

EVALUATING THE POSSIBLE MIXTURES OF THE GIANT SALVINIA WITH AGRICULTURE WASTES FOR BIOMASS FUEL

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Abstract

This study evaluates the possible mixture of the Giant Salvinia and agriculture wastes for biomass fuel by considering the moisture content that affects the heating value to use as a biomass fuel. Biomass is one of many types of weeds that expands rapidly throughout the swamps and causes ecosystem problems. Experimental process, the heating values of giant Salvinia with four different moisture content of 11 ± 0.5 , 12 ± 0.5 , 13 ± 0.5 , $14\pm0.5\%$ were determined by bomb calorimeter. It is found that at 11% moisture content, the Giant Salvinia gives the highest heating value of $2,970\pm15$ cal/g, and the heating value tends to decrease with increasing the moisture content. Considering the mixture between the Giant Salvinia and the agricultural wastes, the highest heating value is the Giant Salvinia with rice husk, wood, charcoal, and rice straw. This study's obtained results can be used as new raw material for biomass fuel, which solves agricultural waste's ecosystem problems and value-added.

Keywords: Giant Salvinia, Agriculture wastes, Heating value, Biomass fuel

Introduction

At present, energy consumption has been continuously increased, while the main energy source is limited. Fossil fuels have been depleted and cannot be replaced in a short time that; especially fuel energy is "oil" Many countries' problem is rising oil prices that affect other parts such as the economy, causing the country's development to be energy consumption of 92,429 ktoe. It is found that the total energy consumption

for renewable energy is 12,608 ktoe or 13.64% of the total energy (Manish *et al.*, 2011). The total energy consumption as biomass is 11,903 ktoe, while the firewood is 1,184 ktoe or 13.64% of the total renewable energy. From the study, it was found that the heating values of the various biomass fuels are 4,796 cal/g for eucalyptus (Antonio *et al.*, 2013), 4,880 cal/g for acacia (Ramandan *et al.*, 2014), 4,608 cal/g for Great Acacia (Tarig *et al.*, 2012),

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4,322 cal/g for pinewood (Monika *et al.*, 2014) and 6,160 cal/g for melaleuca tree (Wang *et al.*, 1983). In general, firewood's heating values are about 4,692.10-4,966.56 cal/g (Telmo *et al.*, 2011). It has been fed to biomass power plants with other agricultural and industrial waste materials (bagasse in sugar factories, rice husk in rice mill). There were various weeds, especially in the rainy season, that can be used as the raw material for biomass fuel (McEniry *et al.*, 2014). Giant Salvinia is a kind of water fern, and a scientific name is *Salvinia molesta* D.S. Mitchell in the family Salviniaceae. It is a floating plant but does not stick to the soil, no real root, the trunk is slightly long under the water surface, giant stalks can belong up to 4 cm. The propagation is splitting the shoots from the original tree's axillary and growing to break out, growing well, instilling water flow conditions. It grows up to cover an area of 100 km² in 3 months. The characteristics of Giant Salvinia are shown in Figure 2. There has been a study of Giant Salvinia's disposal by using in raising tilapia fish culture, which is a biological control (Mcintosh *et al.*, 2003).

Biomass is an organic substance that is natural storage energy and can be used to produce energy. These organic substances are derived from various plants and animals such as wood, waste, agricultural waste, etc. Biomass usage to make heat by burning to produce energy into the electricity generation process can replace fossil fuel energy. There are many biomass sources; crops, agricultural waste, wood, wood residues, industry residues, and community residues. Biomass fuel is in three different forms; solid, liquid, and gas phases. Although it is natural energy, it affects the environment as well when burning, which causes air pollutants such as particles, carbon monoxide, and hydrogen sulfide (Trimble *et al.*, 1984). In Turkey, biomass is used as the main energy source in the country's rural areas that are used in electricity production, household heating as fuel for heating in the production process for industrial plants. In Turkey, biomass is used to produce all energy, about 14%. The amount of biomass, about 17 Mtoe is used to produce 73 MW of electricity (Toklu, 2017). However, biomass fuel has low heating value, high cost of storage, and high-cost transportation. Many studies on mixing biomass fuel with coal for the combustion system significantly reduce environmental problems (Abbas *et al.*, 1996). It is also applied by mixing with charcoal for the Direct Carbon Fuel Cell system (DCFC) (Ahna *et al.*, 2013).

