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CHARACTRAZATION OF BIO-CHAR PRODUCED FROM SESBANIA STEMS (SESBANIA GRANDIFLORA)

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Abstract: It is becoming increasingly popular to manage agricultural wastes in an environmentally friendly manner and to take advantage of this waste by manufacturing a product with good properties and a high carbon percentage and then using it as a substitute for a variety of materials and fillers in several industrial and environmental applications. This process has become increasingly popular as awareness of environmental issues has grown. This study aimed to characterize and evaluate the amount of carbon that was present in the sample. The physicochemical characteristics of biochars produced from sesbania stems that were pyrolyzed at a temperature of 400 degrees Celsius for a period of 0.5, 1, 1.5, and 2 hours. The characterizations of biochar produced from sesbania are done by Energy dispersive spectrometer and Fourier transforms infrared spectroscopy. It was found that as the pyrolysis residence time grew, the yield of biochar and the functional groups decreased, however, the amount of fixed carbon content increased, all these effects contribute to the volatile matters that are present in the material. SSB is going to be an invaluable resource for applications in which high carbon content is required, as well as for use as a filler in a variety of composites.

Keywords: *Agricultural residue; biomass; char production; pyrolysis; waste.*

1. Introduction

The combustion of biomass, such as natural organic biomass, results in the production of black carbon, which accounts for a sizeable amount of the organic carbon found in soil. Biochar is a solid product that can be generated from the pyrolysis of biomass in anoxic or hypoxic circumstances. [1, 2] Because of the rapid turnover of organic matter, the application of organic fertilizers to increase and store carbon in the soils of humid tropical regions has a poor efficiency rate. Therefore, using biochar in agricultural fields can significantly increase the amount of organic matter that is found in the soil [3, 4]. In the meantime, the structure with high porosity and surface features of biochar has the potential to increase the number of soil nutrients for crops while also providing a great living place for microorganisms [5, 6]. As a result, biochar has seen significant application as an amendment to the soil to raise the level of soil productivity.

Producing biochar from agricultural biomass waste through the pyrolysis process offers a one-of-a-kind answer to the problem of how to generate a valuable source of green energy. [7]

The slow pyrolysis method is the most efficient one for the manufacture of biochar, with an average biochar yield of 35.0 percent based on the weight of the dry biomass. The most

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effective way for manufacturing biofuels is called rapid pyrolysis, while the most effective method for making syngas is called gasification. As a result, these two processes are typically employed to generate heat and energy [8]. A higher proportion of oils are often produced by fast pyrolysis as a result of the process's high heating rates and short residence durations. On the other hand, slow pyrolysis tends to produce higher amounts of bio-chars as a result of the slow heating rates and prolonged residence durations [9].

It has been demonstrated that the impacts are dependent on the feedstocks, the thermo-conversion processes, and the production parameters [10]. The results of bioassays that have been conducted on the consequences of these leachates have produced conflicting results. It was discovered by Alburquerque et al. [11] that bio-char water extracts (10 percent w/v) from five lignocellulose agricultural and forest wastes increased the germination of sunflower seeds in comparison to the controls, with calculated germination indices that were higher than 60 percent, which is typical of materials that are not phytotoxic. The leaves and shoots of Flourensia oolepis were pyrolyzed in a prior study [12], and we used Lactuca sativa as a test system to evaluate the aqueous extracts of the bio-chars that were produced. It was discovered that the water extracts from the bio-chars promoted the growth of the roots and shoots by 225 and 160 percent, respectively, and that they did not inhibit the germination of the seeds. In the research on potted cabbage, Lou et al. [13] discovered that the addition of biochar water extracts derived from wheat and maize resulted in a considerable increase in yield and had a good impact on other eco-physiological parameters. It was concluded that there was a great deal of potential for them to be utilized as a liquid amendment. According to the findings of Rogovska et al. [14], higher temperatures did not influence the germination of maize seeds but did reduce the growth of seedlings in three out of six biochar extracts derived from various feedstocks. The germination of radish and corn seeds was inhibited by extracts derived from high volatile matter charcoal made from macadamia nut shells heated to 430 degrees Celsius [15].

The physical and chemical properties of lignocellulose agricultural wastes can vary a lot from one feedstock to the next, which in turn affects how they can be used.

