Use of Hazelnut's Pruning to Produce Biochar by Gasifier Small Scale Plant.

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Received: 27.05.2015 Accepted:29.06.2015

Abstract- Biochar is a product obtained from biomass pyrolysis or gasification. One of the most important application of biochar is in agronomic sector, as soil improver. However in Italy use of biochar as soil amendant is subordinated to insert this product in the national fertilizer list. The aim of this paper is to analyze the biochar obtained from gasification process (using an Imbert downdraft prototype), in particular investigating its energetic aspect in terms of calorific value and chemical composition and its potentiality as soil improver in terms of European and Italian regulations. In this sense results obtained show a biochar with a lower heating value of 25-26 MJ/kg and a carbon content of around 75%. Referring to the agronomic properties, biochar produced shows a low content in heavy metals, an alkaline pH and good soil's water retention capacity without phytotoxicity effects on crops.

Keywords- *biochar, hazelnut, bio-shredding, downdraft gasifier plant, biomass.*

1. Introduction

Biomass gasification, in particular in small plants, is an innovative technology, where a part of the biomass is converted in 'synthesis gas' and another part in solid charcoal residues (biochar).

The biochar is a "porous carbonaceous solid produced by thermo-chemical conversion of organic materials in an oxygen depleted atmosphere which has physiochemical properties suitable for the safe and long-term storage of carbon in the environment and, potentially, soil improvement". A shortly list highlighting the particular use of biochar in several fields with the latest research findings:

- use in animal farming (silage agent, slurry treatment, feed additive);
- use as a soil conditioner (carbon fertilizer, compost, plant protection);
- use in the building sector (insulation, air decontamination, humidity regulation);

Table 1. Typical char yield from thermo-chemical process [8].

Process	Temperature (°C)	Residence time	Char yield (wt%)
Slow pyrolysis	400-600	min-days	20-40
Fast pyrolysis	400-600	≈ 1 sec	10-20
Gasification	800-1000	5-20 sec.	≈ 10
Hydrothermal carbonization	180-250	1-12 h	30-60

- biogas production (biomass additive, biogas slurry treatment);
- the treatment of waste water (active carbon filter, pre-rinsing additive);
- the treatment of drinking water (micro filters);
- other uses (exhaust filters, carbon fibers, semiconductors, etc.) [13];

1.1 Biochar production

Biochar, gas and bio-oil are typical products of thermo-chemical process of biomass. Production of these fractions is connected to the type of the characteristics of the process considered. Depending on the temperature reached, the characteristics and the speed with which the biomass is heated and the residence time of the gas during the process we have a different distribution of the products of the process between the solid phase, liquid and gas. In particular the increased production of the solid fraction or biochar is obtained at low temperatures and low heating rates of biomass, the liquid fraction or bio-oil is favored at low temperatures but also for a high heating speed and for short times of permanence of the gas while the gaseous fraction is predominant at high temperatures.

The thermo-chemical processes used to biochar production are dry or hydrothermal carbonization, gasification and pyrolysis. These processes are characterized by different thermodynamic conditions that affect the characteristics and the yield of biochar (Tab. 1) [1,8].

One of the main parameters that influence the characteristics of the biochar is the process temperature. The increase of temperature from 300°C to 800°C shows increases in the carbon content from 56% to 93% and a reduction in the production of biochar from 67% to 26%. For temperature increases from 400°C to 900°C it was detected increments of the surface mass of 120 m^2/g to 460 m^2/g [14].

1.2 European regulation.

Biochar has implications in various EU policy areas, including environment protection, waste management, agricultural and climate change policy. The main goal is to integrate benefits and impacts into a common framework, finding the most suitable and cost-effective solutions [9].

Legislative requirements for commercial use of biochar are most often associated with ensuring the safety, health and environment protection. The basic premise is the creation of a legal background that would provide these guarantees and would create general confidence in biochar as a useful product [17].

The basic EU legislation governing this area is Waste Framework Directive (W.F.D.), which sets the basic concepts and definitions related to waste management. The revised W.F.D. clarifies key concepts namely, the definitions of waste, recovery and disposal and lays down the appropriate procedures applicable to by-products and to waste that ceases to be waste [11]. Biochar is produced simultaneously with syngas in a reactor. The pyrolysis process is adapted to ensure that biochar will have the necessary technical quality. At the beginning of the process, technical decision was made in order to get desired type of biochar. The further use of biochar is certain in agriculture and gardening. Biochar can be used directly without processing, such as mixing with other substances, which is not an integral part of the manufacturing process. Under these circumstances, biochar should not be considered as a waste. The present situation is such that the law does not distinguish between products, production residues or non-waste by-products. Relevant is only determination whether the material is a waste or not [11]. An object considered a by-product under the W.F.D. is in principle subject to REACH Regulation which applies to waste only [12]. The Commission has a mandate under the W.F.D. to define 'by-product' criteria for specific substances or objects through procedure. Additionally, Member States may set out by-product criteria at national level. Excluded from the scope of the Directive are also straw and other natural non-hazardous agricultural or forestry material used in farming, forestry or for the production of energy from such biomass through processes or methods which do not harm the environment or endanger human health in compliance with the standards of EU environmental legislation. It is therefore obvious that the uncontaminated biomass used as feedstock for pyrolysis process whose output is a syngas and biochar, is not a waste [17].

