A method and furnace for producing biochar

A method of producing biochar by pyrolysis of biomass feedstock, including invasive weeds such as Japanese knotweed, comprises the steps of heating the biomass feedstock within a furnace chamber, and sealing the furnace chamber such that gases can only exit the furnace chamber via a release outlet or to a combustion chamber. Gas from the furnace chamber is then released through the release outlet and whether the released gas is combustible is tested. When the released gas is combustible, the release outlet is sealed, and gases emitted from the furnace chamber subsequently pass to the combustion chamber where they are combusted to further heat the furnace chamber. The contents of the furnace chamber are subsequently allowed to cool.

At least one drawing originally filed was informal and the print reproduced here is taken from a later filed formal copy.
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Drying biomass feedstock

Cutting the biomass feedstock into pieces

Arranging the biomass feedstock within a furnace chamber

Inserting ducts into the biomass feedstock

Heating the furnace chamber by burning fuel within a combustion chamber

Sealing the furnace chamber

Periodically releasing gasses from the furnace chamber through a release valve and testing whether the released gasses are combustible

When the released gasses are combustible sealing the release valve and diverting gasses from the furnace chamber to the combustion chamber

Burning the gasses from the furnace chamber within the combustion chamber to heat furnace chamber until pyrolysis of the biomass feedstock is complete

Allowing the furnace chamber and the pyrolysed biomass feedstock to cool

Removing the pyrolysed biomass feedstock from the furnace chamber

Mixing the pyrolysed biomass feedstock with diluted fertiliser tonic

Crushing the mixture of pyrolysed feedstock and diluted fertiliser tonic

FIG. 1
A Method and Furnace for Producing Biochar

Field of the Invention

The present invention relates to a method of producing biochar by pyrolysis of biomass and a furnace for performing the method. More specifically the present invention relates to a method and furnace for producing biochar by pyrolysis of biomass feedstock within a furnace chamber.

Background to the Invention

Biochar is charged charcoal which is added to soil to improve its physical qualities. Biochar is commonly added to soil in order to improve soil structure, retention of water and consequently retention of water-soluble nutrients. Biochar may also be used for carbon sequestration. Carbon is removed from the atmosphere during the growth of a plant from which the biochar is produced and then locked in the ground for hundreds or thousands of years when the biochar is added to the soil.

Biochar is typically produced by pyrolysis of biomass, a process which produces solid biochar and gaseous syngas products. Liquid bio-oil can also be obtained from this process by condensing the syngas.

The present invention aims to provide an improved method of producing biochar by pyrolysis of biomass.

Summary of the Invention

According to a first aspect of the present invention there is provided a method of producing biochar by pyrolysis of a biomass feedstock, the method comprising the steps of: heating the biomass feedstock within a furnace chamber; sealing the furnace chamber such that oxygen cannot enter the furnace chamber and gasses can only escape the furnace chamber via a release outlet or to a combustion chamber; subsequently releasing gas from the furnace chamber through the release outlet and testing whether the released gas is combustible; when the released gas is combustible sealing the release outlet; gasses emitted from the furnace chamber subsequently passing to the combustion chamber where they are combusted to further heat the furnace chamber; and subsequently allowing the contents of the furnace chamber to cool.
This method may be used to produce biochar from biomass feedstock. The method advantageously allows steam released from the heated biomass feedstock to be released from the chamber until syngas produced by the heating of the biomass feedstock causes the gas within the furnace chamber to be combustible, at which stage the syngas is used to fuel further heating of the furnace chamber and the biomass feedstock until the pyrolysis of the biomass feedstock to produce biochar is complete.

Biomass is plant, animal, or microorganism material which is used as a raw material or for heat and/or energy production. The biomass feedstock is preferably plant material and more preferably weed material such as Japanese knotweed or other invasive weeds. The biomass feedstock may comprise roots, rhizomes and/or above ground plant material.

The biomass feedstock may be dried, preferably having a water content of less than 20% by weight and more preferably having a water content of less than 15%, 12%, 10% or 8% by weight.

The method may comprise the additional step of drying the biomass feedstock before heating it within the furnace chamber. The biomass feedstock may be dried in the open air or may be dried by arranging it within a heated or dehumidified environment. The biomass may be dried until it has a water content of less than 20% by weight and more preferably less than 15%, 12%, 10% or 8% by weight.

