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Physical properties characterization of fuel briquette made from spent bleaching earth

Sri Suhartini [a,*], *Nur Hidayat* [a], *Sieni Wijaya* [b]

[a] *Department of Agricultural Industry Technology, Faculty of Agricultural Technology, University of Brawijaya, Jl. Veteran 1, Malang, East Java 65145, Indonesia*

[b] *Alumni of Department of Agricultural Industry Technology, Faculty of Agricultural Technology, University of Brawijaya, Jl. Veteran 1, Malang, East Java 65145, Indonesia*

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ABSTRACT

Cooking oil industry in Indonesia produces a massive amount of solid waste, called Spent Bleaching Earth (SBE). Briquetting of this waste can be a good alternative to achieve zero-waste, as well as minimizing energy cost, in this industry. Therefore, the valorization of SBE as briquette was studied using different pressure and maltodextrin dosage. The results show that the physical characteristics of SBE briquette were similar to that of standard value for the wood briquette (Indonesian National Standard or SNI 1-6235-2000).

1. Introduction

The global energy consumption increased sharply and is predicted to continuously boost for the next 50 years, caused by the industrialization growth both in developed and developing countries [1]. Indonesia, as a developing country, has vast potential resources for renewable energy, of which only a small portion has been utilized [2]. For example, agricultural and agro-industrial waste which is gradually increasing due to more agricultural production. Currently, biomass is the only clean renewable energy source that can help to significantly diversify fuels throughout the world.

Briquette is a means to convert biomass residues through simple technology that is inexpensive and suitable to be managed by small communities or private firms [3]. Previously, the study of briquetting conducted with wheat straw [4] and agricultural residues such as mustard stalk, maize stalk, and groundnut shells [5]. In Malaysia, palm oil residues, such as shell and fiber, were transformed into briquettes with a gross calorific value of 16.4 MJ kg^{-1}, the ash content of 6%, and the moisture content of 12% [6].

Recently, many studies have been conducted on the production of fuel briquettes from industrial waste. For instance, briquettes from waste paper and coconut husk which had moisture content from 5.4% to 13.3% [7], rice straw and rice bran were feasible to be converted into solid biomass fuel using a hot-pressing temperature [8], pelletized waste (including refuse derived fuel or RDF, wood and paper)

* *Corresponding author*. Tel.: +62 81233118508.
E-mail address: sri_suhartini04@yahoo.com (S. Suhartini).
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compared to coal has a prospective for coal replacement in vertical gasifier system [9], by-product of coke manufacture (coke breeze) usingthe blend of novalac and resol as binder [10], Eucalyptus wood and rice husk from Uruguay as an activated carbon briquettes [11]. Furthermore, waste paper can be converted into briquette as a partial binder material alone or mixed with wheat straw [12,13], as well as the briquettes from cotton plant residues [14], hazelnut shells using 800 MPa pressure and 400 K [15], and sunflower stalk which had a high percentage of ash and 67% efficiency [16].

Spent bleaching earth (SBE) is the residual adsorbent resulted from the refining process of crude palm oil (CPO) in the cooking oil industry and categorized as solid waste. Bleaching earth residue is basically the mixture of fresh bleaching earth and CPO's hydrocarbon component. Hydrocarbon component is transformed into coke or charcoal. SBE waste has become a major problem facing the cooking oil industry as a consequence of its growth [17]. Furthermore, about 0.5–1% of bleaching earth (BE) is consumed to produce 60 million tonne of cooking oil, which all of BE will convert into waste (SBE waste). It is predicted that the production of SBE waste around the world is 600,000 tonne [18].

Indeed, SBE has high calorific value and has the potential as fuel in steam machine, or sold as inexpensive fuel. Although SBE waste has a high calorific value, currently; it is only used as fertilizer. Preparing biomass briquettes from SBE has not been investigated.

In this study, the effects of various maltodextrin dosage and pressures on the physical properties of SBE briquettes (i.e. product yield, water content, burning rate, combustion ashes, caloric value, and compressive strength) were investigated and compared to the that of properties of the wood charcoal standard. In a previous study [19] briquettes were found to have higher compressive strength by the addition of dextrin at level of 561 kg briquette^{-1}. Another study found that one of the factors that prominently influenced the physical characteristics of the briquettes is the pressure applied in briquetting [20].

2. Experimental details

2.1. The raw material collection and characterization

SBE waste was collected from the cooking oil industry in Surabaya, Indonesia. The values of SBE waste characteristics are presented in Table 1.

