วิศวกรรมสาร มข. ปีที่ 34 ฉบับที่ 4 (391 - 398) กรกฎาคม – สิงหาคม 2550 บทความวิจัย
KKU Engineering Journal Vol. 34 No .4 (391 - 398) July – August 2007

Production and Characterization of Rice Husk Based Charcoal Briquettes*

Jindaporn Jamradloedluk[1] and Songchai Wiriyaumpaiwong[2]
[1] Lecturer, Faculty of Engineering, Mahasarakham University. 44150
[2] Assistant Professor, Faculty of Engineering, Mahasarakham University. 44150

Email: wsongchai@yahoo.com

ABSTRACT

Utilization of agricultural residues and weeds as alternative materials for fossil fuel is of interest due to its environmental friendliness. The present study proposes production of rice husk based charcoals briquettes. Three different types of biomass viz. bagasse, rice straw, and water hyacinth were carbonized, crushed and sieved through screens to obtain the particle size of 150-750 μm. Each sieved biocoal was then well mixed with the rice husk charcoal at the mixing ratios between the rice husk charcoal and the other charcoal of 80:20, 60:40, 40:60, and 20:80. The mixtures were densified, using cassava starch as binding agent, via the cold extrusion process. The densified charcoals were finally sun dried. Physical and mechanical properties i.e., density, ultimate stress, and toughness of the mixed biocoal briquettes produced were examined and it was found that the mixing ratio had a significant effect on the physical and mechanical properties of the briquettes. Density, ultimate stress and toughness increased with increasing mixing ratio (rice husk charcoal quantity). The rice husk-bagasse charcoal briquette was found to possess the maximum density, ultimate stress and toughness followed by the rice husk-rice straw and the rice husk-water hyacinth charcoals briquettes. Flue gas temperature and CO, and NO contents were monitored and recorded during the combustion tests. The experimental results revealed that the flue gas temperature was maximized at the greatest proportion of the rice husk charcoal. The rice husk-bagasse briquette provided flue gas with maximum temperature followed by the rice husk-rice straw and the rice husk-water hyacinth briquttes. Investigation on CO and NO contents exhausted showed that they were not significantly affected by the mixing ratio.

Keywords : bagasse, biocoal, rice straw, water hyacinth

* Original manuscript submitted: January 12, 2007 and Final manuscript received: February 20, 2007

INTRODUCTION

Energy generated from biomass is categorized as sustainable and renewable energy. During the plant life cycle, plant biomass materials derived from plant adsorb carbon dioxide (CO_2) through photosynthesis at same rate as they released the gas in the combustion process, thus leading to no net increase in atmospheric CO_2 quantity. Due to the lower contents of sulfur and nitrogen in biomass, its application also creates less environmental pollution and health risk than fossil fuel combustion. This is the reason why utilization of biomass is eco-friendly. Since Thailand is a country which economic status is based on agricultural activity, crop residues i.e., rice straw, rice husk, bagasse, coconut shell, coconut fiber, and corn cob are hence abundant available. These agricultural wastes have been highly promoted to be used in various heating systems, during the past decades. Compared to fossil fuel, however, most of agricultural wastes have higher moisture content and lower density, thus making them technically unsuitable for direct use due to combustion and handling problems. Conversion of biomass wastes to briquettes is a solution for such problems. It improves biomass handling characteristics, increases the volumetric calorific values, and reduces transportation, collection, and storage costs (Grover and Mishra, 1996). Briquetting of non-pretreated agricultural wastes through the extrusion process has been extensively studied (Grover and Mishra, 1996; Chin and Siddiqui, 2000; Ndiema *et al*., 2002; Heinz *et al*., 1983; Husain *et al*., 2002). In addition to non-pretreated biomass, carbonized biomass is generally converted to a briquette form. Densification of rubber wood, corn cob (Medhiyanon *et al*., 2006), saw dust (Wiroonpun *et al*., 2005), rice husk (Maiti *et al*., 2006), cotton stalk (Onaji and Siemons, 1993) and hazelnut shell charcoals (Demirbas *et al*., 1999) were experimentally studied. It was stated that mechanical and physical properties of charcoal briquettes were influenced by several parameters viz. die pressure, dwell time, charcoal particle size and binder type and content. Different materials required different optimum conditions for the briquetting process. Recently, some researchers reported that durability and mechanical strength of the briquettes produced from only one type of biomass can be improved by blending that biomass with another biomass material (Wamukonya and Jenkins, 1995; Yaman *et al*., 2000; Demirbas and Sahin, 1998). However, most of research works focused on briquette derived from only one biomass material, information about the briquettes obtained from the blends of two biomass species is extremely limited.