In addition to the positive benefits of environmental issues, biochar can also be used as a filler material in the composites sector. This use of biochar is becoming increasingly common. Across many different industries, bio-char reinforced polymer composites have a wide number of potential applications that could be utilized. Bio-char-reinforced polymer composites may find a place in the packaging industries as a result of the fact that it is lightweight and has a feature that makes them resistant to fire. Additionally, these composites may be used in the fabrication of interior components for vehicles or airplanes. [16]

The physicochemical properties of biochar are influenced, to varying degrees, by the types of feedstock that are employed as well as the conditions that prevail during the pyrolysis of those feedstocks [17, 18, 19, and 20]. Researchers Hossain et al. (2011) [21] generated biochar by elevating the pyrolysis temperature of the material from 300 degrees Celsius to 700 degrees Celsius throughout the production process. As the pyrolysis temperature increases, the production of biochar and the number of nitrogenous compounds that are available to plants both decrease. However, the amount of trace elements (such as copper, magnesium, zinc, iron, and calcium) that are included in bio-chars continues to increase. Pyrolysis carried out at lower temperatures results in the production of biochar with a pH that is slightly more acidic, whereas pyrolysis carried out at higher temperatures results in biochar with a pH that is slightly more alkaline. Researchers Masek et al. (2013) [22] discovered that the parameters of pyrolysis are directly related to the generation of biochar. It was discovered that the amount of carbon that was fixed in the biochar grew as the temperature of the pyrolysis process went up.

In addition, Shinogi and Kanri (2003) [23] discovered that there were substantial differences between the yields and densities of bio-chars that were created through the pyrolysis of several kinds of waste biomass (e.g. rice bran, bagasse, and activated sludge).

This study's objective is to determine the percentage of carbon that is extracted from sesbania stems bio-char by subjecting it to pyrolysis at a temperature of 400 degrees Celsius and storing it for varying amounts of time so that it can be used as a low-cost and environmentally friendly alternative filler in composites and a variety of environmental applications, as was mentioned in the introduction. This would be performed in place of more expensive fillers, such as carbon nanotubes and graphite.

2. Materials and methods

2.1. Materials

Sesbania stems, also known as Sesbania Grandiflora, were chosen as the type of feedstock to be used since they are naturally occurring plants that are frequently used in the production of charcoal (SS).

The college of engineering/Al-Mustansiryia University in Baghdad, Iraq, was the source of the collected raw feedstocks. Following a thorough chopping, the feedstock was washed in deionized water and then dried in an oven at a temperature of 150 degrees Celsius for three hours. Through the use of a grinding machine, the feedstock was reduced to powder; figure 1 shows the material's sample before and after grinding.

Figure1. Sesbania stems before and after grinding

2.2 Pyrolysis

The feedstock of Sesbania stems was pyrolyzed in a vacuum furnace after first being wrapped in aluminum foil, of the type (CARBOLITE Laboratory Horizontal Tube Furnace) shown in figure 2, at a temperature of 400 degrees Celsius for 0.5, 1, 1.5, and 2 hours each. The bio-chars were collected for later physicochemical investigation when the pyrolysis process was completed; bio-char samples are shown in figure 3.

Figure2. CARBOLITE Laboratory Horizontal Tube Furnace and the alumina boat (Pyrolysis process).

Figure3. Bio-char samples

2.3 Yield of Bio-char

The yield of biochar is represented as the ratio of biochar mass to the initial mass of biomass exposed to pyrolysis. (Qin et al., 2020) [24].

The yield of biochar was calculated as follows:

$$Yield\ (\%) = \frac{\textbf{biochar weight}}{\textbf{feedstock weight}} \times \mathbf{100} \quad (1)$$

2.4 Characterization Methods

2.4.1 EDS analysis

EDS (Bruker inspect S50, US) was used to analyze the surface morphology of the bio-chars. This was done to determine the changes in the structures of biochar and was also utilized for quantitative chemical analysis.

2.4.2 FTIR analysis

Fourier transform infrared spectroscopy (FTIR) analysis for the sesbania stems feedstock was carried out using (IR Affinity-1, Shimadzu), with wave number scanning range between 400 and 4000 cm^{-1}.

3. Results and discussion

3.1 Bio-char yield

The biochar yield for sesbania stems was determined by using equation (1), and the results are displayed in figure 4.

