Original Research Paper

Volume-9 | Issue-5 | May-2019 | PRINT ISSN No 2249 - 555X

Engineering

UTILIZATION OF SOLID AGRICULTURAL BIOMASS WASTES AS AN ALTERNATIVE ENERGY SOURCE

Ramanuj Prasad* Department of Mechanical Engineering, PPIMT Hissar, Haryana, India *Corresponding Author

Suman Bharti Department of Mechanical Engineering, PPIMT Hissar, Haryana, India

ABSTRACT In this paper, an attempt has been made to convert agricultural wastes (such as, wood dust, coconut shell, sugarcane bagasse, and rice husk) into biochar by pyrolysis method which can be used as an alternate source of energy and as a substitute for fossil fuel up to some extent. Consequently, this study includes the characterization of agricultural wastes and their effect on biochar derived from them. This conversion process helps in producing a new carbonaceous product in the form of biochar which can be further used for enhancement of carbon content, soil ameliorant, enhance soil fertility, and in waste water treatment.

In this study biochars derived at temperature 800oC have low ash, high carbon content, Gross Calorific Values (GCV) along with high surface area, which concludes proper utilization of this product for metallurgical purposes as a source of energy.

KEYWORDS : Solid Agricultural wastes; Pyrolysis; Biochar; Gross Calorific Value.

1. INTRODUCTION

In the bronze and iron ages around 5500 years ago probably the first use of char as a fuel took place. Before this, char was used as a drawing medium by artists. Cave paintings made with char have been found, dated to 30,000 years BC [1]. Tar or pitch as by-product of char was used as water proof for wooden structures, in particular ships, as far back as Roman times [2].

In recent years, the rising cost of energy associated with decreasing fossil fuel reserves, are incentives for the development of new green energy technologies using agricultural wastes (AW) [3]. Recycle of AW, which is simply to burn to ash for disposal has seen a sharp increase, posing a serious social problem for our society and it is a major challenge in the protection of environment and natural resources. Biomass (agricultural wastes) is the third largest primary energy sources after coal and oil in the world [4]. India produces near about 350 million tons of agricultural waste per year [5], such as straw, bagasse, coffee husks and rice husks as well as residues from forest-related activities such as wood chips, sawdust and bark etc.

AW is a versatile source of energy which can be readily stored and transformed into electricity and heat. Combustion of AW alone emits less CO_2; the energy produced is less in comparison to that of fossil fuels. Hence utilizing the co-firing of coal and AW fuels is compromising between CO_2 emissions and the energy production [6]. The use of AW is essentially to minimize the environmental impact arising from coal combustion and carbonization and their proper utilization [7-8] in these areas, because it does not affect the natural carbon cycle and gives comparatively less toxic gases.

2. MATERIALS AND METHODS

2.1. Selection of agricultural waste materials

The selection of raw material is mostly dependent on the easily available agricultural wastes in our surrounding areas. Another important criterion for the selection of the raw material is its ability to bind together when compressed. This includes wooden dust (WD), Coconut Shell (CS), Sugarcane bagasse (SB), and Rice Husk (RH); all biomass agricultural wastes samples were collected locally from different places of Haryana, India, which was further prepared for slow pyrolysis at temperature 800±50°C for one hour @ 8-15ºC/min heating rate. The crop residues used varied widely in properties and representative samples of each feedstock was chosen for characterisation on as received basis.

2.2. Characterization methodology

2.2.1. *Proximate and Ultimate analyses, Gross Calorific Value (GCV), Surface Area, and pH determination*

Proximate analysis was performed on agricultural biomass waste samples (WD, CS, SB, and RH) for the determination of ash, moisture (M), volatile matter (VM) and fixed carbon (FC) contents following the (ASTM E871-82, E1755-01, and E872-82) [9]. The fixed carbon content was calculated by difference. The proximate analysis for Wooden dust char (WD_{ch}), Coconut Shell char (CS_{ch}), Sugarcane bagasse (SB_{ch}), and Rice Husk char (RH_{ch}) was determined according to ASTM D1762-84 standard method [10].

ASTM E777, E778 and E775 standard method was followed for ultimate analysis [11] in order to determine the basic elemental composition such as, carbon ©, hydrogen (H), nitrogen (N) and sulphur (S) content of the agricultural waste and corresponding char samples using CHNS analyser. Oxygen (O) content was calculated by the difference.

The Gross Calorific Value (Higher Heating Value) of all the samples was determined by bomb calorific measurement [12].

Surface area was determined on dry biochar samples via N_2 adsorption at 77 K on a Surface Area Analyzer [13].

