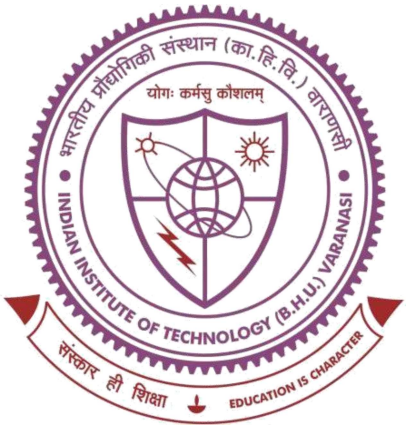
Biodegradable Polymeric Nano-composites for Microbial Growth Control and Wound Healing



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By

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Conclusion and future aspects

5.1 Conclusion

Current environmental regulations, societal concerns, and growing environmental awareness have led the search for eco-friendly products and processes that are compatible with the environment for sustainability. Non-renewable petroleum-based non-biodegradable packaging materials and other plastic wastes are continuously building up in landfills and leaching into the environment to disturb the ecological balance. Managing these wastes urgently is the need of time and switching to the bio-based biodegradable plastics is the possible solution to mitigate some of these issues. Bio-based biodegradable polymers contain polymer chains that are hydrolytically or enzymatically cleaved, resulting in soluble degradation products. Controlled biodegradability is desired in biomedical applications, in which degradation of the fabricated polymeric device ensures sustained drug delivery, bio-absorption and clearance from the body.

To design active antimicrobial films for packaging in the eco-friendly way, green synthesis method has been adopted for synthesizing AgNps to avoid harmful effects of physical and chemical processes on the environment. Active bio-molecules present in the extract of *Ocimum tenuiflorum* have been used to photocatalyze AgNPs biosynthesis. AgNPs displayed antimicrobial activity in the diffusion assay of solution cast active polymeric films.

A chitosan-based AgNPs incorporated fibrous composite nano-layers (FCNLs) for food packaging has been fabricated. FCNLs of PVA and CH (P70-CH30 NL) and AgNPs incorporated P70-CH30-Ag NL possesses good antimicrobial properties against

food degrading bacteria. Their antimicrobial property is due to the inherent characteristics of CH, and it gets synergistically enhanced by the addition of green synthesized AgNPs. These CH-based composite nano-layers can be used to develop novel food packaging materials which can be potentially as functional as the conventional plastics, whilst leaving a significantly lower environmental footprint. Incorporation of nanomaterials into CH-based composite nano-layers can prevent the growth of spoilage and pathogenic microorganisms, improve food quality and safety, and extend shelf-life of the perishable food products such as meat and dairy products. When tested for the packaging of meat, the fabricated P70-CH30-Ag NL displayed extended shelf-life and better organoleptic quality even after a week. It has the potential to meet the consumer's demands for healthy and safe food with minimal use of synthetic inputs.

A biomimetic and biocompatible natural anti-oxidant loaded PVP-Ce-Cur NF was developed for Full-thickness wound (FTW) dressing. It exhibited all the characteristic requirements of a good wound dressing. Its nano-fibrous scaffold prevented microbial infiltration, kept moisture and gaseous exchange at a check, provided high surface area microporous skeletal framework for rapid cell proliferation and granulation. The synergistic anti-oxidant activity of curcumin and cerium helped in the scavenging of ROS and reduced local oxidative stress *in vivo* for accelerated and anti-scar FTW healing. Nano-fibrous scaffold displayed biocompatibility in Wistar rats, and curcumin's inherent characteristic properties helped to induce anti-scar property. The dissolution and bio-absorption of the PVP-Ce-Cur fibrous scaffold with cell maturation protects the patient from the discomfort of wound tissue rupture during removal of the dressing. FTW healed completely within 20 days without any scar.

If somehow biofilm-related infections occur over the open wounds, it poses a tough challenge to healing drugs due to its tolerant nature, thus are extremely difficult to treat. A novel Eudragit RL100 encapsulated gentamicin sulfate (E-G-S) nanoparticle-mediated drug delivery system has been developed to prevent and eradicate the biofilm over the infected site efficiently. It also reduces the tolerant bacterial infection within the subject's body and biological payload of antibiotics. Lower doses of the drug are needed as the nanoparticles can easily penetrate the extra-polymeric substances layer to act directly on the target site without exceeding the systemic toxicity value of the drug and preventing possible side effects. In case of iatrogenic infections, material characteristics and surface properties are critical factors for microbial adhesion and proliferation. Irregularities on the polymeric surface promote biofilm formation because of the increased effective surface area for microbial attachment. The rough surfaces and depressions in the uneven surfaces provide shelter and site for microbial colonization and promotion. In this work stainless steel (SS 316L), polyurethane, silicone rubber, and latex rubber were used to examine the effect of biofilm support surface. *In vitro* studies confirm that both adherence of biofilm and decrease in hydrophilicity increase in the order: SS 316L < polyurethane < silicone < latex for Gram-negative *E. coli*, thus justifying the differential susceptibility of polymer surfaces for the microbial colonization. The formation of biofilm is not uniform among the EIDs. Factors such as hydrophobicity, the surface charge of microorganisms, and material from which catheter is made, size, shape, water contact angle, and morphological features of the surface also play a role in microbial adherence to the catheter surface. The E-G-S nanopowder has better protective property against the biofilm-related infections. The study also confirms that the hydrophobic surfaces in the moderate range are more prone to bacterial cell

attachment and biofilm formation, and the tendency to form biofilm over the biomaterial decreases with increase in hydrophilicity and decreasing hydrophobicity.

5.2 Future aspects

The work reported in this thesis shows the synthesis, characterization and *in vivo* evaluation of biocompatible blend of polymeric nanocomposites with anti-oxidants for anti-scar wound healing and antimicrobial property. Electrospinning method has been used for the development of biomimetic fibrous nano-layers. The blending effect of AgNPs, cerium and curcumin has been explored for its application in developing antimicrobial films, packaging nano-layers and wound dressings. The inherent antimicrobial properties sometimes fail to acts against tolerant bacterial biofilms which were eliminated by controlled delivery of G-S via novel Eudragit RL100 nanoparticle-mediated drug delivery systems.

However, certain aspects that could not be covered in this report may be the subject for future investigation and study could be planned for;

- Modification of fibrous composite nano-layers by addition of nanomaterials to improve strength.
- *In vivo* human trials of fibrous dressing before taking it to the market.
- Development of designer scaffolds according to the need of the patients.
- Incorporation of other medicinal herbs and natural bioactive agents with controlled release for accelerated wound healing.
- Design of 3D scaffolds for deep tertiary intention to temporarily compensate for the damaged barrier and to allow healing to initiate and progress smoothly.

- Fabrications of 3D models of body parts to provide customize shape and size of the wound dressing.
- Designing of scaffolds with inherent biofilm eradication ability.