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Evaluation and Characterization of Different Biomass Residues through Proximate & Ultimate Analysis and Heating Value

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Abstract - **Biomass fuels have been emerged as better energy source in present scenario of rising fossil fuel prices. Biomass fuels are considered better in comparison to fossil fuels in term of their carbon neutral features. Biomass combustion has been widely recognized as key thermal conversion technology for residues in biomass based power plants. Thorough knowledge about their characteristic features needs to be explored for getting better potential of their use in future context of their availability as per the geographical conditions. Important characteristics requiring analysis are proximate analysis, ultimate analysis, moisture content & heating value. In present investigation, Characteristic data of three Agricultural crop residues & one agro industry byproduct (Rice husk) have been analyzed. Proximate analysis & ultimate analysis have been carried out. Further the high heating values (HHV) of these residues have been evaluated experimentally and comparative study has been attempted by using some correlation models on the basis of proximate & ultimate analysis data. These results may be valuable in predicting the basic behaviour of biomass fuels & their characteristics.**

Keywords: **Biomass fuels, Biomass characteristics, High heating values, Correlation models**

I. Introduction

Energy sources are the significant components of sustainable economic growth of any country. Energy is the key aspect which helps to accomplish & retain the economic and social escalation. The rapid population growth in the world makes the trouble worse owing to sharp increase in demand in all the sectors of society consequently put burden on the existing fossil fuels which were the leading energy sources since last five decades. These are of non renewable nature & require millions of years for their replenishment but their limited reserves are running down quickly which make it difficult to keep balance between the existing reserves & consumption [1].

Fossil fuels also initiate the environment hazards since the addition of thousands of tons of carbon, sulphur, nitrogen & other pollutants in the air. These adverse effects signify the need to discover novel & economical alternative fuels. Amid these options, one significant substitute to lessen the pressure from fossil fuels is the utilization of renewable energy sources. Significant research is being carried away in the world on these sources for exploring their applications [2, 3].

Biomass based fuels are considered as renewable fuels. These are the organic wastage available from diverse sources like agriculture, forests & industry. Agro based biomass fuels are mainly the organic waste which remains in abundant quantity in the fields after the chipping of the crops. Some part of this residue is utilized as fodder for animals but still major segment remains in the fields. Crop residues have worth due to their use for energy generation in biomass based power plants e.g. wheat straw & paddy straw. Due to the problem of their proper collection & removal from fields, a large amount of it is burned in the open fields causing the air pollution. These have advantage over fossil fuels due to their carbon neutral characters i.e. these can store the CO_2 during their growth period which can again given back to the environment during combustion. Thus there is no net addition of carbon dioxide i.e. carbon neutral [4]. Worldwide increasing prices & depleting reserves of fossil fuels under heavy demand signifies their advantages over fossil fuels for the future [2, 5].

The economic viability of the biomass as energy source can be better explored because of abundant availability of biomass residues in entire world [3, 6]. A large variety of agricultural residues e.g. wheat straw, wheat husk, mustard straw, paddy straw etc. are available all over the world in abundant quantity which can be efficiently utilized as raw material using different conversion techniques of gasification & combustion [5, 7]. Agro-industry by-products e.g. Paddy husk & bagasse are also valuable biomass residues [8].

Design, operation & efficiency the of thermo-chemical conversion system are largely depends upon the basic characteristic properties e.g. moisture content, elemental composition & bulk density, particle size & porosity etc. Moisture is the most influencing factor which directly reduces the overall energy content of the fuel & hence reduces its thermal conversion efficiency [4, 9, & 10]. One researcher has reported the moisture in the range of 4.3-9.5 in wheat straw [12] while other has reported the moisture content of sugarcane stalk nearly 8.3% moisture [13]. Other researchers also highlighted the significance of moisture content on the boiler design & operation while stating that higher moisture reduces overall thermal efficiency & boiler output [10,13]. Another factor which needs attention is the proper collection of residues from fields & their supply to biomass power plants. Biomass residues have large variations in their characteristics properties thus require a well established data of the biomass residues which may helpful in setting up of systems for their better conversion [14]. Basic characteristic features of the residues which are important for analysis and designing a biomass conversion unit includes proximate analysis (ash content, moisture content, volatile matter & fixed carbon), Ultimate analysis or elemental compositions (carbon, hydrogen, oxygen, sulphur, calcium, nitrogen etc.) & heating value determination. Proper evaluation of these properties consequently enhances the overall plant efficiency. The detailed analysis of the characteristics also needs to be carried out for exploring their future potential [8].

