Technical Journal, University of Engineering and Technology (UET) Taxila, Pakistan *Vol. 26 No. 1-2021*
ISSN:1813-1786 (Print) 2313-7770 (Online)

Potential Effectiveness of Different RDF Binders from Agro Waste

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Abstract- Pakistan being an agrarian country generates large amount of waste products every year. Most of these products are used in animal feed, composting, paper industries and landfills. In addition, such by products can be transformed into solid bricks as energy fuel. This can be elaborated by the current study which used wheat straw, bran, banana peels for making refuse derived fuel (RDF) briquettes. For this purpose three different particle sizes of wheat straw (10-5mm, 5-2mm and less than 2mm) were taken along with banana peels and wheat bran as binders. Their proximate analysis and energy content was tested according to ASTM standard methods. This illustrated that wheat straw had moisture content 8-12 % by weight (wt), volatile matter 70-73%, ash content 5-7% and fixed carbon 11-12%. Among the binders banana peel had least ash content of 1.28% and fixed carbon as 0.32%, compared to wheat bran ash content i.e. 3.52% and fixed carbon be 10.56%. The energy content (tested in bomb calorimeter) of wheat straw of size less than 2mm was highest i.e. 19.91 MJ/kg among other sizes of straw because smaller the size greater will be the surface area for effective burning. So, when this size was combined with both binders separately, the results gave high variation relative to others. The wheat straw of 5-2mm particle size gave the highest peak of calorific value of 42.40 MJ/Kg mixed with wheat bran. These components can be further shaped into briquettes to enhance their efficiency for usage.

Keywords: wheat straw, binders, proximate analysis, calorific value

I. INTRODUCTION

Rapid industrialization and population explosion in Pakistan have led to the waste management one of the major environmental problem. In this regards, globally several waste to energy projects have been developed as part of sustainable solution. For instance, to reduce waste and pollutants load, and generate high calorific fuel, refuse derived fuel (RDF) is the best option. This technique has been well adopted by America, European countries and Japan [1,2]. For producing RDF, binders also play vital role on energy values of RDF briquettes. The binder improves the cohesive characteristic of biomass by forming a gel with water, helping produce a more resilient product. Binders also help to reduce the wear on production equipment and increase the abrasion resistance of the fuel. Another purpose to include binders is to recover the combustion properties, e.g., corrosion, ash melting point and slagging [3].

According to estimate, in Pakistan up to 50 million tons of waste residue is generated every year from major crops which includes 6.88 million tons of sugarcane bagasse. This bagasse is being used for power generation by the sugar industry; subsequently, the remaining 43 million tons of crop waste is available in the Punjab province. Excluding that is used for domestic consumption and commercial usage, the net available resource potential of four crops i.e. rice, wheat, corn and cotton for biomass power generation is expected to be about 10.942 million tons [4]. On the contrary, most of the biomass waste (crop straws) is burned or buried down enhancing environmental problems.

Among the biomass waste, wheat straw has recently received popularity for use as energy fuel due to its easy accessibility [5]. In Pakistan, wheat is considered among essential crops with total production capacity as 20-24 MT/year [6]. Along with the wheat grains, byproducts such as straw, bran are separated out for use in different purposes. Wheat straw has many applications like fodder for animals, in paper and fermentation industry, soil fertilizer, adsorbent for heavy metals and in medicines. Moreover, wheat straw has been used to make biochar [7].

In addition to this, a large quantity of fruit waste is also produced from farms and fruit processing units. For instance, banana farming results in waste fruits, peels, stalks, leaves as main byproducts. In Pakistan, production capacity for banana is 29.7 million tonnes/hectres (MT/ha) with Sindh as the major contributor (around 80%) [8]. After farming large amount of by products and waste is produced. This waste if left untreated can result into emission of greenhouse gases and contamination of aquatic bodies through leachate. One study has reported the use of banana wastes as fossil fuel replacement [9].

In the present study, three types of agricultural waste components were considered for RDF. The wheat straw and bran were chosen for their ease of access while the banana peel was selected for their high lignin content assisting in fuel value. The energy values of briquettes produced from wheat straw by using two different agricultural-product binders were quantified to determine which of these by-products is more efficient and suitable for energy production in domestic/ industrial sectors. The main purpose of the current work is to use agricultural waste products as energy resource that will help to release burden on energy crisis.

II. Material and Methods

2.1. Sampling and preparation

About 3 Kg of wheat straw was taken from the ripe fields of University of the Punjab, Lahore. Wheat straw was divided into three different sizes after drying, grinding and sieving. The main particle sizes for making RDF were kept as 10-5mm, 5-2mm and less than 2mm. Two binders: banana peels and wheat bran were used in the current study. Both of these binders were also dried and grinded before use.

