COMMERCIAL PROCESS FOR LOW COST PRODUCTION OF CHARCOAL, ACTIVATED CARBON, BIO-HYDROGEN, FROM LOW VALUE BIOMASS

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ABSTRACT: An integrated commercial process to exploit low-value biomass is described. This project, developed connecting different commercial technologies, allows to produce charcoal, activated carbon and syn-gas or hydrogen at very attractive prices. The process consists of the following steps: biomass resources of any type, in different sizes and up to 40% humidity are mechanically dried and compacted simultaneously with very low-energy consumption, pellets are carbonised to get a high mechanical resistance charcoal which can be used as such to produce heat, charcoal is processed to a low-cost activated carbon or, alternatively, synthesis gas or hydrogen. From the results of laboratory-scale experiments, a preliminary assessment of the entire process demonstrates that it is possible to produce charcoal at 200 $/t, activated carbon at 600 $/t and hydrogen at 1.150 $/
Keywords: biomass conversion, activated carbon, hydrogen

1 INTRODUCTION

Every country world wide has a large amount of low quality, low value, humid (~50% water content) agro-forestry residues; most of that do not find a practical economic utilisation and a market. In the E.U. countries the agricultural residues alone are esteemed to account to ~1 billion ton/year (world wide perhaps ~10 billion ton/year). Furthermore most of the countries have marginal lands or surplus agricultural land for growing herbaceous crops.

To obtain energy from these materials is difficult and expensive, but recently the integration and development of several new, efficient, low pollution technologies have confirmed the techno-economics viability of a new concept to produce charcoal.

Charcoal can be used as such to produce energy (heat), but can be the basis to produce synthesis gas or hydrogen by gasification or steam reforming. Activated carbon production can be interesting, mainly for developing countries for purification process and in particular to obtain drinking water.

In this paper a new process for the conversion of fresh agro-forestry residues and herbaceous crops is reported.; it is constituted of an integrated chain of 3 steps in which:

– biomass resources of any type and in different sizes and up to 40% humidity will be mechanically dried and compacted simultaneously with very low-energy consumption (50 $kW_e/ton_{pellets}$) obtaining pellets with a specific density 1.4 - 1.8 g/cm^3 and 16% humidity content
– pellets will be carbonised to get a high mechanical resistance charcoal
– all different types of charcoal pellets will be submitted to steam-reforming processing to produce activated carbon or bio-hydrogen, depending on the specific thermal process utilised.

This new process appears economically sustainable because of:

– the wide spectrum of the types of utilisable biomass (residues, waste, energy crops, etc.).
– the proposed new efficient charcoal pellets production directly from any kind of wet agro-forestry residues and/or energy crops.
– the attractive cost for the charcoal steam-reforming process to produce activated carbon or bio-hydrogen

2 THE PLANT

The integrated plant is constituted of three facilities:

– pelletisation unit
– carbonisation kiln
– activation / steam reforming unit

The fig. 1 shows the scheme of the whole plant.

2.1 Pelletisation

Crops or mixtures up to 40% humidity is reduced by a refining mill to sawdust. The material is fed to the pelletising unit provided with an adjustable length pellet cutting device (length ~ 100 mm max). A pneumatic extraction system conveys the pellets to storage.

2.2 Carbonisation

The carbonisation of pellets is performed, at about 600°C in the section consisting in four sections:

– a feeding device of pellets in inert gas atmosphere,
– a carbonisation rotary kiln,
– a separator of char from gases and pyrolysis vapours,
– an ecological furnace connected to the kiln.

The kiln is constituted of:

– A rotary part formed by a cylindrical internally insulated mantle and a internal concentric steel tube. The mantle and the tube are solidly connected. The mantle supports a sequence of radial steel fins.
– Two fixed parts at the ends of the rotary ones, for the charge and discharge of solid and gaseous products.

The biomass is continuously introduced in the carbonisation kiln, running outside the internal concentric tube, and goes through sections at rising temperature. Inside the tube the fumes at high temperature, coming to the furnace, flow counter current. So the temperature of biomass rises approximately up to 600 °C.

The heat required for the carbonisation process is obtained burning the gases and the pyrolysis vapours in the above mentioned ecological furnace. In this way the process is energy independent, except in the starting phase when the use of an external combustible is necessary. The fumes leaving the kiln are sent to the stack.

The charcoal leaving the separator is transferred by suitable Archimede screws into a stocking silo.

2.3 Activation

The activation of the charcoal is performed in a very similar apparatus.

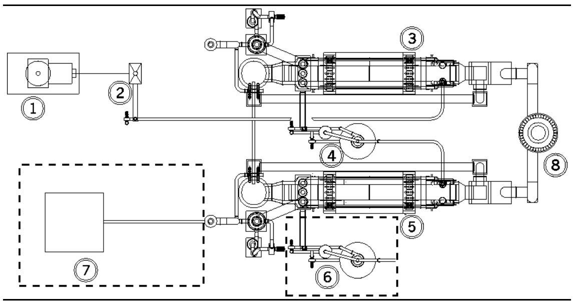
The solid product (charcoal) flows on the external surface of the concentrical pipe and over the wings which are at increasing temperature because in the internal part of the pipe there is a continuous countercurrent flow of flue gases at high temperature.

The necessary heat for the system is obtained burning about 90% of the stream of the vapours generated from the reacting charcoal.

The charcoal is heated progressively at 850 - 900°C in the presence of a thermostructurant agent as steam and/or CO_2, etc. In this phase a porous structure is developed and the surface area increased up to 1500 m^2/g.

