. An ideal scaffold should exhibit biocompatibility, suitable mechanical strength, interconnected porosity, and bioactivity to actively modulate cellular responses[2].

Polyvinyl alcohol (PVA) is a synthetic polymer widely used in biomedical applications owing to its excellent mechanical properties, hydrophilicity, chemical stability, and ease of processing[3]. However, PVA lacks biological recognition sites necessary for effective cell attachment. Collagen, the most abundant structural protein in the ECM, offers superior biocompatibility, biodegradability, and cell affinity[4]. Blending PVA with collagen combines mechanical robustness with biological functionality, making

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PVA/collagen composites promising scaffold candidates for tissue engineering applications[5]. Nevertheless, despite these advantages, such polymeric blends often lack intrinsic bioactivity, limiting their ability to modulate inflammation and accelerate tissue regeneration[6].

Recent advances in biomaterials research have focused on incorporating natural bioactive compounds into polymeric scaffolds to impart therapeutic functionality[7]. Plant-derived extracts have gained particular attention due to their antioxidant, anti-inflammatory, antimicrobial, and osteogenic properties, coupled with low toxicity and cost-effectiveness[8]. *Xanthium strumarium*, a medicinal plant traditionally used in Ayurveda and Chinese medicine, is rich in flavonoids, phenolic acids, sesquiterpene lactones, and alkaloids, which collectively contribute to its broad pharmacological profile[9]. Several studies have demonstrated the anti-inflammatory, antioxidant, antimicrobial, and wound-healing potential of *Xanthium strumarium* extracts[10],[11].

Inflammation plays a critical role in the early stages of wound healing and tissue regeneration. Excessive or prolonged inflammatory responses, characterized by elevated levels of pro-inflammatory cytokines such as tumor necrosis factor-α (TNF-α) and interleukin-6 (IL-6), can impair healing outcomes[12]. Therefore, scaffolds capable of modulating inflammatory pathways are highly desirable. Additionally, scaffold porosity, surface morphology, and mechanical integrity significantly influence cellular behavior and tissue integration[13].

Recent studies from Saveetha Dental College have emphasized the importance of incorporating bioactive agents into polymeric scaffolds to enhance osteogenic differentiation, biocompatibility, and inflammatory regulation in dental and maxillofacial tissue engineering applications[14]–[16]. However, limited data are available on *Xanthium strumarium*-enriched PVA/collagen scaffolds, particularly with comprehensive physicochemical and biological characterization.

Hence, the present study aims to fabricate and characterize a PVA/collagen bioscaffold enriched with *Xanthium strumarium* leaf extract and to evaluate its physicochemical properties, mechanical strength, porosity, cytocompatibility, and anti-inflammatory potential for prospective tissue engineering and wound healing applications.

MATERIALS AND METHOD:

A scaffold was prepared by dissolving 10% (w/v) polyvinyl alcohol (PVA) in distilled water at 80 °C and mixing with 1% (w/v) collagen under constant stirring. Methanolic extract of *Xanthium strumarium* leaves was added to the polymer blend and homogenized. The final solution was cast into Petri dishes and freeze-dried at –80 °C for 48 hours to obtain porous scaffolds. A blank scaffold (without extract) served as control. FTIR spectroscopy was used to identify chemical bonds and confirm functional group interactions between PVA, collagen, and plant extract. Scanning electron microscopy was used to examine surface morphology and pore architecture.EDAX was used to provide elemental composition and distribution on the scaffold surface.

RESULTS:

Physicochemical Characterization

FTIR spectra confirmed characteristic functional groups of PVA and collagen, with additional peaks observed in the extract-enriched scaffold indicating successful incorporation of *Xanthium strumarium* phytochemicals. XRD analysis demonstrated reduced crystallinity in the extract-loaded scaffold, suggesting increased amorphous regions favorable for biological interactions.

Surface Morphology and Elemental Analysis

SEM revealed a highly porous and interconnected scaffold architecture suitable for cellular infiltration and nutrient diffusion. EDAX confirmed the presence of carbon, oxygen, and nitrogen, along with trace bioactive elements in the extract-enriched scaffold.

Mechanical Properties, Cell Viability, and Anti-Inflammatory Activity

The extract-loaded scaffold exhibited improved tensile strength, increased porosity, enhanced cell viability, and significant reduction in TNF-α and IL-6 levels compared to the control scaffold (Table 1). Osteogenic activity observed on the scaffold surface is illustrated in Figure 1.

Figure 1: Osteogenic activity of cells cultured on *Xanthium strumarium*-enriched PVA/collagen scaffold.

