

Bio-charcoal production from municipal organic solid wastes

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Abstract. The economic and environmental problems of handling the increasingly huge amounts of urban and/or suburban organic municipal solid wastes MSW, from collection to end disposal, in addition to the big fluctuations in power supply and other energy form costs for the various civilian needs, is studied for Baghdad city, the ancient and glamorous capital of Iraq, and a simple control device is suggested, built and tested by carbonizing these dried organic wastes in simple environment friendly bio-reactor in order to produce low pollution potential, economical and local charcoal capsules that might be useful for heating, cooking and other municipal uses. That is in addition to the solve of solid wastes management problem which involves huge human and financial resources and causes many lethal health and environmental problems. Leftovers of different social level residential campuses were collected, classified for organic materials then dried in order to be supplied into the bio-reactor, in which it is burnt and then mixed with small amounts of sugar sucrose that is extracted from Iraqi planted sugar cane, to produce well shaped charcoal capsules. The burning process is smoke free as the closed burner's exhaust pipe is buried 1m underground hole, in order to use the subsurface soil as natural gas filter. This process has proved an excellent performance of handling about 120kg/day of classified MSW, producing about 80-100 kg of charcoal capsules, by the use of 200 l reactor volume.

1. Introduction

Municipal solid wastes (MSW) production, has become one of the major problematic issues for the relevant authorities at the developing and underdeveloped countries such Iraq, Lebanon, Egypt, India, etc., as it is significantly increasing, especially for the last few decades, with the limited technical and financial handling resources, leading to the formation of the so-called "trash cities", [10]. Kitchen wastes was determined by many studies as the main resource for these MSW, that may reach about 40-60% of the total annual amount [1, 11]. Energy resources from the other side, has an important priority for the population of these countries especially during the high fluctuations in their prices and their consequent negative impacts on the gross income. The tendency towards converting organic solid wastes to biofuel was one of the significant solutions that were adopted for decades ago, via incineration, gasification, anaerobic digestion, etc., to produce electricity or biogases that are useful for various commercial needs [2]. Carbonization process is one of the important processes to pyrolysis organic wastes and convert it to fossil coal to be used for heating or cooking or other commercial tasks [9]. The carbonization temperature is the main deterministic factor for final product's quality, and the higher the temperature (range of 500C) the better the quality as compared to temperatures of the range 300C [8]. The release of poisonous smoke is considered as the main drawback of carbonization process, and high attention and safety measures should be taken when adopting it, especially with the presence of close residential or commercial areas.



Heat transfer through the walls of carbonization system may affect the steady burning process, hence it is so important to take the required insulation measures according to the following equation [7]:

$$r_2 \ln(r_2 / r_1) = (k / h) \cdot [(T_{hot} - T_{surf}) / (T_{surf} - T_{amb})] \quad (1)$$

where:

r_1, r_2 : inner and outer radius.

k : insulation thermal conductivity.

h : heat convection coefficient.

$T_{hot}, T_{surf}, T_{amb}$: burning chamber, outer wall and ambient temperatures consequently

This paper is dedicated to study green, low cost and easily handled management tool for the organic MSW via the adoption of carbonization process in a closed system in order to produce low pollution potential bio-charcoal that can be useful for various domestic needs as an economic power source.

2. Experimental setup

Carbonizing process is achieved via the burn of organic solid wastes inside a closed chamber that is made of 200 l, steel barrel in which, two main open are made; top open that serves as pouring inlet for the wastes, and a bottom one for the release of final carbonized product to an exterior 50 l, collection pot and is controlled by a circular gate (figure 1). A central rotating mixing roller with supportive fins, is fixed with ball bearing side holders to the carbonizing chamber, to serve for disturbing and equalizing the burning process inside the chamber. Many 3cm diameter side openings (4 at least) are made on the body of chamber to fix ignition and/or aeration ports, that end with a circular one side moving gates to allow inlet air and block outlet smoke. Also, 10cm diameter class window is mounted to the chamber to be used as an observation tool. The resulted smoke is to be released via a top chimney through 15cm diameter exhaust pipe that ends 1m underground in order to use the subsurface soil as a natural bio-filter. A 1m subsurface, 60x30x30cm firmly side packed, tunnel with is made to host the outlet of that exhaust pipe in order to avoid possible clog of that pipe by the subsurface soil. Carbonization chamber is to be insulated by 2-3 cm layer of clay as a low cost insulator to avoid the loss of heat through its walls (equation 1).

3. Methodology

1. Preliminary steps:

- a. dried garden wastes (wood chips, grass, leaves, etc.) are mixed with the well classified and dried organic MSW, to rise its percentage to about 10-15% w.
- b. Mixture is compacted in order to reduce the volume as much as possible.

2. Carbonizing process:

- a. Waste mixture is poured into the carbonizing chamber (30-40 kg/batch).
- b. Ignition torch is introduced through the ignition/aeration ports. Small amount of kerosene may be added to boost the initial burning process.
- c. Mixture is regularly re-mixed via the rotating mixer in order to keep and equalize the burning process, that can be monitored through the observation windows.
- d. Air is to be regularly blew through the aeration ports in order to enhance the burning process to the degree of >400 C.
- e. Process stop after 90, 100 and 120 minutes in order to test the effect of burning time on the quality of the product. This takes place by sprinkles of water through the ignition/aeration ports.
- f. Bottom circular gate is released in order to empty the carbonizing chamber into the underneath collection pot.
- g. Repeat steps a-e in order to determine average representative results for the sake of this study.

3. Molding process:

- Carbonized black waste is well dried and crushed into powder form.
- Powder is mixed with a suitable amount of liquid raw sugar sucrose ($\sim 10\%$ w) so as to form a thick black dough (bio-charcoal).
- Black dough is mechanically rolled to the required thickness, shredded to the required charcoal capsules and left to cool down.

