Journal of AgriSearch, 9 (2): 136-139
An Open Access International Peer Reviewed Quarterly

ISSN : 2348-8808 (Print), 2348-8867 (Online)
https://doi.org/10.21921/jas.v9i02.10118

Investigation on Physicochemical Properties of Biochar Produce Through Different Gas Flow Rates in an Open Core Downdraft Gasifier

KETAN SAKARIYA[1], P M CHAUHAN[2] AND DIVYESH R VAGHELA[3]*

ABSTRACT

Biochar was produced using cotton stalk through open core downdraft gasifier at 18, 20, 22, and 24 m^3/h gas flow rate, and produced biochar was analyzed for physicochemical properties for suitable application. The average bulk density of shredded cotton stalk biochar was found as 179.21 kg/m^3. The proximate analysis of shredded cotton stalk biochar in terms of fixed carbon, volatile matter, ash content; and the ratio of volatile matter to fixed carbon were found as 33.56, 49.48, 5.50 (%, d.b), and 1.47, respectively. The maximum value of gasification efficiency founded at 22 m^3/h thus the values of pH, EC, O.C., available N, P_2O_5, K_2O, S, and CEC of biochar was found as 10.35, 9.90 dS/m, 2.85 %, 0.0014 %, 0.015013 %, 1.284 %, 0.047 % and 48.00 me/100gm, respectively.

Keywords: Cotton stalk biochar (CSB), Open core downdraft gasifier, Gasification, Physicochemical properties, Biomass

ARTICLE INFO

Received on	:	31.03.2022
Accepted	:	01.06.2022
Published online	:	16.06.2022

INTRODUCTION

The term "biochar" is recently on trending position, yet biochar in one form or another have been used for soil improvement. In the Amazon Basin, there exists evidence of extensive use of biochar in the fertile soils known as Terra Preta (black soil) and Terra Mulata (mulatto earth), which were created by ancient, indigenous cultures of the time most likely to enhance localized soil productivity.

To supply the rising demand for food worldwide agriculture has become more reliant on chemical fertilizers as a source of plant nutrients in recent decades. However, in the recent years, the environmentalists and agricultural scientists have realized that continued and unbalanced use of chemical fertilizers deteriorate the soil fertility, cause environmental pollution and affect the soil microbial activity. Thus, increasing awareness is being created on the use of organics including biochar to sustain the soil fertility and plant productivity.

In recent years, biochar has emerged as an amendment with mineral fertilizer and hold a promise to improve the yield of crops. Biochar has been found to have a significant influence on soil fertility, bringing more helpful fungi and bacteria, enhancing crop production, and retaining nutrients without causing hazard to the soil and water environment.

The benefits of biochar to soils for agricultural purposes are numerous. Biochar may be added to soils with the intention to improve the soil, displace an amount of conventional fossil fuel-based fertilizers, and sequester carbon. However, commercial employment of biochar as a soil amendment is still in its infancy. The effect of biochar as a soil amendment on crop productivity is variable due primarily to interactions and processes that occur when biochar is applied to soil, which are not yet fully understood. Currently, Japan has the largest market for biochar products; approximately 15,000 tons/year is traded annually for soil use (Filiberto and Gaunt, 2013). Biochar application also improves the overall sorption capacity of soils and therefore it might influence the toxicity, transport and fate of different heavy metals in the soil. Glaser *et al.* (2002) and Lehmann *et al.* (2003) also reported the increase in the availability of major plant nutrients due to application of biochar.

The beneficial effects of biochar are determined primarily by some of its properties: high porosity, responsible for its high-water retention capacity, high cation exchange capacity, which favors the retention of nutrients and prevent their loss, direct nutrient supply depending on the type of biochar, and the capacity of being a habitat for beneficial microorganisms, which can promote the release and uptake of nutrients by plants was reported by Atkinson *et al.* (2010) and Sohi *et al.* (2009).

However, the use of fossil fuel-based fertilizers contributes to greenhouse gas emissions while similarly encouraging the depletion of the natural nutrient and minerals in healthy soils. Biochar, the solid material obtained from the carbonization of biomass through pyrolysis and gasification, is a potential soil amendment and carbon sequestration medium. Verheijen *et al.* (2009) critically reviewed the effect of the application of biochar on the properties of soils. A compilation of studies for analyzing the effects of biochar application to soils and plant productivity showed that a small but statistically significant positive effect on plant productivity in the majority of cases.

