International Journal of Applied Science & Environmental Engineering – IJASET 2018

Volume 1 : Issue 1 Publication Date : 28 December, 2018

Characterization of biochars from different feedstocks and pyrolysis temperatures:toward a “solar biochar”

[M. Citossi]

***Abstract*— Recently, attention has been given to an innovative class of biochar derived from solar pyrolysis because of its potential to provide an efficient, environmentally acceptable, and cost-effective method for the exploitation of a totally renewable energy source to obtain pyrolyzation, such as solar irradiation. A simple and innovative prototype for biomass pyrolysis is presented, together with some experimental results. The setup allows only the thermal solar energy provided by a system of reflecting mirrors (Linear Mirror II) to heat a selected and local agro-waste biomass. Characterization and effects of biomass which was thermally treated using the Linear Mirror II to perform pyrolysis only through solar energy and without any help from other thermal auxiliary sources is discussed too.**

Keywords—Renewable Energy, biochar; Solar Biomass Conversion; Concentrated Solar Energy; Solar Pyrolysis; Linear Mirror.

I. Introduction: Biomasses and Pyrolysis

Worldwide, there have been many studies to identify biomass sources and quantify their amount, showing that there are at least several billion tons of biomass potentially available for conversion. In particular, agricultural crop residues, besides being used for animal feeding, can have a great potential as a raw under-used energy resource [1]. Historically, biomass has played a relevant role as a renewable energy source at low scale. Unprocessed agricultural residues or woody wastes typically degrade over time due to natural deterioration since they are highly prone to decomposition and breakdown processes with exposure to moisture, pests, and other uncontrolled environmental conditions. One needs therefore a biomass pre-treatment, which can increase its energy density, slow down its biological degradation, and reduce its hydrophilicity. In recent years, several technologies of thermochemical biomass conversion have been developed, and gasification and pyrolysis have shown their capacity to recover the energy stored in plants by the photosynthetic process [2][3]. These thermal processes provide an efficient, environmentally acceptable, and cost-effective method for the exploitation of a sustainable energy source [4][5][6].

This paper is focused on the pyrolysis of biomasses obtained using uniquely solar thermal energy. Pyrolysis is a thermochemical, endothermic process, taking place under inert atmospheric conditions or in a limited supply of air. Among influential process parameters, the maximum temperature reached during the pyrolysis process is the most critical one to influence charcoal yields and properties. This temperature refers to the highest treatment temperature (HTT) for the raw feedstock during the process. Increasing HTT results in a progressive loss of hydrogen and oxygen and a concomitant enrichment in carbon [7]. The resultant C-rich charcoil is more resistant to microbial degradation as compared to fresh biomass. In addition, the pyrolysis process increases the calorific value and transforms the hygroscopic biomass into a hydrophobic material. In conventional pyrolysis, biomass is heated by burning fossil fuels, consuming part of the processed biomass or with the use of an electrical furnace. Alternatively, concentrated thermal solar energy can be used as heat source. Several are the advantages of a solar driven thermal carbonization: i) it delivers a higher carbonized material output per unit of feedstock because no portion of the feedstock is combusted for process heat; ii) the process is CO_2 neutral and discharge of pollutants in the environment is avoided iii) it offers an efficient way of chemically store the intermittent solar energy in the form of a readily transportable fuel. A number of attempts to perform pyrolysis with solar energy based on different solar concentrating systems have been made [8][9].

II. Linear Mirror II

We present in the following tests done with a particularly simple solar concentrating device that has become available very recently, the Linear Mirror II [10]. The Linear Mirror has two particular advantages: 1) its construction is very simple, since its multiple reflecting surfaces are connected to each other by mechanical links, and operated all together by means of only three small motors; 2) the sunlight is concentrated on a target mounted in a fixed position which can be on the ground, unlike for instance the heat exchanger of a parabolic dish. This allows for a wide variety of different applications.

