BIOCHAR RETORT KILN

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ABSTRACT

Systems and methods for a biochar retort kiln are disclosed herein. A method for making biochar includes placing waste biomass in a cylindrical retort chamber. The retort chamber extends outwardly at a first end and a second end from a fire box. Pyrolysis is fueled by igniting the waste biomass. Syn-gasses are evacuated through one or more holes defined by the cylindrical retort chamber, such that the syngasses are driven out of the biomass and out of the retort chamber to be consumed by a fire in the firebox. The byproduct of the described method is biochar.
FIGURE 8. Green Waste Recycling System

- Pyrolysis fuel source
- Biochar
- Biochar/compost blend
- Char material (woody green waste)
- Compostable material (leafy green waste)
- Master composting
- Waste biomass
- To field
- To market
BIOCHAR RETORT KILN

CROSS REFERENCES TO RELATED APPLICATIONS

[0001] This application claims priority to and the benefit of the filing date of U.S. Provisional Patent Application No. 61/304,272 filed Feb. 12, 2010, which is hereby incorporated by reference in its entirety.

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BACKGROUND OF THE INVENTION

[0003] Biochar is known as charcoal when it is used as a soil amendment. The biochar movement began with the recent discovery of Terra Preta (black earth) in the Amazon region. Terra Preta is an anthropogenic soil that is extremely fertile and durable, with biochar being its key ingredient. Soil scientists have undertaken numerous studies to learn what makes Terra Preta exceptional and much of the inquiry has, naturally, focused on biochar. They focused on the function of charcoal in soil ecology, how charcoal varies in make-up, how it changes over long periods of time, and also how it was made. The general conclusion is that Terra Preta is the product of an astute cultural practice of waste management and soil cultivation by many generations of people. Terra Preta was made over a long period of time on a village scale, using an on-going process of slash-and-char burning to convert all of a community’s waste materials into charcoal and compost which were then put back into the surrounding earth, building fertile soil. Modern biochar production methods must reflect this model of sustainability and incorporate enlightened perspectives on recycling, waste management, conservation, low energy use, and local economy.

[0004] Leaders of the Biochar Movement envision that biochar will have enormous positive impact on local and global sustainability in three ways: A. waste management; B. soil improvement; and C. mitigation of climate change. Waste biomass can be converted into biochar, thus solving the problems of “disposing” of organic waste (i.e. burning it or putting it in a landfill). Biochar can be added to soil to create dynamic, fertile soil that is clean, healthy and very productive and which does not require expensive chemical fertilizers. Further, carbon in the form of biochar is stable over a long period of time. This makes it a viable carbon storage which in quantity can offset total atmospheric carbon levels and reduce the greenhouse effect due to high carbon dioxide and methane gas levels. Some further argue that biochar can be converted into biofuels as well as biochar and that this represents a fourth area of biochar’s potential.

[0005] Pyrolysis. Fire is the miracle that gives us biochar. Pyrolysis is the process in which wood or other organic matter is heated in the absence of oxygen to produce charcoal. At high temperatures, wood decomposes. Beginning at about 300°C, volatile gasses and liquids are driven out of the cell structure of the biomass, leaving char. When the temperature is high enough, or the duration long enough, the decomposition is complete and only charcoal and ash remain. The gasses driven out of the cell structure (usually called synthesis gases) typically consist of hydrogen and carbon monoxide. These are generally flammable and a valuable source of energy.

[0006] It is believed that fabrication of charcoal is the oldest human industry. Ancient methods of charcoal production vary, but they all involved beginning to burn wood or other biomass to create sufficient heat and then cutting off the air so that combustion ceases and the heat converts the remaining fuel to charcoal. One technique was an improvement on another if it used less of the energy stored in the fuel source for the burning stage and left a greater proportion of that stored energy in the form of charcoal. This is the intrinsic trade-off confronting any system or apparatus designed to produce charcoal. One can observe increasing efficiency of charcoal production technology over time beginning with earthen mounds and pit kilns. Later, colliers built kilns, large and small, out of bricks or steel and these were in use for many centuries. More recent innovations are retorts, fluid-bed pyrolysis reactors, and gasifiers. In addition to being more efficient, these modern technologies are also safer to operate and pollute less than older ones. Still, even in modern times, charcoal production requires significant energy input.