Biochar samples (10 g) were soaked in (1:20, w/v ratio) slurry in water [14] for the measurement of pH meter.

3. RESULTS AND DISCUSSION

3.1. Proximate and Ultimate analyses of agricultural wastes samples

The proximate and ultimate analyses of the WD, CS, SB, and RH are included in Table 1. From this table, it is observed that all the feedstocks have relatively less ash (2.88-7.92%); higher content of VM (65.55-76.91%), FC (13.61-17.54%), and GCV (3460-3990 kcal/kg). Agricultural biomass contains much more ash-forming elements than most of forestry biomass and hence higher ash contents in agricultural biomass [15]. There is higher content of carbon, oxygen and hydrogen in most of all the feedstocks (C, 38.83-46.01%; O, 46.00-51.93%; H, 4.87-7.39%. Further the lower content of hetero elements (N, 0.54-0.71% and S, 0.04-0.17%) in all the samples is advantageous from the consideration of environmental concerns as agricultural biomass upon thermo-chemical treatment releases a mixture of various types of SOx and NOx gases which are toxic in nature and not environment friendly.

Table 1 Proximate and Ultimate analyses (as received basis) of samples

AW Samples	Proximate Analysis				Ultimate Analysis					GCV (kcal/kg)
	M%	VM%	Ash%	FC%	C%	H%	S%	N%	O%	
Wood Dust (WD)	5.12	74.50	2.88	17.54	46.01	7.39	0.06	0.54	46.00	3990
Coconut Shell (CS)	15.20	65.55	3.17	16.14	44.92	6.38	0.04	0.71	47.95	3950

Sugarcane Bagasse (SB)	6.80	76.91	3.70	16.59	42.46	4.87	0.17	0.57	51.93	3753
Rice Husk (RH)	9.61	68.86	7.92	13.61	38.83	6.53	0.40	0.66	53.58	3460

3.2. Yield, pH, GCV, and surface area of the bio-chars

Yield, pH, GCV, and surface area of the biochars derived from WD, CS, SB, and RH are shown in Table 2. From this table it is observed that there is relatively lower yield of chars at temperature 800°C of pyrolysis. The energy given to the wastes at high temperature may exceed the bond cessation energy which supports the release of the volatile components of the agricultural wastes in the form of gases resulting in less char yield. The reduction in the bio-char yield has been also reported by other workers [16, 17].

The pH value for WD_{ch}, CS_{ch}, SB_{ch}, and RH_{ch} varies from 9.19 to 11.32. The GCV value for these bio-chars varies in the range 4691-5650 kcal/kg [18]. Similarly BET surface area varies in the range 221.62 - 466.70 m^2g^{-1}. Keluweit et al., 2010 [19] also observed the greater in the surface area with higher pyrolysis temperature. The increase in the GCV of the biochars is attributable to the heat contributing components (like FC, C, and H) present in the agricultural wastes. With this pyrolysis temperature, pore blocking substances are driven off or thermally cracked, leading to enhancement in the surface area and pore volume [20].

Biochars have higher in the pH together with significant surface area are suggestive of their better application potential in reducing the soil acidity; refining the cation exchange capacity (CEC) of soil-attributable to its high surface area [21], creating an additional positive habitat for plants [22-25], and treating the soil and water contaminated with toxic elements and organic pollutants [26].

Table 2 Physical and chemical characteristics of the biochars derived from different feedstocks; GWC, CS, GN, WH and CC

SL. NO.	Biochar samples	Char yield (%)	pH	GCV (kcal/kg)	Surface area (m^2/g)
1	**Wood Dust Char (WD_{ch})**	26.00	9.77	5650	466.70
2	**Coconut Shell Char (CS_{ch})**	29.80	9.19	5545	346.90
3	**Sugarcane bagasse (SB_{ch})**	28.40	10.23	5057	323.87
4	**Rice Husk Char (RH_{ch})**	31.33	11.32	4691	221.62

3.3. Proximate and Ultimate analyses of WD_{ch}, CS_{ch}, SB_{ch}, and RH_{ch}

Proximate and Ultimate analyses of all the obtained biochars are shown in Table 3. Biochar is created mainly by the thermal decomposition of lignin and some extractive part of agricultural wastes; whereas the VM is distorted in to the gas phase and minerals in the biomass are left as ashes [27]. The corresponding VM for WD_{ch}, CS_{ch}, SB_{ch}, and RH_{ch} are in the range of 5.50, 3.51, 5.33, 5.20 and 7.63 wt. %, respectively. The presence of lignin in the agricultural waste material can partially resist pyrolytic decomposition at lower temperature but not at temperatures as high as 800°C [28]. The ash content in the corresponding biochars are 3.70, 3.36, 18.88, 22.10 and 17.13 %, respectively. The bio-char derived from ground nut, wheat husk and corn cob showed a high ash content, and this may be because of the partial change in the composition promoted by a possible relation between organic and inorganic constituents [28]. It can be seen that bio-chars with higher content of ash generally have the lower values of fixed carbon and vice versa. Similarly fixed carbon in WD_{ch}, CS_{ch}, SB_{ch}, and RH_{ch} are 84.39, 88.58, 71.80, 67.91 and 73.31 wt%, respectively.