Therefore, in current research investigation biochar was produced through different gas flow rates in an open core downdraft gasifier using cotton stalk and evaluate its performance in terms of physiochemical properties for suitable application.

MATERIALS AND METHODS

Physicochemical properties and proximate analysis of shredded cotton stalk biochar

Cotton stalk was collected from the instructional farm of the

[1]M.Tech Scholar, Deptt. of Renewable Energy Engg., College of Ag. Engg. and Tech., Junagadh Agriculture University, Junagadh, Gujarat, India
[2]Professor, Deptt. of Renewable Energy Engg., College of Ag. Engg. and Tech., Junagadh Agriculture University, Junagadh, Gujarat, India
[3]Assistant Professor, Dett. of Renewable Energy Engineering, Parul Institute of Technology, Parul University, Vadodara, Gujarat, India
*Corresponding Author E-mail: divyesh.vaghela8933@paruluniversity.ac.in

College of Agricultural Engineering and Technology, Junagadh Agriculture University, Junagadh, Gujarat. Biochar obtained through open core gasification of shredded cotton stalk, during the experimental run conducted at all the four levels of gas flow.

Physical properties of shredded cotton stalk biochar

Different size fraction of biochar of shredded cotton stalk were also analysed in terms of weight and length. There samples of randomly selected, 1000 g biochar of shredded cotton stalk obtained from each experiment run were used for the analysis. Size fractions the biochar was divided into five different size fractions i.e. large, material retained in 4 mesh (4.76 mm) opening sieve, medium, material retained in 5 mesh (4.00 mm) opening sieve, small, material retained in 8 mesh (2.38 mm) opening sieve, thin, material retained in 9 mesh (2.00 mm) opening sieve and powder (less than 2 mm) as the material passed through 9 mesh opening sieve. In each case 100 g biochar was used for sieving the biochar manually a total of 10 sieving for each experimental run. The material retained and passed through each subsequent sieve were considered as total five different size fractions. Each size fraction was weighed and measured randomly for its minimum and maximum length of biochar. The bulk density of the biochar was also measured.

Proximate analysis of shredded cotton stalk biochar

Proximate analysis characterizes the biochar moisture content, volatile matter, ash content and fixed carbon. Proximate analysis of the fuel defines its volatility and burning properties. ASTM standard recommended for coal, sparky fuels, etc., which meets the demand of the biomass material largely was used for this analysis.

Moisture content

Moisture content of most of the biomass fuel depends on the type of fuel, its origin and treatment before it is used for gasification. Moisture content of the fuel is usually referred to inherent moisture plus surface moisture. The moisture content below 15 percent by weight is desirable for trouble free and economical operation of gasifier. Fuel moisture content (FMC) of cotton stalk was determined by drying the known weight of sample in hot air oven at 105 ± 2 ºC while keeping the ground sample in Petri dish till constant weight. The ratio of weight of water to the initial weight of the sample was the moisture content of fuel on dry basis (d.b.). For most of the biomass samples 2 h drying is sufficient.

$$\text{FMC, (\%, d.b.)} = \frac{(w_2 - w_3)}{(w_3 - w_1)} \times 100 \qquad \text{............ (1)}$$

Where,

w_1= weight of the empty Petri dish, g

w_2= weight of the wet sample plus Petri dish, g

w_3= weight of dry sample plus Petri dish, g

Volatile matter

Volatile matter and inherently bound water in the fuel were given up in pyrolysis zone forming a vapor consisting of water, tar, oils, and gases. Fuel with high volatile matter content produce more tar. Volatile matters in the fuel determine the design of gasifier for removal of tar. Volatile matter of cotton stalk biomass is the product, exclusive of moisture, given off by a material as a gas or vapor when solid biomass is heated out of contact with air under standardized conditions that may vary according to the nature of the material. Oven-dried biomass sample was kept in the tarred crucible. Two drops of benzene were added in it to displace air in the environment surrounding the sample. The crucible was closed with lid and placed in the muffle furnace and heated at 600±10 °C for six minutes and 900±10 °C for another six minutes. The loss in weight divided by the initial weight of biomass is the volatile matter on dry basis of oven dried biomass fuel.

