

COMBINATION OF DRIED WATER HYACINTH AND OIL PALM EMPTY
FRUIT BUNCH BIOMASS BRIQUETTE AS ALTERNATIVE FUEL

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To my beloved mother, father, husband, daughter

All my siblings and my friends

Thank you for everything

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ABSTRACT

The use of conventional fossil fuels has emitted a large amount of CO₂ that contribute towards enhanced greenhouse gas effect. Thus, a green alternative fuel should substitute the conventional one as a natural way to reduce the emissions of CO₂. In this present study, water hyacinth (*Eichhornia crassipes*) biomass briquette in combination of palm oil mill residues of empty fruit bunch (EFB) fiber was used as the green combustion in coal-fired boilers. Blending ratio of water hyacinth and empty fruit bunch (EFB) fibers (25:75, 50:50, 75:25, 90:10) were used to determine an optimum ratio of waste materials that led to high calorific value, good fuel properties, and less toxic emissions. 100% of water hyacinth briquette act as a reference for this study while the moisture, ash content and calorific value of biomass briquette were compared with commercial sawdust briquettes. As part of the densification process, the waste material was pulverized and compacted into 41 mm diameter mould. The calorific value, proximate analysis and gas emissions were studied comprehensively. The result of calorific value (4101.5 ± 120.2 cal/g) shows that the blending ratio of 25:75 water hyacinth and EFB was significantly different ($p < 0.05$). Proximate analysis of 25:75 briquette ratio shows a significant difference of moisture content ($9.3 \pm 0.03\%$), ash content ($3.73 \pm 0.54\%$) and volatile matter content ($70.87 \pm 1.02\%$). Combustion test shows that the least emissions of CO₂ was obtained by 25:75 blending ratio ($0.23 \pm 0.33\%$) with 39% reduction emission of CO₂ compared to coal. Thus, in this study, 25:75 blending ratio showed the optimum blending ratio of biomass briquette to be applied as alternative energy fuel in coal power plant. In conclusion, the combination of water hyacinth and empty fruit bunch biomass briquette can become a good source of alternative energy fuel to mitigate the emission of greenhouse gaseous towards the environment.

ABSTRAK

Penggunaan bahan api fosil konvensional telah membebaskan sejumlah besar karbon dioksida (CO₂) yang menyumbang ke arah peningkatan kesan gas rumah hijau. Oleh itu, bahan api alternatif mesra alam harus diganti dengan yang konvensional sebagai salah satu cara semula jadi untuk mengurangkan pelepasan CO₂. Di dalam kajian ini, briket biojisim keladi bunting (*Eichhornia crassipes*) dengan gabungan serat tandan buah kosong (TBK) dari sisa-sisa kilang minyak kelapa sawit telah digunakan sebagai pembakaran hijau dalam dandang arang batu. Nisbah keladi bunting dan serat tandan buah kosong (TBK) 25:75, 50:50, 75:25 dan 90:10 telah digunakan untuk menentukan bahan buangan optimum yang membawa kepada nilai kalori yang tinggi, sifat bahan api biojisim yang baik dan kurang membebaskan gas-gas toksik. 100% briket keladi bunting bertindak sebagai briket rujukan dalam kajian ini manakala kadar air, kadar abu dan nilai kalori briket biojisim dibandingkan dengan nilai yang dihasilkan oleh briket habuk kayu komersial. Sebagai sebahagian daripada proses pepadatan, biojisim telah dihaluskan dan dipadatkan ke dalam acuan bersaiz 41 mm diameter. Nilai kalori, analisis proksimat dan pembebasan gas telah dikaji secara komprehensif. Keputusan nilai kalori (4101.5 ± 120.2 cal/g) menunjukkan bahawa nisbah campuran 25:75 keladi bunting dan EFB menunjukkan perbezaan yang signifikan ($p < 0.05$). Analisis proksimat mendapati bahawa pembakaran briket biojisim 25:75 menunjukkan keputusan kadar air ($9.3 \pm 0.03\%$), kadar abu ($3.73 \pm 0.54\%$) dan kadar volatil ($70.87 \pm 1.02\%$) yang mempunyai perbezaan signifikan. Ujian pembakaran menunjukkan bahawa pembebasan gas CO₂ yang paling rendah ($0.23 \pm 0.33\%$) telah ditunjukkan oleh 25:75 briket biojisim dengan 39% pengurangan gas CO₂ berbanding arang batu. Oleh itu, dalam kajian ini, 25:75 nisbah campuran menunjukkan nisbah pencampuran briket biojisim yang optimum untuk digunakan sebagai bahan tenaga api alternatif di loji kuasa arang batu. Kesimpulannya, gabungan keladi bunting dan tandan buah kosong briket biojisim mampu berfungsi sebagai sumber bahan tenaga api alternatif yang baik untuk mengurangkan pelepasan gas rumah hijau ke alam sekitar.

