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COMPARATIVE STUDY ON CHARACTERISTICS AND POTENTIAL OF RICE STRAWS AND DRY LEAVES AS A BINDER IN REFUSE DERIVED FUEL (RDF)

(Kajian Perbandingan Pencirian dan Potensi Jerami Padi dan Daun Kering Sebagai Pengikat Dalam Bahan Bakar Buangan)

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Abstract

Integrated waste management systems are one of the greatest challenges in order to develop the green environment. In this research, two types of binder were chosen in producing of Refuse Derived Fuel (RDF) which is rice straws and dry leaves. The objective of the research is to identify which types of binder that can give the optimum performance. This two binder was mixed with paper and plastic waste with controlled mixing ratio which is 3:1 (ratio 1), 3:1.5(ratio 2) and 3:2 (ratio 3). In order to identify the optimum ratio of RDF, 45 number of samples was prepared and their properties such as moisture content, carbon content, sulfur content, chlorine content and calorific value were evaluated. Result indicated that samples with rice straw as a binder give the optimum result with the ratio of 3:1. The optimum values of the carbon content is 50.9%, moisture content is 5.5%, chlorine content is 0.0%, sulfur content is 2.1% and calorific value is 29.0 MJ/kg. Hence, rice straws shows a great potential to be used as binder in production of RDF.

Keywords: Rice Straws, Dry Leaves, Refuse Derived Fuel, Potential, Characteristics

Abstrak

Sistem pengurusan sisa pepejal bersepadu merupakan satu cabaran terbesar dalam membangunkan persekitaran mesra alam. Dalam penyelidikan ini, dua jenis pengikat telah dipilih untuk menghasilkan Bahan Bakar Buangan iaitu jerami beras dan daun-daun kering. Objektif penyelidikan ialah untuk mengenal pasti jenis pengikat yang boleh memberi prestasi yang optimum. Pengikat akan diadunkan dengan kertas dan bahan buangan plastik dengan nisbah campuran terkawal iaitu 3:1 (nisbah 1), 3:1.5 (nisbah 2) dan 3:2 (nisbah 3). Dalam mengenal pasti nisbah optimum bahan bakar buangan yang dihasilkan, sebanyak 45 sampel telah disediakan dan pencirian sampel seperti kandungan lembapan, kandungan karbon, kandungan sulfur, kandungan klorin dan nilai kalori telah dikenalpasti. Hasil menunjukkan bahawa sampel dengan pengikat jerami padi memberi hasil optimum dengan nisbah 3:1. Nilai-nilai optimum kandungan karbon ialah 50.9%, kandungan lembapan ialah 5.5%, kandungan klorin ialah 0.0%, kandungan sulfur ialah 2.1% dan nilai kalori ialah 29.0 MJ/kg. Oleh itu, jerami beras menunjukkan potensi besar untuk digunakan sebagai pengikat di pengeluaran bahan bakar buangan.

Kata kunci: Jerami Padi, Daun Kering, Bahan Bakar Buangan, Potensi, Pencirian

Introduction

The amount of solid waste generated s one of the most debatable environmental issues. In order to overcome this issue, many initiatives created such as applying the integrated waste management. Waste management is one of the ways the ways to control the production of waste. It includes six strategies which are rethink, refuse, reuse, replace, recycle and remove to pursuit environmentally sustainable development area. Lack of managing in solid waste may affect the eco system and indirectly effect human health. Refused derived fuel (RDF) is a new and alternative way of managing waste beside incineration process.

Refuse Derived Fuel (RDF)
RDF is a solid waste which is consists of paper and plastic use as a fuel for boilers to produce steam or electricity. RDF is frequently burned in utility boilers and also been mixed and burned with coal. Generally it is a waste that has been sorted, reduced in size, and refined by removal of noncombustible such as metals and glass [1]. The concept of processing waste for the purpose of RDF production has received additional impetus in Europe [2]. The aim of the RDF preparation is to improve the quality of the waste stream in a way that the substitute fuel produced can be burned in plants without operational problems and without pollution loading. [3]. Thus process was gained from combustion process. Combustion, in its most basic sense, is the process whereby the hydrogen and carbon in fuel is combined with oxygen from the air to release heat [4]. Energy recovery as RDF is preferred option for utilizing plastic wastes when their potential recycling as raw material for product manufacturing is not possible because their physical properties damaged during long-term exposure to sunlight. However, their high calorific content (18 – 25MJ/kg) remain especially when almost dried completely during summer but purification process is still required if there are to be utilized as energy source [5].

