

From Bones to Buildings: Co-Precipitation of Hydroxyapatite and Calcite Biominerals – Towards Bioengineered Acid Resistant Materials

PELINA TOPRAK¹, ANANT AISHWARYA DUBEY¹,
 ABHIJIT MUKHERJEE¹, CARLOS RODRÍGUEZ-
 NAVARRO², ALLAN PRING³ AND NAVDEEP K DHAMI¹

¹Curtin University

²University of Granada

³University of Adelaide

Hydroxyapatite [$\text{Ca}_{10}(\text{PO}_4)_6(\text{OH})_2$] is one of the most stable calcium phosphate mineral due to its thermodynamic stability in the crystalline state, low solubility over a wide pH range (above 4.4). These minerals are found abundantly in nature, including our bones and teeth, and coexist with different calcium minerals as calcium carbonate¹. Microbially induced precipitation of these minerals offers several advantages, including milder reaction conditions, operational simplicity, lower cost and self-healing². Microbially induced hydroxyapatite closely resembles biogenic hydroxyapatite found in natural bone and tooth enamel in terms of crystallite size and semi-crystalline structure³.

Research on biologically produced minerals for applications in construction industry has primarily focused on Microbially Induced Calcium Carbonate Precipitation (MICP)⁴. However, conventional MICP often exhibits limitations, particularly in acidic environments⁴. Considering these challenges, this study explores the enhancement of MICP through Microbially Induced Phosphate Precipitation (MIPP) by co-precipitating hydroxyapatite alongside calcium carbonate (CaCO_3). Three bacterial strains capable of inducing hydroxyapatite formation were identified and evaluated for their ability to co-precipitate carbonate and phosphate minerals under controlled conditions. Key environmental parameters, including calcium-to-phosphate ratio, pH, and bacterial metabolic activity were systematically optimised to maximise biomineral precipitation efficiency. Confocal laser scanning microscopy (CLSM) was employed to visualise bacterial precipitation dynamics over time, revealing the spatial distribution and progressive growth of mineral phases. Morphological and mineralogical characterisation was conducted using X-ray diffraction (XRD) and scanning electron microscopy (SEM); which confirmed the successful co-precipitation of hydroxyapatite and calcite. Acid resistance and mechanical performance of the precipitated biominerals was conducted using nanoindentation and acid resistance tests; which demonstrated that phosphate incorporation significantly improved the biocement stability, crystalline behaviour and structural integrity. These findings highlight the potential of integrating MICP and MIPP as a novel bioengineering strategy for living materials with improved acid tolerance.

References:

1- Naidu S. et al.. (2016) Journal of the American Ceramic Society. 2016;99(10):3421-3428. doi:10.1111/jace.14355

2- Sassoni E. (2018) Materials (Basel, Switzerland). 2018;11(4) doi:10.3390/ma11040557

3- Dorcioman G. et al. (2023) Pharmaceutics. doi: 10.3390/pharmaceutics15041294.

4- Dhami N.K. et al (2013). Front Microbiol. doi: 10.3389/fmicb.2013.00314.

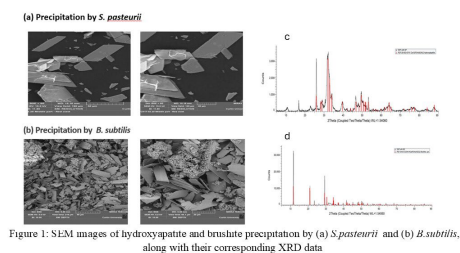


Figure 1: SEM images of hydroxyapatite and brushite precipitation by (a) *S.pasteurii* and (b) *B.subtilis*, along with their corresponding XRD data