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Physical Characteristics of Maize Cob Briquette under Moderate Die Pressure

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Abstract: The potential energy content of maize cob available in Thailand was calculated based on maize productivity, the residue-to-product ratio and the heating value of maize cob. It was found that the computed value was about 74.2 PJ/year. Besides, the potential energy value exceed 1,000 TJ/year was also reported for the case of five provinces of Thailand. Concerning with maize cob briquette, the effect of molasses binder ratio and briquetting pressure on briquette density was experimentally investigated. It was found that the density of the briquettes was strongly influenced by the two factors. Moreover, a relationship between these factors over the studied range was also developed and validated. Thermogravimetric investigation was also carried out. The results showed that the maximum mass loss of maize cob occurred at the temperature of about 353°C. Finally, according to the ultimate analysis of the material, it was found that the maize cob used in the experiment is comprised of 40.50% carbon, 5.68% hydrogen and 0.37% hydrogen, respectively.

Keywords: Agricultural waste, agricultural residues, biomass densification

INTRODUCTION

One of the most important energy sources for mankind is biomass which is referred to all organic materials particularly wood and agricultural residues. It accounts for approximately 14% of total energy consumption in the world[1]. According to the world's energy topics, it is widely accepted that fossil fuel shortage, fuel increasing price, global warming including other environmental problems are critical issues. Therefore, biomass energy has been attracting attention as an energy source since zero net carbon dioxide accumulation in the atmosphere from biomass production and utilization can be achieved. The carbon dioxide released during combustion process is compensated by the carbon dioxide consumption in photosynthesis.

Among several kinds of biomass, agricultural residues have become one of most promising choices. They are available as a free or almost free, indigenous, environmentally friendly and abundant energy source. Some agricultural wastes such as woodchips can be directly utilized as fuels. Nevertheless, the majority of them are not suitable to be utilized as fuel without an appropriate process since they are bulky, uneven and have low energy density. These characteristics make this kind of waste difficult to handle, store, transport and utilize. One of the promising solutions to these problems is the briquetting technology. The technology may be defined as a densification process for improving the handling characteristics of raw material and enhancing the volumetric calorific value of the biomass. Considerable amount of research on briquetting technology has been conducted. Examples of biomass studied are wheat straw[2-3], hazelnut shell[4], olive refuse[5], banana peel[6-7] as well as rice straw and husk[8].

Fuel briquettes produced under different conditions have been reported to have different handling characteristics. Besides, these characteristics are also found to be strongly affected by raw material properties. Briquette density is one of the most important properties which bear on the combustion characteristics, handling characteristics including the ignition behavior of briquettes. This property depends on several factors therefore, it is crucial to understand the effects of these factors on briquette density. Among the factors, die pressure seems to be one of the most important ones. The correlations of briquette density as a function of die pressure for the briquettes produced from several kinds of agricultural residues were studied[9]. Another relationship between die pressure and the density was also purposed for the case of palm fiber and palm shell briquettes[10].

In this study, the amount of potential energy from maize cob in Thailand was studied. In order to

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understand the properties of this raw material, several tests had been conducted. Constituents of the maize cob were investigated by using ultimate analysis technique. Thermogravimetric investigation was carried out in order to understand the mass loss rate of the maize cob as it is being heated at a uniform rate. Moreover, the heating value of the material was also studied. With regard to the briquette density, the effect of moderate die pressure and binder ratio on the density of maize cob briquettes was investigated. Finally, by using regression method, a relationship between briquette density, applied pressure and binder ratio was also purposed and validated.

MATERIALS AND METHODS

Maize cob study: Since Thailand is an agricultural based country, it is generally agreed that agriculture is a crucial part of the economy of the country. Apart from the agricultural products, considerable amounts of agricultural residues have been generated every year. In order to calculate the amount of maize cob generated in Thailand, the residue to product ratio (RPR) of maize cob and the maize productivity of Thailand were used for the calculation purpose. An RPR of 0.273 was used in this study[11]. The calculation was based on the maize productivity of Thailand in 2004[12].