2.2. The process of SBE waste briquetting

A home-made mold was designed and built to make SBE briquette, with the diameter of 8 cm, the center hole diameter of 2 cm and height of 5 cm (Fig. 1). The procedure to prepare the SBE briquette is as follows (Fig. 2): (1) the maltodextrin was diluted to 1:10 (w v^{-1}) and evaporated until the temperature of 70 °C; (2) SBE waste was weighted using a balance and mixed with the maltodextrin liquid using different dosage; (3) the mixture was stirred; (4) the left and right part of mold were assembled; (5) the mixture

Table 1 – Characteristics of SBE waste.

Characteristics	Value
Calorific value	7.28 MJ kg^{-1}
Moisture content	16% [17]
Ash	52.3–58.6%

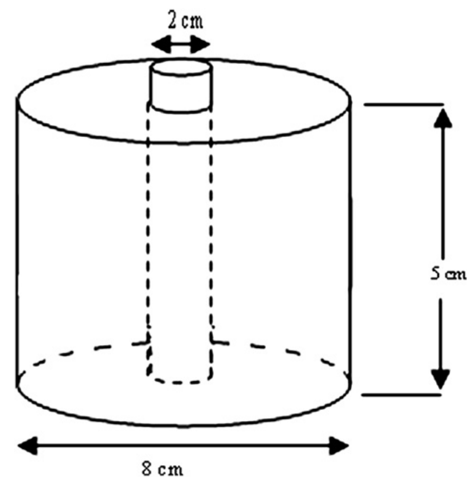

Fig. 1 – SBE briquette mold.

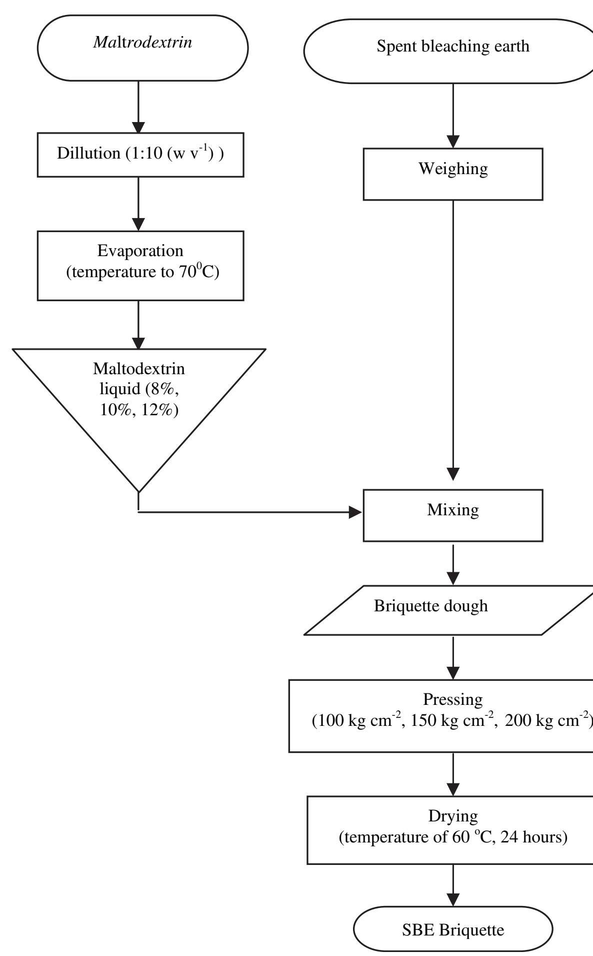

Fig. 2 – The procedure of SBE briquetting.

