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# Chemical and Biological Synthesis of Hydroxy Apatite: Advantage and Application

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## Abstract

Production of nanostructured materials, similar to the complex structure of nano-calcite of hard tissues, egg shell, teeth and bone, are an attractive field of research. Calcium phosphates with clinical applications, such as hydroxyapatite (HA) ($Ca_{10}(PO4)_6(OH)_2$) have been widely used in regeneration of bone and fabrication of medical implants, mainly due to the chemical composition and structure similarity between HA and the mineral part of bones and teeth, and also as gene and drug delivery is used. High surface area of HA make it useful for drug release. Moreover, it has antibacterial property and potential applications in rapid microbial detection, treatment of heavy metals from aqueous solutions. Biological synthesis has been attracted more attention for compatibility to human safety.

**Keywords:** Nanostructured materials; Hydroxyapatite; Thermal behavior; Fuzzy transformation.

## Introduction

Apatite refers to compounds that have the same structure, but do not necessarily have the same composition, so apatite is not a compound, but an attribute for a family of compounds. Theoretically, it is possible to combine several ions to form an apatite, but in practice only structures that are thermodynamically stable can be formed. In particular, hydroxyapatite with the chemical formula $Ca_{10}(PO_4)_6(OH)_2$ and the hexagonal crystalline structure is a combination of calcium phosphate, which forms the main body of the bone tooth tissue, shell and eggs. The hydroxyapatite particles contained in the bone and teeth have, respectively, plate and pinion morphologies with nano dimensions. Hydroxyapatite is in pure white state, although in normal state it can also be brownish-yellow or green [1].

## Mechanical and Properties of Apatite

The properties of hydroxyapatite determine the value and range of applications of this material, including crystallinity, thermal behavior, mechanical properties, density, water solubility and biocompatibility properties [2-5].

X-ray diffraction studies of bone marrow specimens show that hydroxyapatite enamel crystals are larger than dentin and bone. Obviously, the density increases with increasing degree of crystallinity, so the density of hydroxyapatite is more than bone and ivory. Unlike natural hydroxyapatite with a density of about 3.08g/cm$^3$, the density of synthetic hydroxyapatite (synthetic) changes in the range of 3.6-3 g/cm$^3$ [2]. According to the findings of the synthesis of hydroxyapatite studies morphologically, the size of the crystal and composition is different from that of hydroxyapatite. Hydroxyapatite is expressed in terms of the degree of impurity and the rate and amount of temperature received during the synthesis of different behaviors. These behaviors are divided into 3

categories of fuzzy transformation, thermal expansion, and morphology. For example, if the mineral hydroxyapatite is heated at a uniform rate, its crystalline structure undergoes thermal expansion, indicating that with increasing temperature the size of the crystal lattice constants changes to the extent that crystal lattice [3].

The mechanical properties of hydroxyapatite, among the abrasive properties that determine the hardness of hydroxyapatite, show that hydroxyapatite has a low stability in moisture environments and cannot be used in high stress applications because they are strongly sensitive to cracking. Therefore, medical applications are limited to covering bio-materials and use in bone cements. A mineral-coated implantation with bioactive properties gradually connects to the body tissue and as a result, the apatite crystals that form it penetrate into the porosity, which ultimately increases the strength of the implanted component [4].

Among the properties of hydroxyapatite as a biomaterial, the most important feature can be biocompatibility. The biocompatibility of hydroxyapatite enables the ability to bond with the body's cells precisely. In addition, hydroxyapatite induces bone growth and ultimately leads to bone growth. When hydroxyapatite is in the form of pure ceramics or as a coating on metallic implants in the human body, it can facilitate the recovery and regeneration of lost or damaged tissue for the body [5].

## Chemical Synthesis

Chemical production of HA creates processing defects predominantly introduced through hard-particle agglomeration, which lead to weakness in the final implant.

Over the past few years, various methods for the synthesis of hydroxyapatite particles have been reported. These methods generally are co-percipitation and solgel, some chemical methods can be used for sedimentary and sol-gel methods. Also, Nano-hydroxyapatite/chitosan composite is synthesized by solvent casting and evaporation methods for the function of bone manufacture. The results have shown that the surface roughness and micropores of the composite membranes increase with HA content, suitable for adhesion, crawl and growth of cells. The hydroxyapatite holds nano size and distributes uniformly in the composite membranes [6].

In the sediment method, one or more soluble salts react with each other to settle to form an insoluble salt in water. The product solubility of the sediment composition is the most important parameter for the reaction. In this method, the first product is formed immediately after completing of the reaction. When the concentration of the product passes through the reaction of the combined product solubility, the particles begins to form [6].

One of the most commonly used methods is the sol-gel method. This method involves the synthesis of an inorganic mineral network using a mixture of alkaloids and water in the presence of solvents and catalysts, and then processes the hydrolysis, gelling and removal of organic and aqueous phase residues using low temperatures. Factors such as the effect of PH, the effect of solvent and water effect can affect the properties of hydroxyapatite produced by this method [7].

