



Investigation of the Characteristics of Biochar Produced from Pine Wood Gasification Process at Melani Village

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ABSTRACT

Biomass gasification is the process whereby an organic material is thermo-chemically broken down to produce syngas as well as some byproducts. Biochar (char) is one of the byproducts produced during this process from Pine wood. The char used for this study was generated from the downdraft gasifier system and was characterized using FTIR, SEM, CHNS and Calorimeter. The applications of the char were predicted based on its characterization. FTIR spectrum of char confirmed the presence of O-H, C-H, C=C functional groups. Elemental analyser showed 89.4% wt of C, 9.4% wt of O and 1.2% wt of H. A porous structure of char was observed from the SEM. The calorific value of char was 35.37 MJ/Kg. Based on each characteristic, this implied that the char could be applied in a variety of applications. This could also add value to the byproduct and reduce environmental pollution.

1. Introduction

Biomass gasification is the process whereby an organic material is thermo-chemically broken down to produce syngas as well as some byproducts. Biochar is one of the byproducts produced during this process. This highly carbonated material comes as a result of the pyrolysis of organic material under controlled gasifying agent conditions in a closed environment [1]. The gasifying agent may be oxygen, steam or even air and air is commonly used as it is inexpensive. Air gasification of biomass results in relatively high nitrogen concentration in the producer gas with low heating value ranging from 4 to 6 MJ/m³ [2, 3]. The high heating rate of the woody biomass results in a very porous and reactive char, with a highly damaged structure due to the brutal release of volatiles [4].

It has been reported that wood biochar with amorphous carbon has a large number of pore structures [5]. Amorphous structures are well known to have a great adsorbent property due to their high specific surface area and they contain more active sites on the surface which makes biochar more advantageous for the adsorptive property [6]. Wood biochar is largely regarded as a waste product as it is discarded after syngas has been produced. A type of feedstock used in the process determines the type of biochar to be generated. The literature has established that biochar produced from wood based feedstock is coarser and predominantly xylemic in nature, while crop residues and manure generate finer and brittle biochar [7]. The study on variety of feedstocks conducted by Chan and Xu revealed that the pH values of biochar are in the range of 6.2 - 9.6, this suggests basicity [8, 9]. Mukome *et al.*, [10] used chemical and physical characteristics to investigate trends in biochar feedstocks. Amongst the techniques they employed, was IR, where they observed the presence of C-O, C-H, C=C, C=O functional groups in biochar. The characterization of biochar from the gasifier is very important as this would make it easier to be used in other applications.

Klinghoffer in 2013 revealed that char has a surface area that is higher than many typical catalysts, and contains catalytic metals and minerals well scattered on its surface. Therefore, using char as a catalyst would eliminate the need for purchasing expensive catalysts, and deactivation would not be a concern since deactivated char could be easily replaced by fresh char which is produced in the gasifier. In addition, it provides a useful application for the char, which would otherwise be considered to be a low

value product [11]. Char produced from gasification process can also be used in filtering gasification waste water before it is released to the environment [12]. Biochar plays an important role in filtration as well as the maturation of whiskey [13].

The conducted and reported studies show that biochar has a wide range of applications. Therefore, it is of great importance to investigate some of the biochar characteristics specifically generated from the Pinewood gasification process in a downdraft gasifier system at Melani village so as to know whether the biochar produced could be used for similar applications. This could lead to reduced pollution in the environment. The biochar is sometimes referred to as char in this paper.

2. Experimental Methods

2.1 Sample Collection and Preparation

The pine wood material was collected at Melani village in Alice town, Eastern Cape Province of South Africa. Pinewood was used because it's freely available as waste from a local sawmill. It also has a low ash yield; hence it is good for the gasification process. Pieces of wood collected were then cut into small blocks as required by the downdraft gasifier. Wood blocks were dried and used as a feed material in the reactor. The feed material contained an average of 15% moisture content. The resultant char after gasification was then collected and transported to the laboratory for further characterization using different analytical techniques. Table 1 presents proximate and ultimate analysis of the gasification feedstock.