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LIST OF SYMBOLS

ASTM	American Society for Testing and Materials
BDCPG	Biomass direct combustion and power generation
C	Heat capacity
Ca	Calcium
Cd	Cadmium
CO ₂	Carbon dioxide
CO	Carbon monoxide
Co	Cobalt
Cr	Chromium
Cu	Copper
CV	Calorific value
d.b	Dry basis
EFB	Empty fruit bunches
FC	Fixed carbon
GCV	Gross calorific value
GHG	Greenhouse gas
HCN	Hydrogen cyanide
HHV	Higher heating value
Ho	Gross calorific value
Hu	Heat value
K	Potassium
LHV	Lower heating value
MC	Moisture content
Mn	Manganese
MSW	Municipal solid waste
Na	Sodium
Ni	Nickel

NO	Nitric oxide
NO _x	Nitrogen oxides
NO ₂	Nitrogen dioxide
O ₂	Oxygen
PAH	Polycyclic aromatic hydrocarbons
Pb	Plumbum
POME	Palm oil mill effluent
PVC	Polyvinyl chloride
RDF	Refuse-derived fuel
S	Sulfur
SEM	Standard error mean
SO ₂	Sulfur dioxide
SO _x	Sulfur oxide
SPM	Suspended particulate matter
TCPS	Thai Community Products Standards
TOE	Tons of equivalent
VM	Volatile matter
w.b	Wet basis
WH	Water hyacinth

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CHAPTER 1

INTRODUCTION

1.1 Background of the Study

Malaysia has been using natural gas, coal, hydroelectricity, biomass as well as petroleum and other liquids as its energy consumption (Energy Information Administration, 2014). The remarkably increased demand in energy shows the increasing activities of industrial, agricultural and domestic sectors. Besides, environmental concerns keep on growing, and one of the major problems of the present and future of the world community is the predictable global depletion of energy. Hence, alternative energy becomes the priority in today's world energy besides being relied on the depleting fossil fuels.

Apart from that, global warming has been long discussed issues by the environmental engineers and the environmentalists, but the enforcement on mitigating this issue is still lacking. Industries keep on emitting toxic emissions and uncontrolled used of fossil fuels might give harm towards the environment in the near future. Moreover, coal power plant has been using coal for the electricity generation, and the environmental impact are becoming very worst (Basu *et al.*, 2011). Therefore, attention towards biomass conversion into substitute solid biofuel has been proposed. Blending of biomass with coal in the existing coal fired boilers will provide among the most effective means of reducing the net CO₂ emissions from coal-based power plant.

Indeed, this is the cheap way of biomass utilization as it presents renewable and CO₂ neutral energy. Substituting materials to replace coal and other decreasing natural fuel resources can be majorly derived from plants. This natural biomass can be converted into hydrocarbons and biofuels (Hori, 2000). It would be ultimately beneficial to obtain energy from inedible biomass like water hyacinth. Besides, water hyacinths (*Eichhornia crassipes*) can multiply until 1200 plants within a period of about 130 days (Hori, 2000). Leaves of water hyacinth consist of hemicellulose and cellulose, which are the good element in the production of briquette.

At the local market, sawdust briquettes, wood residues and rice husk briquettes are among the commercial biomass briquettes. In Malaysian market, commercial sawdust briquette is the first to be introduced as briquette (Nasrin *et al.*, 2008). However, due to the competitiveness with the cheap wood, charcoal and kerosene, sawdust briquettes are exported to the international market. As for millers, densification of palm biomass is a new thing for them. Thus, substituting the low supply of sawdust and wood residues for briquette and charcoal briquette with palm biomass briquette has been a great effort to fully utilise the waste (Nasrin *et al.*, 2008).

