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Effect on Biodrying and Rapid Drying of Food Wastesfor Biochar Manufacturing

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Abstract

Food waste and food processing wastes which are available in plentiful amount in MSW and rich in carbon content can be attractive renewable substrates for sustainable biochar production due to wide economic prospects in industries. Many studies utilizing common food wastes such as dining hall or restaurant waste and wastes generated from food processing industries have shown good percentages of carbon composition which plays a crucial role in determining high biochar yield. Biodrying can enhance the sortability and heating value of MSW, consequently improving energy recovery where improve its combustibility and reduce potential environmental pollution during the follow-up incineration. Biodrying mechanical-biological treatment plants can produce a high quality solid recovered fuel, high in biomass content. Biochar can be used as a soil amendment with the added benefit of carbon sequestration. Furthermore, excess process heat generated in the pyrolysis process can be harvested for other uses. Biochar is a relatively stable carbonaceous material converted from organic waste. Currently more and more attention and efforts are being given worldwide to development of technologies of converting agricultural waste into biochar.**Keywords:** Biochar; Bio-drying; Pyrolysis; Food waste; Waste to energy

Introduction

The issue regarding the disposal of solid waste has become one of the biggest challenges of public management in Sri Lanka, in view of the serious environmental impacts generated by the "dumps". Food waste is a hot topic at the moment. Food waste management should include reduction, reuse and recycling. Reduction refers to minimize waste volume. If food scraps cannot be reduced, then reuse through the utilization of the waste by existing sources (i.e., food pantries, livestock, or animal shelters). If food scraps cannot be reused, then recycling is preferred in order to utilize the organic, nutrient, and energy value of the waste as a resource. Food losses begin on the farm even before a commodity moves to market for consumption through pre harvest losses. Farmers normally mitigate harvesting losses by using the leftover crops as fertilizer or animal feed. Additional food losses occur in storage and transport, due to insect infestation, mold, deterioration, or improper handling. Food safety regulations also divert some product from human consumption.

Food losses also occur raw commodities like fruit/vegetable are made into final food products. Food waste organics are stabilized through anaerobic digestion with the generated methane recovered as a renewable energy benefit. Bio solids are rich in nutrients and disposal for agricultural or land reclamation purposes serve as a recycling of the waste stream rather than using valuable landfill space Trucking food waste to landfills and incinerating it generates emissions. In landfills food scraps decompose quickly, producing methane, a greenhouse gas at least 21 times more potent in trapping heat in the atmosphere than carbondioxide, plus an acidic liquid residue (leach ate) that can seep into ground water. Home composting (when done properly) makes sense, but it's not always practical for all people everywhere in crowded urban settings, in high-rise buildings, in frigid weather. Using disposals complements composting. So my opinion is onsite composting, however, control of air emissions, loss of organic and nutrient components of food waste and cost invalidate incineration for food waste disposal as it fails to comply with the green initiative. Land filling should only be selected as a food waste management alternative when reuse and recycling is not possible. This is the least preferred management strategy because food waste will decompose an aerobically and readily, and the high water content will add residual leach ate requiring remediation. Landfill gas (generated through anaerobic decomposition) is comprised of approximately 45%-60% methane and 40%-60% carbon dioxide. Composting is an ecological succession of micro-organisms inherently present in the waste. The product characteristics are a function of the environmental factors, the operational parameters, and the technology that is utilized. Environmental factors that must be balanced for successful composting include the availability of nutrients, the proper carbon to available nitrogen ratio.

Food waste consists of 47-48 of carbon percentage [1,2]. Producing biochar will be an option for the food waste management. For that we have to answer two main questions. First, what will that biochar be used for? The final application to a soil (biochar effects vary strongly for different soil types) is only one of many uses and different uses require different qualities. Second, where will the biochar be used? Financial transportation costs might not always be an issue; but, to strengthen local and regional cycles (material, energy, money) the biomass should come from not too far away. So it would be best to examine the area where biochar could be of use and to look for biomass available in abundance and then to use that.

Discussion

Biochar is a byproduct of the pyrolysis process. It is analogous to charcoal manufactured through traditional or modern pyrolysis methods and to black C found naturally in fire-prone ecosystems. Biochar is a solid material obtained from the carbonization of biomass. Biochar may be added to soils with the intention to improve soil functions and to reduce emissions from biomass that would otherwise naturally degrade to greenhouse gases. Biochar also has appreciable carbon sequestration value. These properties are measurable and verifiable in a characterization scheme, or in a carbon emission offset protocol. The ancient method for producing biochar as a soil additive was the "pit" or "trench" method, which created terra preta, or dark soil. While this method is still a potential to produce biochar in rural areas, it does not allow the harvest of either the bio-oil or syngas, and releases a large amount of CO2, black carbon, and other Green House Gases into the air (Wikipedia 2010). Biochar production processes can utilize most urban, agricultural or forestry biomass residues, including wood chips, corn stover, rice or peanut hulls, tree bark, paper mill sludge, animal manure, and recycled organics, for instance [3].