The separation of the products, the activated carbon and the gases, occurs outside the kiln in a suitable separator and the raw activated carbon is transferred by a pneumatic system to a stocking silo.

The quality of the activated carbons is a function of the operative process specifications concerning: the temperature profile inside the kiln, the residence time of the charcoal in the reaction zone, the quality and the concentration of the thermostructurant agent (water, carbon dioxide, both, others). Each activated carbon for general purposes or for specific applications will be produced according to some defined operative specification. It will be constantly controlled for quality and application properties



1 ROTATING MOLDS PELLETIZING PRESS
2 PELLET SILO
3 CARBONISATION ROTATING KILN
4 CHARCOAL SILO
5 ACTIVATION / GASIFICATION ROTATING KILN
6 ACTIVATED CARBON SILO
7 SHIFT CONVERSION UNIT
8 STACK

Fig.1 Scheme of the plant

2.4 Hydrogen production

Hydrogen is produced by the shift reaction of the syn—gas produced by gasification of the charcoal with steam

The production of syn-gas is performed in a plant very alike to the activation one.

The full gasification of the charcoal is obtained increasing the reaction temperature up to about 1000°C and increasing the residence time by adjusting the kiln rotation rate.

To obtaining hydrogen the syn-gas is subjected to a shift conversion process in a conventional plant.

3 LABORATORY SCALE EXPERIMENTAL RESULTS

The whole process was tested at laboratory scale.

Pellets of sorghum bagasse, 10% humidity were carbonised at 600°C.

Charcoal was processed at different temperatures and residence times to obtain activated carbon or syn gas.

The syn-gas, constituted mainly of carbon oxide and hydrogen was submitted to the shift reaction in the presence of a LTS catalyst.

Hydrogen was purified by laboratory tecniques.

Yields were: Charcoal 33.4%, Activated carbon 20.5%, Hydrogen 6.3%

Table 1 reports the characteristics of the sorghum pellets.

Moisture	%wt	10.0
Ash (m.f.)	%wt	6.1
Analysis (m.a.f.)		
C	%wt	47.3
H	%wt	5.7
N	%wt	1.0
O	%wt	46.0
HHV	MJ/kg	15.1

Tab.1 Sorghum pellets analysis

Tables 2, 3, 4 show the characteristics of products, charcoal, activated carbon and hydrogen.

Ash	%wt	18.3
Analysis (m.a.f.)		
C	%wt	86.4
H	%wt	2.9
N	%wt	1.2
O	%wt	9.5
HHV	MJ/kg	26.0

Tab.2 Charcoal analysis

Ash	%wt	29.6
Analysis (m.a.f.)		
C	%wt	86.1
H	%wt	3.0
N	%wt	0.5
O	%wt	10.4
HHV	MJ/kg	22.2

Tab.3 Activated carbon analysis

H_2	%wt	99.995
$CO + CO_2$	ppm	< 1
CH_4 (THC)	ppm	< 0.5
O_2	ppm	< 2
N_2	ppm	4

Tab.4 Hydrogen analysis

4 ECONOMIC ANALYSIS

Tables 5, 6, 7 reports the economic analysis of the industrial process based on the results of preliminary trials carried out by the University of Sassari

Input (Sorghum bagasse. H_2O 30%)	t/y	45,000
Output (Charcoal)	t/y	11,690
Total investment	k$	3,946
Yearly cost of production	k$/y	2,394
Sales	k$/y	3,023
Charcoal price 259 $/t		
Yearly gross profit	k$/y	629
Net profit (Taxation 45%)	k$/y	346
Pay-out time	Years	5.3
Absolute profitability	%	18.8
Charcoal production cost	$/t	200

Tab 5 Charcoal production economic analysis

Input (Sorghum bagasse. H_2O 30%)	t/y	45,000
Output (Activated carbon)	t/y	7,200
Total investment	k$	8,860
Yearly cost of production	k$/y	4,198
Sales	k$/y	6,698
Activated carbon price 930 $/t		
Yearly gross profit	k$/y	2,500
Net profit (Taxation 45%)	k$/y	1,375
Spendable profit	k$/y	2,261
Pay-out time	Years	3.9
Absolute profitability	%	25.5
Activated carbon production cost	$/t	580

Tab.6 Activated carbon production economic analysis

Input (Sorghum bagasse. H_2O 30%)	t/y	45,000
Output (Hydrogen)	t/y	2,200
Total investment	k$	7,200
Yearly cost of production	k$/y	3,430
Sales	k$/y	4,400
Hydrogen price 2,000 $/t		
Yearly gross profit	k$/y	966
Net profit (Taxation 45%)	k$/y	531
Spendable profit	k$/y	1,251
Pay-out time	Years	5.7
Absolute profitability	%	17.4
Hydrogen production cost	$/t	1,150

Tab 7 Hydrogen production economic analysis

5 CONCLUSIONS

By the collaboration between University of Sassari, EUBIA, and Mont-Ele s.r.l., a new process to obtain valuable products from low quality biomass residues was developed.

This process is based on well proven technologies and can provide a competitive source of energy as charcoal, syn-gas, hydrogen, while activated carbon can be used for purification process and in particular for the water purifying.

The assessment of the various phases demonstrates that it is possible, for instance, to produce charcoal at 200$/t, activated carbon at 580 $/t and bio-hydrogen at 1,150 $/t, using a low value residue as sorghum bagasse at 25 $/t.