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The Relationship Between Heating Value and Pollutant Elements of Solid Biomass

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Abstract
Combustion is a dominant feature of converting biomass fuel to energy associated with gas emission which can influence seriously on the environment. In general, the basic elements of biomass such as nitrogen and sulphur represent the source of these gases, therefore the amount of these elements in biomass allow us to predict the type and the quantity of these emissions that likely produced during combustion. The aim of this study was to examine the correlation between heating value with the nitrogen and sulphur proportion in solid biomass in view of their potential negative effects on the environment. A total of 154 of biomass samples together with their heating value were collected from the open literature. Pearson correlation were applied to examine the correlation between biomass nitrogen and sulphur proportion and their heating value. It was found that there is negative correlation between nitrogen and sulphur proportion of biomass and their heating value. In summary, the solid biomass with less nitrogen and sulphur elements are characterized by high heating value and environmentally sound.

Keywords: *Pollutant elements, Solid biomass, Combustion, Heating value, Basic elements*

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I. Introduction

In recent years, there has been an increasing interest in use of biomass as alternative energy (Sheng et al., 2004). Which can utilize them in a sustainable manner with minimal negative impact to atmosphere, thus legislators have established stringent regulations and standards regarding biomass combustion. Therefore, EU has established sustainable objectives for develop biomass industry without creating negative impact on environment associated with the use of bioenergy (Vis *et al.*, 2008). While US environmental protection agency has issue the clean air act emission standards for reducing the release of sulphur and nitrogen oxides (Kaltschmitt *et al*., 2001). The EPA Office of Air Quality Planning and Standards (OAQPS) has set ambient air quality standards for six principal pollutants, including substances that are often linked to biomass combustion such as nitrogen oxides (NOx) and sulphur dioxide (SO2). Nitrogen (N) content in biomass fuel is responsible for NOx formation and their emissions are considered as one of environmental impact factors and in combination with HC they form ozone, which is cause a lung and eye irritant and harming the plants (Nussbaumer, 1989; Baumbach *et al.*, 1997). While sulphur dioxide emissions from biomass combustion depend on the sulphur (S) content in the biomass (Reddy *et al.*, 2002). Sulphur (S) contained in solid biofuels produces gaseous SO2, which is a contaminant emission. Sulphur oxides (Sox) are formed during combustion and contribute significantly to particulate matter (PM) pollution and acid rain (Clarke*et al*, 2011).

Biomass combustion is the most widely recognized method for heat and power production (Nussbaumer, 2003). For each chemical compound that composes a biomass fuel have an effect during the combustion process and often related to emissions of pollutants such as NOx and SO2 based on biomass composition (Villeneuve *et al.*, 2012). Accordingly, characterization of the biomass, including the basic elements such as (Nitrogen and sulphur) allows predicting the type and the quantity of emissions that may be produced during combustion. This study provides new insights into correlation between heating value and basic elements (Nitrogen and sulphur) in solid biomass in view of their environmental impact.

II. Methodology

In the present work, 154 of biomass samples together with their heating values were collected from the open literature, mainly (Friedl, 2005) which are summarised in table 1. lists 11 groups of biomass types were used as following, group 1 consists of 25 samples from Miscanthus, a grass type that is increasingly used for energy production, and other grass types in group 2. Group 3 comprised from spruce wood, bark, wood chips and briquettes; group 4 contains wood waste. In group 5 different types of cereal straw are collected (rye, wheat, barley). Group 6 contains samples from millet, group 7 from sunflower (straw, residue), and group 8 from hemp. In group 9 various types of waste are contained, such as compost, waste from sugar and brewing

industries, poultry litter and sewage sludge. In group 10 other plant materials are collected, for instance straw from flax, maize, rape, and rice. Group 11 contains non-plant materials like residues from olive oil and sugar cane production. For the purpose of analysis, two basic elements (Nitrogen and sulphur) were extracted from ultimate analysis component with reference to their environmental impact. Pearson correlation as shown in equation (1) were applied to examine the correlation between Nitrogen and sulphur with heating value.

$$r = \frac{n(\sum xy) - (\sum xy)(\sum y)}{\sqrt{[n\sum x^2 - (\sum x)^2][n\sum y^2 - (\sum y)^2]}} \quad (1)$$

where x = element measured in ultimate analysis (N and S % dry mass), y = HV (MJ/kg) and n = number of data. All analyses were carried out using excel sheet.

