

Microwave-assisted synthesis of bioabsorbable nanoparticles to be used as reinforcement of PLGA in biomedical applications

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ABSTRACT

Biocomposite materials can be designed to obtain a wide range of mechanical and biological properties. The present work seeks to show the effect of bioabsorbable nanoparticles such as hydroxyapatite and amorphous magnesium phosphates on the mechanical properties of a bioabsorbable polymer in order to develop a biocomposite material 100% bioabsorbable but with mechanical properties superior to those available in the market, which can be used in the manufacture of different biomedical devices. For this work, hydrothermal synthesis assisted by microwave was used to obtain different bioabsorbable nanoparticles which were incorporated into the polymer Poly (L-lactide-co-glycolide) 85:15 (RESOMER LG 857 S, Evonik). The mechanical properties of the biocomposite material were studied using the technique of indentation by AFM and the calculation of the microhardness finding a significant increase of these properties.

Keywords: Biocomposite, hydroxyapatite, amorphous magnesium phosphate, bioabsorbable.

1 INTRODUCTION

Biodegradable polymers have been used in a large number of mass production applications such as packaging, paper coating, fibers, films and other disposable items, as well as in biomedical applications [1]. The physicochemical properties of these polymers depend on the monomers that compose it, in the proportions that it is found and the process by which it is synthesized, being that determines its final molecular weight and thanks to these depends on properties such as crystallinity, viscosity among others [2], [3]. However, the mechanical strength of these limits its use in some applications. On the other hand, there are few reports that are found in the literature on the reinforcement of bioabsorbable polymers [4]–[6]. The present work seeks to show the effect of bioabsorbable nanoparticles such as

hydroxyapatite and amorphous magnesium phosphates on the mechanical properties of a bioabsorbable polymer in order to develop a material 100% bioabsorbable but with mechanical properties superior to those available in the market, which can be used in the manufacture of different biomedical devices.

2 MATERIALS

The polymer (Poly (L-lactide-co-glycolide) 85:15, RESOMER LG 857 S) was donated by Evonik. The Potassium phosphate $\text{KH}_2\text{PO}_4 \cdot 3\text{H}_2\text{O}$, calcium nitrate $\text{Ca}(\text{NO}_3)_2 \cdot 4\text{H}_2\text{O}$, sodium nitrate NaNO_3 , magnesium nitrate $\text{Mg}(\text{NO}_3)_2 \cdot 6\text{H}_2\text{O}$, and nitric acid HNO_3 , sodium bicarbonate NaHCO_3 , were all bought in Merck.

3 METHODS

3.1 Hydroxyapatite

To prepare the hydroxyapatite nanoparticles, two types of surfactants were evaluated. Potassium phosphate and calcium nitrate solutions were used as precursors. This solutions were prepared by dissolving Potassium phosphate $\text{KH}_2\text{PO}_4 \cdot 3\text{H}_2\text{O}$ (0.024M, SLC1) and calcium nitrate $\text{Ca}(\text{NO}_3)_2 \cdot 4\text{H}_2\text{O}$ (0.04M, SLC 2) in deionized water. At first, 50 ml of SLC1 containing various concentrations (0.001, 0.012, 0,024M) of CTAB and (0.005, 0.05, 0.5, 1%) of Pluronic F-127 was prepared under constant stirring for 30 min. This was followed by the gradual addition of 50 ml of SLC2 and the resultant mixture was mixed thoroughly with magnetic stirring. Then the pH of the solution was adjusted to 9 by adding NH_3 . The white suspension thus obtained was put in a ceramic vessel and heated by microwave irradiation (2.45 GHz, 1400W) for 30 min. The material obtained was washed to eliminate residues and subsequently calcined to 900°C.

3.2 Amorphous magnesium phosphate

To prepare the amorphous magnesium phosphate particles, a precursor solution (10 mL) of sodium bicarbonate (0.68g), magnesium chloride (0.62g), and potassium phosphate (0.4g). For the preparation of amorphous calcium and magnesium phosphates the precursor solution (10 mL) was used sodium nitrate (5g), calcium nitrate (1g), magnesium nitrate (0.9g), potassium phosphate (0.34g) and nitric acid (0.5mL). These solutions were subjected to 5 minutes of microwave irradiation (2.45 GHz, 1400W) and subsequently washed and dried to obtain the amorphous phosphate particles.

4 RESULTS

Figure 1 shows the hydroxyapatite nanoparticles obtained by the microwave-assisted hydrothermal synthesis used different concentrations of CTAB and Pluronic F127 and in Figures 2 the particle size distribution obtained by the analysis of the SEM images using the software Imagen J.