[0007] The energy/biochar trade-off takes on even more meaning today. Waste biomass is abundant worldwide. It comes from wood industries and forest management, and from municipal and agricultural green waste. Increasingly, developers are turning to this important renewable resource for energy. Modern biomass reactors and gasifiers are sophisticated processing facilities which are designed to release the energy stored in the material and convert it to fuel. Char is often a byproduct of the process. It is accurate to say, though, that gasifiers which are designed to produce energy do so at the expense of the quantity (and often the quality) of the char byproduct. Changes in the gasification process can be made to produce more char at the expense of biofuel output, but this is contrary to their purpose.

[0008] While there are numerous similar inventions which comprise a retort chamber placed within a furnace or firebox into which waste biomass is placed for pyrolysis to make charcoal, none of these approaches, as defined in their own descriptions, is designed to produce biochar. A handful are designed to produce charcoal from waste biomass. Many are designed to produce biofuel from biomass, while others are, at best, designed to produce biofuel with char as a byproduct. One significant disadvantage of every one of these prior approaches is the complexity of their mechanization and the necessarily high costs of construction and operation that follow from that complexity. These are large-scale operations intended to run continuously and to process large volumes of material. The prior approaches all comprise moving parts to initiate and sustain pyrolysis and to deliver char material. Their design is to mechanize all steps of the process and to limit or eliminate human involvement in operation. None of the prior approaches provides for the synthesis gasses to pass from the retort chamber and enter the furnace fire directly to burn as additional fuel source. The prior art does comprise indirect measure (i.e., tubes or valves) for this purpose. The others direct syngasses away for use as biofuel product. To build and operate any of the prior approaches requires a great deal of capital investment as well as special expertise and
sophisticated fabrication. In none of the prior approaches is there explicit provision for the exclusive use of waste biomass to fuel the pyrolysis process and thereby eliminate the need for additional fuel source.

BRIEF DESCRIPTION OF THE DRAWINGS

[0009] Preferred and alternative examples of the present invention are described in detail below with reference to the following drawings:
[0010] FIG. 1 is a firebox, according to an embodiment of the present invention;
[0011] FIG. 2 is a cylindrical retort chamber placed in the firebox, according to an embodiment of the present invention;
[0012] FIG. 3 is a cross-sectional view of the placement of the retort cylinder inside the firebox, according to an embodiment of the present invention;
[0013] FIG. 4 is a three dimensional view of the ceiling baffle, chimney and location of thermocouple, according to an embodiment of the present invention;
[0014] FIG. 5 is an outside view of the firebox, according to an embodiment of the present invention;
[0015] FIG. 6 shows a method for drying and preheating biomass prior to loading into retort chamber, according to an embodiment of the present invention;
[0016] FIG. 7 is one possible large scale embodiment;
[0017] FIG. 8 is a schematic representation of a green waste recycling system, according to an embodiment of the present invention; and,
[0018] FIG. 9 shows a unit placed on a light duty flatbed truck, according to an embodiment of the present invention.

DETALLED DESCRIPTION OF THE PREFERRED EMBODIMENT

[0019] In the following description, certain specific details are set forth in order to provide a thorough understanding of various embodiments of the invention. However, one skilled in the art will understand that the invention may be practiced without these details or with various combinations of these details. In other instances, well-known systems and methods associated with, but not necessarily limited to, biochar retort kilns, charcoal retorts and methods for operating the same may not be shown or described in detail to avoid unnecessarily obscuring descriptions of the embodiments of the invention.

[0020] The charcoal retort is an elementary apparatus for producing charcoal. It is a heated chamber deprived of oxygen in which biomass is pyrolyzed. There are many dozens of variations on this concept, differing as to methods for providing the heat to the retort chamber, the means for loading and unloading the biomass, fabrication materials, scale, complexity, etc. In general, these all use an external fuel source, such as natural gas or electricity to heat the retort chamber. They employ some sort of mechanized delivery system for placing biomass into the retort chamber, such as a metal auger or conveyor. They also, as a rule, comprise apparatus for containing and directing the flow of syntheses for outside purpose. Further, they tend to be costly, large-scale operations to which large volumes of accumulated biomass are shipped for processing.

