Characterization of Char and Oil From Low Temperature Conversion of Biomass from *Eichhornia Crassipes*

Roberto G. Pereira (Corresponding author)
Federal Fluminense University, Mechanical Engineering Department
TEM, PGMEC, MSG
Rua Passo da Pátria 156, CEP 24.210-240, Niterói-RJ, Brazil
E-mail: temrobe@vm.uff.br

Gilberto A. Romeiro, Raimundo N. Damasceno & Luiz Antonio P. Fernandes Junior
Federal Fluminense University, Organic Chemistry Department
Campus do Valonguinho, CEP 24.210-150, Niterói-RJ, Brazil

Jorge Alberto C. Borda d'Agua
Federal Fluminense University, PGMEC
Rua Passo da Pátria 156, CEP 24.210-240, Niterói-RJ, Brazil

Ednilton T. de Andrade
Federal Fluminense University, Department of Agricultural Engineering and the Environment, PGMEC
Rua Passo da Pátria 156, CEP 24.210-240, Niterói-RJ, Brazil

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Abstract

The present work describes an experimental investigation concerning the characterization of char and oil obtained through Low Temperature Conversion (LTC) process applied to biomass of *Eichhornia crassipes*. Basic analysis (heating values, elemental analysis, total ash and moisture content) of char and oil are reported. The preliminary characteristics of the oil and the char obtained indicate the viability of their use as, for instance, in the generation of energy.

Keywords: Char, Oil, Low temperature conversion, Renewable energy

1. Introduction

In the hydrological basin of Paraíba do Sul River in Rio de Janeiro State, Brazil, the disordered evolution of urban and industrial development in the area promotes a great increase of the pollutant load in the river. This increase of wastes, mainly of organic origin in the rivers, has been promoting the uncontrolled increase of several aquatic organisms.

Among the several species, the *Eichhornia crassipes* is a peculiar aquatic macrophyte because it proliferates inordinately in polluted areas. Due to uncommon reproduction process, flotation islands of *Eichhornia crassipes* form great vegetable masses in the water impeding the river traffic, besides hindering the reception of water for treatment stations and turbines of hydroelectric power stations. To minimize these damages, the governments and the companies are trying to control their proliferation by several means, making use of mechanical, chemical and biological methods. The great amount of *Eichhornia crassipes* residues in the water becomes an environmental problem.

The Low Temperature Conversion (LTC) process is an option for these materials to be used, obtaining char and oil from the aquatic plant biomass.

1.1 The Eichhornia crassipes

When proliferating in a hydro resource the *Eichhornia crassipes* surplus can favor the proliferation of insects, reducing the brightness, as well as reducing the oxygen rate dissolved in the hydro resource, causing ecological unbalance and strongly altering the communities of invertebrate and vertebrate animals (Gopal, 1987). The growth of the *Eichhornia crassipes* surplus can be chemically or biologically controlled. The mechanical control consists of removing the biomass using either a manual process or using machines. In both cases, great amounts of residues are generated. Therefore, an appropriate destination of this biomass is essential.

1.2 Low Temperature Conversion Process

The Low Temperature Conversion (LTC) process was firstly developed from studies about the viability of the fuel production from mud of sewers treatment stations in Germany in the 80's. LTC is a thermochemical process, whose main objective is increasing the cycle of life of the residues. LTC has been applied to several biomasses of urban, industrial and agricultural origin, being sought through the thermal conversion to transform them in products of potential commercial value. Depending on the biomass type used in the process, oil and a char are obtained in variable proportions, besides water and gas. The oil is sent to studies about the viability of its application as fuel or other possible commercial application (as greases, lubricants, resins etc) whereas the char is sent to studies of its activation so that it can be used as active char, besides the possible direct use as energy (Bayer & Kutubuddin, 1988, 1998; Bayer et al., 1995; Lutz et al., 1998, 2000; Romeiro et al., 1999, 2000; Vieira et al., 2009).