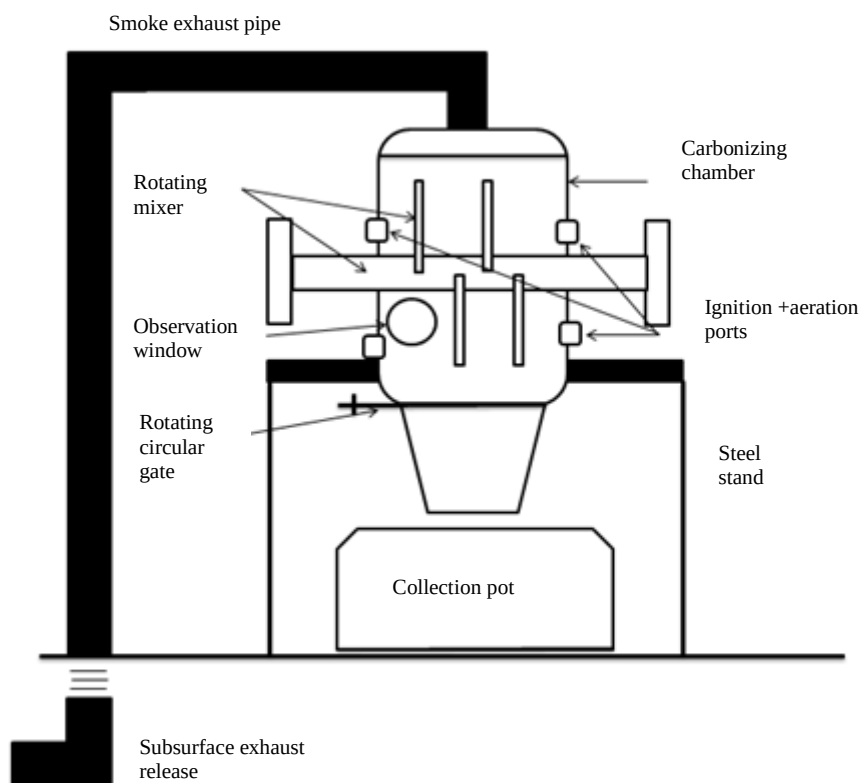


Figure 1. Schematic of the gasification system.

4. Results and discussion

MSW is collected from deliberately selected 10 residential campuses of Baghdad city, Iraq that are different from each other in the sense of educational, social and economic levels. That is to form an average representative study material for the purpose of this paper. Table 1, demonstrates the average general specifications of that MSW for a period of 3 months, with two randomly taken collecting days per week. Results show its constitution of 67% organic materials in the forms of food leftovers, paper, fabrics and gardening wastes, with discard to the hazardous potential materials such as those related to medical uses and leather. Samples of 3-4 kg of organic MSW were taken from the main trash bin of each campus to form a 30-40kg pouring batch for each operation test of the designed carbonizing system, after being well dried and compressed.

Table 1. composition and specifications of average MSW in Baghdad city.

component	Percentage %	Heat value * kj/kg
Food waste	33	4652
Paper	20	16747.2
Plastics	16	32564

Leather	3	
Fabrics	9	17445
Gardening wastes	5	6512.8
Metals	2	697.8
glass	11	139.56
Total	100	

* [6]

The charcoal quality is determined by its moisture, ash and volatile matter contents that are measured by the adoption of ASTM D1762 – 84 standard tests, while heating values and percentage fixed carbon are determined using the ASTM D1102-56, [3, 4]. Table 2, shows a summary of these characteristics for each of the charcoal batches as a result of the three tested burning times. Results suggest operating such systems for periods 100-120min., in order to meet the international standards for good quality charcoal. The moisture and volatile matter contents are highly reduced via the increase of burning time from 90 min. to 100 min. and then moderately decreased with 120 min., while ash content does not show significant decrease for the same time changes, which may be attributed to the type of its raw material and the good initial classification and compression during the preliminary preparation steps. These characteristics are well implicated with the values of fixed carbon content that represent the remainder constituent of charcoal structure where its value increases as a result of the decrease of ash and volatile materials percentages. That in turn leads to rise of the heating value (energy potential indicator) for the produced bio-charcoal as it well represented when burning process reaches 120 min. the heating value is determined to be 3.0689×10^4 kJ/kg. The reduction of moisture content of the product has a great role in increasing its heating value that makes it comparable to the best internationally reported charcoal performance [5].

Table 2. Quality characteristics of carbonization product and their international standards.*

Operation time min.	Moisture % weight		Ash % weight		Volatile material % weight		Density kg/m ³		Heating value kJ/kg		Fixed carbon % weight	
	Experimental	Standards	Experimental	Standards	Experimental	Standards	Experimental	Standards	Experimental	Standards	Experimental	Standards
90	18		4.5		50		593	NA	2.5845×10^4	2.9-3.3	26.5	
100	10	5-15	3.2		33	5-40	502		2.9523×10^4	$\times 10^4$	53.8	
120	7		3.0	0.5-5	25		443		3.0689×10^4		65	55-75

*[12]

5. Conclusions

One solution for the increasingly economic and environmental issues related to the municipal solid wastes, a simple carbonizing system was made via the use of low cost materials in order to handle the organic fraction of these wastes and produce good quality bio-charcoal that is useful for cooking, heating and other commercial activities. The system setup has taken into consideration the importance of avoiding the release of poisonous burning smoke to the surrounding atmosphere, by the burial of its exhaust pipe underground and using its soil as a natural filter without affecting the system's performance. Chemical and physical tests for the product have proved its compatibility to the internationally recorded good quality charcoal.

6. References

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