This study is aimed at producing rice husk based charcoal briquettes prepared by blending rice husk charcoal with the other charcoals viz. bagasse, rice straw, and water hyacinth charcoals. Effect of mixing ratio between each pair of biomass materials on physical properties and combustion characteristics were also investigated.

MATERIALS AND METHODS

Raw materials

Crop residues including rice straw, rice husk, bagasse and water hyacinth are collected from cultivated areas in Mahasarakham province, Thailand.

Carbonization process

The four materials were sun dried and then pyrolysed in a furnace. Proximate analysis and heating values of the biomass charcoals obtained are presented in Table 1.

Biomass/ property	Heating value (cal/g)	%C	%H	%N	%S
Rice husk	4,401-5,771	35.9-36.6	2.36-2.42	0.41-0.45	0.08-0.16
Rice straw	5,105-5,966	49.4-51.8	3.43-3.64	0.77-0.82	0.17-0.19
Water hyacinth	4,069-5,265	23.5-24.2	2.08-2.13	0.70-0.73	0.32-0.38
Bagasse	5,407-6,951	65.3-66.4	3.53-3.78	0.35-0.40	0.13-0.22

Table 1. *Proximate analysis and calorific values of the biomass charcoals*

Briquetting process

The charcoals prepared were firstly milled and sieved through screens to obtain the particle size of 150-750 μm. Thereafter, three pairs of biomass species (rice husk : water hyacinth, rice husk : bagasse, and rice husk : rice straw) were well mixed at the mass mixing ratios of 20:80, 40:60, 60:40, and 80:20. The blends, with different mixing ratios, were then mixed with cassava paste, as binding agent, at the mixing ratio of 7:2 (charcoal : cassava paste). The agitating process was conducted in a heating mixer until the required condition for preparation of moulds was reached. The blends were then briquetted at ambient temperature in an extruder (see fig. 1), designed for the purpose. The densified charcoals obtained were finally sun dried. Final moisture contents of the fuels were 3.92-5.18% d.b.

Fig. 1 *Cold extruder used for densification of mixed charcoals*

Fig. 2 *Rice husk based charcoal briquettes*

Determination of bulk density

Density is an important property of the solid fuel. High density products are desirable in terms of transportation, storage and handling. The bulk density of the briquetted biomass charcoal prepared was determined by measuring dimensions and weighing of 5 samples. Weighing was performed by using an electronic balance (OHAUS, model ARB 120) and the dimension measurement was conducted by using a vernier caliper. Three samples were tested for each experiment and the average density was reported.

Compression test

The compressive strength is a criterion of briquette durability (Richard, 1990). The compressive strengths of the briquettes were determined using an Instron testing machine, according to ASTM D 2166-85. The flat surface of the briquette sample was placed on the horizontal metal plate of the machine. A 2 kN- load was applied at a constant rate of 0.5 mm/min until the briquette failed by cracking or breaking. Ten samples obtained from each experiment were tested and average ultimate stress and toughness derived from the stress-strain curves were analyzed.

Combustion test

To evaluate combustion characteristics, 100 g of briquettes produced were placed over the hearth of the household stove and the burning tests were carried out at the atmospheric condition. Flue gas temperature, CO and NO contents were recorded during the tests.

RESULTS AND DISCUSSION

Density

It has been stated that density of biomass briquettes depends on density of the original biomass (Demirbas and Sahin 1998). Densities of all mixed charcoal briquettes obtained are illustrated in Fig. 3. It was apparent that densities were in the range of 0.578-0.925 g/cm^3. Obviously, for all charcoal briquettes, bulk density increased as rice husk proportion increased. Comparison between each briquette indicated that rice husk-bagasse briquette had the highest density followed by rice husk-rice straw and rice husk-water hyacinth briquettes respectively.

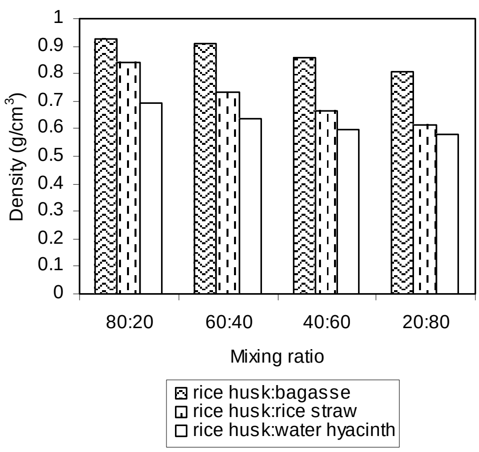

Fig. 3 *Density of different mixed charcoal briquettes with various mixing ratios*

