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Bioflotation: Bacteria-Mineral Interaction for Eco-friendly and Sustainable Mineral Processing

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Abstract

In the current study, the action of two bacteria capable of producing biosurfactants and oxidizing iron (Fe) and sulfur (S), namely *Bacillus pumilus* SKC-2 and *Alicyclobacillus ferrooxydans* SKC/SAA-2, was investigated with respect to their ability in possessing dual-function as either bio-collector or depressant for the development of sulfide bioflotation processes. Both bacterial strains were able to produce high amounts of biosurfactants interacted with pyrite that had an important role in their adhesion on the surface of pyrite as well as the change of pyrite surface properties. Over the course of the experiments, the pH of the solutions gradually decreased to ~3, indicating the active oxidation of pyrite minerals by bacteria. The growth of both bacterial strains resulted in the generation of biosurfactants as represented by the decrease of the surface tension of the solutions and the increase of the contact angle of the pyrite surfaces as a function of time. However, the contact angle of pyrite surfaces gradually decreased after 5 days of incubation until the experiments terminated on 30 days. Scanning electron microscopy equipped with energy dispersive X-ray spectroscopy (SEM-EDS) and Fourier transform Infrared (FTIR) analyses also confirmed the role of both bacterial strains in changing the pyrite surface properties to be more hydrophobic or more hydrophilic depending on the time of incubation. These results indicate that the changes of pyrite surface properties are clearly as the results of bacterial action, likely serving as both bio-collector or bio-frother and depressant that would be very applicable for flotation processes. These results increase our knowledge on the interactions in pyrite-bacteria complexes and could potentially be a very useful result with real exploitable value for those working on sulfide bioflotation processes.

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Keywords: Biosurfactant; S-Fe-oxidizing bacteria; Bioflotation

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1. Introduction

Interactions between minerals and microbes are of some significance for the development of eco-friendly, low-cost and sustainable mineral processing technologies. Since worldwide reserves of high-grade ores are diminishing, the development of metal recovery from low-grade, lower value mineral ores based on the activity of microbes is highly needed. Bioflotation is a biotechnology by employing microbes, in particular bacteria, involving the adhesion of the bacteria on the minerals that meets the industrial needs for more selective and environmentally friendly mineral separation[1,2,3,4,5]. By adhering to the surface of minerals, the bacteria essentially change the surface characteristics of the minerals as a result of interaction of microbes and mineral surfaces followed by active oxidation/reduction of mineral elements by bacteria.[6, 7, 8] The microbial metabolites and activities derived from microbe-mineral interaction bring about the increased efficiency of flotation that depends on the chemical characteristics of mineral surfaces and thus affects the beneficiation process.[1-7]

Utilization of the bacteria in flotation is quite new, especially bacteria producing biosurfactants that are also capable of oxidizing iron (Fe) and sulfur (S). Hence, in this work, the batch bacterial growth experiments for utilizing the bacteria capable of producing biosurfactants and oxidizing iron and sulfur were conducted in direct contact with pyrite under aerobic conditions. Changes in pyrite surface properties as represented by surface tension and contact angle was determined. The interaction of bacterial cells with pyrite was studied by Fourier transform Infrared (FTIR) Spectroscopy. The aggregate behavior of bacterial cells and pyrite particles was observed by scanning electron microscopy (SEM), while the nature of these aggregates was analyzed by energy-dispersive spectroscopy (EDS). These results would be very helpful and give significant insights into the enhancement of bioflotation of sulfide minerals. In this aspect the bacteria used in this study might be applicable for the flotation bioreagents for creating environmentally friendly mineral processing.

2. Materials and Methods

2.1. Pyrite samples

The pyrite used in this study was obtained from Singajaya, Garut, West Java Province, Indonesia and was ground to obtain the grain size of - 200 + 400 mesh. An X-ray powder diffractrometery (XRD) analysis showed the high purity of pyrite (FeS_2) and no other sulfide minerals were detected (Fig. 1a). In addition, ED-XRF analysis of pyrite sample revealed that its chemical composition was SiO_2 (1.63 wt.%), Al_2O_3 (2.29 wt.%), TiO_2 (0.009 wt.%), Fe_2O_3 (42.03 wt.%), MgO (0.056 wt.%), CaO (0.068 wt.%), Na_2O (0.01 wt.%), K_2O (0.013 wt.%), P_2O_5 (0.009 wt.%), SO_3 (53,81 wt.%), Cr_2O_3 (0.038 wt.%), CuO (0.036 wt.%), NiO (0.003 wt.%), ZnO (0.004 wt.%).

2.2. Bacterium and growth medium

The bacteria *Bacillus pumilus* SKC-2 and *Alicyclobacillus ferrooxydans* SKC/SAA-2used in this study were isolated from the South Sulawesi laterite mineral sand an enrichment culture of crude oil, respectively, which have the abilities of producing biosurfactants and oxidizing iron and sulfur. The growth medium used was the modified Luria–Bertani (LB) medium (l^{-1}: 10 g peptone; 5 g yeast extract; 10 g NaCl, supplemented with 0.5 g $Na_2S_2O_3.5H_2O$ and 0.25 g $FeSO_4.7H_2O$).The photomicrograph of bacterial cells of the strains are shown in Fig. 4b (*Bacillus pumilus*) and Fig. 5b (*Alicyclobacillus ferrooxydans*).