1.3 Italian regulation.

The Italian law about the fertilizer use is the Law n. 75/2010 [3]. With this law the fertilizers are classified and characterized according to chemical-physic and toxicological methods of certificated laboratory. One of the fundamental aspects is the traceability of the product. For this reason the fertilizers are inserted in the specific register, and the maker company also are inserted in the book of fertilizer makers.

To insert biochar in commercialized amendant, it is necessary to know the clause 2 in the article 10, that reports as followed: "The request to include of new products or the request to define new types, must be sent to the Agriculture and Forestry Ministry, together with the necessary technical documentation, as described in Attachment 10, and the specific indication of the analysis methods".

In the Attachment 10 there are the information about the kind of amendant to insert, with characteristics about productive process, starting materials and finals products. According to the Italian law every kind of biochar must be characterized, described and approved.

1.4 Common use of biochar

The most common biochar application is soil amendant to mitigate greenhouse gas emission and improve soil health. Other applications include using biochar as a precursor for making catalysts and contaminant adsorbents.

The potential to utilize biochar for various applications depends on its properties. Studies have shown that when biochar is added to soils, as amendant, it is able to increase crop yields, improve soil properties (soil acidity decreases), and the need for some chemical and fertilizer inputs decreases [2].

Due to its porosity increases the soil's ability to retain water and nutrients dissolved in it. Its huge internal surface is a substrate for microbial colonization [17].

In addition, biochar is important for carbon sequestration: the estimated biochar carbon residence time in soil is in the range of hundreds to thousands of years with consequence of a reduction of CO2 air emissions [7]. There are no known negative aspects on soil properties if biochar is produced from uncontaminated feedstock and the production conditions are in accordance with the requirements and continuously controlled [17].

Despite the fact that raw biochar does not have enough nutrients to be classified as a nutrient fertilizer, it can be considered as soil amendant, growing media or soil improver. Soil improvers are primarily applied to improve the physical structure by adding stable organic matter to the soil. Application of biochar into agricultural land must be in accordance with relevant legislation. The core European provisions concerning fertilizers is Regulation EC 2003/2003 relating to fertilizers.

The soils contaminated by heavy metals can be tested by adding biochar. Some studies have demonstrated that metal concentrations decrease with increasing concentrations of biochar [6].

2. Material and methods

This work concerns the study of energy enhancement by gasification of pruning hazelnuts residues (*Corylus Avellana L.*), to obtain solid products (biochar) in add to syngas production. Biomass samples has been obtained directly from local farmers in Viterbo area (central Italy) [4].

The biomass that we have used is hazelnut pruning, that were transformed into bio-shredding, after a period of drying on air of about five months. This treatment has allowed to have a bio-shredding with a moisture in a range of 14% and 19% and a gross calorific value between 16.5 MJ/kg and 17.4 MJ/kg.

Fig. 1. Hazelnut pruning and hazelnut bio-shredding.

2.1 Imbert gasifier Prototype

The biochar production is realized using a fixed bed type Imbert downdraft reactor (Fig.2).

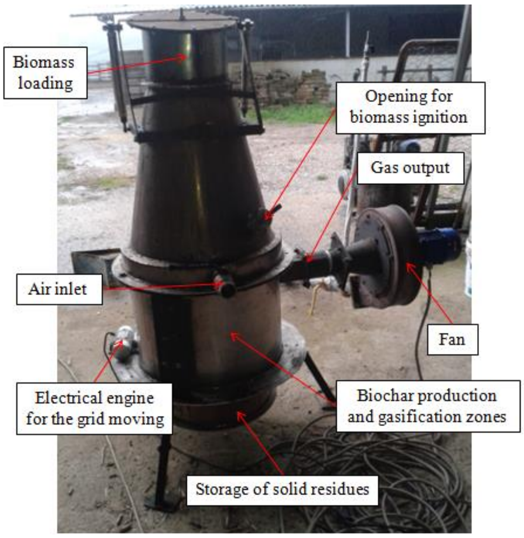

Fig. 2. Downdraft gasifier reactor.

The biomass is loaded from the top while the air is sucked by means of a nozzle in the central part of the body reactor. In the lower part of the reactor there is an electrical engine for the shaking of the inner grid where the char produced in the throat during the gasification process is settled.

Internally the reactor is constituted by a structure that narrows near itself the air intake entrance generating a throat zone: in this area there is the production of char. Below the grid there is the tank for the collection of the solid residue produced by the gasification process.