Table 1 Proximate and Ultimate Analysis of Pinewood Material

Proximate analysis		Ultimate analysis	
Properties	Composition (wt%)	Element	Composition (wt%)
Moisture content	15.2	C	50.6
Volatile matter content	70.2	O	22.2
Ash content	5.92	H	6.3
Fixed carbon	8.41	N	0.3

2.2 Material Characterization

The determination of the usefulness of a material requires an extensive understanding of its properties and composition, and the steps taken to establish their potential use in other areas begins with the characterization of such material using different analytical techniques. The char used for this study was characterized by means of FTIR, SEM,

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CHNS and Calorimeter. These were the most important analytical techniques employed in attempts to establish the application of gasification char based on their composition and properties.

2.2.1 Functional Group Determination

FTIR spectroscopy was used for the determination of functional groups composing the biochar and this was helpful in the determination of areas at which they could be applied. With respect to solid samples, a common technique was to ground the sample and mix it with potassium bromide (KBr) powder in order to form samples that were transparent to FTIR beam. The mixture of biochar sample and KBr powder was then dried in the oven at 105 °C overnight [14]. The dried sample was then inserted into the FTIR for characterization.

2.2.2 Ultimate Analysis

A Perkin Elmer elemental analyser was the type of organic elemental analyser used for the simultaneous determination of the amount (%) of hydrogen, carbon, sulphur and nitrogen contained in biochar. The amount of oxygen was then obtained by difference. Helium was used as a carrier gas. The CHNS analyser had been used by Sugumaran and Seshadri when they were evaluating selected biomass for biochar production in 2009 [15].

2.2.3 Calorific Value Determination

The determination of calorific value, also called heating value was achieved by first calibrating the calorimeter with a 0.5 g of benzoic acid ($C_7H_6O_2$) before measurements were taken. About 1 g of the biochar sample was weighed using a watch-glass. The weighed sample was then transferred into a crucible in the outer electrode connected to the lid of the vessel. The vessel was then pressurized up to 3000 kpa using oxygen gas. The vessel was then taken into the calorimeter for firing to take place. For each mass of the sample input in the calorimeter, the heating value returned was in units of MJ/kg.

2.2.4 Surface Morphology of Biochar

SEM has been proven to be a good technique for the determination of sample size and morphology [16]. The following procedure was applied for the determination of surface morphology and elemental analysis. Biochar sample was mounted on a stub using a carbon double-sided tape. Following this, they were coated with gold-palladium using EIKO IB3 Ion Coater. The sample was then viewed with JEOL JSM6390LV Scanning Electron Microscope using the secondary electron detector operated at 15kV.

3. Results and Discussion

3.1 Functional Group Determination

The dominant functional groups present in gasification char were determined to predict further applications based on the functional groups they show. Fig. 1 presents FTIR spectra of gasification char.

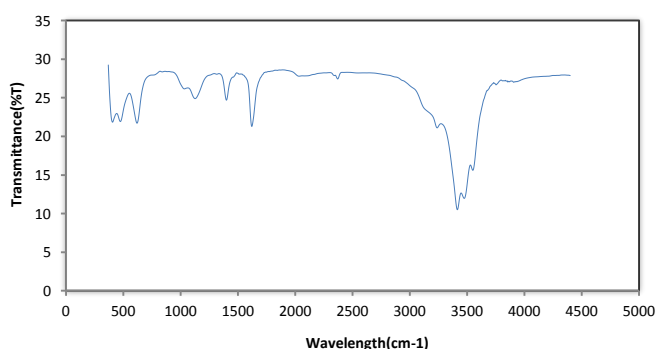


Fig.1 FTIR spectrum of Char

The FTIR spectrum of biochar produced from biomass gasification revealed the presence of O-H peak in the region of 3400 cm^{-1} due to water contamination of the sample, this has previously been observed and reported [17]. A peak at 3228 cm^{-1} indicated small quantities of C-H, of which CH_4 is the most abundant due to cracking of methoxyl groups ($O-CH_3$) [18-20]. A C=C peak was also observed in the region of 1638 cm^{-1} , this was observed due to the presence of aromatic rings [21]. The presence of the latter functional groups implies that the biochar can further be gasified to syngas. The aromatic rings would also assist in trapping of impurities.

