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Study of ratio of energy consumption and gained energy during briquetting process for glycerin-biomass briquette fuel

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HIGHLIGHTS

- Glycerin-biomass briquette fuels were studied.
- Energy used during processes was compared to HV of the briquette.
- Actual HV and correlated HV were compared and found to be within 5%.
- Relationship of total HV was a function of mass fraction of its compositions.

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ABSTRACT

This paper investigated the feasibility of using the mixture of glycerin and biomass as an alternative fuel by measuring the energy used in the densification process and the energy gained from the briquette fuels. The correlation of the heating values between the calculated values and the actual values was also determined. Rice husk, sawdust, sugarcane bagasse, and sugarcane leaf were used as biomass. Different amounts of glycerin were mixed with the biomass during the densification process. The ratios of the energy used compared with the energy gained were approximately 1–3% for domestic-scale solar drying condition and 12–18% for industrial-scale machine drying condition. Heating values of the briquettes increased with the increasing amount of glycerin. Using the mixture of glycerin and biomass in the densification process was considered feasible to be further developed as an alternative fuel.

1. Introduction

In Thailand, an abundance of waste, e.g., palm, jatropha, coconut oil, and used vegetable oil, can be converted to biodiesel. As a result, the Thai government has encouraged and supported biodiesel production in order to reduce crude oil import. The Ministry of Energy also established a policy to increase energy self-dependence by introducing B5 (95% diesel and 5% biodiesel) to the community and the industry [1]. This policy has resulted in the increase in biodiesel production and producers both at the community scale and the industrial scale. During the biodiesel production, glycerin is created as a by-product (1 ton of biodiesel yields 0.11 ton of crude glycerin) [2]. Purified glycerin is commonly used in the cosmetic and food industries but the cost of purifying crude glycerin is relatively high [3–5]. Crude glycerin has high viscosity and flash point, so it cannot be directly used as a fuel, unless it is mixed with other fuels [6,7]. In addition, it is contaminated with salt, alcohol, heavy metals, and water, and normally discarded as waste. Currently, there are many large-scale biodiesel manufacturers and the amount of crude glycerin is greater than the demand of the industry, causing the price of crude glycerin to plummet [3]. Moreover, the number of community-scale biodiesel producers has also risen, creating additional amounts of crude glycerin. The amount of glycerin waste has been rising and creating storage and disposal problems.

Nevertheless, the staggering abundance of glycerin and its low price are considered economically attractive to be studied for alternative fuel. Oezkan et al. observed the performance of biodiesel with glycerin in an engine test and found out that biodiesel with glycerin could be used as fuel with some modifications [8]. Chaiyaomporn and Chavalparit used palm fiber and palm shell mixed with glycerin as a raw material to find the optimum ratio of pelletized fuel, by which they investigated the physical properties of the pellet by varying the ratio of mixture and particle size of raw material. The result showed that the optimum ratio of pelletized fuel (palm fiber:water:waste glycerin) 50:10:40, yielding 982.2 kg/m^3 and 22.5 MJ/kg for the specific gravity and the heating value, respectively [9]. Brady and Tam evaluated the energy of fuel

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pellets containing sawdust and glycerin in a ratio of 1.0–1.3 and found out that the obtained energy content could be adopted as an alternative fuel [10]. Raslavičius evaluated the proportions, durability, characterization of combusion regimes, and emission characteristics of fuel briquettes (glycerol with woody cutting waste) and found out that crude glycerol was suitable as a partial substitute for woody cutting waste in the briquette production. In addition, the fuel briquettes did not show negative impact on the environment because their combusion exposed low CO, SO_2, and NO_x emission levels [11].