2.2 Test method

The test of biochar production are defined by a preliminary phase of experiment preparation with the biomass loading in the reactor and subsequently by the ignition of fan, for air aspiration, and the oxidation of the biomass, to start the gasification process.

The temperature of the process is about 900°C and the biochar production experiment is conducted for a range of air flow from 0,0012 m^3/s to 0,0023 m^3/s with a corresponding biomass flow from 0,0041 kg/s to 0,0056 kg/s.

The first phase of the test is characterized by the production of white smoke, that is rich in water vapor due to the drying biomass phase. Subsequently it develops the production of a flammable gas that confirms the biomass gasification and the char production. After gasification phase, we have stopped the process and we have collected the char on the grid (Fig.3) and the solid residue below the grid.

Fig. 3. Biochar produced on the grid from biomass gasification.

Biochar obtained by gasification process is analyzed for the determinations the calorific value according to the UNI-EN 14918:2010, the total content of carbon, hydrogen and nitrogen according to the UNI-EN 15104:2011 and the ash content UNI-EN 14775:2010.

Fig. 4. Calorimeter

Fig. 5. CHN analyzer

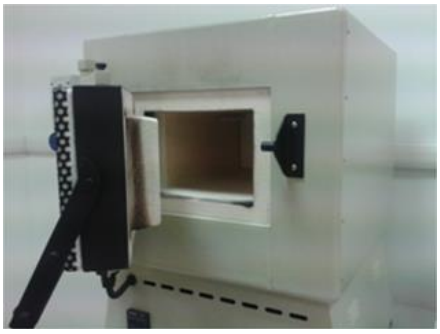

Fig. 6. Muffle furnace

3. Results and Discussion

The characterization tests carried out on the biochar produced during gasification test showed a lower calorific value equal to 25.78 MJ/kg on dry basis and a carbon content of around 75% similar to the carbon content of the coal normally used in the energy field. In Table 2 results about carbon, hydrogen, nitrogen and ash content of biochar are reported.

Characteristics of solid residue obtained at the end of gasification process show lower carbon content values respect to that of biochar obtained during gasification process and no converted in gas. The partial conversion of biochar in gas causes a decrease in the carbon content of solid residue that is related to the air flow inlet: an increase of air flow is connected with a decrease of carbon content and an increase in ash content. In this sense results of characterization of solid residue show that the increase of air flow, in the range considered for the experiment, determines a reduction of the carbon content from 47.01 % to 32.50 % and an increase in ash content from 51.83 % to 65.75 %.

Biochar collected from hazelnut bio-shredding gasification is also investigated for agronomic use to understand its impact on crop development, in this sense one of the most important parameter is the pH value of biochar that, in our case, is of 9.9. Referring to IPA and heavy metal content, results show lower values respect to limits reported on Biochar European Certificate (EBC). Only for copper content is resulted a value of 100 mg/kg that is the limit content value. The first results on use of biochar for growth of vegetable crops show absence of interferences on crop's germination and of phytotoxicity conditions, conversely there is an improve on soil's water retention capacity that results evident for mixture soil-biochar with a value of biochar in soil of about 20% wt.

Results obtained are in agreement with those of other studies: biochars obtained from different types of biomasses such as raw pine sawdust, maize straw or sugarcane bagasse show a carbon content in a range from 60 % to 80 % [8]. Also the energetic aspect in terms of calorific value is in agreement with other studies: biochars obtained from thermo-chemical conversion of lignocellulosic biomass vary from 20 MJ/kg to more than 26 MJ/kg [15]. Referring to the agronomic use is important underline that biochar show characteristics of alkaline pH value and soil's water retention capacity in agreement with biochar produced from biomass [10].

Table 2. Carbon, hydrogen, nitrogen and ash content of biochar.

Parameter	Value (%wt. on dry basis)		
	Maximum	**Minimum**	**Average**
C	76.89	74.26	75.73
H	0.87	0.82	0.84
N	1.09	0.99	1.03
Ash	24.03	19.68	21.78

4. Conclusion

Our study was able to demonstrate capacity to produce biochar using the residual biomass derived from hazelnut pruning and subsequently transformed in hazelnut bio-shredding. Results of this experiment have shown that the biochar obtained is characterized by good chemical and physical characteristics for an agronomic use or an energetic use, regarding on this last aspect it is important to underline that the lower heating value and carbon content are similar to lignite's values and it means that biochar can be used, as a coal, in thermo-chemical processes to energy production.

Regarding on use as fertilizer it is important to highlight that this biochar has good impact on soil characteristics with an increase of soil's water retention capacity and a reduction of soil acidity in consequence of the alkaline pH value. In addition the agronomic use tests of biochar have shown absence of negative impact on crops growth. With other specific analysis it will be possible to have the determination of additional characteristics necessary for the insert of biochar in the list of soil amendant for an agricultural use, as required by Italian regulation.

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