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Ultimate and Proximate Analysis of Malaysia Pineapple Biomass from MD2 Cultivar for Biofuel Application

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MD2 pineapple is a highly demanded hybrid pineapple other than Josephine and Sarawak. The decomposition process of the pineapple biomass by burning may contribute towards carbon emission and increase the greenhouse effect. To address these negative impact, this biomass can be used as a raw material for the alternative solid biofuel to coal and substitute coal for the application in heavy industry or domestic use. The aim of this study is to investigate the characteristic of the MD2 pineapple biomass for their use as a feedstock for biofuel and energy production. The ultimate analysis was carried out by using CHNS Elemental Analyser, where the proximate analysis was identified by the thermo-gravimetric (TGA) analysis under dynamic condition. The results of the conducted study were compared with other biomass reported in the past literature. The ultimate analysis of the MD2 pineapple (i.e. 43.43 wt% C, 6.69 wt% H for leaf and 41.09 wt% C, 6.705 wt% H for stem) appears to correlate with the ultimate analysis range of the other biomass which is used as a raw material of the solid biofuel. The thermo-gravimetric analysis showed that each single part of the MD2 pineapple had pyrolysis and combustion characteristic based on its own main pseudo-components (hemicellulose, cellulose and lignin). The characteristics of the MD2 pineapple had ensured the potential of biomass as raw materials for alternative solid biofuel.

1. Introduction

Dependency on the fossils fuel can be lessened by replacing them with other renewable energies, such as solar, hydroelectric or biomass based on the geographical location and source availability in a country. In term of biomass, renewable energy can be sourced from any agricultural wastes for examples fruits crops (Sellin et al., 2013), bagasse (Brasil et al., 2015), and paddy (Lim et al., 2012). Shafie et al.(2011) in their studies indicate that Malaysia is bestowed with a significant amount of biomass resources. This makes the biomass most promising option, compared to the others a various source of renewable energy in Malaysia. The Malaysia energy sector is still heavily dependent on non-renewable fuel such as fossil fuel and natural gas as a source of energy without preparing the replacement due to depletion and harmful effect of the fossil fuel towards nature The use of biomass in the energy sector is continuously growing all over the world due to a number of factors such as low emissions, need for alternative energy sources, increased government initiatives for renewable energy technologies and a substantial untapped biomass potential (Singh, 2017). Inherently, Malaysia has to give more focus on the development of renewable energy, green technology and energy conservation for the future in order to sustainably feed the rapid growth energy demands for end-use sectors, as well as to face the challenge of global climate change (Chong et al., 2015). In Malaysia, economic growth and carbon dioxide emissions are influenced by energy, as shown by the Granger causality model. In this regard, energy consumption can trigger environmental problems in Malaysia. The increasing energy consumption as the result of economic growth can escalate carbon dioxide emissions (Shaari et al., 2014). To overcome the overwhelming carbon emission problem, green technology should be practised without affecting the quantity of the energy use and disrupt the economic growth.