According to the findings, the amount of biochar produced decreased as the amount of time spent at 400 ° C rose. At half an hour, the SSB had a bio-char output of 114.64 percent, but after two hours, that number dropped to 29.2 percent.

The pyrolysis of biomass produces volatiles mostly from cellulose, while fixed carbon is formed primarily from lignin (Sharma et al., 2004; Yang et al., 2007) [25, 26]. Furthermore, cellulose makes up 70.75% of sesbania biochar, while lignin accounts for 19.49%, as reported by [27].

As stated by Junna Sun [28], the yield of biochar falls when the pyrolysis time is increased while the pyrolysis temperature remains the same. This is because the more volatile matter is emitted during the longer pyrolysis period.

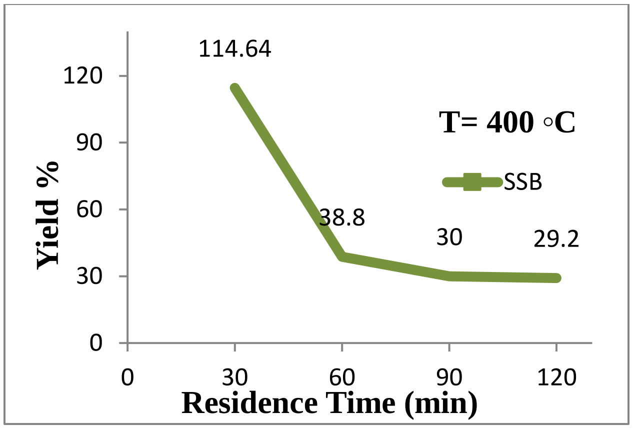

Figure4. Yield percentage of bio-char with residence time

3.2 EDS results

The EDS technique was utilized to do an elemental analysis on the bio-chars derived from sesbania. Table 1 displays the percentage of each component that is present. As can be seen in Figure5, the percentage of biochar that is composed of carbon is found to be much higher than that of the other elemental constituents in all of the samples.

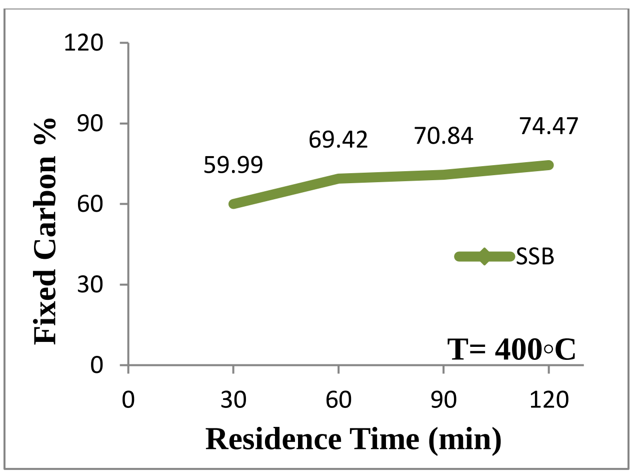

Figure5. Carbon values with residence time

As may be seen in Table.1 and Figure5, respectively. There is a wide range of possible carbon percentages, from 59.99 to 74.47 percent. Oxygen is the second most important element, and then there are a few additional elements that are not as significant (Cl, Na, Mg, K, and Sc).

Because of a significant reduction in the amount of volatile matter present, the proportion of fixed carbon in biochars increased with increasing residence time [28].

Table1. Elemental analysis of sesbania bio-chars at **400◦C** in different residence times **(0.5, 1, 1.5, and 2 hrs.)**

Residence time (0.5 h)							
Element	**C**	**O**	**Mg**	**Na**	**Cl**	**K**	**Sc**
Wt.%	59.99	38.05	0.96	0.04	0.95	-	-
Residence time (1 h)							
Element	**C**	**O**	**Mg**	**Na**	**Cl**	**K**	**Sc**
Wt.%	69.42	28.12	0.51	-	1.95	0.00	-
Residence time (1.5 h)							
Element	**C**	**O**	**Mg**	**Na**	**Cl**	**K**	**Sc**
Wt.%	70.84	19.65	0.28	-	-	-	9.22
Residence time (2 h)							
Element	**C**	**O**	**Mg**	**Na**	**Cl**	**K**	**Sc**
Wt.%	74.47	24.20	0.51	0.00	0.82	-	-

3.3 FTIR results

The modifications in the surface functions of bio-char that are presented in Figure 6 are as follows: The FTIR of the sesbania feedstock and the FTIR of the bio-char sample demonstrate that, in general, there is a decline in the number of functional groups in the biochar sample. This is discovered by comparing the two spectra.

