Reduction of sulfur levels in kerosene by Pseudomonas sp strain in an airlift reactor

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Abstract — Combustion of organic sulfur from fossil fuels can produce acid rain that deteriorates the environment and infrastructure. Sulfur removal by microorganism has appeared as an alternative for this challenge. In this work, biodesulfurization of 50:50 water-kerosene emulsions were carried out at 100 mL scale and in a 0.01 m³ airlift reactor with resting cells of the reference strain ATCC 39327 and Pseudomonas native strains Nº 02, 05 and 06. The reactor conditions were 30°C, pH 8.0 and 0.34 m³ h⁻¹ air flow. After 7 culture days, the mean sulfur removal for the strains Nº 06 and ATCC 39327 was 64 and 53%, respectively, with a mean calorific power loss of 4.5% for both strains. The use of the native strain Nº 06 and the designed airlift reactor is shown as an alternative for biodesulfurization process and constitute a first step for its scale-up to pilot plant.

Keywords — Biodesulfurization, Airlift Reactor, Kerosene, Pseudomonas.

I. INTRODUCTION

The main problem in fossil fuel combustion is sulfur and nitrogen conversion to oxides. These oxides make part of acid rain which deteriorates the environment and infrastructures (Monticello and Finnerty, 1985; Izumi et al., 1994; Oshiro et al., 1995; Sagardia et al., 1975). Furthermore, SO₂ emission is a precursor of sulfated aerosols that are considered as one of the main solid particulate agents that affect the human health (Sagardia et al., 1975).

Worldwide sulfur levels in fuels are between 15 ppm in North America and 5000 ppm in some countries of Africa and Middle East (United Nations Environment Programme, 2007a). In Latin-America, Brazil, Bolivia, Chile, and Argentina have levels between 500 and 2000 ppm, while Venezuela, Ecuador, Peru, Paraguay, Uruguay and Centro-America have sulfur levels up to 5000 ppm in diesel. Mexico is the only Latin country with sulfur levels less than 500 ppm (Felix, 2007; United Nations Environment Programme 2007b). Since 1995, in Colombia some decrees have been created in order to control the sulfur level in fuels. They established for the year 2008 a level up to 300 and 500 ppm in gasoline and diesel, respectively. However, actual sulfur levels are 1200 ppm in Bogotá and 4500 ppm in other places (United Nations Environment Programme 2007b).

The microbiological degradation of sulfur compounds in fossil fuels, biodesulfurization (BDS), has arisen as an alternative instead of the catalytic process of hydrodesulfurization (HDS) which leaves sulfur remnants between 300 and 500 ppm (McFarland et al., 1998). In contrast, some microorganisms with sulfur removal activity show advantages like high sulfur specificity without fuel calorific power lost. BDS processes can be carried out under moderated conditions and allow to have lower sulfur remnant levels than HDS. However, these microorganisms have a high sensibility to organic solvents (Monticello, 2000). At present there are about fifty approved patents for desulfurization processes on derived fossil fuels from petroleum and coal which use microorganisms, enzymes and vectors that keep genes of desulfurization metabolic pathways (Biodesulfurization in United States Patent and Trademark, 2007). It is estimated that the BDS process could reduced CO₂ emissions and up to 80% less energy consumed per barrel compared to HDS (Le Borgne and Quintero, 2003).

In addition to elemental sulfur, sulfate, sulfite and thiosulfate, sulfur can be present in more than 200 organic compounds like sulfides, thiols, thiophenenes, mercaptans, diphenilsulfides, benzothiophenes and dibenzothiophenes (Monticello and Finnerty, 1985; Fedorak and Westlake, 1983; Fedorak and Grbic-Galic, 1991; Lee et al., 1995). Dibenzothiophene (DBT) and its derivates have been the most studied compounds due their resistant to HDS process (Monticello, 2000). Three metabolic pathways for the desulfurization of DBT have been reported: (a) 4S pathway where the sulfur is selectively removed of the molecules without a significant lost in the fuel calorific power, (b) Kodoma’s pathway where hydrophilic products are obtained with a lost in the fuel calorific power, and (c) a completely oxidative pathway where CO₂, SO₂ and H₂O are produced. (Oshiro et al., 1995; Lee et al., 1995; Armstronset al., 1995; Omori et al., 1992; Konishi et al., 1986; Kodama et al., 1973; Kodama et al., 1970). The enzymes and genes involved in 4S pathway have been elucidated and constitute the Dsz desulfurization system that involves four enzymatic steps. Cofactors...