[0021] The simplicity of the charcoal retort is likely advantageous if one is willing to consider consuming the syntheses in-process as a fuel source for the purpose of making only biochar and heat from available biomass. An embodiment of the presently disclosed invention does just that. It preferably comprises a retort chamber which is designed to direct the syntheses into the primary airflow feeding the firebox, thus becoming an additional fuel source. An alternate embodiment of the invention could comprise two or more of these retort chambers within the same firebox. The fire is mainly fueled by combustion of part of the biomass source itself and thereby requires no outside fuel source. In its simplest embodiment, the kiln has no moving parts. The materials of an embodiment of the invention are designed to maximize heat retention in the firebox and heat transfer to the inner retort chamber. Heat from the firebox may additionally be used to dry and preheat incoming biomass. The kiln is designed to produce only biochar and heat.

[0022] It is the small-scale, local, affordable biochar production that drives the design of the invention. Biochar production must be developed in accordance with modern values of sustainability and with regard to the as yet limited inherent market value of biochar itself (i.e. compared to biofuels, especially before a legislative establishment of a standardized carbon offset credit). An affordable, small-scale retort kiln which may be easily integrated on a working farm, in a village or local municipality, on a campus, or a working vineyard, orchard, or sawmill, to process a stream of waste biomass into biochar following a method which is safe, economical, and environmentally responsible. Thereby bringing biochar to all communities all over the world.

[0023] An embodiment of the invention presently disclosed is a Biochar Retort Kiln designed for pyrolysis of waste biomass to produce biochar (charcoal used as a soil amendment). The Biochar Retort Kiln is a device, and also a system of which the device is the feature tool, the system preferably being intended to sort, dry, and pyrolyze waste biomass, using the biomass itself as fuel source as well as material forcharring.

[0024] The kiln is an elementary tool for producing biochar from available waste biomass on location. Its use provides an alternative to disposal of green waste by burning or hauling and dumping. The kiln burns part of a quantity of waste biomass in order to pyrolyze, or char, the remaining quantity. The char produced has value as a soil amendment and for carbon storage. The kiln is designed to be easy, safe, and economical to operate. Its incorporation into existing systems of operation of a farm, village, or campus is straightforward and lasting.

[0025] An embodiment of the invention is a simple, small scale, serial batch retort kiln for the purpose of pyrolyzing waste biomass to produce biochar, with heat as a valuable byproduct. The invention comprises a firebox through which passes a cylindrical retort chamber. The fire in the firebox directly heats the retort chamber. Biomass is placed inside the retort chamber wherein it is subjected to temperatures reaching 750°C. In the absence of oxygen for enough time to be fully pyrolyzed and turned into biochar. The synthesis gasses which are driven out of the biomass during pyrolysis exit the retort chamber and are directly burned in the firebox, further fueling pyrolysis. When the kiln is operated at optimal temperature in an embodiment (500°C-750°C) and air flow the combustion of fuels and syntheses is complete, and clean CO2 and O2 exit the chimney atop the firebox.

[0026] FIG. 1 shows the firebox, in an embodiment, with air ducts in the bottom (1A) and back wall (1D) of the box. Both the outside (1C) and inside (1D) of the box are made from specialized ceramic fiberboard. The air ducts (1A, B) are
made from 4" (1/8" thick) steel square tube. The four walls and floor of the kiln body are made from 2 layers of specialized ceramic fiberboard insulation (see FIG. 1). The outer layer (IC) is designed to provide structural integrity, the inner layer (ID) to provide durability, and both to insulate the fire to conserve heat energy. In its simplest embodiment, the kiln is a cube measuring four feet per side, this dimension deriving from the manufactured size of the fiberboard panels. Other embodiments could be made smaller or larger. Built into the floor and back wall of the kiln body are ventilation ducts (1A, 1B) which supply the primary air to the firebox. The primary air is heated as it passes through the ducts; this improves combustion efficiency.

**FIG. 2** shows the cylindrical retort chamber (2A) placed in the firebox (2B), according to an embodiment of the present invention. The retort cylinder is 18" in diameter and is made from 316 stainless steel. In some embodiments, each end of the cylinder in fact extends 4" outside of box. There is a row of 1" holes (2C) drilled through the cylinder wall. The cylinder is placed in the firebox so that the row of holes faces the back wall of the firebox. This orientation ensures that the syngasses which are driven out of the biomass during pyrolysis will emerge from the retort chamber and enter the stream of primary air (1B) and be consumed in the firebox fire. In an alternate embodiment of the invention, two or more retort chambers are placed within the firebox.