In conventional pyrolysis, biomass is heated by burning fossil fuels, consuming part of the processed biomass or with the use of an electrical furnace. Several are the advantages of a solar driven thermal carbonization: 1) it delivers a higher carbonized material output per unit of feedstock since no portion of the feedstock is combusted for process heat; 2) the process is CO_2 neutral and discharge of pollutants in the environment is avoided; 3) it offers an efficient way of chemically store the discontinuous solar energy in the form of a readily transportable fuel.

III. Characterization of solar carbon

The feedstocks used in this study were wheat straw and vine shoots provided by a local wheat farm located in Friuli Venezia Giulia (Italy). The particles were dried at 105 °C for 8 hours before the experiment. Local feedstocks (wheat straw and vine shoots) have been heated at different temperatures using solar energy provided by Linear Mirror II [11]. The higher heating value (HHV) of the solar carbon was measured using a bomb calorimeter IKA C200 instrument with the DIN 51900-1 standard. The uncertainty of the measurements is about 120 J/g. The high heating value (HHV) of this solar charcoal ranges between 22.6 to 28.5 MJ/kg depending on the analyzed specimen, this variability could be due to an not homogeneous pyrolysis inside the retort, however the values measured are significantly higher than that of common wheat straw (16.9 MJ/kg) and close to the HHV of fossil fuel. HHV of a good quality carbon is about 28-32 MJ/kg [12]. The elemental analysis of solar carbon was performed on a Vario EL Mod X (Vario Inc, USA) [13]. The chemical and physical properties of solar charcoal are summarized in Table I. Such analysis gives the weight percent of carbon, hydrogen, nitrogen, in the samples simultaneously [14]. The oxygen content was estimated by mass difference, i.e. by subtracting from 100% the amount of C, H, N and ash [15]. Raising the temperature, the residual mass percentage decreases as one would expect, and the higher heating value (HHV) increases.

Table I.

Parameters (wt%)	Wheat straw			Vine shoot		
	300°C	400°C	500°C	300°C	400°C	500°C
C	59 ± 1	70 ± 1	74 ± 1	69 ± 1	73 ± 1	80 ± 1
H	5.4 ± 0.1	3.5 ± 0.1	2.8 ± 0.1	4.7 ± 0.1	3.6 ± 0.1	2.9 ± 0.1
N	0.7 ± 0.1	0.9 ± 0.1	0.8 ± 0.1	1.0 ± 0.1	0.8 ± 0.1	0.8 ± 0.1
O	29 ± 1	15 ± 1	10 ± 1	19 ± 1	15 ± 1	7 ± 1
Ash	5.9 ± 0.1	10.1 ± 0.1	12.0 ± 0.1	4.9 ± 0.1	6.4 ± 0.1	7.0 ± 0.1
HHV (MJ/Kg)	22.6 ± 0.1	27.5 ± 0.1	28.5 ± 0.1	24.9 ± 0.1	26.3 ± 0.1	27.9 ± 0.1
Residual Mass (%)	51 ± 1	40 ± 1	31 ± 1	33 ± 1	26 ± 1	23 ± 1

IV. Conclusions

The Linear Mirror II system has been successfully used to drive the pyrolysis of selected agro-waste biomasses such as wheat straw and vine shoots using only the sunlight as source of heating. Solar pyrolysis of cheap biomasses offers an interesting combination of traditional solar thermal energy with biomass energy which can help to substitute fossil fuels.

Acknowledgment

This work was in part sponsored by a grant from Camera di Commercio di Gorizia (Fondo Gorizia) and was supported by Area Science Park Trieste.