For computing the amount of potential energy from maize cob, the net heating value of the material was investigated according to ASTM E711-87 method[13]. The maize cob used in this study was gathered from a local factory in Northern Thailand during summer of 2006. With regard to the apparatus, the calorimeter used was Parr isoperibol bomb calorimeter with an accuracy of 0.0001°C. The moisture content of the material utilized in the briquetting process was also investigated according to ASAE S269.4[14].

The ultimate analysis of the material on dry basis was also carried out in accordance with ASTM D5373-02[15] and ASTM D5291-02[16]. An elemental analyzer was used for this purpose. In addition, according to ASTM E1131-03[17], thermogravimetric test of the maize cob was conducted using a thermal gravity analyzer, Perkin Elmer. The temperature rang of the TGA was from room temperature to 900°C with an accuracy of ± 2°C. The accuracy of the balance of the TGA was 0.1%. The temperature studied was increased from room temperature to 850°C with a heating rate of 20°C/min.

Briquetting: The material was air dried and then cut into small pieces. Then, the sample was sieved in order to remove particles larger than 3 mm before use. A sieve with an accuracy of ± 0.025 mm was used for this purpose. In this study, molasses was utilized as the binder at four levels ratio viz. 10%, 20%, 30% and 40% on the weight basis. A digital balance, with an accurate of ± 0.001 g, was used in this process. After that, by utilizing a mixer, the blending process was carried out until it reached the required condition for making moulds. For each sample, 100 g of the mixture was briquetted at ambient temperature by using a calibrated laboratory-scale hydraulic press. Pressure of the hydraulic machine used in the study was controlled by a pressure switch. The accuracy of the pressure switch was 1% with a maximum pressure of 34 MPa. A hardened steel cylindrical mould with an inner diameter of 38 mm and a height of 250 mm was used as a die to produce briquettes. After feeding the mixture into the die, pressure was applied until it reached the desired value with a dwell time of 10 s. Three ultimate pressures viz. 3, 6 and 9 MPa were applied to the samples. In this study, five briquettes were prepared for each set of the experimental conditions.

Model and validation: Least-squares technique was used for developing an empirical model of maize cob density over the studied range. Normal probability plot of the residuals was used for checking the normal distribution of the residuals. Then, the multiple correlation coefficient; R^2, the adjusted coefficient of determination; R^2_{adjust}, and the coefficient of multiple determination for prediction; $R^2_{prediction}$ were used as criteria for model adequacy checking.

RESULTS AND DISCUSSION

Potential energy: By using the residual to product ratio of maize cob and maize cob productivity of Thailand, the amount of maize cob generated in the country was calculated. The production of maize was 5.26 Mt in 2004[12]. According to the heating value investigation, the result showed that the net heating value of the maize cob was 14.1 MJ/kg. Therefore, the estimated potential energy of maize cob in Thailand was found to be 74.20 PJ/year. However, maize cob is not available in all parts of Thailand since maize plantation depends on the regional climate and conditions. Figure 1 shows the calculated potential energy of maize cob available in each province of Thailand. As can be seen from the figure, there are five provinces with the energy content of maize cob exceed 1,000 TJ/year. Moreover, the numbers of the area which have the potential energy source ranging from 500 to 1,000 TJ/year are reported to be ten provinces. The energy content of these 15 provinces together accounted for approximately 85% of the energy content of the maize cob available in the country.