2.2. Proximate analysis

The above described proportions of wheat straw and binders were subjected for initial tests like moisture content, volatile matter content, ash content, and fixed carbon. These tests were carried out according to the standard methods of American Society for Testing and Materials (ASTM) [10] [11] [12]. The calculations of these tests were done according to developed methods of ASTM.

2.3. Calorific test

In order to determine the heating value of raw materials and their combinations, Automatic Bomb Calorimeter LECO AC 500 was used. The ASTM method [13] for testing calorific value was used. In regards of mixtures, different proportions were made from binders and wheat straw to assess the calorific values as illustrated in another study [14].

III. Results and Discussion

One of the main challenges in any country is to expand the energy services, particularly to the rural and remote areas. To date, non-renewable energy resources have turned out to aggravate health and environmental issues. Therefore, the identification of renewable energy resources and their use must be preferred where possible. In Pakistan crop and wood residues have been identified as biomass waste products (renewable energy resource). Since, Pakistan is agricultural country, so this waste can be used effectively on the large scale for energy production. Usually, this valuable resource is burned on a farmland affecting soil's biodiversity, structure, and nutrients balance. Furthermore, the black carbon and other particulate matters released into the atmosphere during burning leads to environmental and human health problems. However, conversion of these wastes into fuel briquette is a good alternative for Pakistan.

3.1. Physico-chemical characteristics of RDF components

In the present study, estimation of RDF was done for wheat straw by using two binders. The size reduction of all raw materials was done to increase total surface area, porosity of the material and the number of contact points for inter-particle bonding that will help in the combustion process [15]. This will also increase the energy recovery from the desired materials.

The proximate analysis of raw materials was done according to standard methods as indicated in Table 1. Moisture content is an important factor for selection of biomass to convert energy. For thermal conversion technology, biomass fuels with low moisture content are preferred over high moisture content. Therefore, acceptable limit of moisture content in the fuel for high calorific value should lie within 6 – 10 %. [16]. The current study indicates high moisture content for banana

Table 1 Moisture content (MC) and adjusted values of volatile organic matter (VOM), Ash content (AC) and Fixed carbon (FC)

Components	MC (%)	VOM (%)	AC (%)	FC (%)
Wheat straw(10-5mm)	8	73.6	7.36	12.88
Wheat straw (5-2mm)	8	73.6	5.52	11.04
Wheat straw (<2mm)	12	70.4	5.28	12.32
Banana peel	92	6.4	1.28	0.32
Wheat bran	12	73.92	3.52	10.56

peel as it was based on wet weight while wheat straw and wheat bran moisture content was calculated using dry weight. The moisture content also showed variation with particle size of wheat straw. Overall, the moisture content is within acceptable limit and also as per the requirement for gasification process.

Volatile matter of wheat straw (10- <2mm) was approximately same (70.4-73.6%). Wheat bran had the highest fraction of volatile matter among all raw materials (73.92%) while banana peel had the lowest of all.

The results of ash content indicated that large sized particles possess high ash content (7.36%) compared to small sized particles of wheat straw (5.28%). Among binders, banana peel had the lowest ash content (1.28%) as compared to wheat bran (3.52%). The ash content of biomass affects both handling and processing costs of overall biomass energy conversion cost. Biomass fuels having low ash content and high volatile matter make them ideal feedstock for pyrolysis and gasification [17]. In current scenario, the straw of small particle size is suitable for use as fuel and is also comparable to other studies (Table 3).

Table 1 shows slight variation in fixed carbon content for different particle sized wheat straw (11.04-12.88%). Among binders wheat bran has higher fixed carbon content. The fixed carbon is comparatively lower from other biomass origin RDF but higher from RDF produced by MSW (Table 3). The main reason for this difference could be the composition of MSW and the type of binders used. Higher fixed carbon indicates the RDF quality is better. Fixed carbon content together with volatile combustible matter determines how easily the biomass can be burned or gasified to be used as an energy source [18].

3.2. Calorific Potential of Agro-wastes

The calorific value is one of the most important characteristics of a fuel, and it is useful for planning and control of the combustion plants. It indicates the amount of heat that develops from the mass (weight) in its complete combustion with oxygen in a bomb calorimeter. The measured calorific values of the produced briquettes from the selected agricultural by products are shown in Table 2. The results showed that the average calorific value is increased, by using binders. Banana is the second largest produced fruit after citrus [19]**.** Banana peels are also a source of lignin (6-10%) that act as a good source of binding material [20]. Owing to the binding capacity of lignin, a natural material found in banana peels, there is no need to add any type of chemical additives. Particle size of biomass is also dominating the effect of heat transfer, with small, thin particles heating speedily and coarser, thicker particles heating more slowly.