2. Material and Methods

2.1 Char and oil attainment

The aquatic plants (*Eichhornia crassipes*) were collected at Santana and Vigário reservoirs (22°28′53.15″ S and 43°50′17.65″ W, respectively), located in Barra do Piraí, Rio de Janeiro State, Brazil. Grown plants (with similar sizes) were collected and the whole plants were dried in order to be sent to the Low Temperature Conversion Process.

The conversion (batch process) was accomplished in a thermoelectrical reactor (Fig. 1) consisting of a furnace Haerus with temperature controller. The process happens to 380 ℃ inside a fixed bed of glass type boron-silicato Pirex with dimensions 1.40 m x 0.10 m (tube converter), coupled with a system for collection of condensed liquids. This system is composed of a condenser of 0.30 m and a decantation funnel of 500 mL associated to the conversion tube by glass pieces.

Initially, an inert atmosphere is created inside the reactor with a constant flow of nitrogen, lasting about 15 min. The controller is regulated by the process temperature and the fractions are collected after three hours of processing, when the fractions are directed for analysis. During the whole conversion, the flow of nitrogen is maintained, trying to get an inert atmosphere in the reactor.

Elementary Analysis of the char and oil were done by using the LECO equipment, model CHN-600, according to ASTM D5291.

The char and oil heating values were obtained, by using the LECO equipment, model AC350, according to ASTM D1989.

The ashes and moisture tests were done according to ASTM D121 and to ASTM D3302, respectively.

3. Results and Discussion

3.1 Char and oil characterization

The results represent an average of at least three tests.

The yields (percentage in mass) obtained through the LTC were: char (43.6%); oil (10.3%); conversion water (26.1%) and gas (20.0%).

The Elementary Analysis of the char was made: nitrogen (2.66%); carbon (31.9%); sulfur (1.03%) and hydrogen (2.08%).

Table 1 presents properties of the LTC char and other fuels (Garcia, 2002; Parikh et al., 2005; Raveendran & Ganesh, 1996; André et al., 2005).

The char, resulting from the LTC applied to the aquatic plant *Eichhornia crassipes*, presented yield in the order of 45%. In relation to the properties, it is observed that the percentage of sulfur (in the order of 1% in mass), the tenor of ashes (in the order of 40% in mass) and the moisture (in the order of 7% in mass) are below the values found in some Brazilian chars and in other fuels. The higher heating value (in the order of 13000 kJ/kg) is comparable with other fuels and higher than Mineral char: Charqueadas – I1F –RS (Garcia, 2002); Rose apple char (Parikh et al., 2005); Tannary waste (Parikh et al., 2005) and Pine needle (40% clay) (Parikh et al., 2005).

The Elementary Analysis of the oil was made as shown: nitrogen (4.9%); carbon (52.38%); sulfur (0.24%) and hydrogen (6.84 %);

The heating values obtained were: higher heating value equal to 27921 kJ/kg and lower heating value equal to 26447 kJ/kg.

With the comparison purpose, they are presented in Table 2 properties of LTC oil and other fuels (Garcia, 2002; Li et al., 2005; Nwafor, 2004; Carraretto et al., 2004; Barnwal & Sharma, 2005; Demirbas, 2000; Kalligeros et al., 2003).

The yield of the LTC applied to the aquatic plant *Eichhornia crassipes*, found for the oil is about 10%. In relation to the properties, it is observed that the percentage of sulfur (in the order of 0.2% in mass) is below the one found in some Brazilian fuel oils. The higher heating value (in the order of 28000 kJ/kg) is higher than methanol (Barnwal & Sharma, 2005) and presents a good energy potential for use.