For the steel production process, biomass fuel is not suitable for this process. If renewable biomass fuel, however, it can be used to reduce carbon dioxide emissions (Mathieson *et al.*, 2015). In

Sweden, the CO₂ emissions tend to decrease as the biomass fossil fuel 65% used in the electrical generation system is about 20% (Börjesson *et al.*, 1997). For the household and industrial systems, using biomass energy tends to increase. However, it is not confirmed for use in the long term (Hall *et al.*, 1994). Next, the trends of wind energy in a global and Thailand context had been reviewed (Manish and Thananchai). From the past studies, there was not much information about the biomass of the Giant Salvinia. In addition, it has spread in the swamps of Thailand. It was found that the rapid spread of this plant pollutes aquaculture and has a profound impact on the economy of aquaculture farmers. If the introduction of these weeds (Giant Salvinia) is eliminated or utilized in energy, this weed can grow quickly.

The Giant Salvinia is one of many types of weeds that expand rapidly throughout the swamps, causing ecosystem swamp problems. This study aims to determine the heating values of Giant Salvinia with different moisture contents for biomass fuel. In addition, finding possible ways to use the Giant Salvinia for biomass fuel by combining it with agricultural wastes has been investigated.

Materials and Methods

Test apparatus

The experimental system for determining the heating values of the Giant Salvinia of this study is shown in Figure 1, which consists: 1) Bomb calorimeter, which consists of a bomb, a water tank, a fuel cup, a stirrer, a thermometer, and the ignition control unit, 2) ASTM C56 thermometer that is measuring 19-35°C, 0.02-degree resolution with a magnifying glass for fine reading, 3) Oxygen tank with extension cable into the bomb, 4) Weight scales, size 0.0001 g., 5) Watch, 6) Glass syringe with volumetric scale for adding distilled water or fuel, 7) The ignition wire is about 10 cm long, 8) Pure water (distilled water) and 9) Benzoic acid tablets with heating value standard for experiments. Besides, there is a moisture meter, a blender used to spin raw materials into small pieces, and raw material dryers for the preparation process.

Method

Experimental processes are performed to determine the Giant Salvinia's heating values at four different moisture content of 11, 12, 13, 14%. The fresh Giant Salvinia is collected from the swamps, and they are dried at a different moisture content that the oven can control, as shown in Figure 2. Before testing, the prepared Giant

Salvinia must be crushed into the small scales)1 mm(, as shown in Figure 3. Each experiment process performs with the crushed Giant Salvinia with 1g three times for average value. The heating value process can be performed following to ASTM standard. The mixture's heating values between the Giant Salvinia and other agricultural wastes, rice husk, charcoal, rice straw, and wood in the ratio of 1:1 are also performed. Finally, the heating values of various raw materials are done ten times to obtain the average and standard deviation.



Figure 1. Bomb calorimeter system used in the present study



Figure 2. Photograph of the fresh and dry Giant Salvinia



Figure 3. Photograph of the crushed dry Giant Salvinia

Data reduction and uncertainty analysis

The fuel's heating value is the amount of heat transferred from the fuel in the complete combustion system by burning hydrocarbon fuels with oxygen. The obtained products of the complete combustion process are carbon dioxide and water. A bomb calorimeter is a tool for testing the heating value of fuel following ASTM standards.

The uncertainty and accuracy of the measurement are given in Table 1. Uncertainty

estimation can be done by considering the instruments' errors, the measurement variance, and calibration errors. Based on Coleman and Steele (Coleman *et al.*, 1989), the uncertainties of the relevant parameters obtained from the data reduction process are calculated with the maximum uncertainties of the heating value is $\pm 5.0\%$.

Table 1. Accuracy and uncertainty of instruments

Instruments	Accuracy	Uncertainty
Weight scale	0.01%	± 0.01
Thermometer	0.1%	± 0.02
Moisture meter	0.02%	± 0.02

Results and Discussion

In the experimental process, the Giant Salvinia, with moisture contents of 11, 12, 13, 14%, is tested to determine the heating values. The moisture content range used in the analysis process is in the moisture content range (5-50%) for the biomass fuel used in the common heat generators. Table 2 shows the average heating values of Giant Salvinia with four different moisture contents. It can be seen that the moisture content has a significant effect on the heating value of Giant Salvinia. It can be seen that the heating value of four moisture contents is quite different, i.e., 2930 cal/g for 11% moisture content, 2720 cal/g for 12% moisture content, 2470 cal/g for 13% moisture content, and 2310 cal/g for 14% moisture content. Generally, the % ash produced by combustion is inversely related to the moisture content of the fuel. The high moisture content of biomass leads to high %ash content due to incomplete combustion. In the low moisture content of biomass fuels, low %ash content is obtained because the combustion is more complete than higher moisture content. The moisture content can be determined from the following Equation;

$$\%moi = \frac{w_1 - w_2}{w_1} \times 100 \quad (1)$$

Where w_1 and w_2 are the weight before and after baking, respectively.

