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Short communication

Pelletization of brown coal and rice bran in Indonesia: Characteristics of the mixture pellets including safety during transportation

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ABSTRACT

With the aim of utilizing brown coal as fuel in co-firing power plants, a technique for the pelletization of brown coal and rice bran has been developed. By mixing rice bran with brown coal, the calorific value of brown coal was improved and its safety during transportation increased. The calorific value of the mixed pellets with 50% brown coal and 50% rice bran reached 15 MJ/kg, and their durability was sufficiently high at 98%. This technique of pelletization decreases the manufacturing costs because thermal energy for dewatering and drying is not required. In addition, it is beneficial because it uses agricultural residues. Further, if the ratio of brown coal was reduced to below 50%, the mixed pellets did not act as a pyrophoric material (a self-heating substance).
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1. Introduction

Coal, a conventional type of fuel used for power generation, is expected to be in demand in the future because there are huge reserves that are relatively easy to access, i.e., coal is not as unevenly distributed as other fossil fuels. According to statistical data for 2011 [1], the recoverable reserves of coal are estimated to be 891.5 billion tons worldwide, however, more than half of this amount constitutes low-grade coal, which is referred to as sub-bituminous coal and brown coal. Although the reserves of brown coal are large, use of brown coal is complicated by its low calorific value and its high moisture content. Since brown coal contains many functional groups that undergo oxidation reactions that can lead to pyrophoric reactions, it is not used outside of mining areas because of safety concerns associated with its transportation and storage. Some types of brown coal, however, have some advantages such as their low-ash and low-sulfur contents, and they can be mined at low costs because the mining depths tend to be relatively shallow. The process of water removal from coal has been reported by a large number of research studies [2–5]. However, the costs of drying and the associated problems often act as major barriers in the development of competitive brown coal technologies [2,6].

Further, given the background of global warming problems, reductions of CO_2 emissions associated with power generation are highly desirable. Biomass co-firing can likely play a major role in reducing the CO_2 emissions, and various biomass residues have been examined as raw materials for biomass pellets [7–11].

Indonesia, which contains brown coal mining areas, is considering increases in the use of biofuels; in particular, palm oil and empty fruit bunch of palm are becoming major energy resources. Cultivation of oil-bearing plants other than palm, such as *Jatropha*, and *Pongamia*, is also thriving, and fuel utilization of oil and oil-extracted residues has been studied. Indonesia is also the third largest producer of rice in the world [12]; it produces about 60 million tons of rice per year. The rice bran is removed during the rice milling process. Although some parts of the rice bran are used as livestock feed, additional supplies of rice bran are frequently available because this material accounts for 10% of the rice stock, i.e., 6 million tons per year. There is a certain amount of oil in the rice bran. According to an analysis by the acid decomposition method, the amount of oil in the rice bran was 22 g per 100 g of rice bran. Thus, mixing rice bran containing oil with brown coal during pelletization can supplement the calorific value of brown coal. The goal of

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our study is to assess the feasibility of using mixed pellets of brown coal and rice bran prepared in Indonesia during co-firing at domestic coal-fired power plants in Japan. Thus, it is necessary to identify the optimal mixing ratio of the molded pellets intended for use as fuel and to verify the pyrophoric and self-heating properties.

2. Experimental

2.1. Materials

As the base material for the mixed pellets, Pendopo brown coal found in Sumatra and rice bran harvested from West Java were sourced. The properties of Pendopo brown coal reported by PT Pendopo Energi Batubara are shown in Table 1, and the data were derived with the analysis methods recommended by the American Society for Testing and Materials (ASTM). As can be seen, the moisture level of Pendopo brown coal is high at 50% and the calorific value is low at 11.3 MJ/kg.

The procured brown coal and rice bran were mixed at predetermined weight ratios without any processing steps such as drying and pulverization, and then, the material was introduced to the pelletizer. Five sample mixtures were prepared by using the following ratios of brown coal to rice bran: 10:0, 8:2, 5:5, 2:8, and 0:10, in terms of weight on a dry basis. The water contents of each of these sample mixtures at the time of their preparation are listed in Table 2.

