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Evaluation of the production potential of bio-oil from Vietnamese biomass resources by fast pyrolysis

Binh M.Q. Phan [a], Long T. Duong [a], Viet D. Nguyen [a,*], Trong B. Tran [a], My H.H. Nguyen [a], Luong H. Nguyen [a], Duc A. Nguyen [b], Loc C. Luu [c]

[a] PetroVietnam Research and Development Center for Petroleum Processing, 04 Nguyen Thong, District 3, Ho Chi Minh City, Viet Nam

[b] Vietnam Petroleum Institute, 173 Trung Kinh, Cau Giay, Hanoi, Viet Nam

[c] Hochiminh City University of Technology, 268 Ly Thuong Kiet, District 10, Ho Chi Minh City, Viet Nam

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ABSTRACT

Agricultural activities in Vietnam generate about 62 million tonnes of biomass (rice straw, rice husk, bagasse, corn cob, corn stover, etc.) annually. In this work, four different types of biomass from Vietnam, namely rice straw, rice husk, factory bagasse, and corn cob, have been studied as potential raw materials to produce bio-oil by fast pyrolysis technology. Test runs were conducted in a fluidized-bed reactor at a temperature of 500 °C and residence time less than 2 s. Size and moisture content of the feed were less than 2 mm and 2%, respectively. It was found that yields of bio-oil as a liquid product obtained from pyrolysis of these feedstocks were more than 50% and that obtained from the bagasse was the highest. Bio-oil quality from Vietnamese biomass resources satisfies ASTM D7544-12 standard for pyrolysis liquid biofuels. These results showed the potential of using biomass in Vietnam to produce bio-oil which could be directly used as a combustion fuel or upgraded into transportation fuels and chemicals.

1. Introduction

Vietnam is an agricultural country and its main food crops are rice, sugarcane, cassava, and corn. About 62 million tonnes of agricultural residues are produced annually. Among these agricultural residues, the general statistics office estimated that by 2010, productivities of crop residues from rice straw, rice husk, corn cob and factory bagasse were 15.5, 6.7, 3.1 and 3.2 million tonnes, respectively [1].

Currently, biomass is highlighted as one of the promising renewable energy sources due to environmental problems caused by combustion of fossil fuels and the shortage of fossil fuels in the future. International Rice 64 (IR-64) rice (*Oryza sativa* subsp. IR-64) cultivar is one of the most popular rice varieties in Mekong River Delta and Southeastern Region of Vietnam. The time of its maturity is approximate 90–100 days. Straw and husk released from rice mills are dumped mostly into the dense canal and river system [2]. According to the general statistics office, corn is one of several local crops which is used to supply the quickly growing feed industry [1]. Hybrid Corn F1 G-49 corn (*Zea mays* subsp. G-49) grows in both the Northern and Southern regions of Vietnam. The harvest yield of corn is approximate in the range of 6.0–7.0 tons ha^{-1} depending on the strains and growing condition. The time of

* *Corresponding author*. Tel.: +84 839303 323x248; fax: +84 839307 546.
E-mail address: vietnd@pvpro.com.vn (V.D. Nguyen).

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its maturity in Southeast Region is 90–95 days [3]. Sugarcane (*Saccharum L.*) grows at various regions in Vietnam. The average yield of sugar is 5.5–5.8 tons ha^{-1} and the cultivating area is being reduced due to unstable domestic demand [4]. By-products of sugarcane include bagasse and molasses. A part of bagasse is being used to produce microbial fertilizer while molasses is used mostly as a feedstock for ethanol production.

Currently, fast pyrolysis becomes a promising option for the thermo-chemical conversion of lignocellulosic biomass into liquid fuels because of its higher yield and quality of liquid oil compared to other techniques [5–7]. For fast pyrolysis process, a bubbling fluidized bed reactor has been widely used at bench-scale and pilot-scale plants due to its high heat transfer rate [8].

In this study, four Vietnamese typical types of biomass resources were characterized and converted into bio-oil by fast pyrolysis method in a bubbling fluidized bed reactor which had been set-up at capacity of raw material of 60 g h^{-1}. Effects of different reaction conditions (such as temperature, biomass particle size and nitrogen volume flow rate) on the bubbling condition, vapor residence time, heating rate of biomass and the final conversion of biomass were studied in order to find the optimal pyrolysis conditions to obtain the highest yield and quality of bio-oil. The optimal pyrolysis conditions of rice straw pyrolysis were determined first, then these were applied for three other biomass feedstocks (rice husk, bagasse, and corn cob) to get preliminary information.

