Characterization of Fuel Briquettes Made from Sewage Sludge Mixed with Water Hyacinth and Sewage Sludge Mixed with Sedge

N. Supatata, J. Buates, and P. Hariyanont

Abstract—This research aimed to study the quality of the fuel briquettes made from sewage sludge mixed with water hyacinth and sewage sludge mixed with sedge. Sewage sludge were mixed with water hyacinth and sedge at the ratios of 1:1, 1:2, 1:3, 2:1 and 3:1 then compressed these mixtures with hydraulic pressure to obtain fuel briquettes and finalized them by analyzing fuel briquettes properties including moisture content, calorific value and compressive strength, then comparing them to the properties of the wood charcoal standard. The result showed that the ratio of wastewater sludge and sedge at 1:3 provided the highest calorific value (3,362.9 cal/g) but still lower than the standard (5,000 cal/g) and the ratio of wastewater sludge and water hyacinth at 1:3 gave the highest compressive strength value (4,545 N). And the moisture content of them was between 4.78% and 7.86%.

Index Terms—Sewage sludge, water hyacinth, sedge, fuel briquettes.

I. INTRODUCTION

Municipal sewage sludge is residue generated from the wastewater treatment process as a result of the treatment of wastewater released from a variety of sources including homes, industries, medical facilities, street runoff and businesses annually generate millions of tons of sludge worldwide. This sludge management is a crucial part of waste treatment involving substantial cost and effort. Bangkok, a capital city of Thailand, occupies a total area of about 1,570 km² with approximately of 10 million populations generating nearly 3 million m³/day of dry weather flow wastewater which 75% come from households and 25% come from industrial and commercial sectors [1]. 992,000 m³ of wastewater per day has been treated by seven Centralized Wastewater Management (CWWM) plants with the total cost of US\$780 million, with 60-80% subsidized by government and 20-40% by Bangkok Metropolitan Administration (BMA) [2]. This wastewater excess sludge then has been treated by the sludge treatment centre with full capacity of 120 tons dry sludge/day [3].

Biomass is abundant, renewable and sustainable fuel that

can reduce carbon emissions compared with fossil fuels. Consequently, it is likely to be an attractive clean development mechanism (CDM) option for decreasing greenhouse gas (GHG) emission [4], [5]. Such as water hyacinth and sedge which are important sources. At present, most of them are abandoned as waste, also pollutes the environment.

Briquette is a means to convert sewage sludge and biomass residues through simple technology that is inexpensive and suitable to be managed by small communities especially in developing countries. The sewage sludge has some characteristics including high moisture content, ash, density and viscosity, low heat value. On the other hand, biomass residues contain lower ash, and can be made into high heat value products [6], but they are low density and tend to float and fly, which is inconvenient to storage and transportation. If these two materials are mixed in appropriate proportion, it may resolve their problems and compensate their weakness each other.

The aim of this study was to investigate the quality of the fuel briquettes made from sewage sludge mixed with water hyacinth and sewage sludge mixed with sedge. Water content, calorific value, and compressive strength of these productions were studied and compared to the properties of the wood charcoal standard.

II. EXPERIMENTAL

A. The Raw Material Collection and Characterization

The experimental material of sewage sludge was obtained from the central wastewater treatment plant of Si Phraya in Bangkok, Thailand. The water hyacinth was collected in canals near Bangkok. The moisture content was determined after drying a sample at 105 °C according to ASTM D2016-25. To obtain the ash content, a dried sample of 2 g is burned at 800 °C during 5 hours according to ASTM D-5142. The volatile matter was determined according to ISO 562/1974. It was measured by introducing a dry sample of 1 g into a crucible with top at 950 °C during 5 minutes. The proximate analyses of the three materials are listed in Table I.

Table I showed that the volatile matter and ash content of the sewage sludge sample were relatively high. The volatile matter content of sewage sludge was relatively high.