To create fuel briquettes by mixing glycerin with biomass, suitable biomass materials must be selected. Farm wastes such as rice husk, sawdust, sugarcane bagasse, sugarcane leaf, coconut shells, and palm fiber can be considered because they are abundant in Thailand. The only drawback for most of the farm wastes is their bulk volume, which demands large storage and high transportation cost. In general, the steps to convert biomass into energy are shown in Fig. 1a. Biomass are collected and transported, and then converted into energy by the burning process. However, in order to achieve higher energy per volume, a densification process (compacting biomass into fuel briquettes with pressure) is usually added as shown in Fig. 1b [12]. The densification process involves drying, shredding, and pressing, which needs costly equipments and a few energy sources. Since the densification process is an addition to the general biomass energy conversion steps, it is crucial to investigate the ratio of energy consumption and gained energy of the densification process. Based on the aforementioned works, it is also important to determine the feasibility of using the mixture of glycerol and biomass as an alternative fuel. Thus, this research only studied the ratio of energy consumption including drying, shred, and compacted process accounting for the gained energy from the glycerin-biomass briquettes. Different glycerin-biomass ratios were also investigated in order to obtain the optimal ratio for the densification process. In addition, the correlation between the calculated heating values and the measured heating values was examined. Note that the calculation of the energy used in the transportation and collection processes depends on many factors such as distance between the experimental site and the collection site, type of vehicle used for biomass collection, labor cost, etc. [13]. As a result, the energy calculation needs to be dealt with extensively and should be a separate study of its own. However, in this study, the transportation and collection processes could be assumed as a fixed parameter normally occurred in the biomass energy conversion.

2. Experimental methods

2.1. Materials

Four types of biomass normally found from farm wastes were considered in this study: (1) rice husk, (2) sawdust, (3) sugarcane bagasse, and (4) sugarcane leaf. These raw materials were dried and shredded to have approximately 0.2–2.0 mm in length. During the densification process, certain amounts of glycerin were mixed with these raw materials to increase the heating value of briquettes. Note that the type of densification process carried out here was a cold process using molasses as the bonding agent. Seven different ratios (biomass:molass:glycerin) used in the densification process were: (1) 90:10:0, (2) 85:10:10, (3) 80:10:10, (4) 75:10:15, (5) 70:10:20, (6) 65:10:25, and (7) 60:10:30. Note that briquettes could not be easily deformed if the amount of glycerin was higher than 35% [14].

2.2. Machines

The shredding machine used in this study was dual-function with a roller crusher (2 hp motor) and a hammer mill (3 hp motor) having a production capacity of 19.87 kg/h. The densification machine used was a pressure-adjustable piston press (4 hp motor) having a production rate of 30–42 kg/h. The pressure used to compact the materials was 10 MPa [14].

2.3. Testing procedure

In order to observe the energy used in the densification process and the energy gained from briquette fuels, two conditions were studied: (1) domestic-scale solar drying, and (2) industry-scale

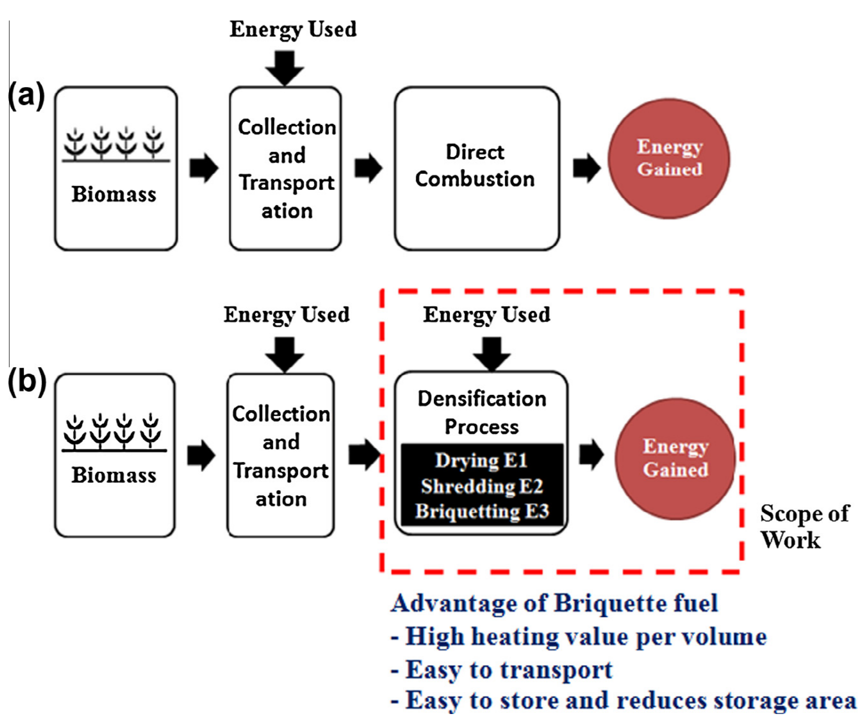

Fig. 1. Conversion of biomass to energy diagram.