

Low-Temperature Dilute Acid Hydrolysis of Oil Palm Frond

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Oil palm frond (OPF) fiber, a lignocellulosic waste from the palm oil industry, contains high cellulose and hemicellulose content, thus it is a potential feedstock for simple sugars production. This paper describes the two-stage hydrolysis process focusing on the use of low-temperature dilute acid hydrolysis to convert the hemicellulose in OPF fiber to simple sugars (xylose, arabinose, and glucose). The objective of the present study was to evaluate the effect of operating conditions of dilute sulfuric acid hydrolysis undertaken in a 1 L self-built batch reactor on xylose production from OPF fiber. The reaction conditions were temperatures (100–140°C), acid concentrations (2–6%), and reaction times (30–240 min). The mass ratio of solid/liquid was kept at 1:30. Analysis of the three main sugars glucose, xylose, and arabinose were determined using high-pressure liquid chromatography. The optimum reaction temperature, reaction time, and acid concentration were found to be 120°C, 120 min, and 2% acid, respectively. Based on the potential amount of xylose (10.8 mg/mL), 94% conversion (10.15 mg/mL) was obtained under the optimum conditions with small amount of furfural (0.016 mg/mL). To enhance the effectiveness of dilute acid hydrolysis, the hydrolysis of OPF fiber was also performed using ultrasonic-pretreated OPF fiber. The effects of ultrasonic parameters power (40–80%) and ultrasonication times (20–60 min) were determined on sugar yields under optimum hydrolysis conditions (2% acid sulfuric, 120°C and 120 min). However, the use of ultrasonication was found to have detrimental effect on the yield of simple sugars due to the 10-fold increase in the formation of furfural.

Keywords: Dilute acid hydrolysis; Lignocelluloses; Oil palm frond (OPF); Optimization; Ultrasound; Xylose

Introduction

Bioconversion of lignocellulosic waste materials to chemicals and fuels has received much consideration as they are cheap, renewable, and extensively available (Nigam and Singh, 2011). Oil palm is a multipurpose plantation and one of the huge sources of lignocellulosic biomass for value-added industries (Basiron, 2007). Oil palm industry produces massive amounts of agricultural biomass such as empty fruit bunch fibers, fronds, trunks, and shells (Salamatinia et al., 2008). During oil palm cultivation, it is reported by Goh et al. (2010) that, 51 million tonnes/year of oil palm fronds (OPFs) is produced which is about 50% of oil palm residues. In contrast to other kinds of raw materials for bioethanol production, it is seen that, OPF fiber is free and inexpensive in terms of collection, storage, and cropping practices.

Therefore, it can be utilized as a cheap renewable material for the production of value-added products such as ethanol, glucose, xylose, and xylitol either chemically or biologically (Goyal et al., 2006; Goh et al., 2010). The OPF biomass mainly contains cellulose (30–40%), hemicellulose (20–30%), and lignin (10–20%) with xylan being the main component of hemicellulose. Xylan is very vulnerable to hydrolysis by mild acid treatment due to the amorphous structure of hemicellulose compared to the extremely crystallized cellulose ally (Goyal et al., 2006).

Dilute acid-catalyzed hydrolysis of various lignocellulosic raw materials, such as sugarcane bagasse, corn stover, sorghum straw, eucalyptus wood, and oil palm fiber, for xylose production has been studied extensively; whereas only a few reports have been found for OPF fiber (Chandel et al., 2007). High cost and low yield are challenges in the hydrolysis process (Sun and Cheng, 2002). In the literature, the hydrolysis of corn gluten was also performed for kinetic study using enzymes (Apar and Özbek, 2010). Dilute acid hydrolysis is easy to perform but it is hampered by formation of undesired compounds such as lignin-derived phenolics, sugar-derived furans, and hemicellulose structure derived compounds (weak acids, extractives, resins). To overcome

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