
SBPMat
B-MRS
SOCIEDADE BRASILEIRA
DE PESQUISA EM MATERIAIS
SALVADOR
XXIII B-MRS Meeting 2025
September 28th to October 2nd
BRICS
Brasil 2025

Innovative 3D-printed bone scaffolds from ozone-modified cassava starch reinforced with hydroxyapatite nanoparticles

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Bone scaffolds serve as models for reconstructing defects, supporting cell adhesion, proliferation, and extracellular matrix formation. They can be produced via 3D printing, which enables material personalization and a wide range of composition options. However, native starch presents challenges such as high swelling, hydrophilicity, low mechanical strength, and poor long-term stability [1]. To overcome these limitations, starch modification techniques have been explored. Among them, ozonation stands out as a green technology, converting residual ozone into oxygen after the reaction [2]. In this study, bone scaffolds were produced using cassava starch modified by ozone and reinforced with hydroxyapatite (HA), known for its osteogenic properties. The aim was to enhance the processability and functionality of starch hydrogels enriched with HA for use in bone tissue engineering. Cassava starch was oxidized with ozone (10 wt%; 1 L/min, 41 mg O_3/L, 25 °C, 30 min), and HA was synthesized following a method adapted from Nassif et al. [3]. Formulations were prepared with native (N) and ozonated (O) starch, without and with HA at concentrations of 1.0, 1.5, and 2.0 g/100 g starch. These were named N_10HA, N_15HA, N_20HA, O_10HA, O_15HA, and O_20HA, and printed using a BioedPrinterV4 (BioEdTech, Brazil). The inks were analyzed for printability and firmness, and the printed scaffolds were evaluated for biodegradability (1, 7, 14, and 21 days), mechanical strength, swelling, and morphology (SEM). Among the samples, N_15HA stood out with the best printability, firmness, and lower biodegradability. As a result, subsequent investigations focused on this formulation. Scaffolds made from ozonated starch exhibited greater porosity than those from native starch, which is favorable for bone tissue formation. These findings indicate that ozonation combined with HA incorporation is a promising strategy for improving cassava starch scaffolds in bone tissue engineering.

Acknowledgements
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