$$\text{Volatile matter (\%, d.b)} = \frac{(w_2 - w_3)}{(w_2 - w_1)} \times 100 \qquad \text{............(2)}$$

Where,

w_1= weight of the empty crucible, g

w_2= initial weight of the sample plus crucible, g

w_3= final weight of sample plus crucible, g

Ash content

Mineral content of fuel, which remains in oxidized form after combustion of fuel, is called ash. In practice, ash also contains some unburned fuel. Ash content and ash composition have impact on smooth running of gasifier. Melting of ashes in reactor causes slagging and clinker formation. If no measure is taken, slagging or clinker formation leads to excessive tar formation or complete blocking of reactor. In general, no slagging occurs with fuel having ash content below 5 percent. In this method, oven-dried biomass sample kept in the silica crucible was placed in the muffle furnace at 750 ± 25 °C till constant weight. The ratio of the final weight to the initial weight of the sample was the ash content of the moisture free biomass sample.

$$\text{Ash content (\%, d.b)} = \frac{(w_3 - w_1)}{(w_2 - w_1)} \times 100 \qquad \text{..........(3)}$$

Where,

w_1= weight of empty crucible, g

w_2= initial weight of the sample plus crucible, g

w_3= final weight of sample (ash) plus crucible, g

Fixed carbon

The fixed carbon represents the non-volatile combustible component of the fuel. The amount of fixed carbon present gives a rough indication of the charcoal yield. Also, a higher fixed carbon material is generally better suited for gasification then a lower fixed carbon material. After determining fuel moisture content (d.b.), volatile matter (d.b.) and fuel ash content (d.b.). The fixed carbon content was estimated from the material balance equation given below

$$\text{FC (\%, d.b.)} = 100 - \text{VM (\%, d.b.)} - \text{ASH (\%, d.b.)} \qquad \text{.........(4)}$$

Where,

FC (%, d.b.)= percentage of fixed carbon on dry basis

VM (%, d.b.)= percentage of volatile matter on dry basis

ASH (%, d.b.) = percentage of ash on dry basis

Chemical analysis of shredded cotton stalk biochar

Chemical analysis of biochars were carried out in terms of pH, electrical conductivity (EC), Organic Carbon, available N, available P_2O_5, available K_2O, available S and cation exchange capacity (CEC) for calculation method was used is given in Table 1.

RESULTS AND DISCUSSION

Proximate analysis of shredded cotton stalk biochar

Proximate analysis in terms of fixed carbon, volatile matter and ash content is determined and results of this analysis are presented in table 2. The fixed carbon, volatile matter, ash

Table 1: Chemical properties of biochar

Sr No.	Particular	Method followed
1	pH (1:10)	pH meter (Richards, 1954)
2	EC (1:10)(dS/m)	EC meter (Jackson, 1974)
3	Organic Carbon (%)	Walkely and black method (Jackson, 1974)
4	Available N (ppm)	Alkaline $KMnO_4$ method (Subbiah and Asija, 1956)
5	Available P_2O_5 (%)	Olsen's method (Olsen *et al*., 1954)
6	Available K_2O (%)	Flame photometric method (Jackson, 1974)
7	Available S (%)	Turbidity method (Chaudhary and Cornfield, 1966)
8	CEC(me/100gm)	Versenate EDTA Method (Jackson, 1974)

content and ratio of volatile matter and fixed carbon were found as 33.56, 49.48, 5.50 (%, d.b) and 1.47, respectively for cotton stalk biochar. Enders *et al*. (2012) found that ash content, volatile matter and fixed carbon of peanut and soyabean biochar as 6.8 %, 45.6 %, 47.6 % and 15.2 %, 47.0 % and 37.8% (w/w), respectively.