The FTIR examination reveals the presence of functional groups in the sample, such as hydroxyl, amine, and alcohol groups. In biochar, the OH group is extended to 3446.79 cm-1 when measured using the wavenumber that corresponds to 3431.86 cm-1. According to the

FTIR analysis, the functional groups respond differently depending on the temperature. [29].

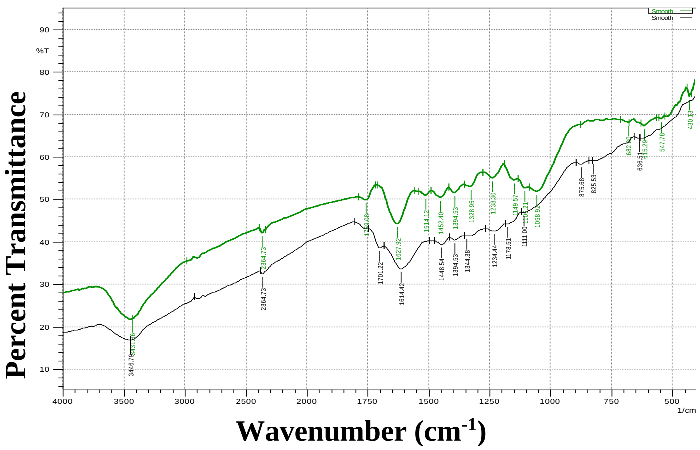

Figure 6. FTIR results (green line refers to the natural raw sesbania and the black line refers to sesbania bio-char)

Other functional groups shown in sesbania feedstock include amines at 1627.92 cm-1, alcohol at 1452.40 cm-1, and alcohol carboxyl at 1238.30 cm-1; all three of these groups dropped in bio-char. At high temperatures, biochar undergoes considerable carbonization, which results in the formation of graphite-like structures; nevertheless, this causes the peak intensity to be reduced [30].

According to the findings of a study, biochar that was produced at high temperatures had lower ratios of oxygen to carbon and hydrogen to carbon. This suggests that the surface did not include any functional groups or that those groups were present in very low concentrations. [31].

4. Conclusions

The purpose of this paper is to provide a review of the effect of residence time on the physic-chemical properties of sesbania stem biochar. The synthesis of biochar from Sesbania stems and the examination done by Energy dispersive spectrometer and Fourier transforms infrared spectroscopy, demonstrated that the biochar generated had these effects over time, which is consistent with the findings of earlier researchers on the topic. Furthermore, in addition to this:

When pyrolysis is carried out for longer periods, the formation of biochar decreases; this is because the emission of volatile materials contributes to the process.

Because the number of volatile materials will decrease as the pyrolysis time increases, the amount of fixed carbon will increase. This is because the number of volatile materials will decrease.

The ability to employ waste stems from sesbania plants in the manufacturing of biochar, which can be utilized in some applications as a low-cost raw material filler with high carbon content.

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Conflict of interest

The authors declare that there are no conflicts of interest regarding the publication of this manuscript.

Abbreviations

SS	*Sesbania stems*
SSB	Sesbania stems bio-char
EDS	Energy dispersive spectrometer
FTIR	Fourier transform infrared spectroscopy

5. References

1. Atkinson, C. J., Fitzgerald, J. D., & Hipps, N. A., (2010). *Potential mechanisms for achieving agricultural benefits from*

biochar application to temperate soils: a review. Plant and soil. Vol.*337*, Issue 1, pp.1-18. DOI: 10.1007/s11104-010-0464-5

2. Singh, B. P., & Cowie, A. L., (2014). *Long-term influence of biochar on native organic carbon mineralization in a low-carbon clayey soil*. Scientific reports. Vol. 4, Issue 1, pp. 1-9. DOI: 10.1038/srep03687
3. Glaser, B., Lehmann, J., & Zech, W., (2002). *Ameliorating physical and chemical properties of highly weathered soils in the tropics with charcoal–a review*. Biology and fertility of soils. Vol.35, Issue 4, pp. 219-230. DOI: 10.1007/s00374-002-0466-4
4. Lehmann, J., Pereira da Silva, J., Steiner, C., Nehls, T., Zech, W., & 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. Vol. 249, Issue 2, pp. 343-357.