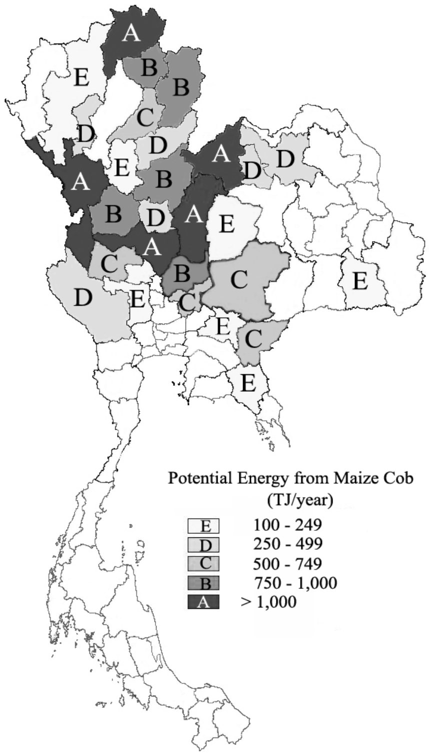

Fig. 1: Potential energy of maize cob in Thailand

Maize cob properties: The ultimate analysis results showed that the maize cob is comprised of 40.50% carbon, 5.68% hydrogen and 0.37% hydrogen. Also, it was found that the moisture content of the samples was about 15.2%.

Figure 2 shows the mass loss profile of the maize cob used in the experiments as the temperature increased. As can be seen from the graph, the mass loss rate can be categorized into three main sections viz. moisture loss, rapid mass loss and slow mass loss sections. These three sections were separated at the temperature of about 160°C and 400°C, respectively. The peak of the graph represents a rapid loss in mass of the material. This may be because of the release of some volatile matters. The maximum rate of mass loss was approximately 13.35%/min at 353°C. Approximately 55% of the mass loss of material occurred in this section.

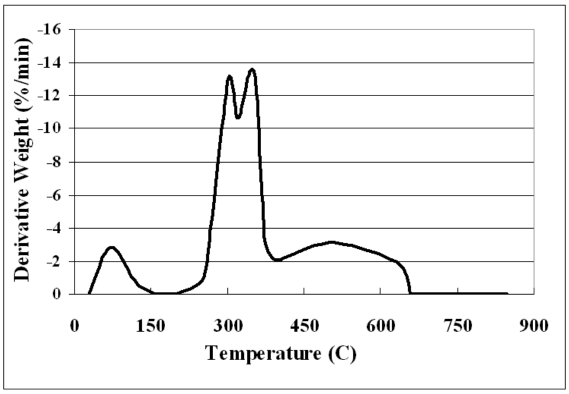

Fig. 2: Mass loss rate of the maize cob from the thermogravimetric analysis

Density model and validation: The relationship between density, briquetting pressure as well as binder ratio over the studied range was developed by using least-squares technique. The purposed relationship is valid for briquetting pressure ranging from 3-9 MPa and molasses binder ratio ranging from 10-40%.

$$D = 87.71 + 689.13P + 54.58B - 35.26P^2 - 6.93BP + 0.346BP^2 - 0.232B^2$$

where D: density (kg/m^3), P: briquetting pressure (MPa) and B: binder ratio (%).

For model adequacy investigation purpose, the multiple correlation coefficient; R^2, the adjusted coefficient of determination; R^2_{adjust}, and the coefficient of multiple determination for prediction; $R^2_{prediction}$ were used as criteria for model adequacy checking. The calculated values of R^2, R^2_{adjust} and $R^2_{prediction}$ are 99.6, 99.5 and 99.5% respectively. The first two values indicate that the model was not over fitted while the last criterion gives the indication of the predictive capability of the regression equation. Finally, in order to check the distribution of the residuals, a normal probability plot was plotted. The ranked residuals were plotted against the expected normal value as shown in Fig. 3.

