Utilization of Waste Phosphogypsum in Bioceramic Material Development

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Introduction

Calcium hydroxyapatite

Calcium hydroxyapatite ($Ca_{10}(PO_4)_6(OH)_2$; CHA) is used to reconstruct bone defects due to its high osteoconductivity and natural bone replacement ability.

- **Bioactive**
- **Osteoconductive**

+ Porous structure

Improved bone regeneration

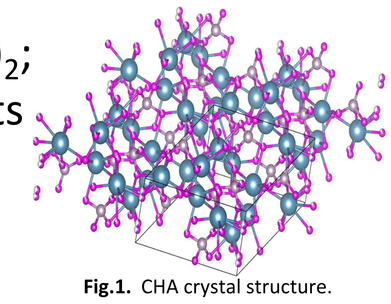


Fig.1. CHA crystal structure.

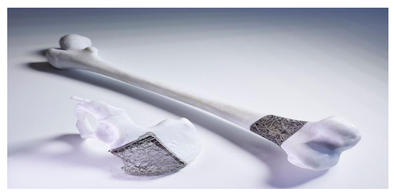


Fig. 2. 3D-Printed Bone Implant.

- **CHA closely resembles the inorganic component of natural bone tissue**

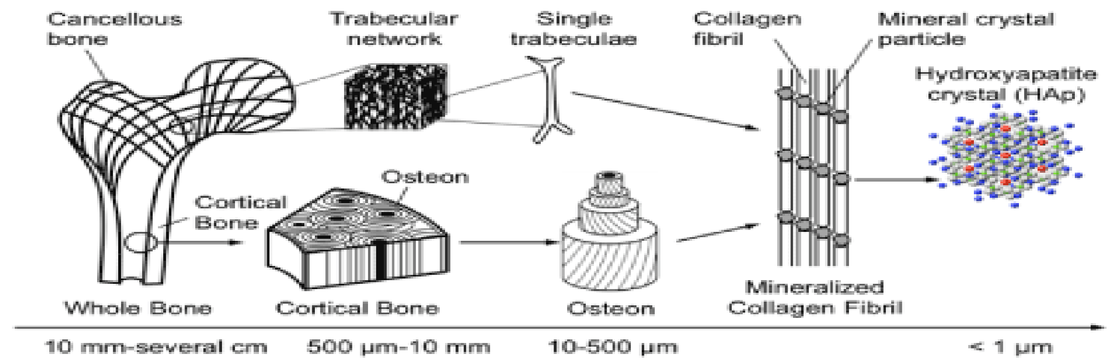


Fig. 3. Anatomy of a bone structure.

Phosphogypsum

Phosphogypsum (PG) is an industrial byproduct of phosphoric acid production, primarily composed of calcium sulfate dihydrate. While often considered waste, its high Ca^{2+} content makes it a promising raw material for synthesizing bioceramics like CHA, offering a cost-effective and sustainable alternative for bone graft materials.

Fig. 4. PG mountains in Kėdainiai.

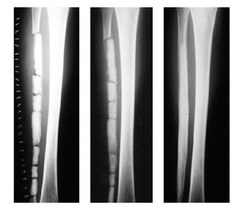


Fig. 5. Utilization of bone graft material in implantology.

Objective and strategy

A strategy to obtain the desired bone implants ➡ **Dissolution – precipitation synthesis**