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Alternative solid biofuel is a part of renewable energy with the green technological approach. It is normally produced from the agricultural crops. Recent research by Zanella et al.(2016) used the orange bagasse and corn starch as a raw material in producing charcoal briquette. They found that the charcoal briquette of orange bagasse with 10 % of corn starch is an appropriate use in a domestic and commercial way. This is due to the obtained charcoal briquettes presented satisfactory mechanical strength (compression and friability test) and good quality (proximate and ultimate analysis), with a high amount of carbon, allowing them to be used as domestic and commercial charcoal. The high value of coal or coke used in power plant is produced from the mechanically robust feedstock, non-hazardous contaminants and moisture resistance. The stability of solid biofuels to moisture exposure, the fuel composition by proximate analysis, briquette mechanical strength, and burning efficiency, are critical characteristics for the performance. Bio-pellet from biomass source is deemed to have environmental advantages compared to coal. Bio-pellet is as perspective and competitive as an alternative energy to substitute coal and its derivatives (Kusumaningrum and Munawar, 2014). Since Malaysia is among the largest pineapple producer in the world (FAO, 2015), the incineration process of the pineapple biomass should be reduced by converting the biomass to something useful. Roda et al.(2014) used the pineapple waste in their study to identify saccharification process as a first step in producing vinegar as a part of an effort for reducing the environmental pollution and the seasonal fruits losses. The result of the study indicated that enzymatic treatments of pineapple waste had a significant effect on the saccharification process. Abdullah and Mat (2008) used the solid and liquid pineapple waste that was collected from the Malaysian Cannery of Malaysia Sdn. Bhd. as feedstocks to examine its characteristic. The analysis of sugar indicated that liquid waste contains mainly sucrose, glucose and fructose while the solid waste does not have the sucrose content. The chemical composition analysis showed its potential to be a good nutrient for the cultivation of bacteria. It also potentially uses a carbon source for organic acid fermentation. Since there is no research on converting the waste from pineapple into energy, the aim of this study is to investigate the characteristics of MD2 pineapple waste and its potential to become a feedstock for alternative solid biofuel. In the article, the details on sample preparation is described. Data collection and analysis were conducted to produce evidence of approval the potential of the pineapple waste to become a feedstock of alternative solid fuel. The conducted analysis includes ultimate analysis and proximate analysis of the biomass from the MD2 cultivar.

2. Materials & methods

2.1 Materials

The selected MD2 cultivar is a pineapple variety produced in cultivation by selective breeding. The planting of MD2 pineapple producing abundant of waste that has not been managed wisely and fully utilised (Paull et al.,2012). The sampled MD2 pineapple biomass is originated from the pineapple plantation located in Alor Bukit, Pekan Nenas, Johor, Malaysia and was divided into three parts (1) leaf, (2) stem, and (3) root. Each part of pineapple biomass was cut manually into 5 cm and undergo drying process by using vertical-forced, convection oven FC-9000 series by Constance brand at 40 °C for 48 h, following the LAP-Preparation of the sample for compositional analysis (Hames et al., 2004). The laboratory blender with a single speed of 230 V by WARING/USA brand was used for reducing the pineapple biomass size into a fine powder. The RETSCH brand sieve shaker AS 200 was used to obtain the desired particle size <500 μm (35 mesh) of the pineapple biomass.

2.2 Methods

The ultimate analysis was conducted to determine the elements present in the biomass. The ELEMENTAR brand CHNS Elemental Analyser was used for the analysis according to ASTM D5373-02. The proximate analyses include analyses of the ash content (Ash), fixed carbon content (FC), moisture content (M) and volatile matter (VM) was carried out according to ASTM Standard D5142-02a. The Thermogravimetric-Analysis STA-8000, Perkin Elmer brand was used for this pyrolysis experiment. Its precision of temperature measurement was ± 5 °C; hang down pan microbalance sensitivity was less than 1.0 μg, while the heating rate was 10 °C/min. The biomass powder of approximately 10 mg each was inserted in a 150 μl alumina crucible next to each other as such the two will not touch. The calibration was performed based on the set heating profiles from the manufacturer. The pyrolysis investigations were carried out using nitrogen and switch to the oxygen as a carrier gas, under dynamic conditions at a heating rate of 10 °C/min. The temperature of the pyrolysis was raised from 30 °C up to 900 °C. The weighted sample was inserted directly into a 150 μl ceramic crucible and the temperature was kept isothermal for one minute until a steady condition was obtained before ramping to the desired temperature. Each sample was pyrolysed at least twice to gain an accurate result. The peak from the result was analysed to gain the value of the information needed (García et al., 2013), while the calorific value was determined by using a model proposed by Sheng and Azevedo (2005).

2.3 Mathematical Formula

The mathematical formula used is based on the fundamental governing equations for determining the oxygen content and the calorific value of the pineapple biomass. The oxygen content was obtained by subtracting from 100 % the sum of (C, H, N, S and Ash) content wt% dry basis as follows Eq(1).

$$O = 100\,\% - (C + H + N + S + Ash) \qquad (1)$$

O is the oxygen content in wt%, dry basis, C is the carbon content in wt%, dry basis, H is the hydrogen content in wt%, dry basis, S is the sulphur content in wt%, dry basis and Ash is the ash content in wt% dry basis.

