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Design and Development of Continuous Biochar Production Unit

Rathinavel S., Angeeswaran R.

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Abstract Global warming, climate change are the most important issues threatening 21st century. Moreover coal availability is decreasing day to day. Biochar production is an existing method of fuel management, but the methods of producing biochar is batch type, time consuming. Hence a continuous biochar production unit with 200 to 400 degree celsius temperature range and 40 to 60 seconds of residence time is designed and evaluated with different biomass samples. The biochar yield varies with temperature and residence time for different biomass samples.

Keywords Biochar, Pyrolysis, Biomass samples, Indirect heating.

Introduction

It was reported that the renewable energy resources available in plenty in the agro processing centers (rice husk, bagasse, molasses, coconut shell, maize cobs, potato wastes, coffee wastes), farm wastes, municipal wastes and industrial wastes are increased day by day during the last 30 years. These residues can be efficiently utilized for producing renewable energy and materials thereby they not only help to meet the needs but also to solve the disposal and pollution problems. It was reported that biomass energy is more economical to produce and it provides more energy than other energy forms. Biomass production is eight times greater than the total annual world consumption for all other energy sources. It was stated that pyrolysis of crop residues to produce renewable energy is one option to reduce the use of fossil fuels. Pyrolysis generates biochar, oil, and gas products that can all be used as fuels.

Earlier a pyrolytic screw conveyor was designed in the name of Lambiotte reactor which is vertical moving bed reactor supplied with the recirculated combusted pyrolysis gases instead of air. The largest Lambiotte reactor has a annual production of 13.500 tons of charcoal. Auger system was developed using high density heat carrier with a capacity of 1 ton per day. Earlier screw reactor was designed. 3D screw reactor model designed to study the biomass residence time and product yields.

In order to improve these design methods and efficiency a continuous biochar production unit was designed (Downie et al. 2009, Erol et al. 2010, Laird 2008, Lehmann 2009).

Materials and Methods

Four different biomasses were selected for production of biochar and coconut shell was used as the fuel. The selected four biomasses for pyrolysis process are: Cotton stalk (*Gossypium* sp.), Coconut shell (*Cocos nucifera*), Casuarina wood (*Casuarina* sp.), Groundnut shell (*Arachis hypogea*).

The properties such as Sample's porosity, bulk density and true density were determined and then

Rathinavel S.*
PG Scholar, Dept of Bioenergy, Tamilnadu Agricultural University, Tamil Nadu, India

Angeeswaran R.
Asst. Prof., Dept of Bioenergy, Tamilnadu Agricultural University, Tamil Nadu, India
e-mail: rathinavelesr@gmail.com
*Corresponding author

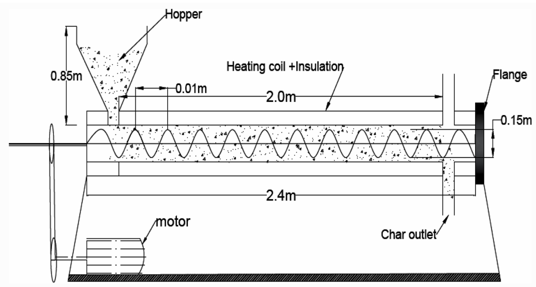

Fig. 1. Continuous biochar production unit.

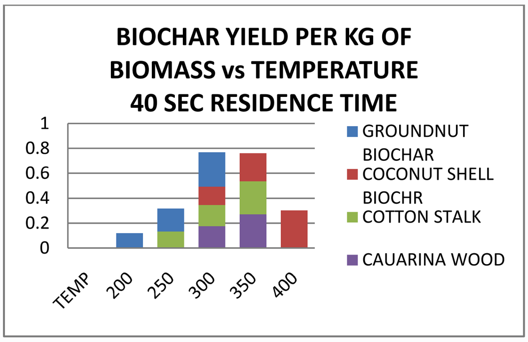

Fig. 2. Biochar production at 40 sec residence time.

properties such as Sample's moisture content, volatile matter, ash content and fixed carbon were determined by ASTM–D3173, D3174 and D3175 methods.

The continuous production of biochar is to be done by using indirect heating method. The reactor shown in Fig. 1, consists of a screw auger of length 2.4 m for conveying the material from one end to the other. The auger is driven by means of a electrical motor. The auger is enclosed with in a cylindrical chamber. The external electrical coils over the chamber are spread over the length of the chamber. The external heating coils are split into three zones. The coils are well insulated with ceramic wool to prevent the heat loss.