Table 2: Proximate analysis of shredded cotton stalk biochar

Sr. No.	Ash content, % d.b	Volatile matter content, % d.b	Fixed carbon content, % d.b	Volatile matter / Fixed carbon
1	5.50	49.48	33.56	1.47

Physical properties of shredded cotton stalk biochar

Table 3 shows the average values of different size fractions of the biochar and minimum and maximum length of the biochar. It can be seen from the table that average weight of the different size fraction were found as 235.207 g, 143.771 g, 244.981 g, 146.090 g and 229.951 g considered as large (more than 4.76 mm) i.e. material retained in 4 mesh opening sieve, medium (4.00 – 4.76 mm) i.e. material retained in 5 mesh opening sieve, small (2.38 – 4.00 mm) i.e. material retained in 8 mesh opening sieve, thin (2.00 – 2.38 mm) i.e. material retained in 9 mesh opening sieve, and powder (< 2 mm) as the material passed through 9 mesh opening sieve, respectively. It can also be seen from the table 3 that percent weight fractions of large, medium, small, thin, and powder were found as 23.52 %, 14.38 %, 24.50 %, 14.61 % and 23.00 %, respectively. It can also be seen from the table 3 that the percent weight fractions were ranged from a minimum value of 14.38 % for medium sized fractions (4.00 – 4.76 mm) to a maximum value of 24.50 % for small sized fractions (2.38 – 4.00 mm). It can also be seen from the table 3 that the minimum and maximum length of different size fractions of large, medium, small and thin were found as 12 - 80 mm, 11 - 53 mm, 9 - 35 mm, and 3 - 22 mm, respectively.

Table 3: Different size fractions of shredded cotton stalk biochar

Sr. No.	Size fractions	Average weight		Length, mm	
		g	%	Minimum	Maximum
1	Large, (more than 4.76 mm)	235.20	23.52	12	80
2	Medium, (4.00 – 4.76 mm)	143.77	14.38	11	53
3	Small, (2.38 – 4.00 mm)	244.98	24.50	09	35
4	Thin, (2.00 – 2.38 mm)	146.09	14.61	03	22
5	Powder, (less than 2 mm)	229.95	23.00	-	-
	Total	1000	100		

Chemical properties of shredded cotton stalk biochar

Table 4 shows the chemical properties of shredded cotton stalk and its biochar.

It can be seen from the table that the values of pH, EC and CEC of biochar obtained at 18, 20, 22 and 24 m^3/h gas flow rates were found as 9.97, 10.54, 10.35, 10.93; 10.57, 9.11, 9.90, 11.97 dS/m and 29.70, 43.30, 48.00, 49.03 meq/100gm, respectively. It can also be seen from the

Table 4: Chemical properties of shredded cotton stalk biochar at different gas flow rates

Sr No.	Particular	Value at different gas flow rates			
		$18m^3/h$	$20m^3/h$	$22m^3/h$	$24m^3/h$
1	pH (1:10)	9.97	10.54	10.35	10.93
2	EC (1:10), dS/m	10.57	9.11	9.90	11.97
3	Organic Carbon,%	3.75	2.4	2.85	3.3
4	Available N, %	0.04	0.08	0.04	0.07
5	Available P_2O_5, %	0.14	0.14	0.15	0.15
6	Available K_2O, %	0.876	1.806	1.284	2.172
7	Available S, %	0.063	0.070	0.047	0.068
8	CEC, me/100gm	29.70	43.03	48.00	49.03

table that the values of O,C, and available N of biochar obtained at 18, 20, 22 and 24 m^3/h gas flow rates were found as 3.75, 2.4, 2.85, 3.3 % and 0.0024, 0.0018, 0.0014, 0.0017 %, respectively. Similarly, the values of available P_2O_5, available K_2O and available S of biochar obtained at 18, 20, 22 and 24 m^3/h gas flow rates were found as 0.014552, 0.014645, 0.015013, 0.015842 %; 0.876, 1.806, 1.284, 2.172 % and 0.063, 0.070, 0.047, 0.068 %, respectively.

Similar kind of results were found by Allaire *et al*. (2015) and presented that the values of pH, N, P_2O_5, K_2O and S of biochar of Maple bark as 8.39, 0.58 %, 806 mg/kg, 8.10 cmol/kg and 1.51%, respectively. Gul *et al*. (2015) also found that N, P_2O_5 and K_2O of wheat straw derived biochar as 0.9%, 3.51 g/kg and 75.5 g/kg, respectively. Venkatesh *et al*. (2013) also found that pH, EC, N, P_2O_5, K_2O and CEC of cotton stalk biochar as 9.3, 0.08 dS/m, 10.5 g/kg, 3.4 g/kg, 4.0 g/kg and 11.2 cmol/kg, respectively.