## Biological Synthesis

Based on the properties mentioned, the applications of hydroxyapatite can be used in tissue engineering, dentistry, drug delivery, chromatography column, catalyst, water purification, industrial effluent and application in sensors. The synthesis of nanoscale hydroxyapatite by many bacteria included *Serratia marcescens, Enterobacteria.*, *Staphylococcus, Alkanindiges illinoisensis* and many other alkaline phosphatase producer microbe has been reported [8,9]. Enzymatic synthesis by phosphatase and urease also are reported that calcium phosphate precipitates are formed at 37°C and pH of 7.4 in urea- and enzyme urease- were found to be amorphous, following overnight drying at 90°C. Crystallization of these precursors started at above 300°C, and after calcination at 1100°C for 6 h, they completely transformed into single-phase of HA.

Plate-shaped hydroxyapatite (HAp) particles with preferred orientation to the c-plane have been synthesized by a homogeneous precipitation method via an enzyme reaction of urea with urease. The starting solutions with a Ca/P ratio of 1.67 were prepared by mixing calcium carbonate, phosphoric acid, and urea [10,11].

Nanoparticles of hydroxyapatite were successfully synthesized by microbial method at proper pressure and temperature, with calcium chloride and organic acid as reactants.

The effect of alkaline on hydroxyapatite production from Geloina coaxans shell has been done by precipitation method. Geloina coaxans shells and $H_3PO_4$ were used to produce HAp. The result showed that nano-HAp can be obtained; however the pH value is important parameter on synthesis of HAp and can influence crystalinity and purity of Hap Selected bacteria. According to studies, Sata and colleagues should have enzyme phosphatase, which is more common in Enterobacteriaceae family. For example, the Gram negative Enterobacter (*Serratia marcescens*, strain PTCC 1187) is used for biogeneration of hydroxyapatite. This bacterium is cultured at a temperature of 30°C and culture medium included phosphate [9].

## Discussion

Compared to other chemical methods, the sol-gel method is more suitable because in the usual chemical methods, higher temperatures are applied to crack the prepared crystals. This is despite the fact that the temperature required for the hydroxylapatite condensation operation in the sol-gel method is much lower. Another advantage of cell-gel compared to other chemical methods is the ability of this method to synthesize one-stage high-level, high-purity hydroxyapatite nanoparticles. In addition, the above method can be used to apply low thickness hydroxyapatite coating on a variety of biomaterials [6].

Another major advantage of this method is the resemblance of hydroxyapatite powder formed with hydroxyapatite in the bone and tooth, but this advantage cannot compete with the hydroxyl apatite synthesis bioassay. In the case of bio-hydroxyapatite synthesized by bacteria in the range of about 25-30 nm, these differences are a motif of morphology that draws the attention of scientists to the synthesis of bifidyroxyapatite. It has also been observed that the distribution of particle size and shape in the biological method is relatively uniform. This can result in smoother sputtering and the production of a piece with more favorable properties than parts made from micronutrients when making a piece of hydroxyapatite powder [7,8].

The disadvantages of the sol-gel method include the possibility of hydrophobic phosphate, the need for accurate pH adjustment, and the high cost of primary materials plus the accumulation of powder thus synthesized, often increasing during the synthesis process. Another disadvantage of this method is that it is usually not possible to achieve a high degree of crystallinity, so the hydroxylapatite synthesized by the chemical-tubular-gel method is not uniform in size and shape. This is where the bacteria synthesized in hydroxyapatite are not observed. In a given grain, visible crystalline plates are all parallel to each other. The parallelism of the plates in a powder particle can result in the conclusion that each particle of powder from a grain crystalline formed. Meanwhile, the size of the powder particles observed is approximately the size of the grain obtained from the Williamson method, which is due to the fact that the particles of powder have been produced in a single crystalline form, which results in relatively high uniformity to chemical methods. Moreover, the amount of hydroxyapatite biosynthesis was lower than the synthesized hydroxyapatites by conventional chemical methods [12-14]. NHA was prepared using sol-gel technique and added to the toothpaste with 7% concentration and the toothpaste containing NHA was more effective than the toothpaste without NHA for the purpose of remineralization [15].

In conclusion nature and concentration of the phosphate precursor, solution pH, treatment duration, ionic and organic additions to the phosphate solution, mineralogical composition of Sandstones, sulphated stones, gypsum s, concrete, wall paintings, archaeological bones, paper, marble and limestone, manufacture different HA. This might be useful for cell culture and tooth paste or be toxic for human safety [16].

In total, the uniform size and shape, and their low melting, are factors that contribute to the mechanical properties of the final piece made of hydroxyapatite. Also, the hydroxyapatite powder produced with organic bases and, along with that particle size, increased the biocompatibility and bioactivity of hydroxyapatite, biological syntheses with enzymes or cells are another way for having nontoxic particles.

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