In Figure 1 wheat straw of different particle sizes mixed with binders in different proportions has been shown. This graph indicates that the wheat straw samples of 5-2mm particle size has the highest value 10128Kcal/Kg combined with wheat bran among all samples. The second highest calorific value was of wheat straw (10-5mm) combined with banana peel in 60/40 ratio. The particle size of <2mm with wheat bran and banana peel individually gave higher calorific value in the proportion 60/40 % by weight and 80/20 % by weight respectively. All the other samples showed approximately the same results in the range of 3000-4000Kcal/Kg.

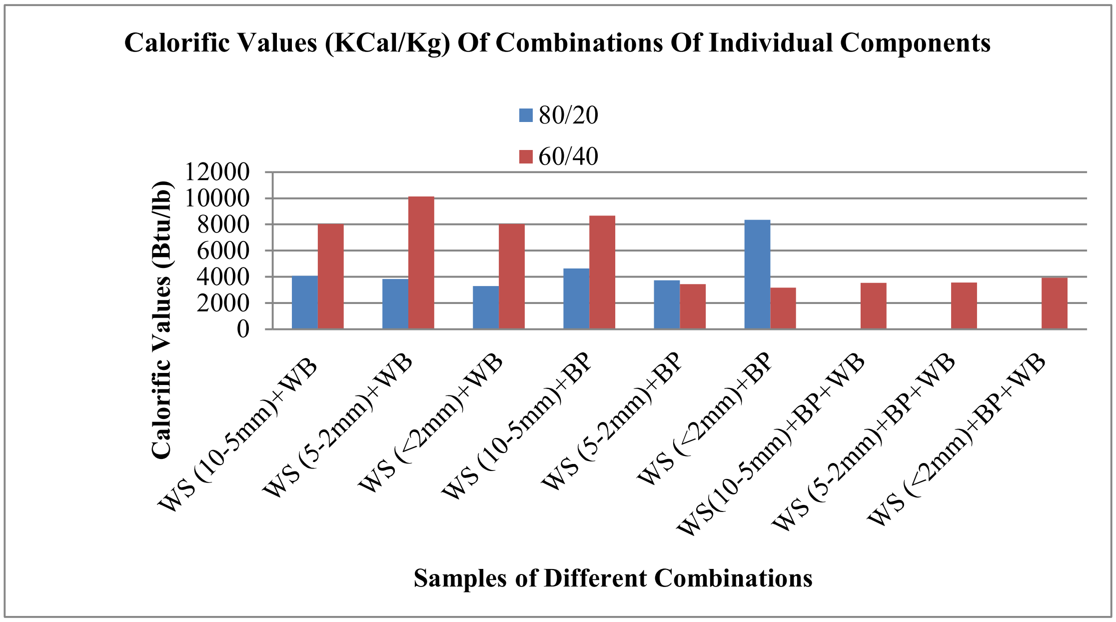

Figure 1 Calorific values for combinations of individual components

Table 2 Comparison of calorific values of samples with typical values

Sr. No.	Components	Ratio (% by wt.)	Calorific Values		
			Observed (Kcal/Kg)	MJ/Kg *	Typical* *
1	Banana peel	100/0	3318.00	13.89	18.9
2	Wheat bran	100/0	3900.00	16.33	17.2
3	Wheat straw(10-5mm)	100/0	3562.00	14.91	17.61
4	Wheat straw(10-5mm) + Banana peel	80/20	4632.00	19.39	-
5	Wheat straw(10-5mm) + Banana peel	60/40	8666.00	36.28	-
6	Wheat straw(10-5mm) + Wheat bran	80/20	4082.00	17.09	-
7	Wheat straw(10-5mm) + Wheat bran	60/40	8026.00	33.60	-
8	Wheat straw(10-5mm) +BP+WB	60/20/20	3547.47	14.85	-
9	Wheat straw (5-2mm)	100/0	3537.00	14.81	17.61
10	Wheat straw(5-2mm) + Banana peel	80/20	3735.00	15.64	-
11	Wheat straw(5-2mm) +Banana peel	60/40	3434.00	14.38	-
12	Wheat straw(5-2mm) + Wheat bran	80/ 20	3844.00	16.09	-
13	Wheat straw(5-2mm) + Wheat bran	60/40	10128.00	42.40	-
14	Wheat straw (5-2mm)+ BP+ WB	60/20/20	3562.00	14.91	-
15	Wheat straw (<2mm)	100/0	4755.00	19.91	17.61
16	Wheat straw(<2mm) + Banana peel	80/20	8342.00	34.93	-
17	Wheat straw(<2mm) + Banana peel	60/40	3179.00	13.31	-
18	Wheat straw(<2mm) + Wheat bran	80/20	3286.00	13.76	-
19	Wheat straw(<2mm) + Wheat bran	60/40	8036.00	33.65	-
20	Wheat straw(<2mm) + BP + WB	60/20/20	3932.00	16.46	-

*0.0041868*Kcal/Kg=MJ/Kg
**Biomass and Bioenergy 27 (2004)

