

## Durian Husk Properties and its Heating Value Equation

Patomsok Wilaipon

Department of Mechanical Engineering, Faculty of Engineering,  
Naresuan University, Phitsanulok, 65000, Thailand

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**Abstract: Problem statement:** Agricultural residue seems to be one of the most promising energy resources for developing countries. Among the other fruits, durian is a popular one for Thai people. Therefore, a large amount of durian husk is left at the shops or factories. This study was aimed to investigate the characteristics and heating value of durian husk and to develop a heating value equation of Thailand's selected biomass. **Approach:** The approximate analysis of 17 kinds of biomass, including durian husk, was carried out. The heating values of these biomass residuals were also examined. Then, the empirical model of the heating value was developed and validated. In order to understand the thermal degradation process of durian husk, the thermo gravimetric analysis was also carried out. **Results:** Durian husk contains about 80% of volatile matter content and small amount of ash content. According to the differential thermo gravimetric analysis result, two peaks centered at 212 and 332°C were reported. A model with an acceptable ability for prediction the heating value obtained by using the step wise forward selection technique was developed. The coefficient of multiple determinations for prediction of the proposed model was about 86.3%. **Conclusion:** It appears that durian husk seems to be one of the promising biomass fuels for Thailand. The proposed equation developed for computing the higher heating value of several biomass samples including durian husk from their proximate analysis data is not over-fitted. Besides, according to the model validation result, it shows that the predictive capability of the model is in the acceptable range.

**Key words:** Durian husk, heating value equation, proximate analyses, residual analysis, thermo gravimetric, volatile matter

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### INTRODUCTION

It is widely accepted that biomass is one of the very important sources of energy in many parts of the world particularly in the developing countries. It is one of primary energy source utilized by humankind. Biomass can be used, with suitable energy conversion technologies, in almost similar ways to fossil fuels. It can be defined as the organic materials produced by plants including the organic matters from animals. Besides, it may be considered as the solar energy stored in chemical form in organic materials. Examples of biomass are leaves, root and stalk from plants and animal manure. Nowadays, more than a half of the world's population still uses biomass as a primary energy sources for living. Several kinds of promising fuel-biomass such as soft wood waste (Khalil *et al.*, 2009), cashew shell waste (Mohod *et al.*, 2010), swine manure (Xiu *et al.*, 2010), coconut oil (Singh *et al.*, 2010) and algae (Hossain *et al.*, 2008) were investigated by many researchers.

Information about some characteristics of biomass is crucial for energy conversion processes. Biomass properties for combustion analyses can be categorized

into three main groups, physical, chemical and thermal properties. The standard indicator of the energy content of biomass is the heating value. The enthalpy of combustion is ascertained at constant pressure. Heating value can be experimentally determined or can be calculated from the ultimate or proximate analyses. Several formulae for estimating the heating value of biomass have been proposed according to the data from China (Yin, 2011; Huang *et al.*, 2008), Turkey (Demirbas, 1997; 2001), Austria (Friedl *et al.*, 2005) and India (Ahmaruzzaman, 2008). The properties of biomass are in dependence of their species. Besides, they also depend on field locations and weather conditions. Thus, the heating value equation developed from the foreign-country biomass data may be not applicable for some practical cases of Thailand's biomass.

The objective of this research was to study the characteristic of durian husk, one of the most popular fruits of Thailand. Besides, its thermal degradation process and the heating value were also examined. Finally, by using regression technique, the relation between the heating value and the proximate analysis data of 17 kinds of biomass including durian husk was developed and validated.

## MATERIALS AND METHODS

Durian husk and other 16 kinds of biomass used in the experiments were obtained from Phitsanulok province during the summer of 2010. The biomass was sundried and then ground into small pieces, less than 2 mm. Then, the proximate analysis of 17 kinds of biomass viz. cassava stalk, eucalyptus bark, bagasse, sawdust, soybean shell, charcoal, coconut husk, soybean pulp, green bean shell, peanut shell, Albizia lebbeck Benth, rice bran, cane trash, rice straw, rice husk, maize cob, maize stalk, maize trash including durian husk, were carried out in accordance with ASTM E870-82 standard. The moisture content investigations were determined according to ASTM E870-81 method. The volatile matter contents and ash contents of the samples were determined according to ASTM E872-82 and ASTM E1755-01 standards, respectively. In addition, the fixed carbon content was computed by difference. The experimental heating values of the biomass samples were determined in a Parr microprocessor controlled oxygen bomb calorimeter.

The thermo gravimetric experiment of durian husk was carried out in a thermo gravimetric analyzer, Mettler-Toledo model SDTA 851. The mass of sample utilized was 7.00 mg. The atmosphere used was nitrogen gas. The temperature range studied was from 50-850°C with a heating rate of 20°C min<sup>-1</sup>.

Multiple regression analysis is a method for examining the relationship between one dependent variable and one or more independent variables. The dependent variable in the study was the higher Heating Value (HV) or gross calorific heating value. The variables of the proposed HV equation are fixed carbon, volatile matter, ash and moisture, respectively. The step wise forward selection technique was employed for selecting the suitable regression equation of selected biomass HV model. One at a time, new regress or was added to the equation. Then, the F-statistic was utilized to test the significant of new variable.

Validation of the equation derived from the above method was subject to residual analysis. The model checking was also carried out by plotting the reference values and the predicted values. Besides, residual analysis was performed by plotting the rank it, the expected normal value, against the ranked residuals. The coefficient of multiple determinations:  $R^2$  was used to describe the quality of fit. Moreover, as the degrees of freedom was taken into account in the equation, the adjusted coefficient of determination:  $R^2_{\text{adjusted}}$ , was used as an indicator of the over fitting model. The coefficient of prediction determination:  $R^2_{\text{prediction}}$ , was also computed to evaluate the quality of the model.