B. The Process of Briquetting

A home-made mold was designed and built to make fuel briquette, with the size of 5.5cm × 5.5cm × 5.5cm (Fig. 1).

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TABLE I: CHARACTERISTICS OF SEWAGE SLUDGE AND WATER HYACINTH

Samples	Moisture content (%)	Volatile matter (%)	Ash content (%)	Calorific value (cal/g)
Sewage sludge	6.64±0.02	45.22±0.22	42.09±0.18	2,057.05 ±5.37
Water hyacinth	4.40±0.04	20.27±0.17	15.16±1.04	2,057.10 ±1.95
Sedge	9.60±0.05	78.25±0.06	6.84±0.97	2,792.00 ±1.95

Fig. 1. Fuel briquette mold

Fig. 2 summarized the sample preparation process. Dried sewage sludge and water hyacinth samples with particle sizes between 74 and 300 μm were blended to produce homogenous mixes with the ratios of sewage sludge and water hyacinth or sedge; 1:1 (water hyacinth or sedge 50%), 1:2 (water hyacinth or sedge 66%), 1:3 (water hyacinth or sedge 75%), 2:1 (water hyacinth or sedge 33%), and 3:1 (water hyacinth or sedge 25%) by weight on a dry basis. Compacted samples were prepared by adding 15 % of starch and pressing at 60 kgf/cm^2 (800 psi) by using hydraulic press machine (type NSP-15) to form the fuel briquette. Then the fuel briquettes were dried in the oven for 48 h at temperature of 75 $^{\circ}\text{C}$.

Fig. 2. The procedure of fuel briquette

C. Experimental Design

The experimental Complete Random Device Factorial with ten treatments and three replications was used to study the effects of various ratios of sewage sludge mixed with water hyacinth and sewage sludge mixed with sedge. Fuel

briquette properties including compressive strength were analyzed by Shimadzu Autograph (AG-1000E) and calorific value were determined by Bomb Calorimeter (AC-300) respectively.

III. RESULTS AND DISCUSSION

A. Physical Properties of Fuel Briquette

The product was basically a cubic solid fuel briquette (Fig. 3) for all test specimens and having different value for every parameter on physical properties as showed in Table II and Table III.

Fig. 3. Fuel briquette from sludge mixed with water hyacinth

All briquettes made from sewage sludge mixed with water hyacinth and sewage sludge mixed with sedge had fractures on the surface (Fig. 3) which will lead to decrease the quality of them because the briquette of high quality has to be with correct shape and durability. The structural integrity of the briquette is effected by the size of particles, moisture, contents of lignin and cellulose. Lignin in biomass can enhance the binding characteristics of densified banquette during the preheating of the material [6]. A higher lignin with a small particle size and low moisture glues the briquette more strongly together [7]. In this study, the fractures on the surface probably were effected by irregular size of particles.

The result in Table II showed that the moisture content of the briquette made from sewage sludge mixed with water hyacinth was between 4.78 % and 6.24 %. The calorific value of the briquette was between 2, 521. 8 cal/g and 2,785.9 cal/g, lower than TCPS standard for Thai community product. The ratio of wastewater sludge and water hyacinth at 1:3 provided the highest calorific value (2, 785. 9 cal/g) and had a closer calorific value to the TCPS standard of wood charcoal briquettes. Many works showed that the colorific value of fuel briquettes increased as the temperature increased due to volatile matter and moisture content were removed from the briquette while the fixed carbon concentration had increased [8], [9]. The ratio of wastewater sludge and water hyacinth at 1:3 showed the highest compressive strength value (4,545 N).