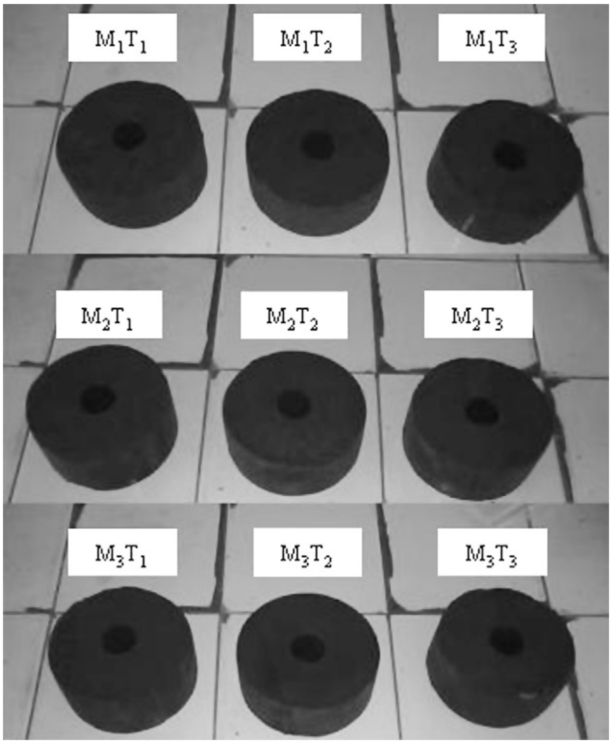

Fig. 3 – SBE briquette.

was then fed into the center of the mold and placed in the space between the upper plate and the lower plate of the hydraulic press machine (type NSP-15); (6) the contents in the mold were pressurized into a SBE briquette; (7) the SBE briquette was taken away from the mold and dried in the oven for 24 h at temperature of 60 °C.

2.3. *Experimental design*

The use of experimental Complete Random Device Factorial with two treatments at three levels and three replications was used to study the main and interaction effects of the factors on the production of briquette from SBE waste. The first factor treatment was maltrodextrin dosage at level of 8%, 10%, and 12%. Then, the next factor was pressure consisted of 100 kg cm^{-2}, 150 kg cm^{-2}, and 200 kg cm^{-2}.

3. Results and discussion

3.1. *Physical properties of SBE briquette*

The product was basically a cylindrical solid fuel (Fig. 3) for all test specimens and having different value for every parameters on physical properties (see Table 2). From this table, it can be seen that all treatments have an accepted water content value compared to SNI standard value.

For a given maltodextrin dosage, as pressure increased, the moisture content of the SBE briquette decreased (Fig. 4a). This result was influenced by the moisture content of maltodextrin (7.85%), which was higher than that of SBE waste (4.96%). The test indicated that the maltodextrin dosage of 12% had a higher moisture content compared to the other two.

In Fig. 4b, as maltodextrin dosage and pressure increased, the compressive strength of the SBE briquette increased, except at the maltodextrin level of 12%. At this level, with a pressure of 200 kg cm^{-2}, the value of the compressive strength decreased, with the decline being somewhat less at a lower maltodextrin level. The results also indicated that maltodextrin dosage at a level of 10% at the given pressure had a high compressive strength value. In the study of briqueting the olive oil refuse [21], resulted that as the briquetting pressure increased, the briquette's compressive strength increased.

The lowest maltodextrin dosage, at the given pressure, was the highest product yield. This result indicated that at a fixed pressure, the effect of the maltodextrin dosage on the product yield is obvious. For instance, at a fixed pressure of 100 kg cm^{-2}, as the maltodextrin dosage increases from 8% (test M_1T_1) to 12% (test M_3T_1), the product yield slightly decreases from 96.51% to 92.60%, respectively (Fig. 4c).

The combustion rate of the SBE briquette was approximately 0.12 g min^{-1} to 0.22 g min^{-1}. The highest combustion rate was achieved from the treatment of maltodextrin dosage (8%) and pressure of 150 kg cm^{-2}, while the lowest were at a maltodextrin dosage of 10% and pressure of 150 kg cm^{-2} and 200 kg cm^{-2} (Fig. 4d). Furthermore, based on ANOVA analysis, it was demonstrated that the interaction between maltodextrin dosage and pressure significantly influenced ($\alpha = 5\%$) the combustion rate of the SBE briquette. The increase of pressure of briquetting process increases the density of briquettes [22,23] which reduces the combustion rate [24].

Table 2 – The physical properties of SBE briquettes and the SNI standard of the wood charcoal briquettes.

Parameters	Treatment									SNI standard value
	M_1T_1	M_1T_2	M_1T_3	M_2T_1	M_2T_2	M_2T_3	M_3T_1	M_3T_2	M_3T_3	
Product yield (%)	96.51	96.85[b]	95.48	92.9	94.21	93.37	92.69	94.19	92.60	–
Water content (%)	4.08[a]	3.95[b]	5.57[a]	6.66[a]	5.88[a]	5.22[a]	7.24[a]	7.01[a]	5.31[a]	≤8
Combustion rate (g min^{-1})	0.14	0.22[b]	0.13	0.16	0.12	0.12	0.16	0.16	0.14	–
Combustion ashes (%)	35.67	37.33	37	34.33[b]	38.00	35.67	40.00	35.67	37.33	–
Calorific value (MJ kg^{-1})	9.66	9.62	10.22	10.96[b]	9.22	9.29	9.39	9.19	9.89	≥20.93
Compressive strength value (kg cm^{-2})	9.57	10.19	10.19	11.86	12.41	13.24[b]	8.32	10.75	10.33	–

a Allowed value by SNI [1].
b Selected from the treatment.