Modern method of biochar production is sought in pyrolysis. This is done on either small or large scale. Small-scale biochar production technologies are replacing the old fashioned way of making biochar. This small scale production allows subsistence farmers to produce small quantities of biochar usable for their farms or garden. Pyrolysis is a form of incineration that chemically decomposes organic materials by heat in the absence of oxygen. Pyrolysis typically occurs under pressure and at operating temperatures above 430 °C (800 °F) (Wikipedia, 2010).

Pyrolysis is the chemical breakdown of a substance under extremely high temperatures in absence of oxygen. The quantity and quality of biochar production depends on the feedstock, pyrolysis temperature, and pyrolysis processing time. A "fast" pyrolysis (~500 °C) produces biochar in a matter of seconds, while a "slow" pyrolysis produces considerably more biochar but in a matter of hours. The yield of products from pyrolysis varies heavily with temperature. The lower the temperature, the more char is created per unit biomass. High temperature pyrolysis is also known as gasification, and produces primarily syngas from the biomass [4]. The two main methods of pyrolysis are "fast" pyrolysis and "slow" pyrolysis. Fast pyrolysis yields 60% bio-oil, 20% biochar, and 20% syngas, and can be done in seconds, whereas slow pyrolysis can be optimized to produce substantially more char (~50%), but takes on the order of hours to complete. For typical inputs, the energy required to run a "fast" pyrolysis is approximately 15% of the energy that it outputs [5]. Modern pyrolysis plants can be run entirely off of the syngas created by the pyrolysis process and thus output 3-9 times the amount of energy required to run. Alternatively, microwave technology has recently been used to efficiently convert organic matter to biochar on an industrial scale, producing ~50% char.

The three main outputs of a biochar production system are syngas, bio-oil, and biochar. The biochar production system is operated using energy produced by the system. Biochar production via pyrolysis is considered a carbon-negative process because the biochar sequesters carbon while simultaneously enhancing the fertility of the soil on which the feedstock used to produce the bio energy grows.

Utilization of food waste to produce bioenergy is gaining momentum owing to the looming shortage of food worldwide. Again, a large amount of food goes to waste everyday across the world. According to UN Food and Agriculture Organization (FAO), 1.3 billion tons of food is wasted every year. This underutilized resource could be a potential energy source provided that economically viable technologies are available. Food waste, which comprises mainly of starch, protein, and fat with a small fraction of cellulose and hemi-cellulose, constitutes a possible source for bio energy production [6].

Paralysis of biomass, in its broad meaning, is a term given to the process in which heat is applied, under oxygen-free or oxygen-limiting atmosphere, to decompose or convert biomass. During the pyrolysis process, the natural complex and polymeric constituents of the biomass (i.e. lignin, cellulose, fats and starches) are thermally broken down into three different fractions: bio-oil (condensed vapors), char (solid fraction), and non-condensable gases [7]. The char is a highly carbonaceous material; if the char is intended to be used in applications where the carbon is not rapidly remineralized (i.e. combusted as a fuel or in metallurgical processes), but retained in its stable form as a means of carbon sequestration, then the term biochar applies.

Depending on the biomass feedstock as well as the process conditions applied in pyrolysis, which include the temperature and the heating rate, different distributions and yields of the pyrolysis product fractions (i.e. gas, bio-oil and char) can be obtained [8,9]. Usually, classification of paralysis processes is according to the heating rate applied to the biomass particle in order to reach the intended paralysis temperature. As such, distinction can be made between fast and slow paralysis (Table 1). In fast paralysis, process conditions (i.e. high heating rates,

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low vapor residence times) are selected to maximize the yield of the bio-oil fraction, which may serve as a crude, liquid fuel or be further upgraded into drop-in biofuels or for the production of renewable chemicals.

Table 1: Typical reaction conditions and product yields in wt%, including char, obtained from different types of (dry) thermo chemical conversion processes. Data based on.

