Influence of initial calcium ion concentration on the precipitation and crystal morphology of calcium carbonate induced by bacterial carbonic anhydrase

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HIGHLIGHTS

- Influence of initial Ca\(^{2+}\) concentration on CaCO\(_3\) precipitation by bacterial CA.
- Change in the amount of deposited Ca\(^{2+}\) was well fitted by the exponential model.
- CaCO\(_3\) precipitation rate increased with increase in initial Ca\(^{2+}\) concentration.
- Overhigh initial Ca\(^{2+}\) concentration had some influence on CaCO\(_3\) precipitation.
- The lower initial Ca\(^{2+}\) concentration favored vaterite formation.

Abstract

Biogenic precipitation of calcium carbonate (CaCO\(_3\)) has attracted much attention due to its role in many geological processes, applications of Geological and Civil Engineering as well as environmental treatments. The present paper focused on the biocatalytic precipitation of CaCO\(_3\) by the extracellular carbonic anhydrase (CA) extracted and partially purified from the culture of Bacillus cereus. The kinetics of CaCO\(_3\) precipitation catalyzed by the bacterial CA at different initial concentrations of Ca\(^{2+}\) (C\(_0\)(Ca\(^{2+}\))) was investigated through the gaseous diffusion system. The polymorph and morphology of CaCO\(_3\) crystals obtained in the precipitation process were also analyzed using XRD, FTIR and FESEM. The results showed that in the process of CaCO\(_3\) precipitation catalyzed by bacterial CA, the change in the amount of deposited Ca\(^{2+}\) at different C\(_0\)(Ca\(^{2+}\)) fitted well with the exponential model. Greater fluctuation of pH occurred in the water control group during the rising process of pH, while in the CA group the pH increased more steadily. This may be related to the role of CA in pH regulation. The precipitation rate of CaCO\(_3\) increased with the increasing C\(_0\)(Ca\(^{2+}\)), but overhigh C\(_0\)(Ca\(^{2+}\)) of 100 mmol/L had a certain negative influence on CaCO\(_3\) precipitation catalyzed by bacterial CA. The integrated results of XRD, FTIR and FESEM analysis showed that the C\(_0\)(Ca\(^{2+}\)) had greater effect on the polymorph and morphology of CaCO\(_3\) crystals formed in the presence of bacterial CA. The lower C\(_0\)(Ca\(^{2+}\)) favored the formation of vaterite and the higher C\(_0\)(Ca\(^{2+}\)) favored the formation of calcite.

1. Introduction

Bacterially induced precipitation of calcium carbonate (CaCO\(_3\)) has attracted much attention from both basic and applied points of view. It has implications for its role in many geological processes, applications of Geological and Civil Engineering as well as environmental treatments [1–4], such as solid-phase capture of inorganic contaminants and atmospheric CO\(_2\) capture. Some mechanisms were proposed for bacterially induced CaCO\(_3\) precipitation. For example, urease-producing bacteria can induce CaCO\(_3\) precipitation by increasing the pH and alkalinity of the environment during degradation of urea [5]. Some bacteria can induce CaCO\(_3\) precipitation through such processes as photosynthesis, ammonification, denitrification, sulphate reduction and anaerobic sulphide oxidation [6,7]. Moreover, extracellular carbonic anhydrase producing bacteria can induce CaCO\(_3\) precipitation based on the catalysis of carbonic anhydrase [8,9]. Achal and Pan have investigated three Bacillus strains, which were characterized for the production of urease and carbonic anhydrase, for calcite production ability [8].