In Indian context, further benefits of these resources can be achieved by setting up decentralized biomass based power units in remote areas for rural electrification. Domestic & small scale industrial units can also be prime areas for implementation of biomass based power. Modernization & technical advancements in the field of biomass conversion further leads to open new possibilities [8, 15]. A number of correlation models have been developed by various researchers using proximate & ultimate analysis results for determining the heating value of fuels. Results show that proximate data is easy & more useful to find the high heating value (HHV) with little deviation than the actual experimental results [16, 17]. Demirbas [18] has also developed the model by using the ultimate & proximate data for high heating value determination. Two correlation models introduced by him depend upon the fixed carbon & volatile matter content of the biomass residue.

The present study includes the proximate analysis and ultimate analysis of four varieties of residues generally available in Punjab along with the determination of their heating values. Some correlation models given by various researchers were used for calculation of heating values along with actual experiments [16, 17]. These results may clearly describe the relationship between the experiments & correlation models & may confirm their usefulness. This study will provide the information about potential agricultural residues available in Punjab. This study may also highlight some other characterization possibilities in this field.

II. Material and Methods

Description of the Agro-Based Biomass & Their Selection

Various countries of the world have wide spread distribution of the renewable energy sources including both the forest trees & agricultural based residues. In India this is also not the exception which has abundance of the biomass waste of wide varieties including Forest wood, industrial waste as by-products & agricultural based waste residue. The agricultural residue is important because of its abundant supply or availability within the region & great economic importance for rural area population.

In the present study the residue/biomass of Wheat husk, Wheat straw, Barley straw, Mustard straw and Rice husk material were collected from fields during different crop seasons. As no standard sampling method of residue collection exists, care has been taken to ensure that the collected sample become representative of the whole collection. After collection, all the samples were stored in air tight polythene bags.

III. Experimental Method

Experimental phase include proximate analysis, ultimate analysis & Heating value determination. All the analysis conducted was according to the Standard methods.

A. Proximate Analysis

Proximate analysis is used for calculation of chemical composition of the residue including Moisture content, Ash content, volatile matter & fixed carbon. Moisture was determined by using standard oven dry method. Determination of ash content in all the samples was determined according to standard procedure of heating in the furnace at $575^0C \pm 25^0C$ temperature. Volatile matter was determined by using cylindrical crucible by heating the sample for 7 min at $925^0C \pm 5^0C$ in furnace. Content of fixed carbon was determined by difference from total composition. High heating values of all the samples were experimentally using bomb calorimeter (Model: Parr 6200, USA at GNDTP, Bathinda). High heating values were also calculated using some correlation models on the basis of proximate & ultimate analysis results.

Biomass residues have specific amount of moisture which directly affects their heating values. Standard method for moisture determination involves heating of 1 gm biomass sample in a hot air oven to 105 ± 5^0C using the following equation.

Moisture (% M) = (W1-W2)/W3×100

W1= Weight of the crucible & the air dried sample (g), W2 = Weight of the crucible & oven dried sample (g), W3 = Weight of the air dried sample taken (g)

Ash is defined as the weight of the residue remained after complete burning of 1gm of the biomass at 575 ± 25^0C.

Ash (% A) = (W4-W5)/W6×100

W4= Weight of the crucible & the oven dried sample (g), W5= Weight of the crucible & residue (g), W6 = Weight of oven dried sample taken (g)

Volatile matter (% VM): It is termed as the weight loss due to heating of 1gm of biomass at $925^0C \pm 5^0C$ in furnace for 7 minutes.

Weight loss due to VM = Total loss of weight- loss due to moisture.

Fixed carbon (FC): The content of fixed carbon is determined by subtracting the sum of A %, VM & % M from total of 100 % composition.

FC= 100- (% A + % VM + % M)

B. Ultimate Analysis

This analysis is important for determining the elemental composition (C, N, H, S, O etc.) of the biomass fuels & is also useful for calculating their heating value. It was carried out by using CHNS analyzer (Model: Elementar Vario micro cube, Germany at SSS-NIRE, Kapurthala)

C. Heating Value

Heating or calorific value of any fuel is the amount of the heat liberated by that under specific conditions of combustion. The heat value in a given fuel is mostly a function of the fuel's chemical composition. The higher heating value (HHV) is the total amount of heat energy that is available in the fuel, including the energy contained in the water vapour in the exhaust gases. The lower heating value (LHV) does not include the energy embodied in the water vapour. Bomb calorimeter is used to determine the calorific value of fuel by combusting a known quantity of the fuel under constant volume in bomb.