Rice Straws
Rice straw is the residue and the excesses of production of rice that was not utilized [6].The main carbohydrate components of rice straw are hemicellulose, cellulose and lignin. For every tonne of grain harvested, about 1.35 tonnes of rice straw remain in the field. Rice straw has a high potential as a source of lignocellulosic biomass because of the high yield of rice straw per hectare [4]. Burning the rice straws away not only pollutes the environment, but also may cause the traffic accident if the field is close to the freeway. Moreover, the abandoned rice straws in the field sometimes may flow into the drainage during the rainy season and cause an obstruction of the drainage, or provide the place for the propagation of the bacteria [7]. The waste that comes from rice straws that utilize into RDF has the potential for becoming a secondary renewable energy in Taiwan [8]. Among the alternative energy resources, the biomass becomes an important renewable energy resource because it has appealing properties, such as low production cost, low greenhouse gas and low acidic gas emissions.

Dry Leaves
In India, sugarcane is harvested manually. The tops and leaves are stripped from the stalks in the field after cutting the stalks. The tops are extensively use as fodder for animals. However, dried leaves are disposed of by burning them in the open field, which is large loss of potentially useful heat energy. Gasification of these leaves offers a better option for their utilization [9].

Materials and Methods

Production of RDF briquettes
The plastics and papers wastes were shredded separately before mix together with ratio 1:1. Rice straw and dry leaves were crash and turn into paste by adding water before mixing with the wastes mixture. The weight ratio of the wastes mixture and binders (rice straw and dry leaves) were varied at 3:1 (ratio 1), 3:1.5 (ratio 2) and 3:2 (ratio 3). The total weight of each briquette is 500 gram (Table 1). The formation of briquette was conducted at room temperature using a 5-hp screw compactor at 15 MPa of compression. After the production process, they were stored under ambient conditions for 5 days before their utilization. Triplicates samples of the RDF produces were tested in the laboratory typical for moisture content, carbon content, calorific value, sulfur and chloride analysis.

Table 1. Sample Ratio

Sample Ratio	Paper + Plastic (Wastes Mixture) : Binder	
	Waste Mixtures : Dry leaves (Binder) (g)	Waste Mixtures : Rice straw (Binder) (g)
3:1	375 : 125	375 :125
3:1.5	333 : 167	333 : 167
3:2	300 : 200	300 : 200

Analyses / Characterization

a) Moisture content: The initial weight of sample was determined and the samples were dry at temperature 77^{o}C for 24 hours using oven. Then, the final weight of sample determined after drying process.

b) Carbon content: The empty ceramic crucible was weight. The sample was put in the empty ceramic crucible. The crucible with the sample was weight and the weight was recorded. The crucible was place into a furnace at room temperature and the crucible was heated for 15 minutes in the 600^{o}C. The crucible in the desiccators was cool before weighing the crucible with the sample. The differences between the initial and the final weight in the amount of volatile solid is determined as carbon content.

c) Energy content: The determination of energy content was conducted by using bomb calorimeter. 10 grams of samples was picking and put into the bomb calorimeter. Then the result of the process release from the display monitor.

d) Chloride content: Quantitatively the chloride solution was transferred into a 250ml Erlenmeyer flask. 10ml of HNO_3 was added while stirring gently during the acid addition. Then, 20ml of standard $AgNO_3$ solution was added. Stopper, mix and let the solution to stand in dark for 15 minutes and cool at room temperature. 5 to 10ml of nitrobenzene was added and shake for 1 min. 8 to 10 drops of $FeNH_4(SO_4)_2$ was added to the solution and titrate with standard KCNS solution against white background. The end point of the determination was reached when solution becomes faintly orange pink in colour.

e) Sulfur content: 5.0g of sample was weight into weight ceramic crucible. The sample was mix with 10.0g of Eschka mixture well. Another 5.0g mixture was added to cover the mixture. The crucible and its content were placed in muffle furnace. The temperature was raised gradually to 815^{o}C within 1 hour. Then, continue heating at this temperature for another one and half hours. The crucible was removed from the furnace and empties all its content into 500ml beaker. 100ml of hot distilled water was added and 15ml of concentrated hydrochloric acid. The solution was stirred for 30 to 45 minutes with occasional stirring. The solution was filter through Whatman filtered paper into 500ml beaker and washes 5 times with hot distilled water. The filtered was collected about 250ml beaker. 3 to 4 drops of methyl orange were added to the filtrate. The filtrate was neutralized with 1:1 ammonia solution until gel was formed. 1:1 hydrochloric acid was added until the solution become pink. 10ml of hot barium chloride was added and stir. The solution was boiled for 15 minutes and allowed it to stand at room temperature for overnight. The solution was filtered through Whatman filter paper and washed for 6 times with hot distilled water. The filter paper was placed in the ceramic crucible and recorded the weight, W_1. Dry in the oven. Then, the filter paper was ignited in furnace at 1000^{o}C for 45 minutes. The crucible was cool in desiccators before weighing. The crucible was weight, W_2. Calculation for the sulfur content is shown as below:

$$\text{Percentage of sulfur (\%)} = [W_1 - W_2] \times 13.738 / M$$

where: M = weight of sample used.
13.738 is the percentage of sulfur atomic weight to the molecular weight of barium sulphate.

Results and Discussion

Moisture Contents

Figure 1 showed the percent of moisture content produced from rice straw and dry leaves as a binder are 3.0% to 7.6%, respectively. Sample 2 of dry leaves which is the ratio of 3:1.5 seems to be the lowest reading with the values of 3.0% while the highest is rice straw with the ratio of 3:2 and value 7.6%. From the figure below, due to differences in morphology of the binders the readings show that the moisture contents increase exponentially with the quantity of rice straw. Researched has been founded if the material is too dry, the surface of the material may carbonize and the binder will burn before the combustion process finished completely, whereas if the material is too wet, then the moisture contained in the pressing cannot escape and enlarges the RDF volume, making it mechanically weak [10].

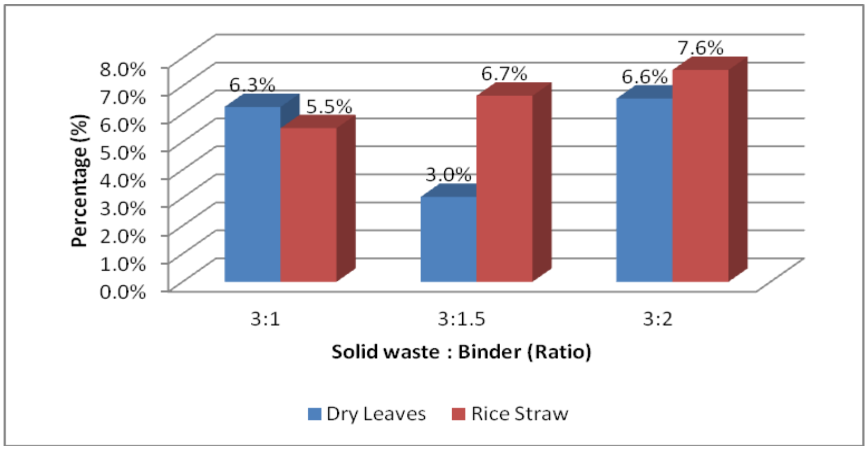

Figure 1. Moisture content

Carbon Contents

Based on the results in figure 2, the sample with ratio 3:1 of rice straw gives the highest reading which is 50.9% where by the lowest is the third sample of rice straw which is 38.6%. The higher carbon content in fuels leads to the higher combustion efficiency [11]. Carbon is present in every hydrocarbon fuel and this will react with oxygen in combustion process [4]. So that in order to choose the good RDF, this parameter must take under consideration.

