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Effect of Maximum Final Temperature on Properties of Wood Based Biocarbon of Tamarix Aphylla

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Abstract- Wood samples of tamarisk (Tamarix aphylla (L.) Karst.) were thermally degraded in a flowing nitrogen atmosphere at different maximum final temperatures (MFT) of 400°, 450°, 500°, 550°, 600° and 650°C with a heating rate of 15°C/minute for a holding time of 120 minutes using a bench scale reactor. Yield, apparent density (AD), void volume (VV), volumetric shrinkage (VS), gross heat of combustion (GHC), ash content (AC), volatile matter content (VMC) and fixed carbon content (FCC) of the biocarbon were evaluated at the different MFT's All the properties studied were found to be affected significantly by the MFT. Increasing the MFT from 400° to 650°C decreased yield from 37.2% to 30.5% and VMC from 30.8% to 16.1% significantly. On the other hand, VV increased from 0.754 m3/g to 0.8 m3/g as well as VS from 29.7% to 43.7%, GHC from 5355 cal/g to 6099 cal/g, AC from 11.31% to 15.47% and FCC from 51.3% to 61.5% with increasing of MFT within this range. Tamarisk biocarbon, irrespective of the yield, was generally lower in its quality than normal one due to its higher contents of ash and volatile matter as well as its lower gross heat of combustion, and fixed carbon contents comparing to other hardwoods at a certain MFT. Accordingly, its suitability as a fuel is confined to the rural and domestic uses.

Keywords- *Biocarbon; Yield; Apparent density; Volumetric shrinkage; Gross heat of combustion; Proximate analysis.*

I. INTRODUCTION

Biomass is a generic term for plant derived materials or animal manures. Sustainability in energy recovery from biomass is becoming attractive because biomass to energy conversion adds no additional greenhouse gases to the atmosphere [1]. Several prominent technologies for biomass to energy conversion are based on thermal, biochemical and physical processing [2]. Thermal degradation processes technologies are confined to combustion, gasification, pyrolysis and liquefaction. The characteristics of the wood charcoals depend not only on the wood used, but also the carbonization system [3]. Biocarbon yield decreases and the char structure become more deranged with increasing temperature [4]. It was explained that the influence of ash on volatiles and rate of volatiles evolution that when the ash elements are removed, both the amount of volatiles and the rate of their evolution increase due to the non-occurrence of charforming secondary reactions [5].

Pyrolyzing waste wood from mulberry, lignin and holocellulose in a flowing nitrogen atmosphere showed that char yield from the lignin was three times that from the holocellulose in the whole temperature region [6]. It was reviewed that species with higher contents of lignin give higher yields of charcoal than those with lower contents of lignin. This is because lignin generally leaves a large residue, due to its relatively high thermal stability, than do the polysaccharides at the end of carbonization process [7] & [8]. It was reported that the composition and yield of charcoal is affected by the temperature and by secondary reactions undergone by volatile decomposition products formed during thermal breakdown of the wood. Further factors influencing initial thermal breakdown and subsequent secondary reactions include: the chemical composition and physical properties of the wood, size and shape properties, moisture content, heating rate, and pressure [9]. The proximate composition depends not only on the starting wood, but also the carbonization system by which they were manufactured. Further, heating wood to a temperature slightly above 100°C already initiates some thermal decomposition; the hemicelluloses are degraded at 200°-260°C; the cellulose at 240°-350°C and the lignin at 280°-500°C [3]. Little works have been carried out in Saudi Arabia relevant to converting wood from local species into biocarbon. Therefore, this study was initiated to evaluate yield and the quality features of biocarbon produced from *Tamarix aphylla* as affected by MFT.

II. Experimental Methods

2.1. *Materials*

Local Saudi hardwood species, namely tamarisk (*Tamarix aphylla* (L.) Karst.) was used for the present investigation. This species is a fast growing, evergreen tree and is tolerant to drought, heat and salt. Therefore, it is used in desert areas for shading, wind breaking and sand dune fixation. Four tamarisk trees were selected from those grown in in Hada Al-Sham region, about 120 Km far from Jeddah. The ages of the selected trees were about 25 years. The diameters outside bark of the selected trees ranged from 33-40 cm.

