Preparation of Charcoal Using Flower Waste

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Abstract

Ethiopia is the second largest flower exporter in Africa. However, finding effective solutions for flowers waste management that are economical, efficient and environmentally friendly is a very difficult task. In this paper, a novel technology to recover energy from flower waste with the objective of producing biochar from flower waste by using pyrolysis has been presented. The pyrolysis reactor has been designed, manufactured and tested. Characterization of the flower waste has also been done by estimating the ultimate and proximate analysis. Besides the energy content has been measured by using Bomb calorimeter. Detailed proximate analysis has been performed and the energy content of the biochar has also been measured. The result shows that 10 kg of biochar is produced by using 18 kg of flower waste with a conversion efficiency of 55.5% and approximately 310.8 kg of biochar can be generated daily. Based on the result, the measured value of lower heating value of the produced biochar is 26.54 MJ/kg and approximately 392.2 kg of firewood is replaced daily. Thus, by adopting this innovative technology and producing biochar, the amount of flower waste is reduced from going to the landfill, energy is recovered from flower waste, income is generated from the selling of the produced biochar and the energy problems of the society is solved and finally environmental impact of the flower waste is reduced.

Keywords

Biochar, Briquette, Flower Waste, Pyrolysis

1. Introduction

Ethiopia is the second largest flower exporter in Africa, with over 100 flower growers on 1700 hectares [1]. This implies that everyday a huge amount of waste is generated at the flower farm in Ethiopia. However, finding effective solutions for flowers waste management that are economical, efficient and environmentally friendly is a very difficult task. This is due to the fact that flower farmers use

pesticides and fertilizers to grow the flowers. Therefore, the flower waste will contain those pesticides. This will affect the environment greatly unless appropriate measure has been taken.

Biochar is defined as carbon-rich product obtained when biomass is heated in a closed container with little or no available air through a process called pyrolysis [2]. It has been used for so long since it mitigates climate change and used for sustainable waste management [3]. The biochar produced from agriculture waste is used for soil amendment, as a smokeless fuel, which can reduce the amount of waste to be sent to the landfill. Besides, it is used to improve soil nutrient retention and water holding capacity [2]-[8]. It is known that the main element of biochar is carbon; it also contains hydrogen, oxygen, nitrogen and sulphur [9]. Since biochar has large specific area and porous structure, it has been used as adsorbent for water pollutants [10].

There are several thermal treatment technologies to produce biochar including pyrolysis, gasification, hydrothermal carbonization, flash carbonization and Torrifaction [11] [12] [13]. Among those technologies pyrolysis is the most adopted technology to produce biochar from biomass. Pyrolysis is defined as a process for decomposing organic materials thermally under oxygen-free conditions in the temperature range, 300°C - 800°C which leads to the production of three main substances, *i.e.*, solid residue (biochar), a liquid product (bio-oil) and non-condensable gas known as Syngas which consist of carbon monoxide (CO), carbon dioxide (CO_2), hydrogen (H_2), and methane (CH_4) [14]. The yields of the pyrolysis products depend on the characteristics of the input biomass materials, the pyrolysis processes adopted and different parameters *i.e.* reaction temperature, heating rate, and residence time [15]. Based on reviewing different literatures, it has been stated that biochar yield, Syngas yield, ash content, pH, and carbon stability increase with increasing pyrolysis temperature [16] [17] [18]. The pyrolysis process conditions can be optimized to produce either a solid char, gas or liquid/oil product. Depending on the residence time in the reactor pyrolysis is divided into two: slow (long residence time) as shown in **Figure 1** and fast pyrolysis (short residence time). Under slow pyrolysis, a biochar yield between 25% - 35% can be reproducibly produced depending on the nature of the feedstock, reactor type as well as the degree of operating conditions optimization. To obtain a high bio-oil yield, fast pyrolysis is recommended. However, fast biomass pyrolysis needs to satisfy four conditions namely, a medium temperature (450°C - 600°C), high heating rate (103 - 104 K/s), short vapor residence time (<2 s) and fast condensation of vapors [17]. Under slow pyrolysis, a biochar yield between 25 % - 35 % can be reproducibly produced depending on the nature of the feedstock, reactor type as well as the degree of operating conditions optimization [18].