Compressive characteristics

Variation of ultimate stress of the different rice husk based charcoals with various mixing ratios is presented in Fig. 4. Ultimate stress measured was 264-2,609 kN/m^2. The tendency of ultimate stress was similar to that of the density. That was probably because ultimate stress of material was related to its density. Material with higher density was more likely to possess higher ultimate stress than that with lower density. As seen in Fig. 4, rice husk-bagasse briquetted charcoal had the highest density followed by rice husk-rice straw and rice husk-water hyacinth briquetted charcoals respectively. It was also found from the figure that ultimate stress increased with increasing rice husk charcoal contents. It is generally accepted that silica is a chemical component of rice husk and it can be converted to silicate, a high strength compound, through the oxidation reaction. Silicate is a material with high strength. Silicate in rice husk charcoal caused the high ultimate stress of the briquette.

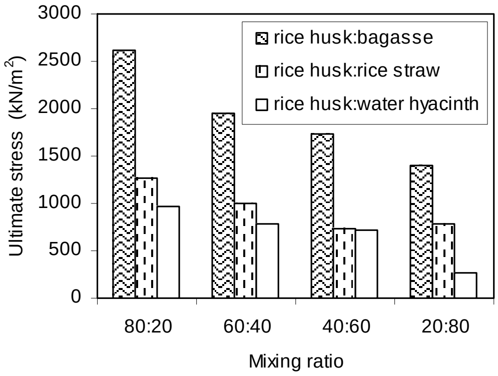

Fig. 4 *Ultimate stress of different charcoal briquettes with various mixing ratios*

Toughness, defined as total area under stress-strain curve, is another important mechanical property. It indicates ability of a material to absorb energy up to fracture. For a material to be tough, it must display both strength and ductility (percent elongation at fracture); often, ductile materials are tougher than brittle ones [12]. The effect of mixing ratio on toughness of the briquettes is illustrated in Fig. 5. As shown in the figure, toughness was in the range of 214-1,925 kN/m^2. Toughness values of all rice husk based coal briquette were maximized at the mixing ratio of 80:20.

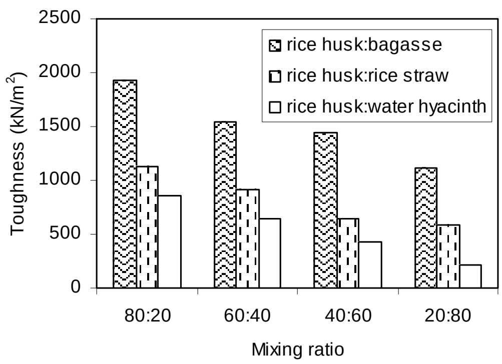

Fig. 5 *Toughness of different charcoal briquettes with various mixing ratios*

Combustion characteristics

Carbon monoxide and nitrogen monoxide contents and the flue gas temperature were monitored during the burning test. Their average values are summarized in Table 2. It was clearly seen that the briquettes with greater amount of rice husk provided the higher average flue gas temperature than those with less amount of rice husk. However, CO contents produced from each briquetted charcoal were not influenced by the quantity of rice husk as pronouncedly as the flue gas temperature. That is to say the CO contents reported were not significantly different. Similarly, NO contents emitted from each briquette sample were not significantly different and they were at the acceptable level.

Mixing ratio	Maximum Temperature (^oC)	Average Temperature (^oC)	Average CO content (ppm)	Average NO content (ppm)
Rice husk:bagasse				
80:20	166.0	115.3	2,616	5.4
60:40	134.3	100.8	2,337	1.9
40:60	129.6	101.5	2,240	5.0
20:80	121.2	85.5	2,080	1.6
Rice husk:rice straw				
80:20	135.8	96.9	2,821	10.2
60:40	112.2	85.0	2,544	6.7
40:60	108.9	81.6	2,247	10.5
20:80	103.7	78.1	1,833	13.1
Rice husk:water hyacinth				
80:20	126.0	91.8	2,497	8.2
60:40	113.0	79.4	2,124	12.0
40:60	112.2	77.8	2,355	17.5
20:80	99.2	72.4	2,051	23.6

Table 2. *Characteristics of flue gases produced from burning different briquetted rice husk based charcoals*

Kinetics of temperature of the flue gases released from burning rice husk-bagasse charcoal briquette are depicted in Fig. 6. It showed that the temperature rapidly increased to the maximum value at the burning time of approximately 5 minutes and then it slowly decreased with time. Kinetics of temperature of the flue gases emitted from burning other charcoal briquettes was similar to that of rice husk-bagasse charcoal briquette.