**FIG. 3** is a cross-sectional view of the placement of the retort cylinder (3A) inside the firebox (3B), according to an embodiment of the present invention. It shows the primary (3C) and secondary (3D) airflow patterns and the flow of the syngasses (3E) once they are driven off of the feedstock (3F) within the retort cylinder (3A) and into the fire (3G). When combustion is complete, exhaust gasses exit chimney (3J). A thermocouple (3K, 4C) is installed to monitor temperature. FIG. 4 further shows a ceiling baffle (3H).

**FIG. 4** is a 3D view of the ceiling baffle (4A), chimney (4B) and location of thermocouple (4C), according to an embodiment of the present invention.

**FIG. 5** shows an outside view of the firebox including doorway (5A), primary air vents (5B), secondary air vents (5C), and biomass loading basket (5D) placed part way into the retort chamber (5E), according to an embodiment of the present invention. A viewing hole (5F) is provided for observation of flow of syngasses. A steel lid (SG) completes the kiln body. The front wall of the kiln has a door opening (5A), the door to which (not pictured) is made from steel and high-temperature ceramic glass and gaskets. This opening provides the means for manually loading biomass fuel into the firebox fire. A steel slab roof (5G) completes the kiln body. Onto this is mounted the chimney (3I, 43B). Manual primary air controls (5B) are located at the bottom of the front wall. Manual secondary air controls (5C) are located to each side of the door and additionally toward the rear and bottom of side walls. Cylindrical stainless steel mesh baskets (5D) containing biomass are placed manually into the retort chamber as shown. This is a preferred method of loading biomass for this simplest embodiment of the invention. Other methods will be discussed further on. A viewing hole (5F) is provided for observation of flow of syngasses.

**FIG. 6** shows a method for drying and preheating biomass prior to loading into retort chamber), according to an embodiment of the present invention. Biomass loading baskets (6A) are placed on top of the lid (6E) of the retort kiln (6B) in a lightweight steel enclosure (6C). The doors of the enclosure are removed in drawing). Ventilation holes (6D) in the roof of enclosure allow water vapor driven off of biomass to escape. Also shown is one of two air tight retort endcaps (6F).

**FIG. 7** shows one possible large scale embodiment of the invention wherein a steady stream of biomass (7A) is moved by a conveyer (7B) into a hopper (7C) which directs part of the biomass stream into the retort antechamber (7D) and part into the kiln fuel supply tube (71). A first piston (71) pushes the biomass into the retort antechamber (7D) and subsequently into the retort chamber (7E). Biochar emerges from a hinged endcap (7G). A second piston (71) pushes biomass through the fuel supply tube (71) into the kiln firebox (7K). Tuyere lines (7L) lightly draw any syngas leakage into firebox. Entire unit is housed (7M) to capture secondary heat and chimney output heat for drying and heating of biomass as it travels on the conveyor. Biochar product is quenched by a water shower (7N) as it accumulates in movable container (7P).

**FIG. 8** is a schematic representation of a green waste recycling system of which the invention is the centerpiece, according to an embodiment of the present invention.

**FIG. 9** shows a unit in place on a light duty flatbed truck (9A) and again on a small utility trailer (9B), according to an embodiment of the present invention.

**FIG. 10** Operation of kiln, according to an embodiment of the present invention: A portion of biomass is used to build a fire in the firebox. This fire is tended and stoked to bring the unit up to a temperature in the preferred range of 500°C -750°C. Manual primary and secondary air controls allow an operator to optimize airflow to the fire and maximize heat output. While the unit is being brought to operating temperature the retort baskets (5D, 5A) are pre-loaded with biomass and placed in the heating/drying enclosure. When the unit is up to operating temperature a first basket may be placed within the reto chamber. Air-tight lids (6F) are then fixed to each end of the retort chamber. The biomass within the retort chamber is now being heated and pyrolysis begins. The residence time for the biomass pyrolysis will depend on the material and its water content as well as the firebox temperature. Syngasses driven out of the biomass are observable through the viewing hole (5F). When the gasses cease to emerge the operator will know pyrolysis is complete and can then remove the reto lid (6F) and withdraw the mesh basket (6A) which now contains biochar. Immediate quenching of the biochar with water is necessary to inhibit combustion once it is exposed to oxygen. After cooling, the biochar is emptied into a container and staged. A fresh charge of biomass is put in the basket and it is placed in the enclosure (6C) to preheat and a new basket of biomass from the enclosure is placed in the retort chamber.