The biomass feedstock is preferably a plurality of pieces of biomass feedstock. The pieces are preferably smaller than 150mm in any dimension and more preferably are less than 120mm, 100mm or 80mm in any dimension.

The method may comprise the additional step of cutting the biomass feedstock into a plurality of pieces before heating it within the furnace chamber (and preferably after drying it). The biomass feedstock is preferably cut into pieces that are smaller than 150mm in any dimension and more preferably are less than 120mm, 100mm or 80mm in any dimension.

After the biomass feedstock is dried and/or cut into multiple pieces, as much foreign (non-biomass) material, such as soil, is removed from the feedstock as possible.
The method may comprise the additional step of arranging the biomass feedstock within the furnace chamber before heating it therein (and preferably after drying and/or cutting it into a plurality of pieces). The biomass feedstock is preferably arranged within the furnace chamber with an air space surrounding the biomass feedstock or pieces thereof so as to improve heat distribution through the feedstock.

The biomass feedstock is preferably inserted into the furnace chamber via a sealable entrance or opening to the furnace chamber; for example, through an opening or entrance which is sealable with an air-tight lid, door or cover.

The furnace chamber is preferably a retort or chamber thereof. A retort is an airtight chemical industrial vessel within which substances are heated in order to cause them to undergo a chemical reaction producing one or more gasses to be collected.

The furnace chamber may be heated by arranging and burning fuel within a combustion chamber (or firebox). This combustion chamber within which fuel is initially burned to heat the furnace chamber is preferably also the combustion chamber into which the gasses emitted from the heated biomass feedstock pass when the release outlet is sealed. Alternatively, it may be an additional or separate combustion chamber.

The, or each, combustion chamber is preferably a chamber separate from, proximate to and in thermal communication with the furnace chamber in which the biomass feedstock is heated. The, or each, combustion chamber may be located below the furnace chamber and/or may comprise one or more flues which extend through the combustion chamber such that smoke or other exhaust gasses from the burning of the fuel within the combustion chamber pass therethrough so as to heat the furnace chamber.

In some embodiments, the method comprises the additional steps of inserting one or more elongate ducts with a plurality of lateral openings along their lengths into the furnace chamber and/or the biomass feedstock. The ducts may be inserted into the furnace chamber before the biomass feedstock is arranged therein or may be inserted into the biomass feedstock within the furnace chamber after it has been arranged therein.
The elongate ducts are preferably arranged generally or substantially vertically within the furnace chamber and preferably extend from the base of the furnace chamber to a point above the top of the biomass feedstock. As the biomass feedstock is heated, gasses (such as steam and syngas) emitted from the biomass feedstock are able to enter one or more ducts through the lateral openings and to rise along the ducts to above the biomass feedstock. This may prevent steam emitted from lower pieces of biomass feedstock from increasing the moisture content of higher pieces of biomass feedstock.

Preferably, the biomass feedstock is heated in the furnace chamber for a period of time before the furnace chamber is sealed such that gas can only escape via the release outlet or to the combustion chamber. During this period of time gasses, such as steam, which are emitted from the heated biomass feedstock, or air from within the furnace chamber displaced by these gasses may escape the furnace chamber. The period of time is preferably a period of time over which the majority of or substantially all of the water content within the biomass feedstock to be evaporated and/or for syngas to start to be released from the heated biomass feedstock. The duration of the period of time may depend upon the quantity and/or moisture content of the feedstock but is typically several hours.

The furnace chamber may be sealed by sealing all entrances or openings into the furnace chamber except the release outlet and the conduit or other connection through which gasses are able to pass from the furnace chamber to the combustion chamber. Sealing the furnace chamber may advantageously prevent ingress of oxygen into the furnace chamber (thereby allowing pyrolysis of the biomass feedstock) and may prevent uncontrolled release of syngas (thereby allowing the syngas to be subsequently used as fuel for heating the furnace chamber).

Syngas is a fuel gas consisting of hydrogen, carbon monoxide and carbon dioxide and is produced by pyrolysis of the biomass feedstock (thermal decomposition of the biomass feedstock in the absence of oxygen).