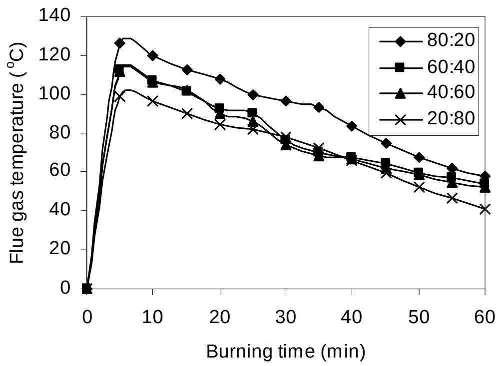

Fig. 6 *Temperatures of the flue gas obtained by burning rice husk-bagasse charcoal briquette*

CONCLUSIONS

Charcoals of rice husk, rice straw, bagasse and water hyacinth were used to produce rice husk based charcoals briquettes. Effects of the mixing ratio between rice husk and the other biomass coal on density, ultimate stress, toughness, CO and NO contents, and flue gas temperature was reported. The mixing ratio was found to significantly affect the physical properties and compression characteristics. Bulk density, ultimate stress and toughness increased with the increase of rice husk charcoal quantity. Combustion test showed that flue gas temperature was maximized at the greatest rice husk proportion, for all briquettes. However, effects of the mixing ratio on the CO and NO quantities were not as pronounced as on the compression parameter.

ACKNOWLEDGEMENTS

The authors express their sincere gratitude to the Faculty of Engineering, Mahasarakham University for financial support. Thanks are due to Mr. Nathapol Chinon and Mr. Prasit Phomnopat for collecting all experimental data.

REFERENCES

Grover P.D. and Mishra S.K. 1996. "Biomass Briquetting Technology and Practices." **Food and Agriculture Organization (FAO)**, UN, Document No. 46.

Chin O.C. and Siddiqui K.M. 2000. "Characteristics of Some Biomass Briquettes Prepared under Modest Die Pressures." **Biomass and Bioenergy.** 18: 223-228.

Ndiema C.K.W., Manga P.N. and Ruttoh C.R. 2002. "Densification Characteristics of Rice Straw Briquettes." **Journal of the Institute of Energy.** 75: 11-13.

Heinz J.K.K., Siemers W. and Stuven U. 1983. "Technical and Economic Assessment of Charcoal and Densified Fuel from Water Hyacinths and Cotton Stalks." **Fuel Processing Technology.** 7: 23-42.

Husain Z., Zainac Z. and Abdullah Z. 2002. "Briquetting of Palm Fibre and Shell from the Processing of Palm Nuts to Palm Oil." **Biomass and Bioenergy.** 22: 505-509.

Wamukonya L. and Jenkins B. 1995. "Durability and Relaxation of Sawdust and Wheat-Straw Briquettes as Possible Fuels for Kenya." **Biomass and Bioenergy.** 8: 175-179.

Demirbas A. and Sahin A. 1998. "Evaluation of Biomass Residue 1. Briquetting Waste Paper and Wheat Straw Mixtures." **Fuel Processing Technology.** 55: 175-183.

Yaman S., Sahan M., Haykiri-Acma H., Sesen K., and Kucukbayrak S. 2000. "Production of Fuel Briquettes form Olive Refuse and Paper Mill Waste." **Fuel Processing Technology.** 68: 23-31.

Richard S.R. 1990. "Briquetting Peat and Peat-Coal Mixtures." **Fuel Processing Technology.** 25: 175-190.

ASTM Annual Book of ASTM Standards. 1981. **Standard Test Method for Unconfined Compressive Strength of Cohesive Soil**. ASTM D2166-85, 1981.

William D. Callister Jr. 2003. **Materials Science and Engineering An Introduction**, John Wiley & Sons, Inc.: USA.

Onaji P.B. and Siemons R.V. 1993. "Production of Charcoal Briquettes from Cotton Stalks in Malawi: Methodology for Feasibility Studies using Experiences in Sudan." **Biomass and Bioenergy.** 4: 199-211.

Medhiyanon T., Sathitruangsak P., Sungworagan, S., and Soponronnarit S. 2006. "Solid Fuel Producing from Rubber Wood Char and Corn-Cob Char by Extrusion Technique Using

Paste as Binder" In proceeding of **the 20th Conference of Mechanical Engineering Network of Thailand**, October 18-20, 2006, Nakhonrajasima.