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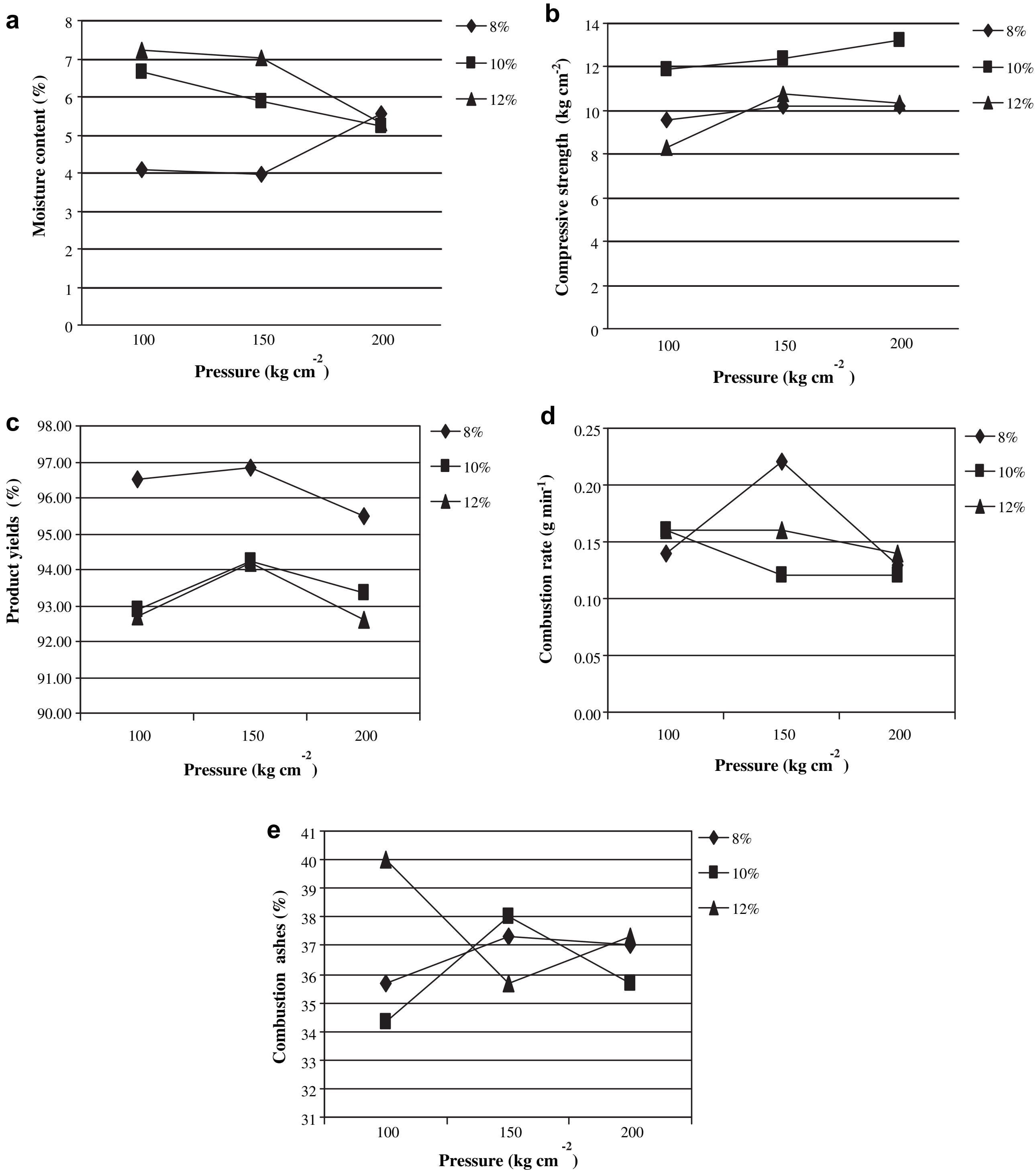

Fig. 4 – Physical properties of SBE briquettes: (a) moisture content, (b) compressive strength, (c) product yields, (d) combustion rate, and (e) combustion ashes.