The speed of the augur can be controlled using variable frequency drive to set the desired rpm. The temperature can also be controlled manually. T_1, T_3 and T_4 are temperature indicators while T_2 is temperature controller sensor.

The materials are fed into the reactor by means of a hopper and the char output is collected in a container. The flue gas leaves through the provision for exhaust from the reactor.

The experiments were carried out in such a way that the biomass is fed into the hopper which was then sealed gas tight. The heating elements were switched on simultaneously to reach the desired temperature for pyrolysis. When the reactor reaches the desired temperature the motor was switched on in a certain adjusted rotation speed to feed biomass into the reactor at a uniform rate.

By this process the temperature of biomass increases continuously, followed by the emission of volatile matter which then forms the pyrolysis gas. The gas leaves the reactor into atmosphere through flue gas outlet. Simultaneously the carbonized char leaves the reactor through the provision at the bottom in a container. The char is allowed to cool to room

Table 1. Characteristics of biomass samples.

Sl. No.	Biomass	Bulk density	Moisture content	Volatile matter	Carbon	Ash
1.	Cotton stalk	180	11.6	75.52	20.03	4.45
2.	Coconut shell	153	5.80	75.57	23.85	0.58
3.	Casuarina wood	225.68	6.03	76.63	20.59	2.78
4.	Ground-nut shell	250	13.89	77.65	18.31	4.04

Table 2. Characteristics of biomass samples.

Sl. No.	Biomass	Hemi-cellulose	Cellulose (%)	Lignin	Calorific value
1.	Cotton stalk	39.62	32.15	21.74	3742
2.	Coconut shell	32.45	15.67	43.21	4468
3.	Casuarina wood	28.57	46.63	27.13	4785
4.	Ground-nut shell	26.93	43.46	23.56	4524

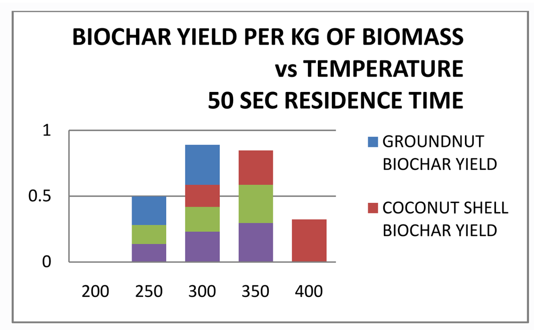

Fig. 3. Biochar production at 50 sec residence time.

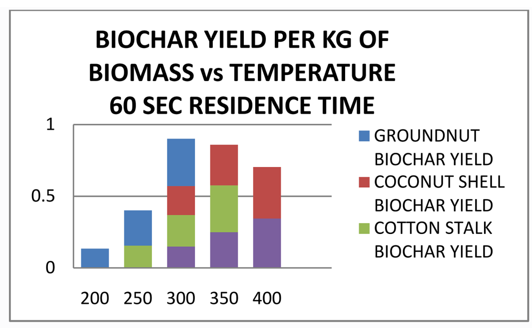

Fig. 4. Biochar production at 60 sec residence time.

temperature, measured and then a representative sample is taken to further chemical analysis of the biochar.

The biochar obtained from the pyrolysis of selected biomass was powdered and sieved to less than 40 microns and their important physical and chemical properties were studied.

Results and Discussion

The obtained biochar from different biomass samples were found to be with less moisture content, ash content, volatile matter comparing the raw biomass samples (Tables 1 and 2). Carbon present in the biochar was found increased comparing the raw biomass samples. The carbon present in the biochar was to be 78.64% to 84.08%. The moisture content was found to be 0.17% to 1.26% and volatile matter was 17.42%.

The highest biochar production was found to be at 60 second residence time and 300 degree celsius temperature for groundnut shell, 350 degree celsius for casuarin as wood and cotton stalk, which can be noticed in Figs. 2 to 4.

Maximum biochar production obtained are 33% yield from groundnut shell, 32.7% from cotton stalk, 34.4% from casuarin as wood, 36% from coconut shell biomass samples.

Conclusion

As biochar not only used for thermal applications, it can be used as organic input for agricultural farms. Hence further research on biochar production and increasing the efficiency of the biochar production methods can be useful for enhancing bioenergy usage. Several other feed stocks can be subjected for evaluation and different level of biochar production can be obtained.

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