PREFACE

Over the years, researchers have investigated studies on a wide array of inorganic materials for potential application in a number of disciplines, including water treatment, agriculture, medicine, cosmetics, and plenty of other applications. In the future, they may be harmful to the environment and pose significant environmental and health issues. In addition, they are both non-biodegradable and non-recyclable, which drives up the price of production. As a direct consequence of this, there is a high demand for the utilization of natural fibers compared to synthetic components. As a result, efforts to switch to natural fibers from synthetic ones are taking shape. Natural polymers are gaining attention due to their numerous traits, including sustainability, non-toxicity, cost-effectiveness, flexibility in fabrication, excellent biocompatibility, eco-friendly characteristics and biodegradability. Natural fibers have several benefits, including availability, affordable production, biodegradability, mechanical strength, etc. One such material that piqued the researcher's interest was luffa cylindrica also known as luffa or loofah.

Luffa cylindrica (LC), is a species of vine with tendrils, widely recognized as sponge gourd and has a short harvesting period. It is extremely lightweight with fibrous architecture predominantly cultivated in tropical regions. The primary chemical combination of LC is comprised of 60% cellulose, 30% hemicellulose and 10% lignin. Components of luffa plants and fruits exhibit the significant potential to be utilized in medicine, cosmetics and several other relevant applications. The LC possesses high mechanical strength, cost-effectiveness, eco-friendly, abundantly available, hydrophilic and oleophilic characteristics. LC comprises phenolics, flavonoids, oleanolic acid, ascorbic acid, α-tocopherol, carotenoids, chlorophylls, triterpenoids, and ribosome-inactivating proteins components enabling them to be utilized for several therapeutic applications. Surface modification facilitates LC to be utilized as a reinforced composite material in various fields of tissue engineering and biomedical applications. Nutritional studies of LC revealed their several therapeutic applications in biomedical engineering. The porous architecture, biocompatible, and antibacterial and antioxidant nature of LC revealed their wide applications in medicine, cosmetology, and tissue engineering applications.

The first part of the thesis presents the development of biocompatible porous luffa-based composite scaffolds through freeze-drying technique. Fabricated scaffolds were crosslinked with glutaraldehyde (GTA). The fabricated were characterized through Fourier transform infrared (FTIR) spectroscopy, differential scanning calorimetry (DSC), and Scanning electron microscopy (SEM). The average pore size of the scaffolds was observed in a range of 20–240 mm. The scaffolds were found significantly stable for a prolonged duration in lysozyme-containing solution at room temperature. The hydrophilic behavior of the samples was quantified by water contact angle measurements. As per the obtained data, the apparent and effective porosities were estimated as 57.08 ± 4.38%, 50.58 ± 4.09%, 59.45 ± 1.60% and 51.37 ± 3.36%, 47.94 ± 4.57%, and 53.09 ± 5.45 % for 3% LC, 5% LC and control (C) scaffolds, respectively. The liquid retention capacity of the scaffolds revealed that the luffa-based scaffolds gained lower retention capacity compared to the control (C) scaffold; indicating an increase in scaffold stiffness due to the addition of luffa. A compressive strength study demonstrated that the mechanical stability of the fabricated luffa-based scaffolds increased significantly from 1.5 to 9.5 MPa, which is comparable to that of trabecular bone. The MTT assay demonstrated that the scaffolds exhibited negligible adverse effects on the cells, while the metabolic activity of the cells on the scaffolds was enhanced throughout the culture period, indicating the proliferation of the cells in all types of scaffolds. The obtained results demonstrate that the fabricated novel luffa-based scaffolds exhibit good cytocompatibility, remarkable porosity and excellent mechanical strength comparable to native human bone. Therefore, we anticipate that the developed luffa-based scaffolds could be a promising candidate for bone tissue engineering applications.