CONCLUSION

According to the characterization of biochar obtained by different gas flow rates in an open core downdraft gasifier of cotton stalk, we can conclude that produce biochar possessing different properties at different gas flow rates. Average bulk density of shredded cotton stalk biochar was found as 179.21 kg/m^3. The maximum value of gasification efficiency founded at 22 m^3/h thus the values of pH, EC, O.C., available N, P_2O_5, K_2O, S and CEC of biochar were found as 10.35, 9.90 dS/m, 2.85 %, 0.0014 %, 0.015013 %, 1.284 %, 0.047 % and 48.00 me/100gm, respectively. The findings of present study justified that cotton stalk derived biochar possesses a good potential for the soil amendment.

REFERENCES

Allaire S E, Lange S F, Auclair I K, Quinche M and Greffard L. 2015. Report: Analyses of biochar properties. *Centre de Recherche sur les Matériaux Renouvelables, Université Laval, Québec, Canada,* p 59.

Atkinson C J, Fitzgerald J D and Hipps N A. 2010. Potential mechanisms for achieving agricultural benefits from biochar application to temperate soils: a review. *Plant Soil* **33:** 1–18.

Chaudhary A and Cornfield A H. 1966. The home of premier fundamental discoveries, inventions and applications in the analytical and bioanalytical sciences. *Analyst* **91:**528-530.

Filiberto D M and Gaunt J L. 2013. Practicality of biochar additions to enhance soil and crop productivity. *Agriculture* **3(4)**: 715-725.

Glaser B, Lehmann J and Zech W. 2002. Ameliorating physical and chemical properties of highly weathered soils in the tropics with charcoal–a review. *Biology and Fertility of Soils* **35(4)**: 219-230.

Gul S, Whalen J K, Thomas B W, Sachdeva V and Deng H. 2015. Physico-chemical properties and microbial responses in biochar-amended soils: Mechanisms and future directions. *Agriculture, Ecosystems and Environment* **206:**46–59.

Jackson M L. 1974. Soil Chemical Analysis. Prentice Hall of India Pvt. Ltd., New Delhi, pp. 327-350.

Lehmann J, da Silva J P, Steiner C, Nehls T, Zech W and Glaser B. 2003. Nutrient availability and leaching in an archaeological anthrosol and a ferralsol of the Central Amazon basin: fertilizer, manure and charcoal amendments. *Plant and soil* ***249*(2):** 343-357.

Olsen S R, Cole C V, Watanabe F S and Dean L A. 1954. Estimation of available phosphorus in soil by extraction with sodium bicarbonate. *Circ. U. S. Dept. Agric*., 939.

Richards L A. 1954. Diagnosis and Improvement of saline and alkali soils. USDA Hand Book No. 60. pp. 112.

Sohi S, Lopez-Capel E, Krull E and Bol R. 2009. Biochar, climate change and soil: A review to guide future research. *CSIRO Land and Water Science Report* **5**(09): 17-31.

Subbiah B V and Asija G L. 1956.A rapid procedure for the estimation of available nitrogen in soils. *Current Sci.* **25** (7): 259-260.

Venkatesh G, Venkateswarlu B, Gopinath KA, Srinivarao Ch, Korwar GR, Raddy B S, Prasad JNVS, Grover M, Raju B M K, Sasikala C H and Venkanna K. 2013. Biochar production tecnology for conversion of cotton stalk bioresidue into biochar and its characterization for soil amendment qualities. *Central Research Institute for Dryland Agriculture*, Hyderabad-500059, *Andhra Pradesh*. *Indian J. dryland Agric. Res. & Dev.* **28**(1):48-57.

Verheijen FGA, Jeffery S, Bastos AC, van der Velde M and Diafas I. 2009. Biochar Application to Soils – A Critical Scientific Review of Effects on Soil Properties, Processes and Functions. EUR 24099 EN, Office for the Official Publications of the European Communities, Luxembourg, 149pp.

Citation:

Sakariya K, Chauhan PM and Vaghela D. 2022. Investigation on physicochemical properties of biochar produce through different gas flow rates in an open core downdraft gasifier. *Journal of AgriSearch* **9**(2)136-139