In Ethiopia, charcoal is commonly produced using the traditional earth kiln method—earth mound kiln and earth pit kiln; earth mound kiln being the most frequent method with an efficiency of 10% - 15% [19]. It has to be noted that high amounts of gases and other unburned hydrocarbons are released into the
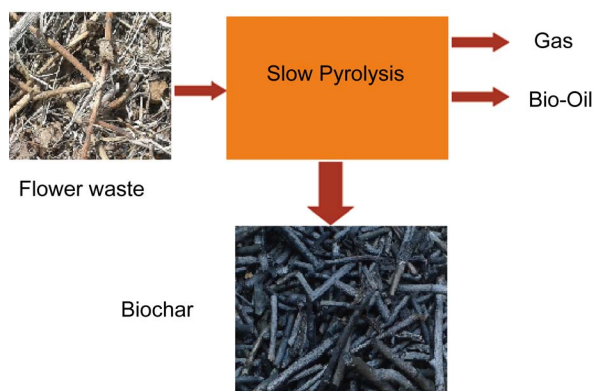
Figure 1. Slow pyrolysis to produce biochar from flower waste [3].

atmosphere. This traditional technology is inefficient and leads to deforestation since most of the people use woody biomass to produce charcoal in Ethiopia. In order to reduce the environmental impact of charcoal using these traditional kilns, new alternatives can be implemented to convert biomass into valuable products. Innovative slow pyrolysis technologies must be adopted in developing countries to produce biochar that is efficient and environmentally friendly. Thus, instead of using woody biomass as the only means to produce biochar in Ethiopia, several biomasses can be used like flower wastes, agricultural wastes, bamboo and others.

Even though biochar has a lot of advantages from energy and environmental perspective point of view, it is has not been used widely in Ethiopia. Most of the biochar reactor that has been used before has low conversion efficiency [20], very small scale and rarely found in rural areas even though 85% of the population of Ethiopia lives in rural areas. Besides, approximately 90% of the Ethiopian population used biomass for cooking purpose [21]. This will leads to indoor air pollution and creates healthy problems for the society [22]. However, finding a long-term solution that will solve rural society problem efficiently, economically, and environmental friendly is a very challenging task.

Therefore, in this paper, a novel, efficient and cost effective technology has been designed, manufactured and tested to produce biochar from flower waste. The biochar will be used for various purposes like cooking purpose and for soil amendment. Thus, the waste is converted into an opportunity. Besides, it will help to generate incomes, reduce landfill areas and reduce environmental impact.

2. Materials and Methods

First, the flower waste is collected. The leaves are separated from the woody party of the flower waste since the leaves is not used to produce biochar for this research. The woody part of the flower is collected in a daily basis. The mass of the woody part of the flower is measured at wet and dry conditions. Thus, by measuring the flower waste for about 15 days, the average daily dry flower waste is estimated. Data has been collected from one of the flower farms in Ethiopia that

is generating a daily dry flower waste of 560 kg. The general methodology is shown in Figure 2.

The feedstock used in the study is waste flower from leftover of horticulture farms as shown in Figure 3. The sample has been dried to remove the moisture and cut in small size.

Thermo-chemical behavior of flower waste biomass such as moisture content, ash content, volatile matter and fixed carbon were determined by standard procedures. The moisture content is determined by the loss in weight that occurs when a sample is dried in a laboratory oven at 105°C for 1 hour. The volatile matter has been determined by involving measurement of weight loss following combustion of about 1 g biomass in a furnace at 950°C for 6 min. To determine the ash content, the biochar samples were heated in a laboratory ash furnace at 750°C for at least 3 hours. The results of the proximate and ultimate analyses of the flower waste are shown in Table 1. The experimental results of the proximate and ultimate analyses of the flower waste are shown in Table 2. The chemical elements, such as carbon, hydrogen, oxygen, nitrogen and Sulfur, that constitute the biomass is estimated by using ultimate analysis. The results of ultimate analysis by using ultimate analyzer are 48.5%, 5.8%, 42.0%, 3.62%, and 0.08% for contents of carbon, hydrogen, oxygen, nitrogen, and sulphur, respectively as shown on Table 2.