The calorific value was obtained by using the equations developed by (Sheng and Azevedo, 2005) as follows Eq(2).

$$CV\ (MJ/kg) = -1.3675 + 0.3137 * C + 0.7009 * H + 0.0318 * O \qquad (2)$$

CV is the calorific value of the pineapple biomass in wt%, dry basis. MJ/kg is a unit for measuring the calorific value which is mega joules per kilogramme.

3. Results & discussions

There is two equipment used in determining the ultimate and proximate analysis. For the ultimate analysis which is determining the Carbon, Hydrogen, Nitrogen and Sulphur, CHNS Elementar analyzer has been used. For the proximate analysis, the sample has undergo the themal analysis by using Thermogravimetric Analyzer. It has produced the graph and from the slope, the value of information needed can be calculated.

3.1 Ultimate Analysis

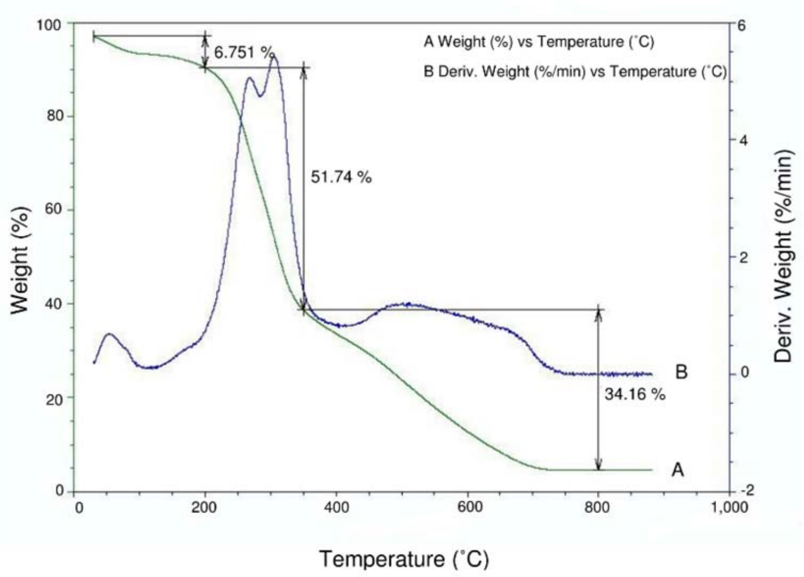
The ultimate analysis of the MD2 pineapple biomass waste was done by using ELEMENTAR brand CHNS Elemental Analyser. The waste was divided into three parts to investigate in detail and find the accurate data for each part of it. The results of ultimate analysis of the MD2 pineapple biomass gave average (43.43 %, 6.69 %, 1.73 %, 0.04 %, and 59.26 % of leaf, 41.09 %, 6.705 %, 1.44 %, 0.56 %, and 57.28 % of stem and 23.71 %, 5.39 %, 1.01 %, 0.23 % and 75.42 % of root) for contents of C, H, N, S and O. The amount of C and H content in the pineapple biomass contributed significantly to the combustibility of any substance in which they are found (Loison et al., 1989). The low S and N contents in the alternative solid fuel have welcomed the development as there will be the minimal release of sulphur and nitrogen oxides into the atmosphere and that is an indication that the burning of biomass examined in this work will not pollute the environment (Enweremadu et al., 2004). Besides that, higher sulphur content of solid fuel will reduce the quality of metal or slag if it is use in heavy metal industries (Loison et al., 1989). From the data, the biomass used in this work can act as a good solid fuel and may not be harmful toward metal industries especially in term of product quality. Sulphur content may also causing the corrosion towards equipment or furnace by sulphuric acid formed during and after combustion process. From here, the biomass used in this work can reduce the corrosion severity impact toward the equipment use and can reduce the cost for maintenance. In most cases, biomass is considerably has less sulphur content than a coal. Meaning that, an increasing of using biomass as a solid fuel or as thermal output makes the SO2 emissions decrease proportionally (Haykiri-Acma et al., 2008). From the data in detailed provided in Table 1, leaf and stem part of the pineapple biomass showed the value in the range of the standard agricultural waste ultimate analysis which is C (40.0 – 53.0), H (4.5 – 7.5), N (0.1 – 8.0), S (0.0 – 0.7) and O (31.0 – 52.0) as stated in (Bhaskar and Pandey, 2015) while the root, its carbon content is lower than the minimum range. Besides that, all part of the MD2 pineapple waste showed the high oxygen content compared with the range provided. This is possible to design the necessary pre-treatment process.