Table 1: Mechanical properties, cell viability, and cytokine levels of control and extract-enriched scaffolds.

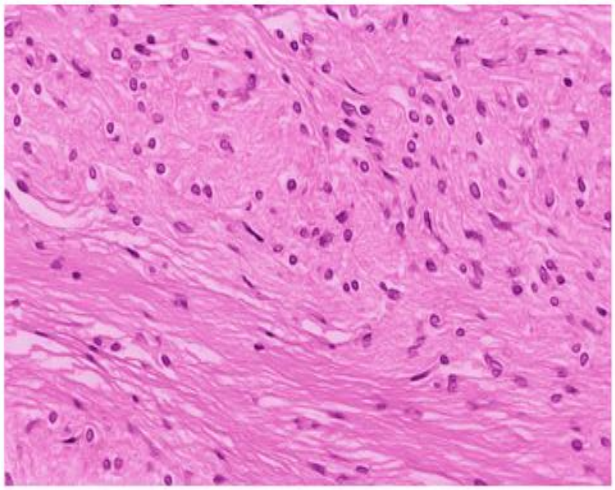

Figure 1: image showing osteogenic activity of cells

Parameter	PVA COLLAGEN Scaffold	X. strumarium Scaffold
Tensile Strength (MPa)	2.6 ± 0.3	3.8 ± 0.2
Porosity (%)	78.4 ± 2.1	82.3 ± 1.9
Cell Viability (%)	93.2 ± 2.1	96.8 ± 1.7
TNF-α (pg/mL)	138.5 ± 5.4	81.3 ± 3.7
IL-6(pg/mL)	170.2 ± 4.6	95.5 ± 3.4

Table 1: table showing mechanical properties ,cell viability and reduction in the levels of IL6

DISCUSSION:

The present study successfully demonstrated that incorporation of *Xanthium strumarium* leaf extract into a PVA/collagen scaffold significantly enhances its physicochemical and biological performance. FTIR findings confirmed molecular interactions between PVA, collagen, and phytochemicals, consistent with earlier reports on plant-based scaffold functionalization[17]. The reduction in crystallinity observed in XRD analysis suggests increased polymer chain mobility, which has been shown to favor cell adhesion and proliferation[18].

SEM analysis revealed an interconnected porous architecture within the optimal pore size range (50–150 µm), facilitating cell migration and vascularization[13]. Such structural characteristics are essential for tissue regeneration, particularly in bone and soft tissue engineering. Similar morphological improvements have been reported in herbal extract-loaded scaffolds developed at Saveetha Dental College, highlighting the translational relevance of phytochemical incorporation[14],[15].

Mechanical testing demonstrated improved tensile strength without compromising flexibility, making the scaffold suitable for non–load-bearing applications such as wound healing, periodontal regeneration, and oral mucosal repair. The increase in porosity further enhances biological performance by promoting nutrient diffusion and waste removal[19].

Biological evaluation revealed excellent cytocompatibility, with cell viability exceeding 95%, confirming the non-toxic nature of the scaffold. More importantly, the significant reduction in TNF-α and IL-6 levels indicates effective modulation of inflammatory pathways. This anti-inflammatory effect is likely attributable to flavonoids and phenolic compounds present in *Xanthium strumarium*, which are known to inhibit NF-κB signaling and cytokine production[10],[20].

Recent Saveetha-based studies have emphasized the importance of scaffolds that combine structural support with biological modulation, particularly for dental and maxillofacial applications[15],[16]. The findings of the present study align well with these observations and further support the concept of plant-based biofunctional scaffolds.

Overall, the integration of *Xanthium strumarium* extract transformed a passive polymeric scaffold into an active biomaterial capable of regulating inflammation and supporting tissue regeneration, thereby enhancing its translational potential.

CONCLUSION:

The *Xanthium strumarium*–enriched PVA/Collagen scaffold demonstrated excellent physicochemical and biological performance. FTIR and XRD confirmed the successful incorporation of phytochemicals and a semi-crystalline matrix structure. Enhanced thermal stability, porosity, and tensile strength indicate that the scaffold is structurally suitable for tissue engineering applications. The scaffold exhibited high biocompatibility with MG-63 osteoblast-like cells and significantly reduced pro-inflammatory cytokine levels (TNF-α and IL-6), suggesting

strong anti-inflammatory potential. Furthermore, osteogenic differentiation studies confirmed mineralization capacity, supporting its role in bone tissue regeneration. Overall, the developed bioscaffold offers a promising, plant-based alternative for biomedical applications, particularly in bone repair and wound healing

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