D. Correlation Model

Correlation models were developed by different researchers for direct estimation of the heating values using the proximate & ultimate analysis results. Ash content is considered important because it is easy & simple to determine & also the heating value of biomass is considered to be in linear relation to the ash content. These correlation models help in getting significant information about the heating value of biomass residues directly.

Jain [14] has developed three types of the models for evaluating both the Lower heating value & higher heating value. Here only one Model (Model 1) is used for estimation of HHV by using the ash content. These models have sufficient accuracy & give nearly ± 5 % differences in comparison to the experimental values.

Model: 1. HHV = 19.24-0.22× A (Based on the ash content of biomass residue)

Two models (Model 2 & 3) have been developed by Demirbas [18]. In model 2, the fixed carbon is taken for calculating the high heating value.

Model: 2. HHV (MJ/Kg) = 0.196 FC+14.119

Model 3 has been developed for calculating the high heating value on the basis of fixed carbon present in the fuel using proximate results.

Model: 3. HHV (MJ/Kg) = {33.5 (C) + 142.3 (H) - 15.4 (O) - 14.5(N)} $\times 10^{-2}$

IV. Results

Results of proximate analysis for different residue samples were given in table I. Overall moisture content varies between 4.65 % & 6.86 % with minimum for rice husk and maximum for mustard straw. This shows that all the samples were stored well before being collected. Ash content varies more than moisture. Its value ranges between 9.29 % & 14.98 %. Mustard straw give maximum (14.98%) ash while the rice husk have minimum (9.29 %).

Further results show that volatile matter has very narrow range i.e. 68.89 to 71.34. Content of Fixed carbon vary widely between four samples. Mustard straw have lowest 7.38 % & rice husk had maximum 17.17 % volatile matter.

In general, the results of proximate analysis show that all the samples contained higher content of volatile matter than the fixed carbon whereas ash content & fixed carbon have small difference.

Ultimate analysis value for all the samples were shown in table II. Carbon content is highest in all the samples than other components & oxygen is the second highest component after carbon. Hydrogen lies within very narrow range of 5.332 to 5.930. Content of Sulphur is nearly negligible in all the samples. The comparison for all the models (1-3) & experimental results has been given in Table III. The difference (% age) from the actual experimental values are also given to conclude the results.

Table I Proximate Analysis

Biomass	Moisture content (M %)	Ash content (A %)	Volatile matter (VM %)	Fixed carbon (FC%)
Wheat husk	5.98	12.11	69.19	12.72
Wheat straw	6.40	12.59	71.34	9.67
Mustard straw	6.86	14.98	70.78	7.38
Rice husk	4.65	9.29	68.89	17.17

Table II Ultimate Analysis

Biomass	Elemental composition				
	C	N	H	S	O
Wheat Husk	41.47	2.55	5.825	0.10	37.945
Wheat Straw	43.50	3.43	5.930	0.00	34.550
Mustard straw	41.98	0.00	5.710	0.48	36.855
Rice Husk	43.10	0.00	5.332	0.00	42.270

Table III Comparison B/W The Results of Experiments & Models With Relative Difference (Diff. %)M1-Model 1, M2-Model 2, M3-Model 3, Bm-Biomass, Wh: Wheat Husk, Ws: Wheat Straw, Ms: Mustard Straw, Rh: Rice Husk

BM	Exp.	M1	Diff. (%)	M2	Diff. (%)	M3	Diff. (%)
WH	16.42	16.58	0.90	16.61	1.2	15.97	-2.7
WS	16.63	16.47	-1.0	16.01	-3.7	17.20	3.4
MS	16.12	15.94	-1.1	15.57	-3.4	16.51	2.4
RH	16.93	17.20	1.6	17.48	3.3	15.51	8.4

V. Discussion

On the basis of proximate analysis the rice husk is found to be most useful residue because of lowest moisture content. It is also clear from the HHV that rice husk have higher values as shown by model 1 & model 2 and actual experimental results. All the samples have lower moisture which implies that samples were stored for proper time before collection. Most of the samples have higher hydrocarbon content which reveals their burning characters. This in turn produce long smokes which requires higher system temperature. Samples with higher ash content may create combustion chamber problems thus regular cleaning of the bed or grate needs to be maintained. The values of the HHV from model based on proximate analyses give higher heating value in quite similar to the experimental results.

VI. Conclusion

In the present study, correlation models proposed by researchers have been used for finding High heating value of agricultural based residues. Proximate & ultimate analysis has been carried out to get the chemical & elemental data. The calculated HHV from the correlation models have been compared with the actual experimental results. The results have shown the variation in the range of -5.3% to 0.4%. The experimental results are in agreement with the correlation models.

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