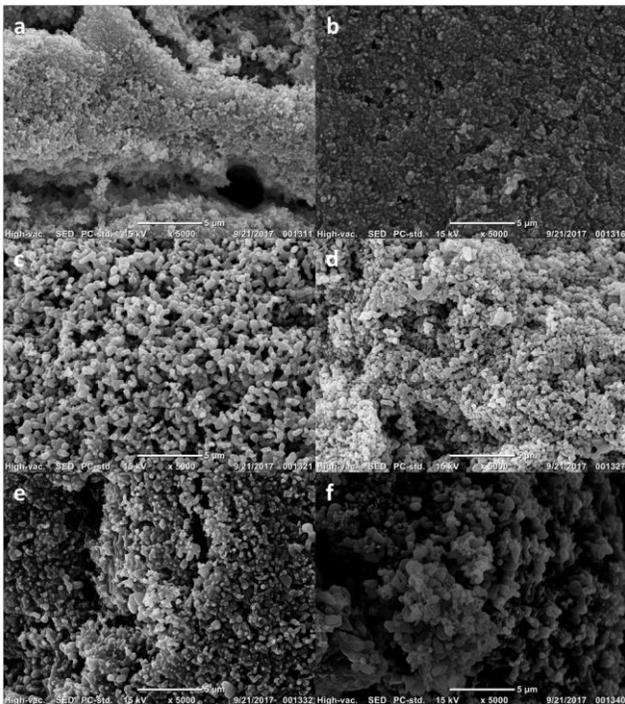


Figure 1. SEM images at 5000 magnifications of hydroxyapatite particles obtained by the microwave-assisted hydrothermal synthesis method using different amounts of surfactant a) 0.001M CTAB, b) 0.01M CTAB, c) 0.02 CTAB, d) 0.05% Pluronic F127, e) 0.1% Pluronic F127, f) 0.02% Pluronic F127.

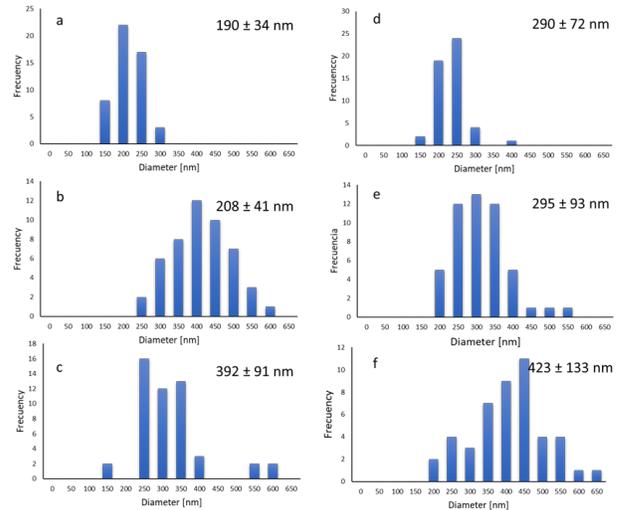


Figure 2. Histograms of the particle size distribution for the hydroxyapatite samples shown in Figure 1 a) 0.001M CTAB, b) 0.01M CTAB, c) 0.02 CTAB, d) 0.05% Pluronic F127, e) 0.1% Pluronic F127, f) 0.02% Pluronic F127.

The morphology of the samples that were obtained with the different concentrations of CTAB and Pluronic F-127 were similar, however if a significant change in the size or diameter of the hydroxyapatite particles was observed for each of the trials as observed in Figure 2.

Using the energy dispersive X-ray spectroscopy (EDX), the approximate composition of calcium and phosphorus of the hydroxyapatite was determined to be valid if the Ca / P ratio was around 1.65. Figure 3 shows an EDX obtained for the hydroxyapatite used CTAB at 0.001M.

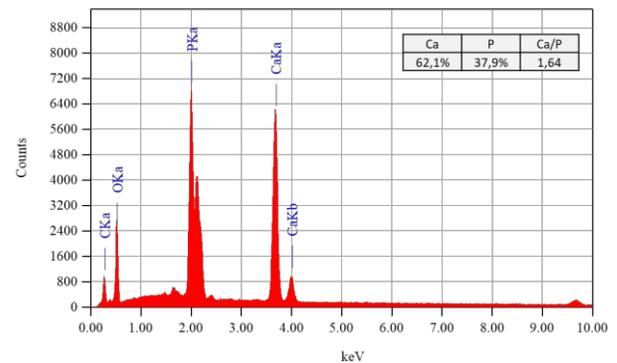


Figure 3. EDX hydroxyapatite produced with 0.001M CTAB

Amorphous magnesium phosphate and amorphous calcium and magnesium phosphate were also sintered using a methodology similar to that used for the production of hydroxyapatite. The SEM images obtained and the EDX of some samples are shown in Figures 4-6.