Table 1: Ultimate analyses of pineapple biomass from MD2 cultivar (wt%, dry basis)

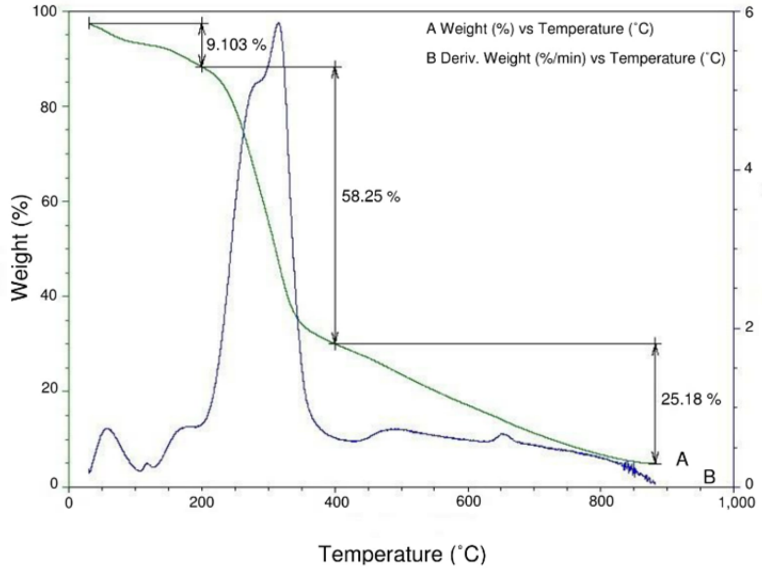
Part/element	C	H	N	S	O	Atomic Ratios	
						H/C	O/C
Leaf	43.3806	6.6036	1.7914	0.0373	59.1619	0.1522	1.3637
	43.4886	6.7811	1.6840	0.0499	59.3526	0.1559	1.3647
Average	43.4346	6.6924	1.7377	0.0436	59.2573	0.1541	1.3642
Stem	41.1076	6.6634	1.4258	0.5793	57.2431	0.1620	1.3925
	41.0788	6.7466	1.4612	0.5560	57.3096	0.1642	1.3951
Average	41.0932	6.705	1.4435	0.5677	57.2764	0.1631	1.3938
Root	38.6013	5.2731	0.9616	0.2163	75.1253	0.1366	1.9461
	38.8096	5.5207	1.0669	0.2498	75.7200	0.1422	1.9511
Average	38.7055	5.3969	1.0143	0.2331	75.4227	0.1394	1.9486

3.2 Proximate Analysis

The thermal behaviour of pineapple waste biomass can be studied by measuring the rate of weight loss as a function of time and temperature. The value of proximate analysis was analysed precisely and directly from the thermal gravimetric curves (Kristof, 2003). In the proximate analysis, the initial mass loss observed (in Figure 1) under a nitrogen atmosphere is due to loss of moisture, occurring at a temperature below 200 °C. The moisture determined represents only physically bound water for the dry basis biomass waste. Water was released by chemical reactions during pyrolysis is summarised among volatiles. In the range 200 °C and 900 °C, a huge mass loss is observed. At a temperature between 200 °C and 600 °C, CO_2 and CO_4 are released from hemicellulose, cellulose and lignin and later chemically bounded CO_2 and chemically formed water (Mathew et al., 2015). From 600 °C to 900 °C, the mass loss rate decreases due to the evolution of carbon containing species. Later the charcoal undergoes oxidation to form ash until constant weight is attained (Haykiri-Açma, 2003).