Table 1.Biomass samples from open literature

Group No	n	Biomass	HVMJ\Kg	N%	S%
1	25	Energy grass Miscanthus	19.14	0.6	0.1
2	17	Energy grass, other	18.04	2.1	0.2
3	18	Wood material	19.59	0.4	0.11
4	9	Wood waste	18.47	1.7	0.30
5	16	Cereals	18.61	1.2	0.17
6	6	Millet	18.17	0.9	0.20
7	6	Sunflower	20.26	0.3	0.03
8	6	Hemp	18.03	0.6	0.29
9	13	Waste	15.97	2.4	0.40
10	28	Other plant material	19.79	0.8	0.19
11	10	Other non-plant material	20.32	0.2	0.09
	154	All	18.86	2.2	0.13

Source (Friedl *et al.*, 2005).

III. Result and discussion

The aim of this study to examine the correlation between heating value with the nitrogen (N) and sulphur (S) of solid biomass in view of their potential negative effects on the environment. Pearson correlations with 0.05 significance level as described in equation (1) were carried out to examine the relation between N and S with high value of biomass as shown in table 1. The result show that there is strong and negative correlation between N and heating value with correlation coefficient values of -0.91. A clear trend can be seen in Fig. 1 that the heating value of biomass decreases with the increase of N proportion in biomass materials or vice versa. this result agrees with Acar *et al* (2011) who assuming that the effect of the N content of biomass fuel on its heating value is negative. While disagrees with Setyawati *et al* (2015) stated that N contents have moderate positive correlation with heating value. If we turn to S Fig 2there is also negative correlation between S and heating value with correlation coefficient values of -0.59. Therefore, it is unfavourable to have large contents of N and S contents in biomass fuel. Anyway, the volatile matter is the gaseous phase formed from the thermal degradation when the biomass is heated. and nitrogen (N) content in biomass fuel is responsible for NOx formation and their emissions. as well as Sox emissions from biomass combustion depend on the sulphur (S) content in the biomass. And a high volatile content is directly proportional to a lower heating value, resulting in the low energy density of biofuels. This finding supports our results that N and S content in biomass is correlate with heating value negatively because NOx and Sox are part of volatile matter. On the other hand, significant quantities of N and S are linked to the ashes which is also correlate negatively with heating value (Nussbaumer, 2003). In summary, these results show that the high heating value of biomass combustion tending to be associated with low nitrogen oxides or sulphur oxides emissions if compared with other fuels.

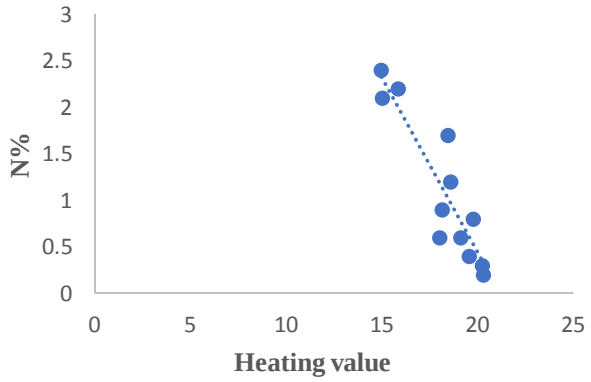

Fig 1.Scatter plot of high heating value versus nitrogen content in biomass fuel

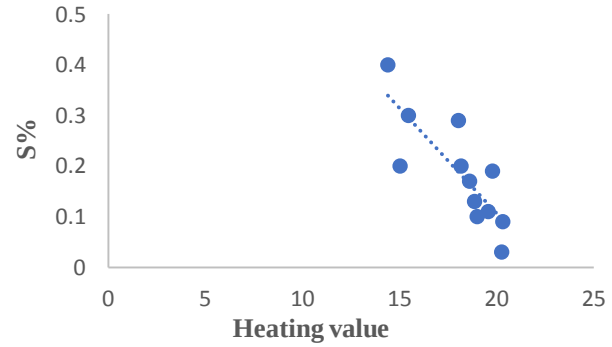

Fig 2.Scatter plot of high heating value versus sulphur content in biomass fuel

IV. Conclusion

Biomass combustion is often related to emissions of pollutants such as nitrogen dioxides (NOx) and Sulphur dioxides (SO2). there is relation between biomass heating value and pollutants emission. This study has shown that this relation is negative that means sulphur dioxides and nitrogen dioxides emission is decrease with increase of biomass feedstock heating value. this strengthens the idea that biomass selection with less pollutants elements is extremely important which is determine the efficient use of biomass. In general, therefore, it seems that biomass can replace fossil fuels for heat and power generation without creating negative impact on environment.

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