## RESULTS

Thermo gravimetric result of durian husk is shown in Fig. 1. As can be seen from the figure, there are two levels of steep slopes, represent two peaks with regard to the differential thermo gravimetric analysis. The first peak starts at 160°C and it is centered at 212°C. This first one overlaps with the second peak, which is centered at 332°C. The final residue accounts for 26.765% of the initial weight of the sample.

According to the proximate analysis and the heating value investigation of durian husk, it was found that the composition of this biomass is mainly volatile matter, approximately four-fifth of the sample. Besides, durian husk contains 9.24% of moisture content, 4.34% of ash content and 6.43% of fixed carbon, respectively. The experimental higher heating value of the biomass residue was found to be about 3802 cal.g<sup>-1</sup>.

With regard to other 15 kinds of biomass materials, it was found that the moisture, volatile matter, ash and fixed carbon contents were in the range of 7.60-11.81, 67.08-82.43, 1.04-16.97 and 5.30-14.49%, respectively. The heating values of these 15 biomass samples were in the range of 3190-4833 cal.g<sup>-1</sup>. The characteristics of charcoal, different from other fresh biomass, was found to be 6.51% moisture content, 35.90% volatile matter content, 21.77% ash content, 35.83% fixed carbon and 4833 cal.g<sup>-1</sup> of heating value.

By using the step wise forward selection technique for selecting the suitable regression equation of selected biomass HV model, the higher heating value of biomass materials can be correlated with the data obtained from the proximate analysis. With regard to the model validation, it was found that the values of  $R^2$ ,  $R^2_{\text{adjusted}}$  and  $R^2_{\text{prediction}}$  are 91.4, 89.5 and 86.3% respectively. Figure 2 shows the comparison between the experimental heating value and the predicted heating value computed from the proposed equation.

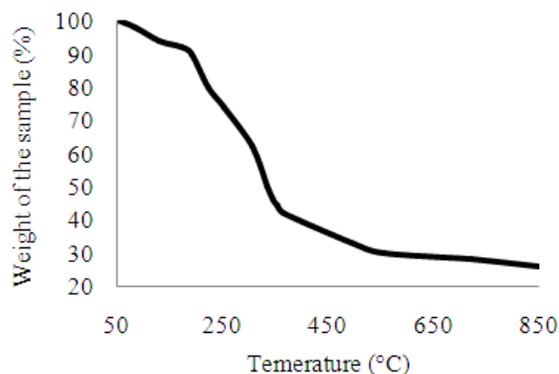


Fig. 1: Thermo gravimetric result of durian husk

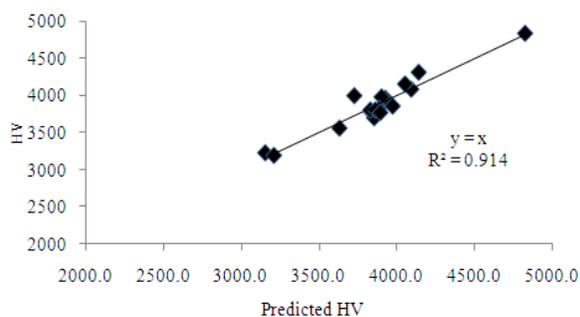


Fig. 2: Experimental heating value Vs. predicted heating value from the equation

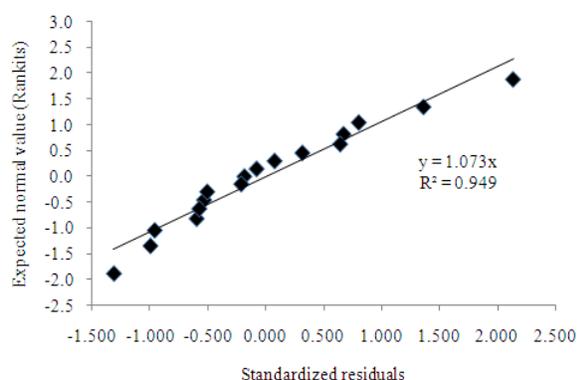


Fig. 3: Model adequacy checking (expected normal value Vs. standardized residuals)

Besides, a graph between expected normal value and standardized residuals was also plotted as shown in Fig. 3:

$$HV = 3719.1 - 0.742 (VM) (FC) - 1.620 (M^2) (A) - 75.61 (A)$$

Where:

HV = Heating value ( $\text{cal.g}^{-1}$ )  
 VM, FC, M and A = Volatile matter, fixed carbon, moisture and ash contents respectively (wt %)

### DISCUSSION

Durian husk is one of the promising biomass fuels for Thailand. Its heating value is in the middle range compared to other biomass. With regard to the proposed heating value model, the  $R^2$  and  $R^2_{\text{adjusted}}$  values show that the proposed relationship was not over-fitted while the  $R^2_{\text{prediction}}$  value, an indication of the predictive capability of the model, was in the acceptable range.

### CONCLUSION

One of the most important agricultural products of Thailand is durian. Therefore, a large amount of durian husk is available in this region. With regard to its characteristics and heating value, durian husk has high potential as an alternative fuel. Moreover, the equation was developed for computing the higher heating value of several biomass samples including durian husk from their proximate analysis data. According to the values of  $R^2$ ,  $R^2_{\text{adjusted}}$  and  $R^2_{\text{prediction}}$ , which are 91.4, 89.5 and 86.3% respectively, it may be concluded that the proposed equation developed in this research shows good agreement with the experimental heating values of the studied samples.

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