The result from Table III showed that the moisture content of the briquette made from sewage sludge mixed with sedge was between 6.04 % and 7.86 % higher than the briquette made from sewage sludge mixed with water hyacinth. The calorific value of this mixture was between 2, 774. 5 cal/g and 3, 362. 1 cal/g and the ratio of sewage sludge and sedge at 1:3 gave the highest calorific value. Even though its calorific value was higher than briquette made from sewage sludge mixed with water hyacinth (2, 521. 8 cal/g - 2, 785. 9 cal/g), it was still lower than TCPS standard for Thai community product (5,000 cal/g). The ratio of sewage sludge

and sedge at 1:3 showed the highest compressive strength value (1,068 N) but lower than the briquette made from sewage sludge and water hyacinth at the ratio of 1:3.

TABLE II: THE PHYSICAL PROPERTIES OF FUEL BRIQUETTES MADE FROM SEWAGE SLUDGE MIXED WITH WATER HYACINTH AND TCPS STANDARD OF THE WOOD CHARCOAL BRIQUETTES

Parameters	Treatment (sewage sludge : water hyacinth)					TCPS standard
	1:3 (Water hyacinth 75%)	1:2 (Water hyacinth 66%)	1:1 (Water hyacinth 50%)	2:1 (Water hyacinth 33%)	3:1 (Water hyacinth 25%)	
Moisture content (%)	4.78 ±1.04	5.57±0.36	5.88±0.22	6.01±0.17	6.24±0.02	≤ 8
Calorific value (cal/g)	2,785.9±8.65	2,725.3±22.19	2,638.9±9.90	2,585.1±14.84	2,521.8±13.14	≥ 5,000
Compressive strength value (N)	4,545±8.65	4,047.5±12.5	2,147.5±12.5	2,137.5±17.5	1,030±25	-

TCPS standard: Thai Community Product Standard

TABLE III: THE PHYSICAL PROPERTIES OF FUEL BRIQUETTES MADE FROM SEWAGE SLUDGE MIXED WITH SEDGE AND TCPS STANDARD OF THE WOOD CHARCOAL BRIQUETTES

Parameters	Treatment (sewage sludge : sedge)					TCPS standard
	1:3 (sedge 75%)	1:2 (sedge 66%)	1:1 (sedge 50%)	2:1 (sedge 33%)	3:1 (sedge 25%)	
Moisture content (%)	7.86 ±0.48	7.54±0.27	6.98±1.02	6.73±0.97	6.04±0.76	≤ 8
Calorific value (cal/g)	3,362.1±17.83	3,196.6±18.43	2,962.5±29.34	2,814.2±17.03	2,774.5±31.49	≥ 5,000
Compressive strength value (N)	1,068.43±119.30	948.33±126.62	852.5±116.67	796.67±242.71	463.33±49.32	-

TCPS standard: Thai Community Product Standard

To produce good briquette, 3 major physiochemical characteristics have to be considered including moisture content, ash content, and flow characteristics. First, moisture content should be low because high moisture content will cause problems in firing and excessive energy will be needed for drying, moreover can lead to affect the quality of combustion. Second, ash content should be less than 4% because biomass with high ash content mostly composed of huge alkaline earth metals. These components have low fusion temperature which leads to an increment in the slagging potential. Third, flow characterization should be high. The particles with low flow characteristics will cause briquetting. The more granular homogeneous materials can flow easily in conveyors, bunkers and storage silo, which are appropriated for briquetting [6].

IV. CONCLUSION

In Thailand, according to TCPS standard of the wood charcoal briquettes have a maximum moisture content of 8% and a minimum calorific value of 5,000 cal/g. If we consider calorific value as a major quality index for fuels and compare with TCPS standard for wood charcoal briquette (see Table II and Table III), the treatment with ratios of 1 sewage sludge: 3 sedge (75% of sedge) will be selected as the treatment with the most beneficial characteristic as a renewable energy source, as it had a closer calorific value to the TCPS standard of wood charcoal briquettes. To make these briquettes made from sludge mixed with water hyacinth and sedge more efficient, this study will require more development such as reducing ash, grinding and sieving with homogenous size of particles, pressing in other shapes to increase more flow characterization etc.

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