The second part of the thesis presents the biocompatibility of the fabricated luffa-based scaffolds (which were prepared in first part of thesis) when implanted in a subcutaneous region and evaluates the impact of these implanted scaffolds on the heart, liver and kidneys of Wistar rats. Subcutaneous implantation serves as a safe and minimally invasive approach to thoroughly evaluate the scaffold's compatibility with surrounding tissues. Male Wistar rats were divided into four distinct groups, each group consisting of three rats. Group A, B, C and D are referred to 3% LC implanted scaffolds, 5% LC implanted scaffolds, control (without luffa scaffolds), and Sham (without any scaffold implantation), respectively. The histological analysis was investigated in all the groups, indicating that the animal models did not exhibit any signs of inflammation or toxicity, suggesting favorable tissue response to the implanted scaffolds. Initial observations revealed elevated levels of enzymes and biomarkers, such as aspartate aminotransferase (AST), alanine aminotransferase (ALT), alkaline phosphatase (ALP), bilirubin, creatine kinase-MB (CK-MB), and serum creatinine within the experimental groups after a 24-day interval. However, it was observed that these parameters became normalized after a period of 3 weeks following implantation, and there was no further significant increase in these parameters compared to the control groups. The obtained results reveal that the fabricated scaffolds have excellent in vivo biocompatibility, implanted luffa-based scaffolds did not induce any adverse effects on the heart, liver, and kidney, absence of inflammatory responses, and overall tissue compatibility highlight the immense potential of these luffa-based scaffolds in various tissue engineering and regenerative medicine applications.

In addition, we have proposed composite forms of LC and polydimethylsiloxane (PDMS) to address the remove the oil and organic components that might be hazardous to aquatic organisms. The elimination of oil spillage from seawater has been a major contributor to environmental deterioration. As a result, a significant amount of effort has been spent on investigating and developing the sorbent materials capable of separating oil from water. Thus, the sorbent materials that could be effective, particularly in oil spill disposal and resolve such environmental issue remain to be explored. The fabricated scaffolds using hand lay-up method with various forms of luffa cylindrica i.e., LC mat, flakes and powder were analyzed various characterizations such as scanning electron microscopy (SEM), atomic force microscopy (AFM), thermogravimetric analysis (TGA), effective porosity, surface wettability, mechanical stability, cytotoxicity and sorption behavior with respect to oil, phosphate buffer saline (PBS) and few organic solvents were performed. The results showed that the scaffold in combination with P-L flakes was highly effective in eradicating oil spills and removing harmful components of crude oil. Scaffolds composed of P-L mat, P-L flakes, P-L powder, and PDMS (P) exhibited oil absorption efficacy around 16.09 ± 4.62%, 24.49 ± 3.55%, 15.52 ± 2.67% and 5.52 ± 1.44%, respectively. The fabricated scaffolds have shown tremendous potential to provide a solution to this significant environmental remediation issue and to serve as a cost-effective method for removing oil spills and hazardous crude oil components.

The primary aim of this thesis is to explore the potential applications of Luffa cylindrica (LC) and investigate the physico-chemical and mechanical characteristics of scaffolds fabricated using advanced technologies for biomedical and environmental applications. LC exhibits remarkable attributes, including high mechanical strength, cost-effectiveness, eco-friendly, abundant availability, hydrophilicity and good oleophilic properties; rendering it suitable for diverse fields including packaging, automobiles and water treatment. The current thesis work demonstrates the development and fabrication of various three-dimensional structures by utilizing freeze-drying technique followed by in vitro characterization of all the fabricated scaffolds. Morphological examination of the freeze-dried scaffolds using SEM micrographs

revealed pore size was ranging between 20-240 μm, ideal for bone tissue engineering applications. Incorporating LC into the composite scaffold significantly enhances its mechanical stability, water retention, degradation, tissue adherence and cell proliferation. ATR-FTIR analysis showed the presence of native functional groups and bonds within the scaffolds. The thesis also focuses on various forms of luffa-based scaffolds impregnated with PDMS for oil-water separation. Various forms of luffa-PDMS composite scaffolds were successfully fabricated using a hand lay-up approach. This study demonstrates the comparison of various luffa-based scaffolds for oil-water separation. Numerous characterizations including surface roughness, porosity, surface wettability, oil and PBS absorption, degradation, thermal stability, oil spillage and mechanical properties were performed. Results indicate that PDMS-Luffa flakes exhibit significantly higher capacity for absorbing oil, PBS and a few organic solvents this is probably because of the high microcapillary properties of luffa flakes. Additionally, the hydrophobic characteristics of PDMS enable buoyant forces to overcome the weight of the luffa-PDMS composite membrane and prevent it from sinking. The outcomes suggest that luffa-PDMS-based scaffolds might be a desired material for environmental remediation applications.

Keywords:

Luffa cylindrica, Gelatin, Psyllium husk, Hydroxyapatite, polydimethylsiloxane, freeze-drying, Hand-layup, tissue engineering, Scaffolds, Oil- water separation.