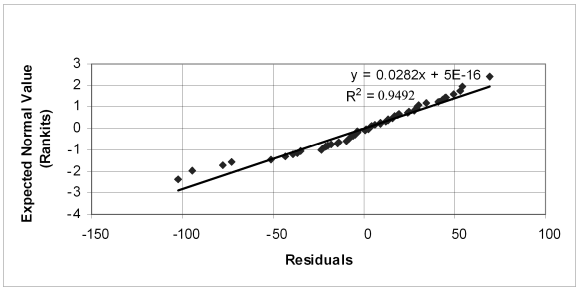

Fig. 3: The normal probability plot of residuals

CONCLUSION

Maize cob was found to be one of the most promising biomass energy sources of Thailand. The calculated energy content of such an agricultural residue was about 74.2 PJ/year. Nevertheless, maize cob is not available in all part of the country. Therefore, concerning with the transportation cost, only some provinces of the country are suitable for using the residue as an energy source. With regard to the material, maize cob, the rapid mass loss rate occurred after the temperature reached 160°C. Besides, the rapid mass loss section and the slow mass loss zone were separated at the temperature of about 400°C. With regard to the briquette, maize cob with molasses can be compacted in to fuel briquettes by moderate-pressure briquetting process. The density of the briquettes is strongly affected by the die pressure and the binder ratio. The purposed relationship between the density, briquetting pressure and binder ratio gave a good result in predicting new observation over the studied range.

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REFERENCES

1. Kaygusaz, K. and M.F. Turker, 2002. Biomass energy potential in Turkey. Biomass and Bioenergy, 26: 661-678.
2. Demirbas, A., 1999. Physical properties of briquettes from waste paper and wheat straw mixtures. Energy Conversion and Management, 40: 437-445.
3. Demirbas, A and A. Sahin. 1998. Evaluation of biomass residue 1: briquetting waste paper and wheat straw mixtures. Fuel Processing Technology, 55: 175-183.
4. Demirbas, A., 1999. Properties of charcoal derived from hazelnut shell and production of briquettes using pyrolytic oil. Energy, 24: 141-150.
5. Yaman, S., M. Sahan, H. Haykiri-acma, K. Sesen and S. Kucukbayrak. 2000. Production of fuel briquettes from olive refuse and paper mill waste. Fuel Processing Technology, 68: 23-31.
6. Wilaipon, P. and C.C. Fung. The effect of moderate die pressure on banana-peel briquette: a case study at Phitsanulok, Thailand. The 6th International Conference on New Energy System and Conservations. Korea, Nov 9-13, 2003. The Korean Hydrogen and New Energy Society.
7. Wilaipon, P., K. Trirattanasirichai and K. Tangchaichit. The effects of moderate die pressure on banana-peel briquettes. The 2nd International Conference on Thermal Engineering and Applications. United Arab Emirates, Jan 3-6, 2006. UAE University.
8. Ndiema, C.K.W., P.N. Manga and C.R. Ruttoh. 2002. Influence of die pressure on relaxation characteristics of briquetted biomass. Energy Conversion and Management, 43: 2157-2161.
9. Chin, O.C. and K.M. Siddiqui. 2000. Characteristics of some biomass briquettes prepared under modest die pressures. Biomass and Bioenergy, 18: 223-228.
10. Husain, Z., Z. Zainac and Z. Abdullah. 2002. Briquetting of palm fibre and shell from the processing of palm nuts to palm oil. Biomass and Bioenergy, 22: 505-509.
11. Yokoyama, S., T. Ogi and A. Nalampoon. 2000. Biomass energy potential in Thailand. Biomass and Bioenergy, 18: 405-410.
12. Department of Agricultural Extension. 2005. Statistics of Individual Crops Cultivation: Crop Year 2004. Department of Agricultural Extension, Bangkok.
13. ASTM E711-87 Standard Test Method for Gross Calorific Value of Refuse-Derived Fuel by the Bomb Calorimeter. 2004. Annual Book of ASTM Standards, 11.04. ASTM International.
14. ASAE S269.4 Cubes, pellets, and crumble – definitions and methods for determining density, durability and moisture content. 1996. Annual Book of ASAE Standards. ASAE.
15. ASTM D5373-02 Standard Test Methods for Instrumental Determination of Carbon, Hydrogen and Nitrogen in Laboratory Samples of Coal and Coke. 2003. Annual Book of ASTM Standards, 05.06. ASTM International.
16. ASTM D5291-02 Standard Test Methods for Instrumental Determination of Carbon, Hydrogen and Nitrogen in Petroleum Products and Lubricants: Test Method B. 2003. Annual Book of ASTM Standards, 05.03. ASTM International.
17. ASTM E1131-03 Standard Test Method for Compositional Analysis by Thermogravimetry. 2004. Annual Book of ASTM Standards, 14.02. ASTM International.