2.2. *Samples preparation*

From each of the selected stems, one bolt (1.5 cm tangentially and one meter longitudinally) was cut at a height of one meter above ground level. From each bolt, one diametric strip (1.5 cm tangentially and one meter longitudinally) was removed. From each strip, one stick (nominal 1.5 cm radially and tangentially and one meter longitudinally) was removed from the heartwood region. The selected sticks were subsequently cross-cut into cubic samples free of visible defects. Each twelve subsequent cubic samples were assigned for each thermal degradation run to determine the different properties of produced biocarbon.

2.3. *Determination of wood properties*

The studied traits for wood samples were: specific gravity (SG), total extractives content (TEC), lignin content (LC), holocellulose content (HC) and ash content (AC). The SG was calculated based on oven-dry weight and saturated volume. The remainder mass of the collected samples were ground, sieved and specified for the determinations of total extractives content (TEC), lignin content (LC), hollocellulose content (HC) and ash content (AC) of the eight lignocellulosic materials. For each determination, five samples were taken randomly from each tree (15 samples of each lignocellulosic material. Accordingly, 120 samples were specified for the eight resources used for each determination. The TEC was determined according to ASTM [10]. Then, each sample was divided into two equal portions. One of them was assigned for LC determination and the other for HC test. LC was determined according to ASTM [11] using H_2SO_4 (72 %). HC was determined according to the chlorite method [12]. To measure AC of wood, air-dried samples were ignited at 600°C until all carbon is eliminated [13].

2.4. *Thermal degradation procedure*

The twelve samples were placed in a Pyrex tube of 2.8 cm in an identified sequence and centered in the heated zone of carbolite muffle controlled by a microprocessor temperature programmer with an error of ±5°C. A chromel alumel thermocouple of the digital thermometer (type K with an error of ±1°C) was positioned with the samples inside heated zone of the tube furnace. Nitrogen flow was introduced at 300 ml/minute until a steady gas flow was obtained, then the entire system was purged of oxygen by increasing the nitrogen flow rate to 825 ml/minute, for 10 minutes before starting a run Maximum final temperatures (MFT) of 400°, 450°, 500°, 550°, 600° and 650°C at a heating rate of 15°C/minute and a holding time of 120 minutes were used in this study.

2.5. Determination of biocarbon properties

The studied traits for biocarbon samples were yield, apparent density (AD), volumetric shrinkage (VS), gross heat of combustion (GHC) and proximate analysis, namely Volatile matter content (VMC), ash content (AC) and fixed carbon content (FCC). Yield was calculated based on the oven-dry weight of the parent wood For AD, the volume of a specified oven-dried sample was measured by mercury displacement using Amsler volume meter. The AD was calculated based on oven-dry weight and volume The VS was determined based on oven-dry weight and volume7. The GHC was determined using an adiabatic oxygen bomb calorimeter, Parr 1341, according to procedures recommended by Parr instruction manual and in accordance with ASTM [14]. The VMC, AC and FCC were determined according to ASTM [15]. The data were analyzed using the randomized complete block design [16]. The LSD0.05 method was used to detect the differences between species means, thermal degradation conditions, and the interactions between species and thermal degradation for the biocarbon properties determined in the study.

III. Results and Discussion

3.1. Characterization of biocarbon

Mean values of chemical constituents of the tamarisk wood, namely total extractives, holocellulose, lignin and ash are shown in Fig. 1. For the resultant tamarisk biocarbon made under the different MFT, the mean values of yield, VS, AC, VMC and FCC are presented in Fig.2. Further, AD and VV are shown in Fig. 3. and GHC is presented in Fig. 4.

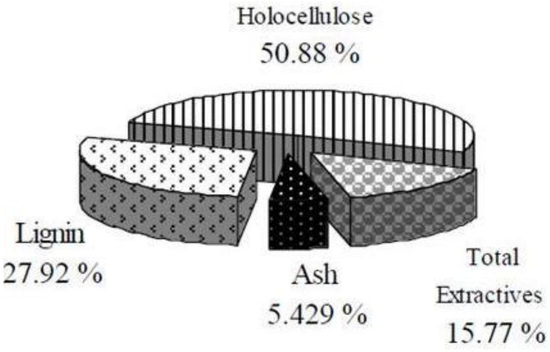

Figure 1. Chemical constituents of tamarisk wood.