Table 3 summarizes the characterization of LTC products using: *Eichhornia crassipes* as biomass (present study); sugar-cane by-products one (Lutz et al., 1998); Brazilian municipal and industrial sludge (Lutz et al., 2000) and sludge generated in an industrial wastewater treatment station (Vieira et al., 2009). As we can see, we obtain more char using *Eichhornia crassipes* as biomass than using bagasse and filter mud. We also obtain more oil using *Eichhornia crassipes* as biomass than using bagasse, Brazilian molasses and alcohol sludge. The percentage of gas obtained with *Eichhornia crassipes* as biomass is higher than the other biomass, except in the case of Brazilian molasses biomassas. Regarding the Elementary Analysis, the char of *Eichhornia crassipes* has more carbon than the char of: alcohol sludge; activated sludge; digested sludge and lacquer sludge. In case of the oil, the *Eichhornia crassipes* biomass shows the lesser value for carbon.

4. Conclusions

The application of the Low Temperature Conversion (LTC) process to the *Eichhornia crassipes* biomass seems to be a quite viable alternative for the reduction of the damages provoked in the environment because of the great amount of biomass of the aquatic plants that are happening along the basin of the Paraíba do Sul River, as well as for the utilization of others available amounts of *Eichhornia crassipes* biomass.

Oil and char with preliminary characteristics that indicate the viability of their use, as for instance, in the generation of energy, were obtained.

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References

André, R.N., Pinto, F., Franco, C., Dias, M., & Gulyurtlu, I. (2005). Fluidised bed co-gasification of coal and olive industry wastes. *Fuel*, *84*, 1635-1644. http://dx.doi.org/10.1016/j.fuel.2005.02.018

Barnwal, B.K., & Sharma, M.P. (2005). Prospects of biodiesel production from vegetable oils in India. *Renewable & Sustainable Energy Reviews*, *9*, 363-378. http://dx.doi.org/10.1016/j.rser.2004.05.007

Bayer, E., Maurer, A., Becker, G., & Kutubuddin, M. (1995). Recovery of activated carbon from wastes via low temperature conversion - PART 1: Preparation and determination of pore structure. *Fressenius Envir. Bull*, *4*, 533–538.

Bayer, E., Maurer, A., Becker, G., & Kutubuddin, M. (1995). Recovery of activated carbon from wastes via low temperature conversion - PART 2: Analysis and evaluation of applicability. *Fressenius Envir. Bull*, *4*, 539–544.

Bayer, E., & Kutubuddin, M. (1998). Thermocatalytic Conversion of Lipid-Rich Biomass to Oleochemical and Fuel in: Bridgewater A V, Kuester J I, editors. *Elsevier Applied Science*, 518-530.

Bayer, E., & Kutubuddin, M. (1988). Thermocatalytic Conversion of Lipid-rich biomass to oleochemicals and fuel. *Research in thermochemical biomass conversion*. Phoenix, Arizona, USA.

Carraretto, C., Macor, A., Mirandola, A., Stoppato, A., & Tonon, S. (2004). Biodiesel as alternative fuel: Experimental analysis and energetic evaluations. *Energy*, *29*, 2195-2211. http://dx.doi.org/10.1016/j.energy.2004.03.042

Demirbas, A. (2000). A direct route to the calculation of heating values of liquid fuels by using their density and viscosity measurements. *Energy Conversion & Management*, *41*, 1609-1614. http://dx.doi.org/10.1016/S0196-8904(00)00012-1

Garcia, R. (2002). *Fuels and industrial combustion*, Editora Interciência, RJ - Brazil (in Portuguese).

Gopal, B. (1987). *Water hyacinth*. New York: Elsevier.

Kalligeros, S., Zannikos, F., Stournas, S., Lois, E., Anastopoulos, T.C., & Sakellaropoulos, G. (2003). An investigation of using biodiesel/marine diesel blends on the performance of a stationary diesel engine. *Biomass and Bioenergy*, *24*, 141-149. http://dx.doi.org/10.1016/S0961-9534(02)00092-2

Li, X., Qiao, X., Zhang, L., Fang, J., Huang, Z., & Xia, H. (2005). Combustion and emission characteristics of a two-stroke diesel engine operating on alcohol. *Renewable Energy*, *30*(13), 2075-2084. http://dx.doi.org/10.1016/j.renene.2004.05.014