DOI: 10.1023/a:1022833116184
5. Steiner, C., Glaser, B., Geraldes Teixeira, W., Lehmann, J., Blum, W. E., & Zech, W., (2008). *Nitrogen retention and plant uptake on a highly weathered central Amazonian Ferralsol amended with compost and charcoal*. Journal of plant nutrition and soil science. Vol. 171, Issue 6, pp. 893-899. DOI: 10.1002/jpln.200625199
6. Kolb, S. E., Fermanich, K. J., & Dornbush, M. E., (2009). *Effect of charcoal quantity on microbial biomass and activity in temperate soils.* Soil Science Society of America Journal. Vol. 73, Issue 6, pp. 1173-1181. DOI: 10.2136/sssaj2008.0232
7. Suman, S., (2020). *Conversion of Solid Biomass into Bio-char: Act as a Green, Eco-Friendly Energy Source and a Substitute of Fossil Fuel Inputs*. In Multidisciplinary Digital Publishing Institute Proceedings. Vol. 58, Issue 1, pp. 34. DOI: 10.3390/wef-06916
8. Cheah, S., Jablonski, W. S., Olstad, J. L., Carpenter, D. L., Barthelemy, K. D., Robichaud, D. J., ... & Westover, T. L., (2016). *Effects of thermal pretreatment and catalyst on biomass gasification efficiency and syngas composition.* Green Chemistry. Vol. 18, Issue 23, pp. 6291-6304. DOI: 10.1039/c6gc01661h
9. Daful, A. G., & Chandraratne, R. M., (2018). *Biochar production from biomass waste-derived material*. Reference Module in Materials Science and Materials Engineering. DOI: 10.1016/b978-0-12-803581-8.11249-4
10. Ahmed, H. P., & Schoenau, J. J., (2015). *Effects of biochar on yield, nutrient recovery, and soil properties in a canola (Brassica napus L)-wheat (Triticum aestivum L) rotation grown under controlled environmental conditions.* BioEnergy Research. Vol. 8, Issue 3, pp. 1183-1196. DOI: 10.1007/s12155-014-9574-x
11. Alburquerque, J. A., Calero, J. M., Barrón, V., Torrent, J., del Campillo, M. C., Gallardo, A., & Villar, R., (2014). *Effects of biochars produced from different feedstocks on soil properties and sunflower growth.* Journal of plant nutrition and soil science. Vol. 177, Issue 1, pp. 16-25.

DOI: 10.1002/jpln.201200652
12. Silva, M. P., Moyano, E. L., & Scopel, A. L., (2017). *Potential applications of biochar and terpene-enriched bio-oil produced from a semi-arid native Asteraceae*. Journal of Analytical and