Further the ultimate analysis (Table 3) of WD_{ch} varies significantly in respect of C, H, N, S, and O contents; the content being 82.02, 3.35, 1.98, 0.13 and 8.82 wt%, respectively. Similar is the trend in case of CS_{ch}, SB_{ch}, and Rh_{ch}.

Table 3 Proximate and Ultimate analyses of WD_{ch}, CS_{ch}, SB_{ch}, and Rh_{ch}

Biochar samples	Proximate Analysis				Ultimate Analysis				
	M%	VM%	Ash%	FC%	C%	H%	S%	N%	O%
WD_{ch}	1.39	15.84	7.74	76.17	78.40	1.36	0.07	1.57	18.45
CS_{ch}	11.67	8.93	7.84	71.56	76.79	1.95	0.47	1.42	19.37
SB_{ch}	1.98	24.02	5.94	68.06	80.85	2.17	0.07	1.56	15.35
RH_{ch}	1.67	5.67	32.41	60.24	59.73	1.39	0.10	1.93	36.85

4. CONCLUSIONS

The results obtained in this study showed that the pyrolysis of different types of feedstock strongly influences the properties of the derived biochar.

- Pyrolysis of the biomass enhances the calorific value of the derived biochar for example calorific value of WD, 3990 kcal/kg enhances to 5650 kcal/kg of Wd_{ch}.
- Similarly, FC and C percentage increases in all cases of biochar derived from biomass.
- Surface area of derived biochar can help to achieve uniform and complete combustion of fuel.
- Derived biochar can be used as a reductant in Iron and Steel making.

Finally, derived biochar can become a potential option to be used as a substitute of renewable energy sources; soil ameliorant, enhance soil fertility, and in waste water treatment.

5. REFERENCES

[1] Syred C, Griffiths AJ, Syred N, Beedie D, James D. A clean, efficient system for producing Charcoal, Heat and Power (CHaP), Fuel 2006; 85:1566-1578.

[2] Kelley DW. Charcoal and charcoal burning. Bukinghamshire: Shire Publications Ltd; 1986.

[3] Brassard P, Palacios JH, Godbout S, Bussieres D, Lagace R, Larouche JP, Pelletier P. Comparison of the gaseous and particulate matter emissions from the combustion of agricultural and forest biomasses. Bioresource Technology 2014; 155:300–306.

[4] Bapat, DW, Kulkarni SV, Bhandarkar VP. Design and operating experience on fluidized bed boiler burning biomass fuels. 14th International Conference on Fluidized Bed Combustion 1997; New York: Petro FDS.

[5] Pallavi HV, Swamy SS, Kiran BM, Vyshnavi DR, Ashwin CA. Briquetting Agricultural Wastes as an Energy source,J.of Engg. Sc., Comp. Sc. and Engg. & Tech. 2014; 2:160-172.

[6] Khudzir H, Mohd Ishak MA. Investigation On The Thermal Behaviour During Pyrolysis And Combustion Of Blends Biomass With Malaysian Coal Via Thermogravimetric Analysis, Institute of Research, Development and Commercialiaztion, University of Technology MARA 2006.

[7] Miles TR and Miles TR Jr. Densification systems for agricultural residues. Jones JL, Radding SB, editors, 1990, Symposium Series, 130 .

[8] Werther J, Saenger M, Hartge EU, Ogada T, Siagi Z. Combustion of agricultural residues. Progress in Energy and Combustion Science 2000; 26(1):1-27.

[9] Demirbas A. Effects of temperature and particle size on bio-char yield from pyrolysis of agricultural residues. J. Ana. and App. Pyro. 2004; 72:243–248.

[10] Demirbas A. Combustion Characteristics of different biomass fuels. Prog. in En. and Comb. Sci. 2004; 30: 219–230.

[11] Suman S & Gautam S. A comparative study between time, temperature, and fixed carbon using different biochar reductants as an alternate source of energy, Energy Sources, Part A: Recovery, Utilization, and Environmental Effects, 2017; 39(10): 1029-1035.