3.2 Ultimate Analysis

The elemental analyser was employed for the quantification of C, H, N, S and O was obtained by difference and the results were reported in %weight. Table 2 presents an elemental analysis of gasification char.

Table 2 Elemental Analysis of Gasification Char

Sample	%C	%H	%N	%S	%O
Char	89.4	1.2	-	-	9.4

The elemental analysis of the samples presented in Table 2 show higher quantities of carbon, oxygen and hydrogen respectively. The higher level of these elements is due to the carbohydrate structure which is majorly composed of carbon, hydrogen and oxygen elements. The results display the inverse proportion relationship between carbon and oxygen. A biomass sample may or may not contain nitrogen or sulphur; hence char does not show traces of nitrogen and sulphur. The lower quantities of nitrogen and sulphur in the biomass are considered as important for selection of biomass as feedstock for bio-oil production [22]. The elemental analysis of the char obtained by CHNS analyser was also in agreement with existing literature [23]. The high carbon content makes the char suitable for application as a soil conditioner.

3.3 Calorific Value Determination

An oxygen calorimeter was used to determine the calorific value of the gasification char. Table 3 presents the calorific values of the resultant char.

Table 3 The calorific values of gasification char

Sample type	Calorific Values (MJ/Kg)				
	Trial 1	Trial 2	Trial 3	Mean	SD
Char	35.30	36.05	34.75	35.37	0.46

The high calorific value of char, which is comparable with good quality coal is due to low ash yields from partially combusted pine wood material. The formation of the char is largely contributed by lignin, while cellulose contributes to formation of volatile matter [24]. The volatile matter is removed during gasification leaving the lignin behind, which then results in a high calorific value of the char. The calorific value of any material in thermochemical process is hugely affected by moisture content, volatile matter as well as its ash content. A 1% increase in carbon concentration will elevate the calorific value of approximately 0.39 MJ/Kg [24]. This, therefore, implies that the gasification char could be a good candidate for re-gasification purposes or combustion for heat applications.

3.4 Surface Morphology and Elemental Composition of Biochar

The SEM was employed for the determination of surface structure of the biochar. Fig. 2 presents the surface morphology of gasification char.

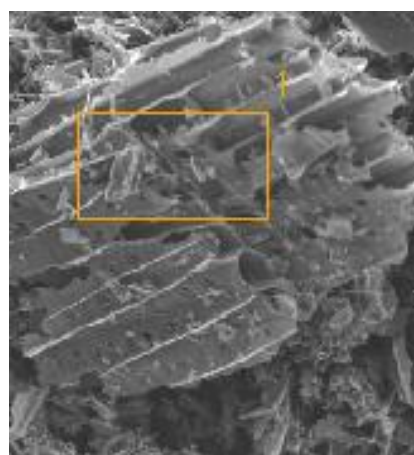


Fig. 2 The surface morphology of gasification char

The SEM microphotograph of char in Fig. 2 have shown the porous structure as expected. The images obtained confirmed the amorphous and heterogeneous structure of the char. With reference to the existing literature, the biomass chars are highly disordered carbonaceous materials that may have structural defects [25]. Since high gasification temperatures become destructive to char; then the structure appears distorted. The porosity of char makes it more useful in waste water filtration because of its high surface area.

4. Conclusion

The char is composed of O-H, C=C, C-H dominant functional groups, this has been revealed via FTIR spectrum. The higher carbon content observed from elemental analysis contributes enormously to the higher heating value of a char. The porosity of char makes it more useful in waste water filtration. The applications of gasification char have also been successfully investigated through physical and chemical properties. Based on the results, the char can be applied in different areas rather than being treated as a waste product. The study indicates that the char produced has enormous value and can be used for various applications.

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