2. Experimental

2.1. *Feedstock preparation*

IR-64 rice straw and rice husk used in this study were harvested in summer 2012 in a field in Binh Chanh district, Ho Chi Minh city, Vietnam (10°42.137′N, 106°34.549′E). G-49 corn cob was collected in summer 2012 in a field in Go Dau district, Tay Ninh province, Vietnam (11°08.409′N, 106°18.889′E). The sugarcane bagasse was harvested in summer 2012 in a field of Bien Hoa Sugar Company in Duong Minh Chau district, Tay Ninh Province, Vietnam (11°14.716′N, 106°14.960′E). All raw materials were air dried at 35 °C within 2–3 days to remove their moisture contents. The dried materials were milled by a cutting mill (SM 100) and sieved by a sieve shaker (Octagon 2000) to obtain samples with different particle size ranges (0.18 mm–0.50 mm, 0.50 mm–1.00 mm, and 1.00 mm–2.00 mm). Then, the materials were dried again at 105 °C until their moisture contents were less than 2%. These dried samples were stored in plastic bags at room temperature under dry condition. In each experiment, these samples were dried again at 105 °C to remain the dry matter content reached at 98%.

2.2. *Experimental set-up*

Fig. 1 showed the experimental system for fast pyrolysis of biomass. The system is composed of a heating chamber surrounded by electrical furnace (Thermcraft), a biomass hopper, KT-20 Auger screw feeder (K-Tron), a fluidized bed reactor, two cyclones, a condenser, an electrostatic precipitator and a gas test meter. Nitrogen gas (N_2) is delivered to the reactor for fluidization by Mass Flow Controllers (Parker) and considered as the inert environment for pyrolysis. Char in the product stream was separated from the vapor stream by a cyclone system. Condensable and non-condensable gases went through a condenser and an electrostatic precipitator in which most of condensable gas is trapped in liquid phase (referred as bio-oil). Thermocouples (Omega Engineering) and digital pressure indicators (SMC) were installed to monitor temperature and pressure of the reaction system.

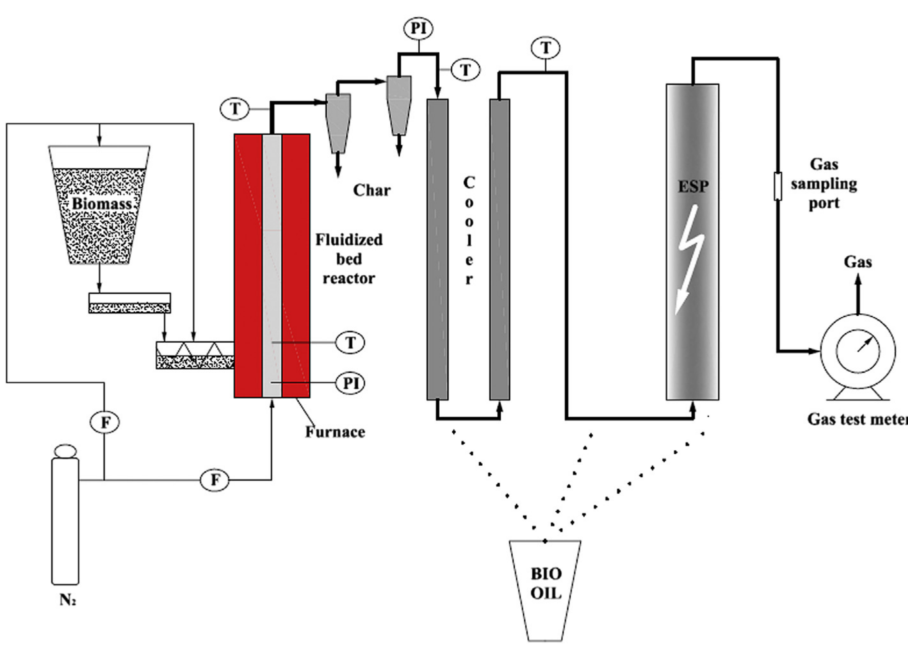

Fig. 1 – Biomass fast pyrolysis experimental system.