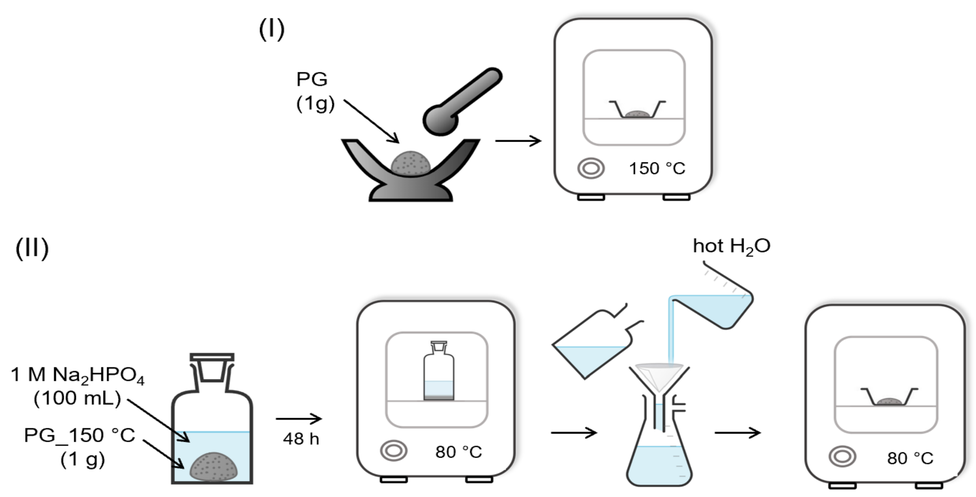
Our study aims to explore the potential of PG waste as a sustainable raw material for synthesizing high-quality, cost-effective CHA for artificial bone implants.

Materials and Methods

① Experimental

PG, disodium hydrogen phosphate (Na_2HPO_4, 98%, Merck), and sodium dihydrogen phosphate (NaH_2PO_4, 99%, Merck) were used as starting materials for the fabrication of CHA powders *via* a dissolution-precipitation reaction. In the synthesis process, an initial 1.00 g portion of waste PG was placed in the reaction vessel and mixed with a 100.0 mL solution of 1.00 M Na_2HPO_4 or with a mixture containing 50.0 mL of 1.00 M Na_2HPO_4 and 50.0 mL of 1.00 M NaH_2PO_4. The resultant mixture was left for 48 h, 96 h, 144 h and 192 h allowing the reaction to progress in an oven at ~80 °C temperature. After synthesis, the liquid phase was decanted, and the resulting powders was rinsed with 500 mL of hot (~80 °C) deionized water, followed by several additional rinses with 250 mL of room-temperature deionized water. Finally, the vacuum-filtered product was dried at 80 °C for 2 h.

② The scheme of the synthesis



Results

SEM

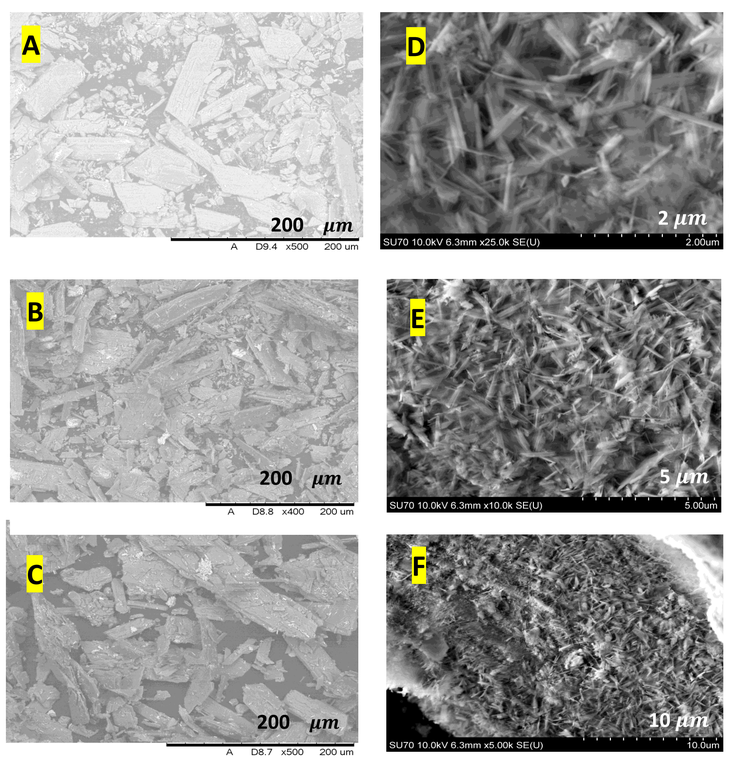


Fig. 6. SEM images: a) PG; (b) PG heated at 100 °C; (c) PG heated at 1000 °C; (d, e, f) CHA powder.