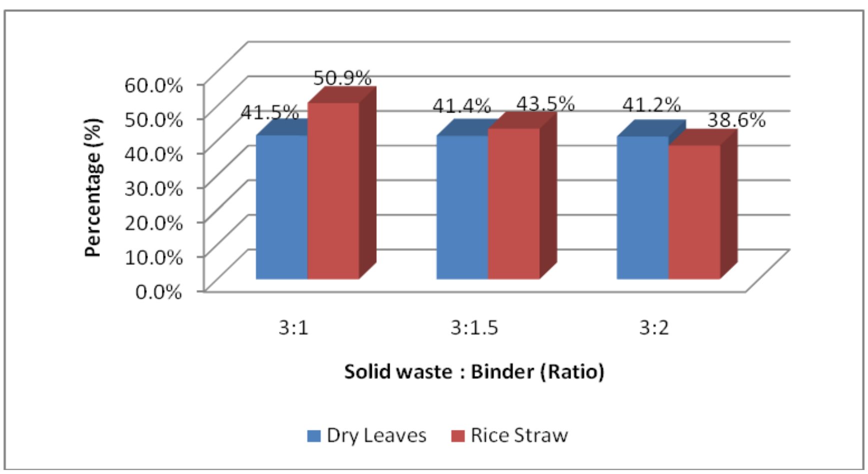

Figure 2. Carbon content

Calorific Value

Figure 3 below shows the reading of sample 1 with ratio 3:1 get the highest value which is 29 MJ/kg while the third sample shows the lowest reading that is 20.40 MJ/kg. The sample ratio 1 of rice straw gives the higher value of energy content may because of the amount of solid waste mixed is less compare to sample ratio 2 and 3. The reading for calorific value of rice straw obtained as 27.5 MJ/kg to 38.5 MJ/kg [1]. While, the calorific value of rice straw in Europe is about 15.3 MJ/kg [12]. For typical value for plastic wastes is 28 MJ/kg to 37 MJ/kg [12]. In order to produce the good performance of RDF, high energy content is required from the sample for better performance in combustion process.

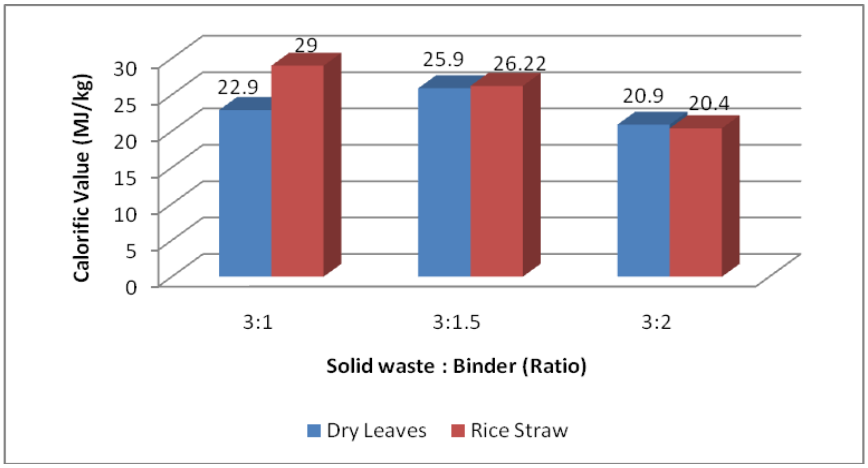

Figure 3. Energy content

Chloride Content & Sulfur Content

Table 2 illustrates the percentage of chloride and sulfur in the composition of wastes while rice straw and dry leaves which acts as the binder. Based on Table 1, the percentage of chloride varies from 0.0% to 0.01% as rice straw as a binder and dry leaves as well. The ratio 1 of rice straw as a binder gives the lowest reading 0.0% whereby the ratio 3 contains the highest amount of chloride, 0.1%. Same goes to sulfur in sample ratio 1 indicates the lowest value while the ratio 3 gives the highest value. Meanwhile, the result for dry leaves as a binder indicated the constant reading of sulfur content in all 3 ratio which is 2.2% and for chloride content showed the ratio 2 is the lowest percentage. High chlorine and sulfur can lead to higher emission of acidic gaseous pollutants such as HCl, SO_X and organic chlorinated compounds for example PCCDs and PCDFs in the incineration process [13]. With these limitations, it is suggested that the preparation of plastic wastes should be blended with other low chlorine containing materials before being used as RDF in order to comply with the specified limit [1].

Table 2. Chloride and Sulfur content

Sample	Ratio of wastes : Binder (rice straw) weight ratio		Ratio of wastes : Binder (dry leaves) weight ratio	
	Chloride Content (%)	Sulfur Content (%)	Chloride Content (%)	Sulfur Content (%)
1	0.0	2.1	0.1	2.2
2	0.0	2.2	0.0	2.2
3	0.1	2.7	0.1	2.2

Conclusion

After all the experiment have been conducted and data analyzed, the result indicated that samples with rice straw as a binder give the optimum result with the ratio of 3:1 (ratio 1) meanwhile the sample with dry leaves as a binder indicated the sample with ratio 3:1.5 (ratio 2) as the optimum result. After further consideration related to literature review such as the carbon content in ratio 2 is not so high because the higher carbon content in fuels leads to the higher combustion efficiency. Furthermore, the characteristic of energy content is also important because it shows the ability of material can be combustible and produce the energy. Hence, rice straws with ratio 3:1 have a great potential as a binder to produce refuse derived fuel (RDF) for application purpose compare to dry leaves.

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