Transforming Waste into Biomaterials: Ion-Engineered Calcium Phosphate for Dental and Toothpaste Applications

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The increase in human life expectancy has created new challenges for modern medicine, particularly in the field of regenerative medicine. According to the World Health Organization (WHO), dental and oral diseases are among the most significant public health problems worldwide, affecting approximately 3.5 billion people globally. It is estimated that complete tooth loss affects about 7% of adults worldwide and approximately 23% of people over the age of 60. In this context, the development of advanced biomaterials capable of supporting dental tissue regeneration and improving oral health is of great importance [1].
Calcium phosphate based materials play a key role in these applications due to their excellent bioactivity, biocompatibility, and chemical similarity to the inorganic components of human hard tissues, such as tooth enamel and bone. As a result, they are widely investigated for implant surface modifications, bone and dental tissue regeneration, as well as functional additives in toothpaste formulations aimed at enhancing enamel remineralization. At the same time increasing attention is being paid to sustainable approaches to biomaterials synthesis, particularly those that utilize industrial waste liquid as raw materials [2], [3].
The aim of this study was to synthesize calcium phosphate materials via the wet precipitation method using a model wastewater from ammonia recovery in the industrial Solvay process, containing: 1.1 M $CaCl_2$ and 0.95 M NaCl, as a sustainable source of calcium.
As a result of the synthesis brushite powder with an irregular lamellar morphology was obtained. Furthermore, selected ions with well-documented benefits for dental applications were incorporated via ion substitution. During the synthesis process, part of the calcium ions was replaced with 1% and 2.5% molar percentage of silver and zinc ions, as well as 0.1 molar % of fluoride ions.
The incorporation of these ions into calcium phosphate materials enhance their antibacterial properties, potentially reducing bacterial colonization in the oral cavity. These features make the materials particularly promising for dental applications, including implant coatings and remineralizing toothpaste formulations. Overall, this study demonstrates that calcium phosphate materials derived from industrial waste can serve as sustainable and functional biomaterials, combining waste valorization with potential benefits for oral health.

Keywords:
calcium phosphate; ion substitution, biomaterials, antibacterial activity, dentistry

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