XRD

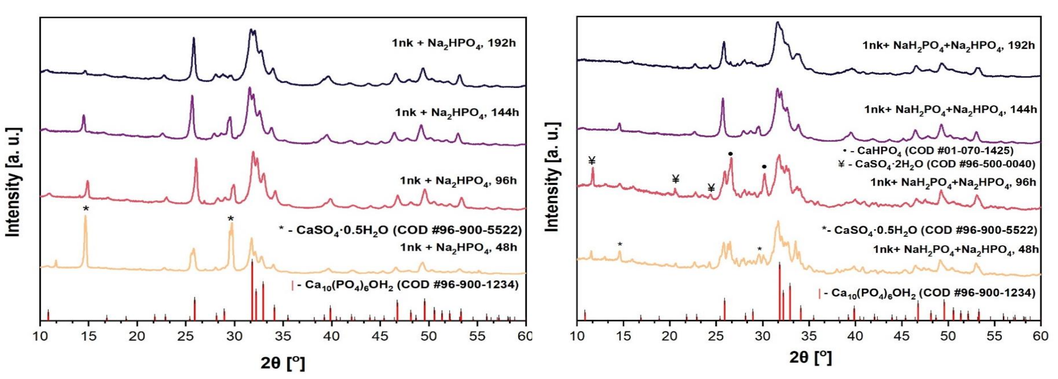


Fig. 7. XRD patterns of CHA derived from PG samples 1) using Na_2HPO_4 in the dissolution-precipitation reaction; 2) mixture of NaH_2PO_4 and Na_2HPO_4 in the dissolution-precipitation reaction

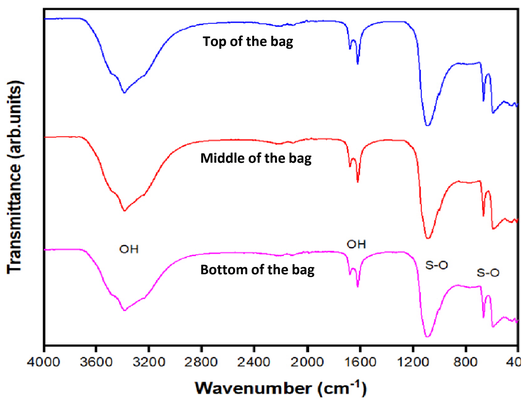


Fig. 8. FTIR spectrum for PG samples taken from three different parts of the collected waste bag.

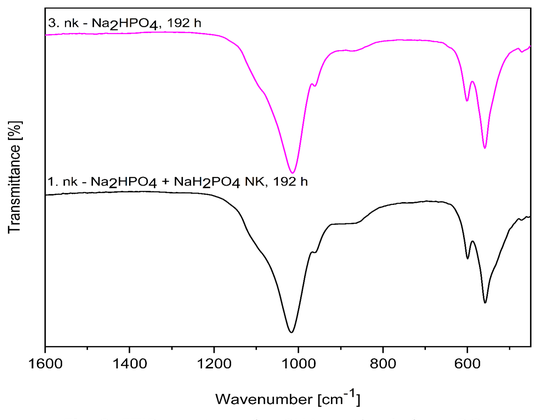


Fig. 9. FTIR spectrum for CHA synthesis from PG.

Conclusion

PG has emerged as a valuable raw material for synthesizing bioceramic materials, particularly CHA, which is extensively used in biomedical applications. Experimental findings demonstrate that PG can be efficiently processed via a dissolution-precipitation reaction, resulting in the formation of CHA. This process allows PG to be converted into a biocompatible material suitable for various medical uses, offering both an environmentally sustainable solution and a cost-effective approach for producing high-quality CHA.

References

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