It can be seen from Fig. 1. that tamarisk wood contained high AC since the living tree collect minerals from soil solution and accumulates them in the woody cells. However, the high AC is undesirable for heating purposes due to minerals consume some of the emitted heat reducing the overall GHC of wood. On the other hand, HC of tamarisk wood was low comparing to other common wood species [7]&[17]. All the properties studied for tamarisk biocarbon were found to be affected significantly by the MFT. Increasing the MFT from 400° to 650°C decreased yield from 37.2% to 30.5%, AD from 0.377 to 0.306 g/cm3 and VMC from 30.8% to 16.1% significantly. On the other hand, VV increased from 0.754 m3/g to 0.8 m3/g as well as VS from 29.7% to 43.7%, GHC from 5355 cal/g to 6099 cal/g, AC from 11.31% to 15.47% and FCC from 51.3% to 61.5% with increasing of MFT within this range (Fig.'s 2, 3 and 4).

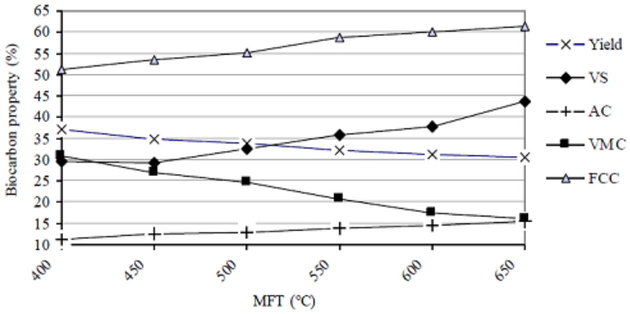

Figure 2. Yield, volumetric shrinkage (VS), ash content (AC), volatile matter content (VMC) and fixed carbon content (FCC) of tamarisk biocarbon made under different maximum final temperatures (MFT).

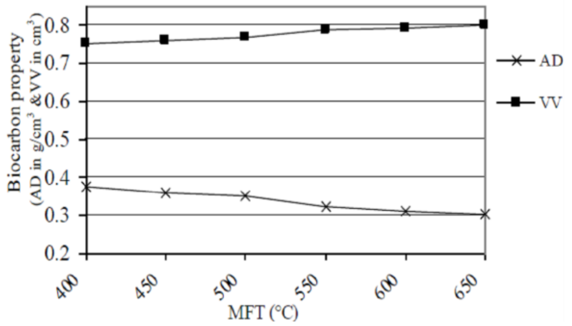

Figure 3. Apparent density (AD) and void volume (VV) of tamarisk biocarbon made under different maximum final temperatures (MFT).

Since LC and TEC, AC of wood may affect the biocarbon yield [7], [8]&[18], the reasonably high yield of tamarisk biocarbon can be attributed to the chemical constituents of the parent wood, namely LC (27.92 %), TEC (15.77 %) and AC (5.429%) as shown in Fig.'s 1 and 2. The decrease in yield, AD and VM as well as the increase in VS can be attributed to that thermal degradation of the remainder lignin proceeds above 400°C. The increase in VV with the increasing of the MFT can be related to that more carbon atoms released in a form carbon mono- or dioxide that causing nano-holes. The GHC of tamarisk wood (4385 cal/g) was lower than that for the biocarbon made under the different MFT's. In addition, the GHC of biocarbon is increased with the increasing of MFT (Figure 4).

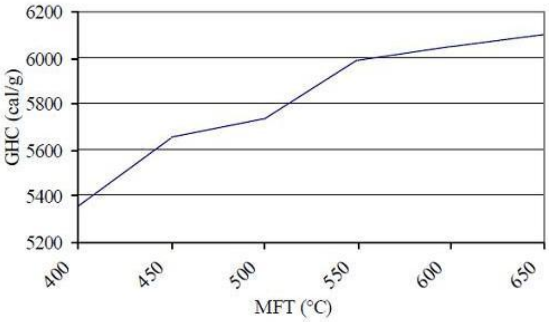

Figure 4. Gross heat of combustion (GHC) of tamarisk biocarbon made under different maximum final temperatures (MFT).

This finding can be attributed to the increasing in FCC with the increasing of MFT where a direct relationship between GHC and FCC were established earlier for this species [7], [19], [20]&[21]. It is considerable to note that lower GHC of tamarisk wood and biocarbon than normal cases is due to their higher contents of ash [7].

CONCLUSION

Fuel characteristics of *Tamarix aphylla* biocarbon were studied as a function of MFT. A chemical and physical evaluation of the parent wood was also done as an illustration tool for biocarbon trend toward the MFT. All the properties studied were found to be affected significantly by the MFT. Increasing the MFT from 400° to 650°C decreased yield and VMC from significantly. On the other hand, VV, VS, AC, FCC and GHC were increased with increasing of MFT within this range. Tamarisk biocarbon, irrespective of the yield, was generally lower in its quality than normal one due to its higher contents of ash and volatile matter as well as its lower gross heat of combustion, and fixed carbon contents comparing to other hardwoods at a certain MFT. Accordingly, its suitability as a fuel is confined to the rural and domestic uses.