Malaysia has a vast amount of palm oil mill residues that are loosely bounded and low in energy density (Nasrin *et al.*, 2011). From the milling process of palm oil waste, empty fruit bunch is the main solid waste which is suitable to be used as an alternative energy for combustion purposes. By utilising the abundant waste of EFB, dump areas near the mill can ultimately be reduced. Briquetting the poor physical properties of empty fruit bunch (EFB) is one of the method to upgrade the biomass into a useful solid fuel. This can be done through various technology (Yuhazri *et al.*, 2012).

Besides, by mixing dried water hyacinth biomass with a portion of waste from palm oil mill, the combustion properties of biomass briquette can be enhanced and indirectly affect its energy production (Nasrin *et al.*, 2011). Thus, it is predictable that the combination of dried water hyacinth biomass with co-other waste

briquette (palm oil mill waste) can be applied in coal-fired boilers at the existing coal power plant. In conclusion, biomass bio-briquette is non-conventional energy source of biomass bio-briquette, an eco-friendly waste product and economical renewable in nature product which does not polluted the environment.

1.2 Problem Statement

Apparent degradation of the environment shows the increasing human activities across the world. Environmental problem is not about dealing with the polluted water, but also encompassing the nature as a whole. It includes the toxic gases emissions, greenhouse effect, ozone depletion as well as acid precipitation that later can cause a tremendous impact to the environments. Those phenomenons obviously contribute towards the unhealthy ecosystem.

Moreover, fossil fuels have been utilized for many years and until now it has become an adverse towards the environment and the burning of fossil fuels itself release toxic gases. The combustion of fossil fuels in all kinds of sectors and industries as well as from a coal power plant contribute towards those emissions. It is also important to understand that the burning of fossil fuels in coal power plant also makes coal plant as nation's top source of carbon dioxide (CO₂) emissions and indirectly contributes towards global warming.

Mann and Spath (2001) reported that coal burning by the coal-fired power plant contributed more than 89% of CO₂ emission for the entire system. Besides carbon dioxide, methane and N₂O (nitrous oxide) also are the potential global warming contributors. Apart from that, Mann and Spath (2001) also stated that the availability of biomass in coal power plant is not for the cofiring purpose. Thus, carbon cycle does not occur and this condition could contribute towards higher emission of greenhouse gas and lead to the global warming potential.

As the third largest primary energy resource in the world goes to biomass after coal and oil, much attention has also been focused on identifying suitable species of certain biomass in providing great energy outputs for replacing conventional fossil fuel energy sources. Those sources of energy can ultimately be obtained from tons of agricultural waste that was being sent to landfill.

In achieving sustainable environment, long term actions should be strategised and well conducted. Thus, the most efficient and effective solution is to turn into renewable energy resources that will give benefits towards the reduction of the polluted environment as well as sustaining the environment (Dincer, 2000). By relating renewable energy and sustainable environment, biomass possesses the ultimate potential towards contributing the future energy supply (Berndes *et al.*, 2003).

1.3 Objectives of the Study

1. To determine the fuel properties of biomass briquette at different mixing composition ratios.
2. To estimate the calorific value of biomass briquette based on different mixing ratios.
3. To analyse the gaseous emissions of the biomass briquette during combustion.

1.4 Scope of the Study

The study fully utilized water hyacinth biomass briquette by combining with palm oil mill waste of empty fruit bunches (EFBs) as co-combustion, as an alternative choice for green burning energy sources. Cassava starch was used as binding agent in biomass briquette production. Source of empty fruit bunches (EFB) fiber was taken from palm oil mill in Kulai, Johor. The main idea of the study is to

help in the reduction of greenhouse gas (GHG) emissions via the combustion of biomass briquette with the existing coal material in coal fired boilers.

Water hyacinth plant was selected, and proper setting up of culturing and harvesting areas was conducted to grow the biomass effectively. In this study, the common water hyacinth (*Eicchornia crassipes*) species was chosen for biomass solid fuel (briquette). The purpose is not only due to its easy accessed and cultured, but its about the benefits of utilising ecosystem surplus of water hyacinth itself. The matured growth of biomass was being investigated and ready for harvesting period. Next, biomass preparation of biomass briquette of water hyacinth and empty fruit bunch fibers was conducted for the briquetting process. The best ratio that fulfills the biomass briquette combustion for co-combustion in coal-fired boilers was selected.