[12] Suman S & Gautam S. Pyrolysis of coconut husk biomass: Analysis of its biochar properties, Energy Sources, Part A: Recovery, Utilization, and Environmental Effects, 2017; 39(8): 761-767.

[13] Zhang G, Zhang O, Sun K, Liu X, Zheng W, Zhaoil Y. Sorption of simazine to corn straw biochars prepared at different pyrolytic temperatures. Environ. Pollut. 2011; 159:2594–2601.

[14] Gaspard S, Altenor S, Dawson EA, Barnes PA, Ouensanga A. Activated carbon from vetiver roots: gas and liquid adsorption studies. J. Hazard. Mater. 2007; 144:73–81.

[15] Cuiping L, Yanyongjie CW, Haitao H. Chemical elemental characteristics of biomass fuels in China. Biomass Bioenerg 2004; 27:119–30.

[16] Choi HS, Choi YS, Park HC. Fast pyrolysis characteristics of lignocellulosic biomass with varying reaction conditions. Renew Energy 2012; 42:131–5.

[17] Putun AE, Ozcan A, Putun E. Pyrolysis of hazelnut shells in a fixed-bed tubular reactor: yields and structural analysis of bio-oil. J. Anal. Appl. Pyrol 1999; 52:33–49.

[18] Kumar JV, and Pratt BC. Determination of calorific values of some renewable biofuels. Thermochimica Acta 1996; 279 :111-120.

[19] Keiluweit M, Nico PS, Johnson MG, Kleber M. Dynamic molecular structure of plant biomass-derived black carbon (Biochar). Environmental Science & Technology 2010; 44:1247–1253.

[20] Rafiq MK, Bachmann RT, Rafiq MT , Shang Z, Joseph S , Long R. Influence of Pyrolysis Temperature on Physico-Chemical Properties of Corn Stover (Zea mays L.) Biochar and Feasibility for Carbon Capture and Energy Balance, PLOS ONE 2016. DOI:10.1371/journal.pone.0156894 June 21.

[21] Liang B, Lehmann J, Solomon D, Kinyangi J, Grossman J, O'Neill B, Skjemstad J, Thies J, Luizao FJ, Petersen J, Neves EG. Black Carbon Increases Cation Exchange Capacity in Soils, Published in Soil Sci. Soc. Am. J. 2006; 70:1719–1730. doi:10.2136/sssaj2005.0383.

[22] Mary GS, Sugumaran P, Niveditha S, Ramalakshmi B, Ravichandran P, Seshadri S. Production, characterization and evaluation of biochar from pod (Pisum sativum), leaf (Brassica oleracea) and peel (Citrus sinensis) wastes. Int J Recycl Org Waste Agricult 2016; 5:43–53 DOI 10.1007/s40093-016-0116-8.

[23] Lehmann J, Gaunt J, Rondon M. Bio-char sequestration in terrestrial ecosystems a review. Mitig Adapt Strateg Glob Change 2006; 11:403–427. doi:10.1007/s11027-005-9006-5.

[24] Spokas KA, Cantrell KB, Novak JM, Archer DW, Ippolito JA, Collins HP, Boateng AA, Lima IM, Lamb MC, McAloon AJ, Lentz RD, Nichols KA. Biochar: a synthesis of its agronomic impact beyond carbon sequestration. J Environ Qual 2012; 41:973–989. doi:10.2134/jeq2011.0069.

[25] Novak JM, Busscher WJ, Watts DW, Amonette JE, Ippolito JA, Lima IM, Gaskin J, Das KC, Steiner C, Ahmedna M, Rehrah D, Schomberg H. Biochars impact on soil-moisture storage in an ultisol and two aridisols. Soil Sci 2012; 177(5):310–320. doi:10.

1097/SS.0b013e31824-5593.
[26] Ahmad M, Rajapaksha AU, Lim JE, Zhang M, Bolan N, Mohan D, Vithanage M, Lee SS, Ok YS. Biochar as a sorbent for contaminant management in soil and water: A review. Chemosphere 2014; 99:19–33.
[27] Sukiran MA, Kheang LS, Bakar NA, May CY. Production and characterization of biochar from the pyrolysis of empty fruit bunches. Am. J. Appl. Sci. 2011; 8:984–988.
[28] Jindo K, Mizumoto H, Sawada Y, Sanchez-Monedero MA, Sonoki T. Physical and chemical characterization of biochars derived from different agricultural residues. Biogeosciences 2014; 11: 6613–6621.