The results for the combustion ashes were varied, from 34.33% to 40% (Fig. 4e). For instance, at fixed pressure of 100 kg cm^{-2}, as the maltodextrin dosage increases from 8% (test M_1) to 12% (test M_3), the combustion ashes of the SBE briquettes raises from 35.67% to 40%. While, at fixed pressure of 150 kg cm^{-2}, the combustion ashes decreased as the maltodextrin dosage increased. On the other hand, at a fixed pressure of 200 kg cm^{-2}, the combustion ashes remained the same at 8% and 12% of maltodextrin and decreased at the level of 10% maltodextrin dosage. However, the ANOVA analysis results showed that the variation in maltodextrin dosage or pressure and its interaction had no effect on the combustion ashes of SBE briquette.

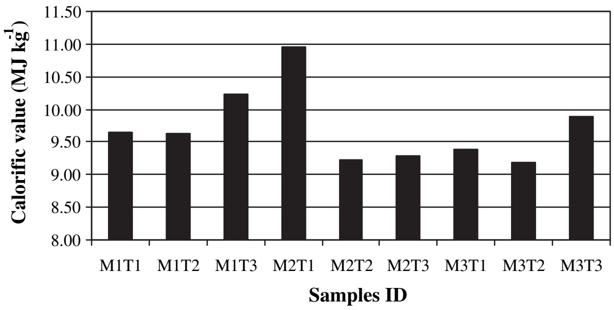

Fig. 5 – Calorific value of SBE briquettes.

3.2. *Calorific value of SBE briquette*

The calorific value of the SBE briquette was between 9.18 MJ kg^{-1} and 10.96 MJ kg^{-1} (Fig. 5). The ANOVA analysis showed that the maltodextrin dosage, pressure and interaction between both factors were not significantly influenced the calorific value with almost having the same value. Similarly, two different studies has demonstrated that the increase of binder concentration [25] andcompaction pressure [26] did not significantly influence the calorific value of the final product. Moreover, different work has showed that the calorific value of fuel briquettes increased as the temperature increased because the volatile matter and moisture content were removed from the briquette while the fixed carbon concentration had increased [27].

Indeed, the calorific value of the SBE briquette was higher than that of the SBE waste (7.28 MJ kg^{-1}). This improvement was caused by the addition of maltodextrin, which has a high calorific value and accounted for 14.44 MJ kg^{-1}. However, such an addition did not significantly increase the calorific value of the SBE briquette, since there was a dilution treatment of maltodextrin which may reduce the primary calorific value.

3.3. *The selection of the closer calorific value to the SNI standard*

In Indonesia, according to SNI standard, the wood charcoal briquettes have a maximum moisture content of 8% and a minimum calorific value of 20.93 MJ kg^{-1}. It is clear that calorific value is a major quality index for fuels. Compared with SNI standard for wood charcoal briquette (see Table 2), the test M_2T_1 was selected as the treatment with the most beneficial characteristic as a renewable energy resource, as it had a closer calorific value to the SNI standard of wood charcoal briquettes. The research result showed that this specimen has the highest calorific value (10.96 MJ kg^{-1}) and less moisture content (6.66%).

4. Conclusion

The present work examined the effects of maltrodextrin dosage and pressure on the physical properties of the SBE briquette. It was found that all these variables significantly affected water content, combustion rate, compressive strength and product yield. However, there were no significant effects for calorific value and combustion ashes. Among the treatments, the addition of 10% maltodextrin at a pressure of 100 kg cm^{-2} had the highest calorific value, and the same characteristics value compared with SNI 1-6235-2000 (standard value for the wood briquette). Thus, the SBE waste is feasible for feedstock in briquetting.

