Chapter 3

The objectives of the Work

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As mentioned earlier in Chapter 1, the demand for orthopedic implants is on the rise as a result of diseases such as osteoporosis and osteoarthritis, which cause bone weakening and joint inflammation, respectively. Consequently, there is a corresponding increase in research into the development of reliable bone implants. Our research in the introduction and literature review showed that the elastic modulus of a ceramic implant might be decreased by inserting pores into its bulk. This would solve a major issue with traditional metallic implants: the stress shielding effect. Also covered are the many methods that have been used to create porous implants.

When taking into consideration the benefits of generating porous ceramic implant material, the primary objective of the study work that is being presented is to produce a ceramic-based composite that is low in cost. This will be accomplished through the efficient utilization of Rice Husk Ash (RHA) and Animal Waste Bone (AWB) wastes for a variety of applications. Initially, RH was utilized as a source of silica, which has been proven to be a dependable method for improving the material characterization and ceramic matrix. In addition to this, RH also functions as a source of silica (SiO2), which contributes to the enhancement of the strength and improved hydrothermal ageing resistance of the ceramic-based biocompatible material. The findings presented here provide a contribution to the continuing investigation of advanced biomaterials and offer prospective pathways for the creation of improved biocompatible materials that have enhanced performance in biological applications. The biocompatibility, osteoinduction, and osteointegration capabilities of the ATZ composites are all enhanced as a result of these. Overall, the utilization of AWB not only increases bioactivity but also reduces the costs associated with zirconia-based biomaterials, so strengthening the principles of biocircularity and bioeconomy through a method that is considered to be really sustainable.

The main objectives of the present work are as follows:

3.1. Identification and selection of potential waste materials

As previously discussed, the primary objective of this research is to develop a cost-effective implant material suitable for biomedical applications. To achieve this, the study focuses on utilizing waste materials that are both economical and environmentally friendly. Specifically, two types of biowaste have been selected as raw materials: **rice husk (RH)**, an agricultural byproduct, and **animal bone waste (ABW)**, a byproduct from the meat industry. These materials were chosen due to their natural abundance, low cost, and potential to provide the essential bioactive components required for implant materials.

3.2. Development and synthesis of different ceramic-based composites

The experimental work in this research is divided into three distinct phases, each designed to explore the potential of waste-derived materials in developing advanced biomedical implant composites.

> **Experiment 1:** Silica-Based Compacts from **Rice Husk-**The first experiment evaluates the physico-mechanical properties of silica compacts synthesized using **amorphous and crystalline silica derived from rice husk ash (RHA).** Rice husk, an abundant agricultural waste, is rich in silica (SiO_2) and is a cost-effective and sustainable raw material. The resulting silica compacts are analyzed to understand their mechanical performance, density, and structural integrity.
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> **Experiment 2: Biocomposite with Silica-Doped Alumina Toughened Zirconia (ATZ)** The second experiment investigates the **microstructural characteristics and biocompatibility** of **Alumina Toughened Zirconia (ATZ)** biocomposites doped with RHA-derived amorphous and crystalline silica. The addition of silica into the ATZ matrix aims to enhance the composite's toughness, thermal stability,

and biological performance. Comprehensive characterization is carried out to evaluate the potential of these composites for implant applications.

Experiment 3: Triphasic Calcium Phosphate-Reinforced ATZ Biocomposite

The third experiment strengthens **bio-circularity** by incorporating **Triphasic Calcium Phosphate (TCP)** derived from **animal bone waste (ABW)** into the ATZ matrix. ABW is a natural source of **hydroxyapatite (HAp)**, which is known for its excellent bioactivity and compatibility with human bone. In this study, RHA also serves as a space holder and secondary source of silica to create porosity and improve the biological interaction of the composite.

In this experiment, different weight percentages of RHA are mixed with the ATZ matrix to form two green (unsintered) composites: **ATZ-SiO_2** and **ATZ-HAp**. These samples are then sintered at various temperatures to produce dense, bioactive composites with embedded silica and hydroxyapatite. The sintering process aids in achieving optimal mechanical strength and enhances the overall bioactivity of the final implant material.

3.3 Advanced physical and structural characterization

- To measure the apparent porosity of sintered samples to determine their densification behavior.
- Characterize different elemental compositions present in the samples.
- To identify the phase formed in the samples, they were characterized by using an X-ray diffractometer (XRD).
- To determine the microstructural and surface morphology of the porous samples with the help of Scanning Electron Microscopy (SEM) and Transmission Electron Microscopy (TEM).

3.4. Mechanical characterizations

- To study the failure behavior of developed composite Samples under UTM machine compression and Bending Strength.
- To determine the apparent porosity, Bulk modulus, and linear shrinkage through Archimedes' principle of the developed porous sample and to compare its value with that of rigid samples.
- To determine the Hardness of Various temperature-sintered samples

3.5. Biological characterization

To study the ability of the developed Sample to form an apatite layer on its surface, a bioactivity test and pH value variation with time were performed by immersing the samples in simulated body fluid (SBF) for different periods.