Table 2. The heating value of the Giant Salvinia

Moisture (%)	Heating Value (cal/g)
11.00 $\pm$ 0.5	2,930 $\pm$ 15
12.00 $\pm$ 0.5	2,720 $\pm$ 15
13.00 $\pm$ 0.5	2,470 $\pm$ 15
14.00 $\pm$ 0.5	2,310 $\pm$ 15

This means that the heating value and % ash tend to increase with decreasing moisture content (%moi), as shown in Table 2. With 11% moisture content, the Giant Salvinia gives the highest heating value of $2,930 \pm 15$ cal/g compared with other moisture contents. Based on the results, the relationship between the heating value and the moisture is proposed as in the following correlation;

$$\text{Heating value} = -0.25(\% \text{moi})^4 + 19.259(\% \text{moi})^3 - 474.72(\% \text{moi})^2 + 4567.3(\% \text{moi}) - 11836 \quad (2)$$

The application range is $10 < \% \text{moi} < 15$ and gives $R^2 = 0.9994$

The comparison of the Giant Salvinia's heating value with other agricultural wastes is shown in Table 3. It can be seen that Giant Salvinia has the potential for the raw material for biomass fuel. However, it can be seen that the heating value of Giant Salvinia is lower than that of almost all agricultural wastes. In this study, the Giant Salvinia's higher heating value can be improved by mixing with other agricultural wastes with high heating values, as shown in Table 4. The experiments are performed by mixing the Giant Salvinia with other agricultural wastes; rice husk, charcoal, rice straw, and wood with a ratio of 1:1

by mass. The heating value of the mixing Giant Salvinia with four different agricultural wastes is quite different. The two highest heating values are obtained from Giant Salvinia with rice husk and wood, respectively. Because the heat values of rice husk and wood are already high, when mixed with a Giant Salvinia, the heat values of the mixed tests will be increased as well. It was found that the heating values of the mixture of Giant Salvinia with other agricultural wastes are 5,924.95, 5,788.18, 5,428.50, and 4,081.99 cal/g for rice husk, wood, charcoal, and rice straw, respectively.

Conclusions

This research is to determine the Giant Salvinia's heating value and experiment to find the relationship of the moisture content that affects the heating value of the combustion in the laboratory. Experiments are performed with the Giant Salvinia with the different moisture content of 11 ± 0.5 , 12 ± 0.5 , 13 ± 0.5 , and $14 \pm 0.5\%$. The results showed that the Giant Salvinia at 11% moisture content gives the highest heating value of $2,970 \pm 15$ cal/g and decreases with increasing moisture content. The comparison of the heating value of the giant Salvinia biomass with other types of biomass with a 1:1 ratio, it is found that

Table 3. Comparison of the heating value from Giant Salvinia and other agricultural wastes

Biomass	Heating Value (cal/g)	Remark
Acacia	6,972	**
auriculiformis sp.		
Leucaena leucocephala	7,617	**
Melaleuca Leucadendron, Linn	4,474	**
Wood Charcoal	6,732	**
Compress rice husk	3,740	**
Rubberwood charcoal	7,220	**
Rice husk	3,407	**
Rice straw	4,148	**
Zea mays Linn.(Corn cob)	4,351	**
Cocos nucifera Linn.(Coconut shell)	4,631	**
Sawdust	4,461	**
Hevea Brasiliense Mull. Arg. (Rubberwood scrap)	4,580	**
Rice husk	7,628	*
Charcoal	6,572	*
Rice straw	4,303	*
Wood	7,574	*
Giant Salvinia	2,930	*

* Present study

** Royal Forest Department, (2017)

Table 4. Heating values of the mixing of the Giant Salvinia and the agriculture wastes

Mixtures (1:1)	Heating values (cal/g)
Giant Salvinia with rice husk	$5,920 \pm 15$
Giant Salvinia with charcoal	$5,415 \pm 15$
Giant Salvinia with rice straw	$4,080 \pm 15$
Giant Salvinia with wood	$5,785 \pm 15$

the heating value closes to that of the other agricultural wastes such as rice husk, corn cob, coconut shell, sawdust, and rubberwood scrap. However, the Giant Salvinia's heating values can be improved by mixing with agricultural wastes with heating values. However, for the proper proportioning of each substance for obtaining the maximum heat value, it has been continuously studied. The selection of agricultural waste types to mix with the Giant Silvinai depends on the agricultural waste quantity and the seasons. The obtained results are the ecosystem problem solve and are value-added of farming wastes.

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