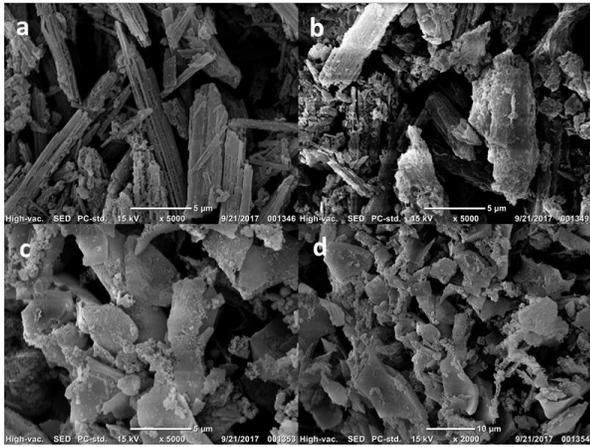


Figure 4. Images SEM a) and b) amorphous magnesium phosphate, c) and d) calcium and magnesium amorphous phosphate.

As seen in Figure 4, the particles obtained for both phosphates not have a defined shape, they have irregular shapes that was what was looking.

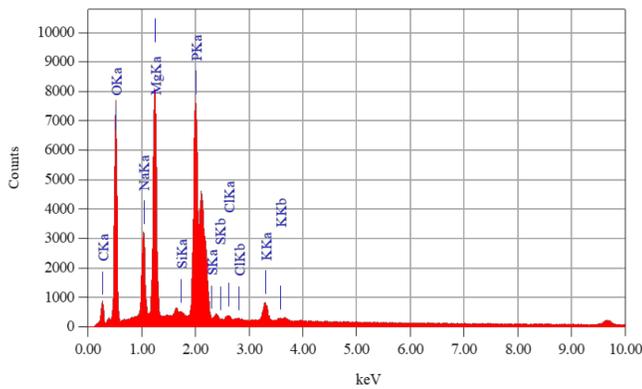


Figure 5. EDX for amorphous magnesium phosphate.

In Figure 5 greater intensity of the characteristic peaks of phosphate and magnesium is observed as expected for this material.

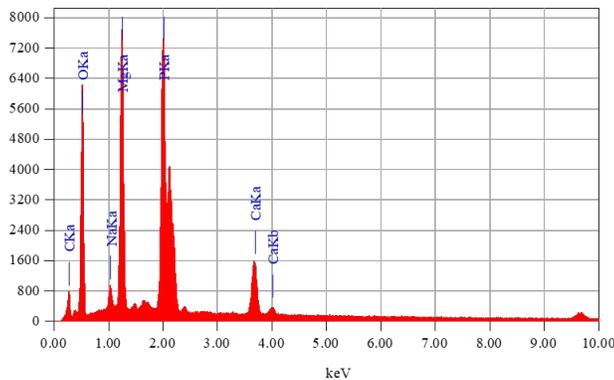


Figure 6. EDX for amorphous calcium and magnesium phosphate.

Hydroxyapatite manufactured with 0.001M of CTAB and the two phosphates were selected to be evaluated. The three materials were evaluated to reinforce the PLGA, making increasing additions of the bioabsorbable reinforcing particles with which circular specimens of 0.5mm diameter and 1mm thickness were made to be evaluated in triplicate in the AFM, by means of the indentation technique.

At the moment the AFM tests are being carried out but the preliminary results have shown an improvement in the mechanical properties of the polymer, which validates our hypothesis of using these materials in the development of biomedical applications.

5 CONCLUSION

For this work, different bioabsorbable nanoparticles were successfully synthesized using the microwave-assisted hydrothermal synthesis technique. Additionally, the analysis of the material by AFM allowed identifying the increase in the resistance of the material. It is expected to be able to evaluate in the future the resistance of these materials over time in a simulated biological environment, which allows identifying how the resistance of the composite material changes with respect to the degradation rate. In the same way, verify the complete degradation of the material to better guide the final applications of the said composite as well as the realization of all the biological safety tests associated with this material.

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