A dried flower waste biomass sample is weighted and placed in a digital Bomb calorimeter for calorific value or heating value determination. The digital Bomb calorimeter is then sealed and the biomass sample is ignited electrically. The complete combustion of the biomass releases heat and it is measured through the temperature change, which is measured by using a digital sensor, of the water bath surrounding the bomb calorimeter. The heat of combustion can be calculated from the resulting rise in temperature. To check the accuracy of heating
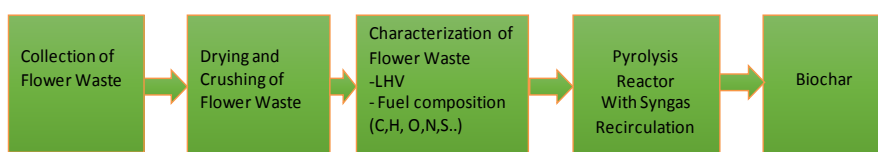

Figure 2. General methodology [4].

Figure 3. Flower waste [1].

Table 1. Final products of biomass during pyrolysis and gasification process [16] [17] [18].

`	Condition	Liquid (bio-oil)	Solid (biochar)	Gas (Syngas)
Fast Pyrolysis	• Moderate temperature (~500˚C) • Short vapor residence time (<2 s)	75%	12%	13%
Intermediate Pyrolysis	• Low-moderate temperature • Moderate hot vapor residence time	50%	25%	25%
Slow Pyrolysis	• Low-moderate temperature • Long residence time	30%	35%	35%
Gasification	• High temperature (>800˚C) • Long vapor residence time	5% tar	10%	85%

Table 2. Proximate analysis and lower heating value of flower waste.

Proximate analysis	
Moisture content (wt%)	8.335
Ash content (wt%)	5.960
Volatile content (wt%)	71.310
Fixed carbon (wt%)	14.395
Ultimate analysis (wt%)	
Carbon (wt%)	48.5
Hydrogen (wt%)	5.8
Nitrogen (wt%)	3.62
Oxygen (wt%)	42
Sulphur (wt%)	0.08
Molecular formula	$C_{4.04}H_{5.8}O_{2.625}N_{0.259}S_{0.003}$
Lower heating value (MJ/kg)	17.9 MJ/kg

values of same samples, few experiments have been repeated. The result is reported as shown in Table 2.

The heat required for the pyrolysis reactor is supplied by burning a portion of flower waste. This heat is transferred to the reactor to convert waste flower into biochar. The reactor is covered with a refractory coverage to avoid heat loses. Besides, the portion of the produced gas is re-circulated to increase the efficiency of the system. The inside diameter of the reactor is 0.25 m, height of the inside reactor is 1m. The reactor is a double barrel reactor where the inside one is the pyrolysis reactor and the external one is where combustion is occurring. Air is inserted at the bottom of the combustion chamber. Thus, the heat released from combustion is used for the inside pyrolysis reactor. The sectional view and manufactured prototype of waste flower to biochar reactor is shown in Figures 4-7.

The produced charcoal is mixed with a small amount of molasses. To produce Briquette charcoal a manually operated screw type extruder machine is designed and manufactured as shown in Figure 8. The produced biochar and the main steps till combustion of the biochar are shown in Figure 9.
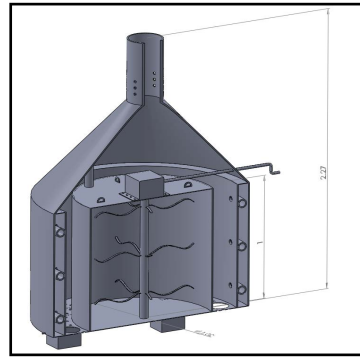
Figure 4. Sectional view of the reactor.

Figure 5. Manufactured prototype.

Figure 6. Inside of the reactor before covering.

Figure 7. Inside of the reactor with produced biochar.

Figure 8. Extruder machine.

Figure 9. Produced biochar before compaction, mixing, briquette and combustion of biochar [21].

3. Results and Discussion

3.1. Conversion Efficiency

The conversion efficiency of the biochar reactor has been obtained by the following formulae:

Conversion efficiency (%) = Flower waste input (W_{in})/biochar produced (B_{prod}).

The experimental results show that 10 kg of biochar is produced by using 18 kg of flower waste with a conversion efficiency of 55.5%. It takes 30 minutes to complete one batch biochar production. However, Batch biochar production takes a lot of time. Thus, a separate research is undergoing to produce biochar from flower waste continuously. The measured lower heating value of the produced biochar is 26.54 MJ/kg. Data has been collected from one of the flower farms in Ethiopia that is generating a daily dry flower waste of 560 kg.

Thus, based on the result, approximately 310.8 kg of biochar can be generated daily. Thus, by adopting this innovative technology and producing biochar, the amount of flower waste is reduced from going to the landfill, energy is recovered from flower waste, income is generated from the selling of the produced biochar and the energy problems of the society is solved and finally environmental impact of the flower waste is reduced.