The samples used had calorific values in the range of 13.76-42.4 MJ/Kg. The highest values were of wheat straw (5-2mm) with wheat bran as a binder (Table 2). This is because the calorific value of wheat bran itself is high and also the particle size of wheat straw is such that it can be burned effectively with low energy requirements. The second highest calorific value obtained was of wheat straw (10-5mm) when combined with banana peel in a proportion of 60/40% by weight. This indicates that the binder ratio had an effect on raising the calorific value of wheat straw (10-5mm) which individually had not high calorific value. While the particle size of (<2mm) also possess high calorific value when combined with banana peel and wheat bran in 80/20 and 60/40 proportion (%) by weight. This indicates that wheat straw of smallest size will burn efficiently with potential binders.

Overall the calorific value obtained from different mixtures is good as it is comparable to values in literature (Table 3). For instance, Demirbas [18] worked on wheat straw with waste paper as binder but the heating value (17 MJ/Kg) is very low as compared to the current study. While, other similar studies used MSW and biomass waste components for briquetting have lower calorific value as compared to 42.40 MJ/Kg (current study). Moreover, further work is needed to improve the properties of RDF for obtaining optimum energy from wheat straw by combining with suitable binders.

Table 3 Comparative studies done on RDF potential using different binders along with their proximate analysis and their calorific values (CV)

Country of study	**Raw materials for briquettes**	**Binders**	**MC (%**	**VOM (%)**	**FC (%)**	**AC (%)**	**Average CV (MJ/Kg)**	**References**
Turkey	Wheat straw	Waste paper	22	-	-	13.6	17	[18]
India	Maize straw	Waste paper	8.67	78.93	20.46	14.72	18.75	[21]
Poland	MSW	-	1.6	71.2	4.9	21.3	24.17	[22]
	MSW+ wheat straw	-	4.9	74.7	9.7	10.7	20.54	
Thailand	MSW	Glycerin	6.26	55.56	37.33	0.84	18.20	[23]
USA	MSW	Water glass	1.54	79.9	1.26	20.14	26.63	[24]
Spain	Biomass+ plastic waste	-	6.21	-	-	31.71	15.54	[25]
Egypt	MSW	-	-	-	-	-	86.34	[26]
India	WH +SD	Cow dung	-	-	-	-	16.74	[27]
India	Paper, card, textiles	-	4.6	73.7	5.3	16.4	15.86	[28]
Malaysia	Risk husk	Kraft lignin	14	40.5	46	3.97	17.69	[29]
India	Coconut	-	-	71	22.1	6.9	23.98	[30]
	Sugarcane	-	-	55.5	42.7	1.8	18.89	
	Sawdust	-	-	60	11.87	28.13	20.37	
Indonesia	Coconut husks	-	1.56	22.11	65.96	10.37	22.05	[31]
Pakistan	Wheat straw	Banana peel+ wheat bran	9.33	72.53	12.08	6.05	13.76-42.40	Current study

Where, WH: water hyacinth, SD: Saw dust

IV. CONCLUSION

This research came with the conclusion that not only wheat straw alone has enough potential also when wheat straw was combined with different binders its efficiency was improved. The results showed that the wheat straw with size particles of (5-2mm) was best for producing RDF briquettes when combined with wheat bran as its calorific value reached almost three times (42.40MJ/Kg) to the standard. While the wheat straw of particle size <2mm also gave good results with both binders in the range of 30-35MJ/Kg.

V. RECOMMENDATIONS

Further research is required to check the durability and strength of these RDF components in order to get a marketable product. The type of pollutants emitted during burning of these RDF components also needs testing to make sure this fuel is environment friendly. Moreover, the burning residues can be used as a filler in road banks or compost after fulfilling the standard requirements. The binders used in the present research work, have easy access and there production is abundant in our country that's why they can be used as potential binders. In a nutshell, the prepared RDF fuel and its by products can be used by industries such as paper and pulp, cosmetics, construction and composting for alleviating the burden on other resources. This type of fuel can be used in rural and remote areas where access to other resources is less as it will cost less in terms of transportation and labor. However the grinding process could require energy which will be supplemented by RDF of wheat straw.

VI. HIGHLIGHTS

- Wheat straw along with agricultural products as binders was tested for energy content.
- It was seen that wheat straw can give high efficiency of burning when combined with binders.
- The concluded results showed that wheat bran was best binder when combined with wheat straw of 5-2mm size as its calorific value reached three times to that of standard.
- While the overall good results were obtained of wheat straw <2mm size.

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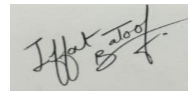

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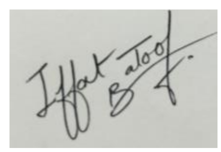
2	Dr. Soniya Munir (2nd Author)	Concept of the Paper Supervisor Corresponding Author	
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