Lutz, H., Esuoso, K., Kutubuddin, M., & Bayer, E. (1998). Low Temperature Conversion of Sugar-Cane by Products. *Biomass and Bioenergy*, *15*, 155-162. http://dx.doi.org/10.1016/S0961-9534(98)00032-4

Lutz, H., Romeiro, G.A., Damasceno, R.N., Kutubuddin, M, & Bayer, E. (2000). Low Temperature Conversion of some Brazilian municipal and industrial sludges. *Bioresource Technology*, *74*, 103-107. http://dx.doi.org/10.1016/S0960-8524(00)00011-0

Nwafor, O.M.I. (2004). Emission characteristics of diesel engine running on vegetable oil with elevated fuel inlet temperature. *Biomass and Bioenergy*, *27*, 507-511. http://dx.doi.org/10.1016/j.biombioe.2004.02.004

Parikh, J., Channiwala, S.A., & Ghosal, G.K. (2005). A correlation for calculating HHV from proximate analysis of solid fuels. *Fuel*, *84*, 487-494. http://dx.doi.org/10.1016/j.fuel.2004.10.010

Raveendran, K., & Ganesh, A. (1996). Heating value of biomass and biomass pyrolysis products. *Fuel*, *75*(15), 1715-1720. http://dx.doi.org/10.1016/S0016-2361(96)00158-5

Romeiro, G.A., Damasceno, R.N., Lutz, H., Kutubuddin, & M., Bayer, E. (1999). Identification of fatty acids in oil from Low Temperature Convertion (LTC) using fast atom bombardment (FABMS) and field desorption (FDMS). *Fresenius Envir. Bull*, *9*, 163-170.

Romeiro, G.A., Vieira, G.E.G., Teixeira, F.E.C., Damasceno, R.N., Santos, M.S., Kunigami, C.N., Lutz, H., Bayer, E., & Kutubuddin, M. (2000). Low temperature conversion of beverage industry residues - GC/MS evaluation. *Adv. Food Sci.*, *22*, No. 5/6, 170–177.

Vieira, G.E.G, Romeiro, G.A., Sella, S.M., Damasceno, R.N., & Pereira, R.G. (2009). Low Temperature Conversion (LTC) – An alternative method to treat sludge generated in an industrial wastewater treatment station – Batch and continuous process comparation. *Bioresource Technology*, *100*, 1544-1547. http://dx.doi.org/10.1016/j.biortech.2008.08.040

Table 1. Properties of LTC char and other fuels

Char	**Ashes** (mass %)	**Sulfur** (mass %)	**Moisture** (mass %)	**Higher Heating value** (kJ/kg)	**Lower Heating value** (kJ/kg)
Eichhornia crassipes LTC char (present study)	40.2	1.03	7.5	13031	12583
Mineral char: Candiota – RS (a)	51.4	1.3	15.0	13813	n.a.
Mineral char: Charqueadas – I1F – RS (a)	56.6	1.6	8.0	12265	n.a.
Mineral char: Charqueadas – I2B – RS (a)	45.0	1.2	8.8	16702	n.a.
Mineral char: Santa Catarina (a)	31.7	2.0	2.4	23588	n.a.
Rose apple char (b)	65.6	n.a.	n.a.	7577	n.a.
Rice husk char (b)	52.9	n.a.	n.a.	14944	n.a.
Coal sample (b)	40.0	n.a.	n.a.	14772	n.a.

Eucalyptus (b)	3.35	0	n.a.	18640	n.a.
Rice straw (b)	15.50	0	n.a.	15614	n.a.
Tannary waste (b)	54.00	n.a.	n.a.	7685	n.a.
Pine needle (40% clay) (b)	77.70	n.a.	n.a.	5700	n.a.
Coconut shell char-750 ℃ (b)	2.9	0	n.a.	31124	n.a.
Coir pith char (c)	n.a.	n.a.	n.a.	25000	n.a.
Wood char (c)	n.a.	n.a.	n.a.	24100	n.a.
Puertollano coal (d)	32.3	1.27	5.5	30650	n.a.