References

[1] B. V. Babu, Biomass pyrolysis: a state-of- the-art review, Biofuels, Bioprod. Bioref. 2:393–414 (2008).
http://dx.doi.org/10.1002/bbb.92

[2] H. Grassmann, T.F.M. Chang, M. Taverna, L. Iseppi L (2013). The Solar Age: Utopia and Dystopia. How to Transform Green Waste Esternalities in Energy and Biochar. Society, Integration, Education, Proceed-ings of the International Scientific Conference, Sabiedriba, Integracija, Izglitiba, vol. 3, p. 165-176, ISSN: 1691-5887, WOS: 000327802500015, DOI: 10.13140/2.1.1542.3688, Udine;

[3] T.F.M. Chang, L. Iseppi, H. Grassmann (2015), Transforming vegetal and animal waste flows and stocks in energy through solar "Line-ar Mirror II", Accademia dei Lincei, Fondazione ENI- E. Matteri, La sfida dei Terawatt: quale ricerca per l'energia del futuro?, Rome, DOI: 10.13140/2.1.4444.8328.

[4] L. Montanarella and E. Lugato, The application of Biochar in the EU: Challenges and Opportunities, Agronomy (2013), 3, 462-473.
http://dx.doi.org/10.3390/agronomy3020462

[5] Verheijen, F.G.A., Jeffrey, S., Bastos, A.C.,van der Velde, M., and Diafas, I., Biochar Application to Soils - A Critical Scientific Review of Effects on Soil Properties,P and Functions, (2009), EUR 24099 EN, Office for the Official Publications of the European Communities, Luxembourg, 149pp.

[6] S.P. Sohi, E. Krull, E. Lopez-Capel, and R. Bol, A Review of Biochar and its Use and Function in Soil, Advances in Agronomy, (2010), Volume 105.
http://dx.doi.org/10.1016/s0065-2113(10)05002-9

[7] Demirbas, Biomass resource facilities and biomass conversion processing for fuels and chemicals, Energy Conversion and Management 42 (2001), 1357-1378.
http://dx.doi.org/10.1016/S0196-8904(00)00137-0

[8] F. Ateş and M. A. Işıkdağ, Evaluation of the Role of the Pyrolysis Temperature in Straw Biomass Samples and Characterization of the Oils by GC/MS, Energy & Fuels 22 (2008), 1936-1943.
http://dx.doi.org/10.1021/ef7006276

[9] S. Morales, R. Miranda, D. Bustos, T. Cazares, H. Tran, Solar biomass pyrolysis for the production of bio-fuels and chemical commodities, J. Anal. Appl. Pyrolysis 109 (2014) 65–78.
http://dx.doi.org/10.1016/j.jaap.2014.07.012

[10] H. Grassmann et al., First Measurements with a Linear Mirror device of second generation, Smart Grid and Renewable Energy, 2013, 4, 253-258.

[11] Grassmann, H. , Boaro, M. , Citossi, M. , Cobal, M. , Ersettis, E. , Kapllaj, E. and Pizzariello, A. (2015) Solar Biomass Pyrolysis with the Linear Mirror II. Smart Grid and Renewable Energy, 6, 179-186. doi: 10.4236/sgre.2015.67016

[12] Jenkins B., Properties of Biomass, Appendix to Biomass Energy Fundamentals, EPRI Report TR-102017,January (1993), [http://cta.ornl.gov/bedb/appendix_a/Heat_Content_Ranges_for_Various_Biomass_Fuels.xls].

[13] [http://www.emme3-srl.it/wp-content/uploads/2015/03/1365413604BR_VarioELCube.pdf].

[14] B.M. Jenkins, L.L. Baxter, T.R. Miles, Jr.T.R. Miles, Fuel Processing Technology 54 (1998) 17–46.
http://dx.doi.org/10.1016/S0378-3820(97)00059-3

[15] M. Keiluweit, P.S. Nico, M.G. Johnson and M. Kleber, Environ. Sci. Technology 44 (2010), 1247-1253.
http://dx.doi.org/10.1021/es9031419

About Author (s):

Solar pyrolysis of cheap biomasses offers an interesting combination of traditional solar thermal energy with biomass energy which can help to substitute fossil fuels.