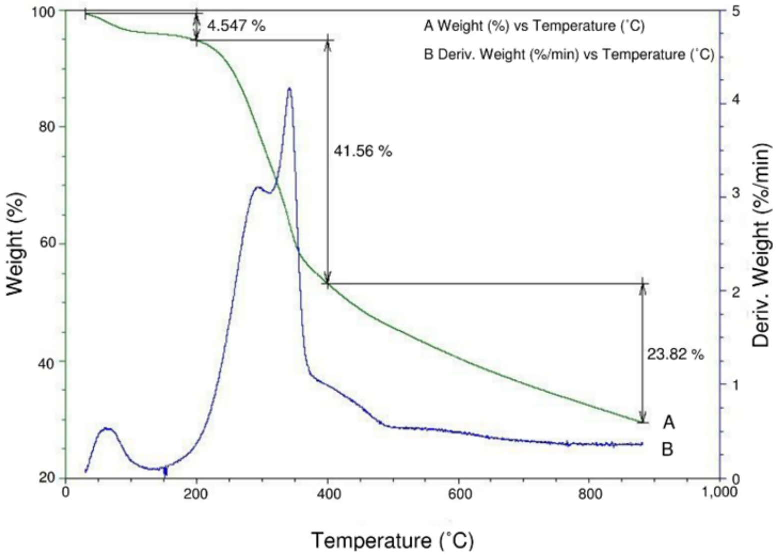


(a)



(b)

Figure 1: TG and DTG curves for MD2 pineapple biomass (a) leaf (b) stem and (c) root



(c)

Figure 1: TG and DTG curves for MD2 pineapple biomass (a) leaf (b) stem and (c) root

The proximate analysis through TGA experiment for pyrolysis of the MD2 pineapple biomass is summarised in Table 2. The resulting ash fraction is not representative of the original ash due to the oxidation process employed in its determinations. The proximate analysis showed that both pineapple stem and leaf had high volatile matter content. It is also considered has a high calorific value which has the potential to become an alternative solid biofuel feedstock. It is proved by the low ash content for every part of the pineapple since the high non-combustible component (ash content) will lower the calorific value of the biomass with the ratio 1 % ash = 0.2 MJ/kg (Loison et al., 1989). Besides causing combustion problem, high ash content can also cause severe corrosion damage toward the systems, while the Hydrogen/Carbon ratio could affect the total mass during volatile combustion phase (Loison et al., 1989).

Table 2: Proximate analyses of pineapple biomass from MD2 cultivar (wt%, dry basis)

Part	Moisture Content (wt%)	Ash Dry Content (wt%)	Volatile Matter (wt%)	Fixed Carbon Content (wt%)	Calorific Value (MJ/kg)
Leaf	6.751	7.349	51.74	34.16	18.7508
Stem	9.103	7.467	58.25	25.18	18.0187
Root	4.547	30.073	41.56	28.82	16.8266

As stated in Table 1, low H/C ratio for leaves (0.15), stem (0.16) and root (0.14) showed that high total mass will be lost during the volatile combustion. This was proven by the high volatile matter content for each part of the pineapple biomass from the proximate analysis data. The volatile matter content is reflected through the weight loss of the sample during combustion. Since the pineapple biomass had higher volatile matter content, this proves their reactiveness as solid biofuels during combustion (Loison et al., 1989).

4. Conclusions

Conclusion can be made that from the present study, the ultimate and proximate analysis of the MD2 pineapple biomass showed similar characteristic with others biomass that have been used as the feedstock for producing biofuel. Based on the high calorific value, it will enhance the potential to become a feedstock for alternative solid biofuels. The value of the ultimate and proximate analysis is dependent on the sample collected from the similar field and might be slightly different with the previous studies and others biomass due to the other factors affecting for example during sample preparation and the conducting process of the analysis.

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