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Production of anhydrous ethanol using oil palm empty fruit bunch in a pilot plant

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ABSTRACT

Bioethanol production from lignocellulosic biomass for use as an alternative energy resource has attracted increasing interest, but short-term commercialization will require several technologies such as low cost feedstock. The huge amount of oil palm empty fruit bunches (EFB) generated from palm oil industries can be used as a raw material for cheap, renewable feedstock for further commercial exploitation. Using a pilot-scale bioethanol plant, this study investigated the possibility of utilizing oil palm empty fruit bunches as a renewable resource. All bioethanol production processes such as pretreatment, hydrolysis, fermentation, and purification were constructed as automatically controlled integrated processes. The mass balance was calculated from operational results. Changhae ethanol multiexplosion pretreatment with sodium hydroxide was conducted to improve the enzymatic hydrolysis process, and a separate hydrolysis and fermentation process was used for producing bioethanol at an 83.6% ethanol conversion rate. In order to purify the ethanol, a distillation and dehydration facility was operated. Distillation and dehydration efficiencies were 98.9% and 99.2%, respectively. The material balance could be calculated using results obtained from the operation of the pilot-scale bioethanol plant. As a result, it was possible to produce 144.4 kg anhydrous ethanol (99.7 wt%) from 1000 kg EFB. This result constitutes a significant contribution to the feasibility of bioethanol production from lignocellulosic biomass and justifies the pilot plant's scale-up to a commercial-scale plant.

1. Introduction

In order to find solutions to the global environmental problem such as global warming and the shortage of fossil fuel, alternative means of producing chemicals and transportation fuels need to be developed [1]. A potential alternative energy resource is biomass-based bioethanol. Usually, bioethanol is commercially produced by fermenting monomer sugar extracted from starch-based or sugar-based

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feedstock such as corn, cassava, and grain or sugar cane [2]. However, the use of these feedstocks has raised ethical concerns regarding food usage. The rapid growth of bioethanol production based on starch or sugar has increased the price of crops and foodstuffs; thus, it is important to identify non-edible forms of biomass for biofuel production. Lignocellulosic biomasses such as oil palm empty fruit bunches (EFB), *Miscanthus*, and corn stover are abundant around the plant, and they are renewable substrates for bioethanol production that do not affect food or animal feed production [3]. These feedstocks are also suitable in terms of environmental sustainability [4].

As one of the biggest exporters of palm oil, the Indonesian palm oil industry generates large quantities of biomasses such as oil palm empty fruit bunches (EFB), oil palm shells (OPS), and oil palm fibers (OPF) [5]. The potential for using these types of biomasses from palm oil production is substantial, but the technology is yet to be researched and developed. EFB are a primary waste stream of palm oil production. Currently, EFB are used as fertilizers and are usually burned in incinerators to obtain bunch ash or dumped for mulching in oil palm plantations [6]. The potential utilization of EFB for ethanol production requires an intimate knowledge and the development of an integrated processing system.

Pilot plants and commercial-scale facilities for converting lingnocellulosic biomass to ethanol have previously been researched and developed. All such conversion processes used acid in the hydrolysis process for converting cellulose to glucose. For example, Seholler (1937) developed an acid percolation process [7], which was further refined at the U.S. Forest Products Laboratory in Madison, Wisconsin [8,9], and by the Tennessee Valley Authority [10]. The pilot plants that applied acid-hydrolysis have limited applicability, however, for incorporation into an integrated process [11]. Many recently developed bioethanol plants have limited potential in terms of incorporation into a continuous and integrated process.

A number of lignocellulosic biofuel production facilities are under construction or operating in the U.S., Canada, China, Denmark, Italy, Germany, or Spain. All these facilities strive to increase production capacities, and the facilities located in the U.S. are focusing on satisfying the federal renewable fuel standard (RFS). The RFS was amended in 2005 to cover biofuels based on lignocellulosic biomass. Despite the global recession, the biofuel industry now has facilities and projects under development in more than 30 U.S. states, amounting to billions of dollars in private investment. As a part of that effort, several companies are constructing and operating demonstration or commercial plants for bioethanol production from lignocellulosic biomass. For example, the Iogen demo fuel production plant located in Ottawa, Canada has produced 1 MGY bioethanol from cereal straw, bagasse, corn stover, and grasses since 2005. Beta Renewable began the operation of a commercial facility in Crescentino, Italy in 2012. This facility uses a mix of wheat straw, rice straw, bagasse, arundo donax, corn stover, and poplar as a feedstock and currently produces 20 MGY ethanol [12].

In the present study, we investigated the possibility of bioethanol production from oil palm empty fruit bunches. The purpose of the study was to construct a pilot-scale plant and integrate all processes such as pretreatment, hydrolysis, fermentation, and purification. The potential amount of ethanol production from EFB was determined on the basis of the pilot-plant operation. Finally, this study determined the mass balance of bioethanol production from 500 kg EFB.

Fig. 1 – The pilot plant of bioethanol production using EFB in Indonesia. And in order to operate automatically, a programmable logic controller (PLC) system and human machine interface (HMI) were installed.