3.2. Proximate Analysis of the Biochar

Proximate analyses of the biochar produced from flower waste are determined experimentally as shown in Table 3. The biochar produced shows a very high fixed carbon content of 67.91% and low content of volatile matter of 14.91%. As a matter of fact the ash content (10.775%) of the produced biochar is higher

Table 3. Proximate analysis and calorific value of the produced charcoal.

Proximate Analysis	
Moisture Content (wt%)	6.405
Ash Content (wt%)	10.775
Volatile Content (wt%)	14.910
Fixed Carbon (wt%)	67.910
Total (wt%)	100.000
Heating Value	
Lower Heating Value	26.54 J/kg

than the ash content (5.96%) of the input feedstock. The results also show that the moisture content of the biochar is reduced as shown in Table 3. This is due to the fact that during pyrolysis process a portion of the moisture is removed.

3.3. Estimation of Firewood Replaced

Based on the experimental result, approximately 310.8 kg of biochar can be generated daily. Thus, considering lower heating value of 26.54 MJ/kg for the produced biochar, the amount of firewood replaced daily is approximately 392.2 kg.

3.4. Income Generated

Income can be generated from the selling of the produced biochar. In Ethiopia, 50 kg of wood charcoal can be sold approximately 170 Ethiopian Birr. Thus, by selling 310.8 kg of the produced charcoal 1056.72 Ethiopian Birr can be obtained daily.

3.5. Sensitivity Analysis

A. Effects of Temperature on Biochar Yield

The biochar yield decreases with increasing pyrolysis temperature. This is due to the fact that the volatile mater is liberated as shown in Figure 10. biochar yield decreases by almost 9% when pyrolysis temperature increases from 400 to 500°C. Besides, at high temperature biochar yield decreases, bio-oil and gas yield increases.

B. Effect of Carbonization on Fixed Carbon Content

During carbonization the fixed carbon content increases considerably from 14.395% (input biomass) to 67.91% C (biochar produced) showing that the biochar became more carbonaceous during carbonization.

4. Conclusion

In this paper, a novel pyrolysis technology to produce biochar has been designed, manufactured and tested. Characterization of the flower waste has also been done by estimating the ultimate and proximate analysis. Data have been collected from one of the flower farms in Ethiopia that is generating a daily dry flower waste of 560 kg. Besides, the sizing of the reactor has been done by esti-
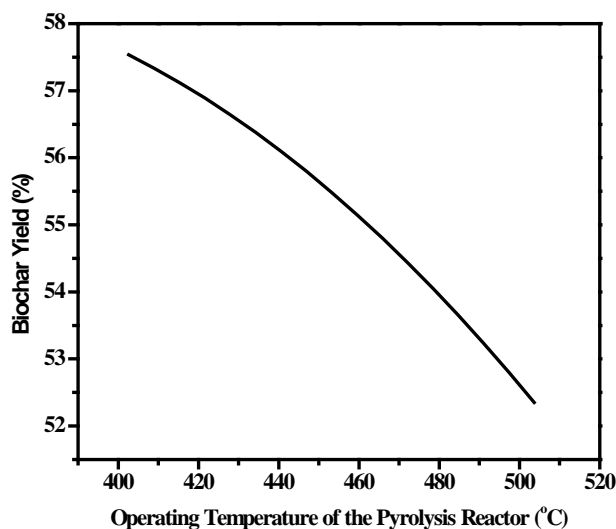
Figure 10. Effects of temperature of the pyrolysis reactor on biochar yield.

mating the amount heat required to convert the biomass into biochar efficiently. Based on the result, a pyrolysis rector with 55.5% conversion efficiency has been obtained and approximately 310.8 kg of biochar can be generated daily. Besides, based on the experimental result, the lower heating value of the produced biochar is 26.54 MJ/kg and approximately 392.2 kg of firewood is replaced daily. In Ethiopia, 50 kg of wood charcoal can be sold approximately 170 Ethiopian Birr. Therefore, by selling 310.8 kg of the produced charcoal, 1056.72 Ethiopian Birr can be obtained daily. Thus, by adopting this innovative technology and producing biochar, the amount of flower waste is reduced from going to the landfill, energy is recovered from flower waste, income is generated from the selling of the produced biochar and the energy problems of the society is solved and finally environmental impact of the flower waste is reduced.

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