n.a., not available; (a) Garcia, 2002; (b) Parikh et al., 2005; (c) Raveendran & Ganesh, 1996; (d) André et al., 2005

Table 1 above presents properties of the LTC char and other fuels

Table 2. Properties of LTC oil and other fuels

Fuel	**Sulfur** (mass %)	**Higher Heating value** (kJ/kg)	**Lower Heating value** (kJ/kg)
Eichhornia crassipes LTC oil (present study)	0.24	27921	26447
Brazilian fuel oil -1A (a)	3.8	42856	n.a.
Brazilian fuel oil - 8A (a)	4.8	41839	n.a.
Brazilian fuel oil -1B (a)	0.8	44079	n.a.
Brazilian fuel oil – 4B (a)	1.0	43530	n.a.
Alcohol (b)	n.a.	n.a.	20500
Diesel (b)	n.a.	n.a.	42500
Diesel (c)	n.a.	45230	n.a.
Diesel D2 (d)	0.001	n.a.	42999
Biodiesel (d)	0.018	n.a.	36970
Peanut biodiesel (e)	n.a.	n.a.	33600
Babassu biodiesel (e)	n.a.	n.a.	31800
Sunflower biodiesel (e)	n.a.	n.a.	33500
Diesel (e)	n.a.	n.a.	43800
Methanol (f)	n.a.	22360	n.a.
Ethanol (f)	n.a.	29850	n.a.
Marine diesel (g)	0.22	n.a.	42191
Olive biodiesel (g)	0.0010	n.a.	32781

n.a., not available; (a) Garcia, 2002; (b) Li et al., 2005; (c) Nwafor, 2004; (d) Carraretto et al., 2004; (e) Barnwal & Sharma, 2005; (f) Demirbas, 2000; (g) Kalligeros et al., 2003

Table 2 above presents properties of LTC oil and other fuels.

Table 3. Characterization of LTC products

	*Eichhornia crassipes_* (present study)	Bagasse (a)	Brazilian molasses (a)	Filter mud (a)	Alcohol Sludge (b)	Activated Sludge* (c)	Digested Sludge* (c)	Lacquer Sludge* (c)	Sludge* (d)
Yield of the conversion products									
Char (%)	43.6	35.4	51.6	40.1	77.6	50.1	69.4	68.0	47.0
Oil (%)	10.3	5.5	1.3	20.6	5.9	31.4	11.0	14.2	40.0
Water (%)	26.1	45.7	22.8	23.5	10.4	6.8	10.2	10.1	5.0
Gas (%)	20.0	13.4	24.3	15.8	6.1	11.7	9.4	7.7	8.0
Analysis of the LTC char									
C (%)	31.9	71.6	69.3	46.3	20.8	23.8	20.9	11.5	n.a.
H (%)	2.08	4.35	3.16	2.60	1.71	1.8	1.6	1.4	n.a.
N (%)	2.66	0.53	0.68	3.30	0.97	2.1	2.3	0.82	n.a.
S (%)	1.03	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Ash (%)	40.2	4.70	19.8	44.7	71.0	58.6	71.4	81.5	n.a.
Heating value (kJ/kg)	13031	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Analysis of the LTC oil									
C (%)	52.38	61.8	71.6	70.6	73.4	77.4	76.1	79.3	86.1
H (%)	6.84	7.49	9.70	10.4	10.2	12.0	10.6	11.2	9.0
N (%)	4.9	0.32	4.80	2.64	1.61	2.1	2.9	1.6	3.6
S (%)	0.24	n.a.	n.a.	3.82	n.a.	n.a.	n.a.	n.a.	n.a.
Heating value (kJ/kg)	27921	24500	34500	33300	35200	n.a	n.a	n.a	40200

n.a., not available; *Dry sludges; (a) Lutz et al., 1998; (b) Bayer & Kutubuddin, 1988; (c) Lutz et al., 2000; (d) Vieira et al., 2009.

Figure 1. Thermoelectrical reactor

Figure 1 above depicts the thermoelectrical reactor consisting of a furnace Haerus with temperature controller.