	Thermo Chemical Conversion Process Type			
	Fast Pyrolysis	**Slow Pyrolysis**	**Gasification**	**Torre Faction**
Temperature	~ 500 °C	>400 °C	600-1800 °C	<300 °C
Heating rate	Fast, up 1000 °C/min	<80 °C/min		
Reaction time	Few seconds	Hours ~days-		<2h
Pressure	Atmospheric and (vacuum)	Atmospheric or (elevated up to 1MPa)	Atmospheric, pressurized up to 8MPa	Atmospheric
Medium	Oxygen-free	Oxygen-free/ oxygen-limited	Oxygen- limited (air or steam/oxygen)	Oxygen-free
Liquids (bio-oil)	75%	30%	5%	5%
Non- condensable	13%	35%	85%	15%
Char/solids	12%	35%	10%	80%

Slow pyrolysis is characterized by lower heating rates which result in maximum yields in solid product or biochar. The terms "slow pyralysis" and "carbonization" are often used interchangeably, however slow pyrolysis can be considered a broader term, which covers both carbonization (i.e. pyralysis of biomass into highly carbonaceous, charcoal-like material) as well as torrefaction (i.e. a low temperature paralysis process that serves as a pretreatment process) [10].

As already detailed in Table 1 selecting the prevailing process conditions (temperature, heating rate, and type of atmosphere) allows for the differentiation into fast pyrolysis, slow pyrolysis and gasification. Each process type results in different yields of the char fraction and could be ranked, in descending order of char yield as: slow pyrolysis >fast pyrolysis >gasification. Torre faction is excluded from this list, as its resulting solid product does not meet the criteria for a stable biochar (H/Corg >0.7). Slow pyrolysis can be considered the process of choice for biochar production, as the char itself is considered the primary product and consequently, the choice of process conditions (with respect to the quality of the resulting biochar) is less constrained by the optimization towards bio-oil quantity and quality (in case of fast pyrolysis) or syngas quantity (in case of gasification).

Biochar can be an important tool to increase food security and cropland diversity in areas with severely depleted soils, scarce organic resources, and inadequate water and chemical fertilizer supplies. Also improves water quality and quantity by increasing soil retention of nutrients and agrochemicals for plant and crop utilization. More nutrients stay in the soil instead of leaching into groundwater and causing pollution. Biochar and bioenergy co-production can help combat global climate change by displacing fossil fuel use and by sequestering carbon instable soil carbon pools. It may also reduce emissions of nitrous oxide According to latest findings one could regard Biochar as a way to increase the nutrient holding capacity of any soil but this is depending on several factors like soil pH, parent soil characteristics, climate and farming practices/ cultivation techniques. In this sense Biochar has to be regarded as a soil amendment rather than a fertilizer since it does not release nutrients fast enough to supply commercial crops. Indeed the very idea of Biochar applications is to increase the organic carbon content of a soil long term with this highly recalcitrant form of organic matter. Estimations range from several hundred to several thousand years of residence time in the soil. There are several techniques to produce biochar from waste materials; the only consideration I feel would be prerequisite would be the amount of carbon that is initially present in your wastes. Carbonaceous materials are usually subjected to pyrolysis (slow or fast) in vacuum to produce residual pure carbon (biochar).

Biodrying is the process by which biodegradable waste is rapidly heated through initial stages of composting to remove moisture from a waste stream and hence reduce its overall weight [11] Biodrying technology is regarded as a good solution to remove water from wet MSW and it is expected to constrain organics degradation, preserving energy for subsequent utilization, such as residues-derived fuels [12]. But also, this will accompanied by aqueous secondary pollutants. The high water content will reduce the efficiency of its energy recovery and the feasibility of mechanical separation for beneficial utilization. The bio-drying technology, aiming at removing water with the help of microbial activities, is regarded as a good solution to reduce water content of MSW [12].

Biodrying (biological drying) is an option for the bioconversion reactor in mechanical- biological treatment (MBT) plants, a significant alternative for treating residual municipal solid waste (MSW). Waste treatment plants defined as MBT integrate mechanical processing, such as size reduction and air classification, with bioconversion reactors, such as composting or anaerobic digestion. During these composting process bacteria, actinomycetes, fungi, molds, and yeast oxidize long and short chain fatty acids, paper products, other pollutants and produce heat leading to an reduction of waste due to microbial conversion and water evaporation [13].

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Composting aims for the maximal conversion of organic material. Therefore, water is added to the process when the organic matrix reaches certain dryness in order to preserve moisture for optimal microbial activity and hence maximal organic conversion. As a consequence, long residence times of circa 50 days are required, which is less practical for large quantities of sludge. Composting has significant uncertainties since it is increasing the dry solid content due the water evaporation by biologically produced heat, while decreasing the caloric value of mixed sludge to values, which are critical for an economically attractive combustion [14].

Biodrying is designed to remove water, while composting focuses on bio-stabilization of materials where biodrying process is used aeration mainly for water evaporation, as well as oxygen supply; the requisite airflow amount is usually higher than that of the composting process. Therefore, forced ventilation is usually used for biodrying owing to its powerful aeration capacity and ventilation mode is critical for biodrying.

