Bioresource Technology 115 (2012) 208–214

Contents lists available at SciVerse ScienceDirect

Bioresource Technology

journal homepage: www.elsevier.com/locate/biortech

Scaling up of ethanol production from sugar molasses using yeast immobilized with alginate-based MCM-41 mesoporous zeolite composite carrier

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ARTICLE INFO

Article history:
Received 23 May 2011
Received in revised form 14 November 2011
Accepted 16 November 2011
Available online 25 November 2011

Keywords:
Ethanol
Immobilization
Saccharomyces cerevisiae
Alginate
MCM-41 zeolite

ABSTRACT

Microporous and mesoporous zeolites, including ZSM-5, H-β, H-Y, and MCM-41, were modified with 3-aminopropyl-triethoxysilane (APTES), then inorganic fillers, such as abovementioned zeolites or mesoporous materials, (α-AlOOH or γ-Al_2O_3), were mixed with alginate embedded with yeast; and finally these carriers were cross-linked through the double oxirane. The alginate-based immobilized yeast with MCM-41 exhibited much shorter fermentation time and higher ethanol concentration than pure alginate and other composite carriers with the highest cell concentration of 4.8×10^9 cells/mL. The composite carrier maintains the highest ethanol productivity of 6.55 g/L/h for 60 days in continuous fermentation process, implying good operational durability for commercial applications. The reason for the higher bio-catalytical function of the immobilized yeast might lay in the uniformly yeast distribution in the bio-reactor and high yeast cell concentration, which contributed by the improved transmission of fermentation media and combined effects of yeast adsorption by MCM-41 and embedment by alginate.

1. Introduction

The oil crisis of the last 30 years has focused research conducted in the scientific area of ethanol fermentation primarily toward increasing the ethanol productivity of bioprocesses and reduction of energy demands. In addition to providing a solution to the environmental issue arising from the disposal of sugar molasses, the production of ethanol as a fuel can also help stabilize the agricultural sector in sugar-producing countries (Kopsahelis et al., 2007; Thomas and Kwong, 2001). The fermentation of sugar molasses has continued to enhance ethanol productivity (Nahvi et al., 2002). To increase ethanol productivity and to reduce labor intensity, aspects such as bioreactor volume, energy consumption in the production of ethanol, and cell immobilization for ethanol production have been extensively studied and reviewed (Kopsahelis et al., 2009; Kourkoutas et al., 2004; Marignetti et al., 1997). Various adjuncts have been proposed by different researchers for yeast and bacteria immobilization for application in ethanol fermentation from various raw materials. These research efforts included the use of inorganic and organic adjuncts in batch and continuous processes, including organic materials such as calcium alginate, polyvinyl alcohol, and polyacrylamide (Kourkoutas et al., 2004) and inorganic materials such as alumina (Loukatos et al., 2000), silica (Gill and Ballesteros, 1998) and zeolite (Hartmann, 2005; Kourkoutas et al., 2004). The reduction of costs involved in ethanol production from bioprocesses employing immobilized cells systems are associated with aspects such as the cost of raw materials, the use of cheap, abundant and stable immobilization adjuncts, the high cell concentration in the bioreactors, the simplicity and low cost of immobilization techniques, the stability of the immobilized biocatalyst in its operational state, ease of regeneration and the design and development of a suitable bioreactor system (Kourkoutas et al., 2004; Wang et al., 2011). Alginate, as a carrier, has a high immobilized yeast concentration; however, its biochemical stability and mechanical strength is poor, and, therefore, the industrial application of organic materials is restricted. The MCM-41, a type of ordered mesoporous inorganic materials, has been applied successfully as a carrier in immobilizing cells processes (Tope et al., 2001). It has good mechanical property, permeability and renewability, all of which increase the mechanical strength of immobilized yeast, and enhance the transportation of fermentation products; however, it has low immobilized yeast concentration for relying on weak physical or chemical adsorption with microorganisms. Therefore, the preparation of organic–inorganic composite materials for yeast immobilization appears very attractive as a prospective method because it combines features of organic and inorganic materials. These organic–inorganic carriers not only utilize their good embedded affinity to organic materials and fast propagation of yeast cells, but also possess good mechanical properties and permeability to inorganic materials; these traits prolong the operating life of carriers, and effectively improve the

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doi:10.1016/j.biortech.2011.11.056