Applied Pyrolysis. Vol. 126, pp. 39-49. DOI: 10.1016/j.jaap.2017.06.026

13. Lou, Y., Joseph, S., Li, L., Graber, E. R., Liu, X., & Pan, G., (2016). *Water extract from straw biochar used for plant growth promotion: an initial test.* BioResources. Vol. 11, Issue 1, pp. 249-266.
DOI: 10.15376/biores.11.1.249-266
14. Rogovska, N., Laird, D., Cruse, R. M., Trabue, S., & Heaton, E., (2012). *Germination tests for assessing biochar quality*. Journal of environmental quality. Vol. 41, Issue 4, pp. 1014-1022. DOI: 10.2134/jeq2011.0103
15. Deenik, J. L., Diarra, A., Uehara, G., Campbell, S., Sumiyoshi, Y., & Antal Jr, M. J., (2011). *Charcoal ash and volatile matter effects soil properties and plant growth in an acid Ultisol.* Soil Science. Vol. 176, Issue 7, pp. 336-345. DOI: 10.1097/ss.0b013e31821fbfea
16. Fan, Y., Cheng, Y. J., & Huang, Z. X., (2017). *2016 IEEE MTT-S "International Microwave Workshop Series on Advanced Materials and Processes for RF and THz Applications*" [Conference Reports]. IEEE Microwave Magazine. pp. 100-102.
DOI: 10.1109/mmm.2015.2507562
17. Gaskin, J. W., Steiner, C., Harris, K., Das, K. C., & Bibens, B., (2008). *Effect of low-temperature pyrolysis conditions on biochar for agricultural use*. Transactions of the ASABE. Vol. 51, Issue 6, pp. 2061-2069.
DOI: 10.13031/2013.25409
18. Yuan, J. H., Xu, R. K., & Zhang, H., (2011). *The forms of alkalis in biochar are produced from crop residues at different temperatures.* Bioresource Technology. Vol. 102, Issue 3, pp. 3488-3497.
DOI: 10.1016/j.biortech.2010.11.018
19. Lehmann J., (2007). *Bio-energy in the black.* Front Ecol Environ. Vol. 5, pp. 381–387.
DOI: 10.1890/060133
20. Novak, J. M., Busscher, W. J., Laird, D. L., Ahmedna, M., Watts, D. W., & Niandou, M. A., (2009). *Impact of biochar amendment on fertility of southeastern coastal plain soil*. Soil science. Vol. 174, Issue 2, pp. 105-112. DOI: 10.1097/ss.0b013e3181981d9a
21. Hossain, M. K., Strezov, V., Chan, K. Y., Ziolkowski, A., & Nelson, P. F., (2011). *Influence of pyrolysis temperature on production and nutrient properties of wastewater sludge biochar*. Journal of environmental management. Vol. 92, Issue 2, pp. 223-228.
DOI: 10.1016/j.jenvman.2010.09.008
22. Mašek, O., Brownsort, P., Cross, A., & Sohi, S., (2013). *Influence of production conditions on the yield and environmental stability of biochar*. Fuel. Vol. 103, pp. 151-155. DOI: 10.1016/j.fuel.2011.08.044
23. Shinogi, Y., & Kanri, Y., (2003). *Pyrolysis of plant, animal and human waste: physical and chemical characterization of the pyrolytic products*. Bioresource Technology. Vol. 90, Issue 3, pp. 241-247. DOI: 10.1016/s0960-8524(03)00147-0
24. Qin, L., Wu, Y., Hou, Z., & Jiang, E., (2020). *Influence of biomass components, temperature, and pressure on the pyrolysis behavior and biochar properties of pine nut shells*. Bioresource Technology. Vol. 313, Issue 12, pp. 36-82. DOI: 10.1016/j.biortech.2020.123682
25. Sharma RK, Wooten JB, Baliga VL, Lin X, Geoffrey Chan W, Hajaligol MR., (2004). *Characterization of chars from*

pyrolysis of lignin. Fuel. Vol. 83, pp.1469–1482.
DOI: 10.1016/j.fuel.2003.11.015

26. Yang H, Yan R, Chen H, Lee DH, Zheng C., (2007). *Characteristics of hemicellulose, cellulose, and lignin pyrolysis.* Fuel. Vol.86, pp.1781–1788.
DOI: 10.1016/j.fuel.2006.12.013

27. Savitha, K., Annapoorani, G. S., Sampath, V. R., & Atalie, D., (2019). *Physical characterization of cellulosic fibers from Sesbania grandiflora stem.*

28. Sun, J., He, F., Pan, Y., & Zhang, Z., (2017). *Effects of pyrolysis temperature and residence time on physicochemical properties of different biochar types.* Acta Agriculturae Scandinavica, Section B—Soil & Plant Science. Vol. 67, Issue 1, pp. 12-22. DOI: 10.1080/09064710.2016.1214745

29. Singh, B., Singh, B. P., & Cowie, A. L., (2010). *Characterization and evaluation of biochars for their application as a soil amendment.* Soil Research. Vol. 48, Issue 7, pp. 516-525. DOI: 10.1071/sr10058

30. Li, S., & Chen, G., (2018). *Thermogravimetric, thermochemical, and infrared spectral characterization of feedstocks and biochar derived at different pyrolysis temperatures.* Waste Management. Vol. 78, pp. 198-207.
DOI: 10.1016/j.wasman.2018.05.048

31. Behazin, E., Ogunsona, E., Rodriguez-Uribe, A., Mohanty, A. K., Misra, M., & Anyia, A.O., (2016). *Mechanical, chemical, and physical properties of wood and perennial grass biocharsforpossiblecompositeapplication*. BioResources. Vol. 11, Issue 1, pp. 1334-48. DOI: 10.15376/biores.1.1334-1348