Other techniques such as thermal drying or direct combustion do not rely on microbial produced heat. Instead external energy needs to be supplied to evaporate water leading to high costs. A new technology, which is based on a similar process as composting, is the biodrying concept. The eventual goal of this concept is different from the conventional composting process and does not aim towards a complete mineralization of the waste [15].

Instead the metabolic heat is used to remove water from the waste matrix at the lowest possible residence time and minimal biodegradation hence preserving most of the gross calorific value of the waste matrix. During this process the organic matrix is both: substrate for microorganisms (which produce heat for drying) and the end product. The end product (fuel/granules) contains a high energy value and can be used as a replacement of coal and for thermal energy generation. This principle has been described for municipal waste and is often referred to as mechanical biological treatment (MBT) [16,17].

The effects of bio-drying and waste particle size on heating values, acid gas and heavy metal emission potential were investigated. The results show that, the water content of MSW decreased from 73.0% to 48.3% after bio-drying, whereas its lower heating value (LHV) increased by 157%. The heavy metal concentrations increased by around 60% due to the loss of dry materials mainly resulting from biodegradation of food residues [18].

Biodrying is a variation of aerobic decomposition, used within mechanical-biological treatment (MBT) plants to dry and partially stabilize residual municipal waste. The process of biodrying could be a good solution for municipal solid waste management. Within the biodrying reactors, waste is dried by air convection, the necessary heat provided by exothermic decomposition of the readily decomposable waste fraction. Biodrying is distinct from composting in attempting to dry and preserve most of biomass content of the waste matrix, rather than fully stabilize it. These biodried food waste MSW can be used to biochar production with effective and efficient way.

The objective of biochar production systems should not be to enhance soil nutrient status and improve land productivity with biochar additions, but instead to use the renewable and abundant food waste that is annually produced through MSW to generate biofuels, reduce environmental pollutant risk, and improve land health. Fast-pyrolysis system offers a solution to biomass accumulation in ecosystems, and may improve the economic and environmental impact of biomass utilization for crop production and soil health while additional impacts on greenhouse gas balance (Table 2).

Table 2

	Bio Drying
Maximal temperature (°C)	70
Minimal temperature (°C) (>3days)	55
Humidity (%)	Not significant
Oxygen (% v/v)	>10%
Specific weight (t/m3)	<0.7

Potential Disadvantages of Biochar

Recognizing that biochar technology is in its early stages of development, there are many concerns about the applicability of the technology in the United States. Three issues paramount to technology adoption are feedstock availability, biochar handling, and biochar system deployment. Successful implementation of biochar technology is rooted in the ability of the agricultural community to afford and operate a system that is complementary to current farming practices.

Feed stock availability

The availability of a plentiful feed supply for biochar production is an area for further study. To date, feedstock for biochar has consisted of mostly plant and crop residues, a primary domain of the agricultural community. There may be a role for the forestry community to be involved as woody biomass is deemed a cost-effective, readily available, feasible feedstock. Little is known about the advantages of using manure as a biomass feedstock. Some researchers have stated that manure-based biochar "has advantages over typically used plant- derived material because it is a by-product of another industry and in some regions is considered a waste material with little or no value. It can therefore provide a lower cost base and alleviate sustainability concerns related to using purpose-grown biomass for the process. [19].

Biochar handling

The spreading of biochar onto soil as a fertilizer is ripe for further exploration. Specifically, the ideal time to apply biochar and ensure that it remains in place once applied and does not cause a risk to human health or degrade air quality are concerns

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[20]. Particulate matter, in the form of dust that is hard for the human body to filter, may be distributed in abnormal quantities if the biochar is mishandled. Additionally, there are potential public safety concerns for the handling of biochar as it is a flammable substance.

Biochar system development

Biochar systems are designed based on the feedstock to be decomposed and the energy needs of an operation. It would be ambitious to expect a "one size fits all" standard biochar system. According to proponents, a series of mass-produced biochar systems designed for the needs of a segment of the agriculture or forestry communities might prove to be feasible (e.g., forestry community in the southeastern region, corn grower community in the mid western region, poultry producer community in the mid-Atlantic region). Extensive deployment of biochar systems would be dependent upon system costs, operation time, collaboration with utility providers for the sale of bio-oil, and availability of information about technology reliability.

Conclusion

It has been reported that the waste utilization is the most economical process for renewable energy production (biogas and hydrogen/biohydrogen) and to clean the environment [21]. Thus, it is suggested that enhanced biochar production from food waste and food processing waste can be achieved using controlled conditions as elaborated in this review. On another perspective, biodrying food waste in early stage of for biochar production has the potential to create an impact on the saving energy by reducing MC of food waste [22-28].

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