REFERENCES

[1] V. Strezov, M. Patterson, V. Zymia, K. Fisher, T. J. Evan and P. F. Nelson. Fundamental aspects of biomass carbonization. J. Analytical and Applied Pyrolysis. 79, 91-100 (2007).

[2] P. Mckendry. Energy production from biomass (Part 2): Conversion technologies. Bioresour. Technol. 83: 47-54 (2002).

[3] J. Pastor-Villegas, J. F. Pastor-Valle, J. M. M. Rodríguez and M. G. García. Study of commercial wood charcoals for the preparation of carbon adsorbents. Journal of Analytical and Applied Pyrolysis, 76 (1-2), 103-108 (2006).

[4] K. O. Davidsson and J. B. C. Pettersson. Birch wood particle shrinkage during rapid pyrolysis. Fuel, 81(3), 263-270 (2002).

[5] K. Raveendran, A. Ganesh, and K.C. Khilar. Influence of mineral matter on biomass pyrolysis characteristics. Fuel. 74 (12), 1812-1822 (1995).

[6] M. Sadakata, K. Takahashi, M. Saito and T. Sakai. Production of fuel gas and char from wood, lignin and holocellulose by carbonization. Fuel. 66: 1667-1671.(1987)

[7] S. S. Hindi. Charcoal properties as affected by raw material and charcoaling parameters. MSc. Unpubl. Thesis, Fac. of Agric. Alexandria Univ.92 pp (1994).

[8] S. S. Hindi (2001). Pyrolytic products properties as affected by raw material. PhD. Unpubl. Thesis, Fac. of Agric. Alexandria Univ. 201pp (2001).

[9] Connor, M A. and Viljoen. M H. 1995. Understanding the fundamental process of wood carbonization- where to from here? Paper presented at: IUFRO XX World Congress, 6-12 August, 1995.Tampere, Finland.

[10] ASTM. D 1105-84. Standard method for preparation of extractive-free wood. Philadelphia, Pa. U.S.A. (1989).

[11] ASTM. D 1106-84. Standard test method for acid-insoluble lignin in wood. Philadelphia, Pa. U.S.A. (1989).

[12] Wise, L.E., Merphy, M, M. D., Adieco, M. Chlorite holocellulose, its fractionation and bearing on summative wood analysis and on studies on the hemicelluloses. Paper Trade Journal. 122, 35-43 (1946).

[13] ASTM, D 1102-84. Standard test method for ash in wood. Philadelphia, Pa. U.S.A. (1989).

[14] ASTM. D 2015-85. Standard test method for gross calorific value of coal and coke by the adiabatic bomb calorimeter. Philadelphia, Pa. U.S.A (1987).

[15] ASTM, D 1762-84. 1989. Standard method for chemical analysis of wood charcoal. Philadelphia, Pa. U.S.A.

[16] R. G. D. Steel and T. H. Torrie. Principles and procedures of statistics. N. Y., U. S. A. (1980).

[17] S. S. Hindi. A. A. Bakhashwain and A. El-Feel. Physico-chemical characterization of some Saudi lignocellulosic natural resources and their suitability for fiber production. JKAU; Met. Env. Arid Land Agric. Sci. 21 (2):45-55 (2010).

[18] A. Demirbas. Effects of temperature and particle size on bio-char yield from pyrolysis of agricultural residues. J. of Analytical and Applied Pyrolysis. 72(2), 243-248 (2004).

[19] W. M. Abd El-Dayem, M. M. El-Morshedy, S. S. Hindi and M. L. M. El-Osta, M. L. M. Charcoal properties made from different tree organs of *Taxodium disticum*, L. Egypt. J. Appl. Sci. 13: 242-255 (1998).

[20] M. M. Megahed, M. M., M. L. M. El-Osta, H. A. Abou-Gazzia and A. El-Baha. Properties of plantation grown leguminous species and their relation to utilization in Egypt. Menofiya J. Agric. Res., 23, 1729-1751 (1998).

[21] S. S. Hindi. Effect of wood material and pyrolytic conditions on biocarbon production. Inter. J. of Modern Eng. Res. (IJMER). 2 (3),1386-1394 (2012).