The combustion characteristics of biomass briquette of water hyacinth: empty fruit bunch fibers are moisture content, volatile matter, ash and fixed carbon. All blending ratios were compared with 100 percent water hyacinth briquette. Next, calorific value of each briquette was determined. The calorific value of densified biomass briquette is the key indicator in measuring the energy in biomass fuel. Besides, the gaseous emission from each briquette in open combustion was evaluated. Hence, from this study, the desired biomass briquette blending ratio could become a co-combustion agent to the coal fired boilers for mitigating the emission of toxic gaseous.

1.5 Significance of the Study

Biomass briquette from the combination of dried water hyacinth and palm oil waste can be applied as biomass-coal co-combustion. It presents a near-term, low-risk, low-cost and sustainable renewable energy option that promises reduction of toxic gases during the burning processes. By biomass briquetting, the portion of biomass waste is fully utilized apart from being disposed that will undergo

decomposition process. Hence, the production of toxic gases from fossil fuel burning and emission factor due to biomass decomposition can be reduced.

There are several privileges in the production of biomass briquette, which can be supplemented coal-fired boilers in coal power plant. Blending of biomass with coal in the existing coal-fired boilers will provide among the most effective means of reducing the net CO₂ emissions from coal-based power plants. Furthermore, this is one of the cheap way of biomass utilisation, and the biomass combustion itself presents renewable and CO₂-neutral energy. Coal combustion promotes high atmospheric carbon dioxide due to only one-way geological transfer of carbon towards the atmosphere. Thus, it is different with biomass combustion that absorbs the atmospheric carbon dioxide during its growth and then the CO₂ is emitted back towards the atmosphere during the combustion process (Demirbas, 2004). Thus, it helps to reduce the build up of CO₂.

For most of the countries, their main source of energy has been fossil fuels. The use of fossil fuels is not sustainable as this is a non-renewable source of energy. Thus, in providing partial substitution of fossil fuels, biomass combustion has the potential to be carbon dioxide (CO₂) neutral compared to the burning of fossil fuels alone that will contribute towards “greenhouse” effect. Biomass briquette is one of the alternative of renewable energy for a healthy environment and economy.

In Malaysia, the demand for energy is getting higher and higher with the increasing amount of population. Thus, low cost of alternative energy fuel from renewable energy is the sensible option to cope with the high demand of energy. The effort of utilizing the benefits of renewable energy is in-line with the Fifth-Fuel Policy under the 8th and 9th Malaysian plan, Energy Efficiency in Commercial Buildings (MS1525), The Kyoto Protocol, the Malaysian Building Integrated Photovoltaic Programme (MBIPV), and Biomass (Haw *et al.*, 2006).

1.6 Thesis Overview

In chapter 2, an overview on the characteristics of water hyacinth (*Eicchornia crassipes*) together with its application was given. Besides, the overview also includes the energy potential of water hyacinth biomass. The proposed water hyacinth biomass is to replace a portion of coal in coal-fired boilers as to mitigate the greenhouse gases. Thus, an overview about the coal burning issues and its impact towards the environment was also informed.

Moreover, the solution was also given by explaining on the biomass-coal blending as the target in coal fired power plant with empty fruit bunch (EFB) fibers as the co-combustion. The specific portion of biomass fuel properties was needed in order to avoid any big problems inside the coal fired boilers due to the alkaline content of biomass. Besides, an overview of briquetting process also was informed. Besides traditional process of briquetting, the existing briquetting technology was informed in this chapter.

While in Chapter 3, the experimental methodology on the biomass preparation of WH and EFB was explained, as well as the flow of briquetting process of biomass bio-briquette. The description given in the experimental procedure used in Chapter 4 was for the purpose of the reproducible manufacture of briquettes for blending with coal in coal fired power plant. Chapter 3 provides a means by which the biomass fuel properties, calorific value and its toxic gas emissions from different blending ratios can be compared.

Chapter 4 discussed on the results of each biomass fuel properties, the heating value gained in this study and the toxic emission from each blending ratios. The significant results were compared with the reference briquette in this study, and also the commercial briquette was compared with the moisture content, ash content and calorific value of WH: EFB biomass bio-briquette. The overview for the last chapter 5 includes the conclusion of this study and the recommendations made for the future work of this study.

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