REFERENCES

[1] Goswam DY, Kreith F. Global energy system. In: Kreith F, Goswami D, editors. Handbook of energy efficiency and renewable energy. Florida: Taylor& Francis Group, LLC; 2007. p. 1–20.
[2] Hermawan, Hadi SP. Existing sustainable (Renewable) energy system in Indonesia. The 2nd Joint International Conference on Sustainable Energy and Environment (SEE 2006), Bangkok, Thailand, 2006.
[3] Badan Pengkajian dan Penerapan Teknologi (The Agency for the Assessment and Application Technology). Briket batubara sebagai alternatif pengganti minyak tanah [Charcoal as an alternative fuel. 2007], http://www.ristek.go.id; 25 November 2009 [Indonesian].
[4] Smith I, Probert S, Stokes R, Hansford R. The briquetting of wheat straw. J Agric Eng Res 1977;22:105–11.
[5] Tripathi AK, Iyer PVR, Kandpal TC. A techno-economic evaluation of biomass briquetting in India. Biomass Bioenerg 1998;14(5–6):479–88.
[6] Husain Z, Zainac Z, Abdullah Z. Briquetting of palm fibre and shell from the processing of palm nuts to palm oil. Biomass Bioenerg 2002;22:505–9.
[7] Olorunnisola A. Production of fuel briquettes from waste paper and coconut husk admixtures. Agric Eng Int CIGR Ejournal 2007;9:1–11.
[8] Chou CS, Lin SH, Lu WC. Preparation and characterization of solid biomass fuel made from rice straw and rice bran. Fuel Process Technol 2009;90:980–7.
[9] Marsh R, Griffiths AJ, Williams KP. Measurement of heat transfer and change in compressive strength of waste derived solid fuels due to devolatisation. Fuel 2008;87:1724–33.
[10] Benk A, Talu M, Coban AP. Phenolic resin binder for the production of metallurgical quality briquettes from coke breeze: part I. Fuel Process Technol 2008;89:28–37.
[11] Amaya A, Medero N, Tancredi N, Silva H, Deiana C. Activated carbon briquettes from biomass materials. Bioresour Technol 2007;98:1635–41.
[12] Demirbaş A. Physical properties of briquettes from waste paper and wheat straw mixtures. Energy Convers Manag 1999;40:437–45.
[13] Demirbaş A, Şahin A. Short communication: evaluation of biomass residue 1. briquetting waste paper and wheat straw mixtures. Fuel Process Technol 1998;55:175–83.
[14] Coates W. Using cotton plant residue to produce briquettes. Biomass Bioenerg 2000;18:201–8.
[15] Demirbaş A. Properties of charcoal derived from hazelnut shell and the production of briquettes using pyrolytic oil. Energy 1999;24:141–50.
[16] Smith GM, Lindle JA. An evaluation of two sunflower residue fuels. Biomass 1988;17:215–24.
[17] Seng CE, Lee CG, Liew KY. Adsorption of chromium (VI) and nickel (II) ions on acid- and heat- activated deoiled spent bleaching clay. JAOCS 2001;78(8):831–5.
[18] Ng KF, Nair NK, Liew KY, Noor AM. Surface and poor structure of deoiled acid- and heat- treated spent bleaching clays. JAOCS 1997;74(8):963–9.

[19] Ozbayoglu G, Kejhanak RT. Briquetting of Iran- angouran smithsonite fines. Physicochem Probl Miner Process 2003;37: 115–22.
[20] Ndiema CKW, Manga PN, Ruttoh CR. Influence of die pressure on relaxation characteristics of briquetted biomass. Energy Convers Manag 2002;43:2157–61.
[21] Yaman S, Şahan M, Haykiri-açma H, Şeşen K, Küçükbayrak S. Production of fuel briquettes from olive refuse and paper mill waste. Fuel Process Technol 2000;68:23–31.
[22] Wilaipon P. The effects of briquetting pressure on banana-peel briquette and the banana waste in northern Thailand. Am J Appl Sci 2009;6(1):167–71.
[23] Chin OC, Siddiqui KM. Characteristics of some biomass briquettes prepared under modest die pressures. Biomass Bioenergy 2000;18(3):223–8.
[24] Demirbaş A, Sahin-Demirbaş A, Demirbaş AH. Briquetting properties of biomass waste materials. Energ Sources 2004; 26(1):83–91.
[25] Sotannde OA, Oluyege AO, Abah GB. Research paper: physical and combustion properties of briquettes from sawdust of *Azadirachta indica*. J For Res 2010;21(1): 63–7.
[26] Faizal HM, Latiff ZA, Wahid MA, Darus AN. Physical and combustion characteristics of biomass residues from palm oil mills. The 8th WSEAS International Conference on Heat Transfer, Thermal Engineering and Environment (HTE '10) Taipei, Taiwan, 2010, pp. 34–38.
[27] Debdoubi A, Amarti AE, Colacio E. Production of fuel briquettes from esparto partially pyrolyzed. Energy Convers Manag 2005;46:1877–84.

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