2.2. Pellet equipment

Pellets were produced by using a small-scale pellet manufacturing device (KP280, Kikukawa Co., Ltd., Japan) with a production capacity of 30 kg/h; this device is shown in Fig. 1. The device consists of a die and a compression roller with a large number of cylindrical stomas, and the charged material is pushed into a small hole (6.2 mm) with the compression roller and shaped into pellets. Although the pelletizer can use both the ring die and flat die methods, the flat die (diameter: 280 mm; thickness: 35 mm) method was employed in our experiment. The operating conditions were the same as those used for the production of wood pellets, i.e., a feeding rate of 20 kg/h. In general, each composite sample of about 5 kg was molded in 15 min in this experiment. Although moisture adjustment is very important in pellet production, water content was not controlled in this experiment to allow for the examination of the effects of reductions in the moisture content of brown coal through the addition of rice bran.

2.3. Pellet analysis

The heating value, the bulk density, the fines ratio, and the mechanical durability of the five molded pellets were measured. Further, the concentrations of water, ash, sulfur, nitrogen, and chlorine were analyzed. In this study, the brown coal mixed pellets were assumed to be used in thermal power plants and not for domestic use. Therefore, while the mixed pellets were not compared to the quality standards that conform to the EU pellet standards [13], an evaluation of their physical and chemical properties based on the wood pellet quality standards was carried out for reference.

Table 2
Water content of mixing materials.

	Brown coal:rice bran				
	10:0	8:2	5:5	2:8	0:10
Water content (%)	50.6	43.3	32.4	21.4	14.1

In order to evaluate the safety of storing and transporting pellets containing brown coal, the pyrophoric and self-heating properties of the mixed pellets were evaluated based on the dangerous goods shipping and transportation storage rules [14,15]. These tests are adequate for assessing the relative hazards of substances liable to spontaneous combust, and tests were executed at an official testing organization (Japan Marine Surveyors and Sworn Measurers' Association). Pyrophoric test was performed to determine if the solid will ignites within the regulation time of coming into contact with air. Moreover, an examination of the self-generation of heat was carried out by measuring the self-thermal capability.

3. Results and discussion

3.1. Moldability of the mixed pellet

Similar to the standard flow of woody biomass pellet production [16], it was possible to mold the pellets without humidification. However, depending on the mixing ratio of materials, the moldability of the pellets varied considerably. Although the pellets made from only rice bran were significantly inferior in terms of moldability, and also very fragile, the pellets consisting of brown coal showed excellent formability and appeared hard, as shown in Fig. 2; the mixed samples displayed better moldability than the rice bran only product. The scanning electron microscope (SEM) photographs and the particle size distributions of brown coal and rice bran were measured, and the results are shown in Fig. 3. The particle sizes were quite different for the two products. While the average particle size of the rice bran was 130 μm, the value for brown coal was only 5 μm, and thus, it consisted of fine particles. Note that dense and hard pellets were formed if the brown coal ratio was high, and fragile and easily collapsible pellets were formed if the rice bran ratio was high. However, since there were no major problems in terms of the moldability with the 20%-brown coal pellets, brown coal was believed to have acted as an effective binder.

3.2. Characteristics of the mixed pellet

The analyses results for the heating values, bulk densities, fine contents, mechanical durability, moisture levels, ash contents, and the contents of different elements (sulfur, nitrogen, chlorine) in the mixed pellets are summarized in Table 3.

The overall water content of the mixed pellets had been reduced slightly as compared to the values at the time of material mixing even

Table 1
Certificate of Pendopo brown coal.

Property	Measurement value			Test method
	As received basis	Air dried basis	Dried basis	
Total moisture (wt%)	49.92	–	–	ASTM D 3302M–12
Proximate analysis				
Inherent moisture (wt%)	–	16.81	–	ASTM D 3173–11
Ash content (wt%)	5.48	9.10	10.94	ASTM D 3174–12
Volatile matter (wt%)	26.75	44.43	53.41	ASTM D 3175–11
Fixed carbon (wt%)	17.86	29.66	35.65	ASTM D 3172–07a
Total sulfur (wt%)	0.11	0.19	0.23	ASTM D 4239–12
Gross calorific value (MJ/kg)	11.2	18.6	22.3	ASTM D 5865–12

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