**FIG. 11** In its simplest embodiment the kiln has no moving parts. It is straightforward in both its construction and operation. Its concept can be modified to incorporate a variety of construction methods based on what materials and expertise are available locally. For example, the firebox could be constructed of concrete block and the retort chamber of some type of carbon steel of more structural capacity, even something salvaged. Because of its simplicity and viability the invention could have special appeal to developing parts of the world. Further, the operation of the simplest embodiment of the invention requires the direct involvement of at least two workers. It is believed that human labor will be essential to a future sustainable model for small-scale, local biochar production from available waste biomass. Each of the aforementioned prior art approaches to charcoal production, however,
involve mechanized apparatus intended to eliminate human labor from the process. This preference necessarily translates into large-scale systems which then require large volumes to operate efficiently. The large scale necessitates greater energy use as well as shipping of biomass in volumes. This requirement betrays the sustainability model intrinsic to biochar as expressed above.

[0037] The kiln, according to an embodiment of the present invention, is designed to burn waste material. Its operation is independent of any energy source and may be applied wherever there is a steady source of waste biomass that needs to be processed. The energy efficiency of the unit itself is very high by virtue of its shape, insulation, and thermal mass. Further, it is designed to burn continuously as the serial batches are processed. This represents a significant improvement over single batch retort kilns in which material is pyrolyzed by a fire which is started, burns, and burns out.

[0038] The kiln, according to an embodiment of the present invention, is versatile as it is designed so that it may be the feature tool in a processing System, such as but not limited to the one represented in FIG. 8. The process by which waste biomass is converted to biochar and compost shown in FIG. 8 is a straightforward System, applicable on any site that produces waste biomass. The System can be modified to meet the specific requirements of the site and of the nature and volume of the biomass stream. For example, the method by which the biomass is cycled through the unit may be modified to increase production capacity, this being a change to the System of which the invention is the feature tool, rather than a change to the invention itself. FIG. 7 shows one possible large scale embodiment of the System wherein a steady stream of biomass (7A) is moved by a conveyor (7B) into a hopper (7C) which directs part of the biomass stream into the retort anechamber (7D) and into the kiln fuel supply tube (7H). A first piston (7E) pushes the biomass into the retort anechamber (7D) and subsequently into the retort chamber (7F). Biochar emerges from a hinged endcap (7G). A second piston (7J) pushes biomass through the fuel supply tube (7H) into the kiln firebox (7K). Tuyere lines (7L) lightly draw any syngas leakage into the firebox. Entire unit is housed (7M) to capture secondary heat for drying and heating of biomass as it travels on the conveyor. Biochar product is quenched by a water shower (7N) as it accumulates in movable container (7P).

[0039] The kiln, according to some embodiments of the present invention, is a mobile device. FIG. 9 shows the unit in place on a light duty flatbed truck and small utility trailer. This embodiment lends itself to seasonal or other periodic biomass processing requiring movement from one location to the next. This advantage is presented in none of the prior art cited above.

[0040] While the preferred embodiment of the invention has been illustrated and described, as noted above, many changes can be made without departing from the spirit and scope of the invention.

The embodiments of the invention in which an exclusive property or privilege is claimed are defined as follows:

1. A method for making biochar comprising:
   - placing waste biomass in a cylindrical retort chamber, that extends outwardly at a first end and a second end from a fire box;
   - fueling pyrolysis by igniting the waste biomass placed in the cylindrical retort chamber such that biochar is created; and
   - evacuating syngasses through one or more holes defined by the cylindrical retort chamber, such that the syngasses are driven out of the biomass and out of the retort chamber to be consumed by a fire in the fire box.

2. A clean burning kiln apparatus comprising:
   - a firebox configured to fuel a fire using waste biomass; and a cylindrical retort chamber, sized to also contain woody biomass, extending through the fire box and terminating outside the firebox at a first and second end, the cylindrical retort chamber defines one or more holes;
   - wherein when the firebox is used to achieve pyrolysis such that biochar is made from waste biomass, syngasses are driven out of the biomass and emerge from the retort chamber and are consumed by a fire in the firebox as an additional fuel source.

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