After the furnace chamber is sealed gas can only escape the furnace chamber via a release outlet or to the combustion chamber. The release outlet is preferably a valve between the furnace chamber and the exterior of the furnace which may be opened to allow gas to escape therethrough. The heated gas within the furnace chamber will
typically have a greater pressure than the exterior of the furnace, ensuring that gas will pass through the valve when it is opened.

Gasses are preferably able to pass from the furnace chamber to the combustion chamber through an opening, passage or conduit. In preferred embodiments gasses are able to pass to the combustion chamber through a passage or conduit extending from an upper part of furnace chamber to the combustion chamber which is preferably beneath the furnace chamber. The passage or conduit preferably extends from the top of the furnace chamber or a point near or adjacent thereto and may extend from near where the release outlet opens into the interior of the furnace chamber.

In preferred embodiments, the opening, passage or conduit is continuously open to allow gasses to pass from the furnace chamber to the combustion chamber. In use, when the release outlet is sealed, pressure within the furnace chamber will increase when gasses are released from the heated biomass feedstock and gasses from the furnace chamber will pass through and/or down the opening, passage or conduit due to the pressure differential between the furnace chamber and the combustion chamber. When the release outlet is opened, the gasses may exit the furnace chamber therethrough in addition to or instead of passing through or down the opening, passage or conduit.

In alternative embodiments, one or more valves may regulate the flow of gasses through the opening, passage or conduit; these valves may be one-way valves or manually operable valves for blocking the opening, passage or conduit.

In some embodiments, gasses may be able to pass through a plurality of openings, passages and/or conduits to the combustion chamber or to a plurality of such combustion chambers.

After sealing the furnace chamber, gas is released from the furnace chamber through the release outlet and whether the released gas is combustible is tested. Gas may be released through the release outlet continuously or for discrete periods. For example, the release outlet may be opened (or partially opened) for discrete periods to allow gas from inside the furnace chamber to escape to be tested. The discrete periods may be regular periods with a constant separation or may be on any other suitable schedule.
Whether the released gas is combustible may be tested by exposing the released gas to a flame and testing whether it ignites. Alternatively or additionally the combustibility of the released gas may be tested by testing if or how much water vapour condenses from the released gas (for example, by passing the gas over a cooled surface); this will allow the amount of steam present in the released gas and by extension its combustibility, to be determined.

Initially after the furnace chamber is sealed the gas contents of the furnace chamber which will escape through the release outlet will be expected to be mix of syngas and steam which is not combustible. After the biomass feedstock is heated within the sealed furnace chamber, more syngas will be produced and the concentration of syngas within the furnace chamber will increase.

After the concentration has increased to a sufficient level for the gas to be combustible (such that the gaseous contents of the furnace chamber is suitable to be burned as fuel to further heat the furnace chamber) the release outlet is sealed.

The release outlet is a sealable outlet for gasses to be released from the furnace chamber through. The release outlet may be or may comprise a release valve, which may be closed to seal the release outlet. This valve, or another valve comprised by the release outlet may be a one-way valve. Additionally, or alternatively, the release outlet may be or may comprise a release pipe or conduit through which gasses are released from the chamber. In preferred embodiments, the release outlet is sealed by sealing a valve defining or comprised by the release outlet. In other embodiments, the release outlet may be sealed with a lid, cover, door, bung, or stopper.

After the release outlet is sealed, gasses from the furnace chamber pass to the combustion chamber where they are combusted to further heat the furnace chamber.

In some embodiments, gasses from within the furnace chamber are free to pass into the combustion chamber before the release outlet is sealed; for example, via an opening, conduit or passage as described above. In such embodiments, after the release outlet is sealed the gasses from the furnace chamber may enter the combustion chamber due to a pressure differential between the furnace chamber and the combustion chamber. Sealing the release outlet may therefore divert gasses from the furnace chamber into the combustion chamber.
In other embodiments a sealable valve may regulate the passage of gasses from the furnace chamber to the combustion chamber. In such embodiments, this valve may be sealed until the gas released from the release outlet is found to be combustible, when or after the release outlet is sealed this valve is preferably opened to allow gasses from the furnace chamber to pass to the combustion chamber. The valve may be comprised by or provided in or at an end of a passage or conduit between the furnace chamber and the combustion chamber.

In some embodiments gasses from the furnace chamber may be pumped into the combustion chamber after the gas released from the release outlet is found to be combustible (and preferably after the release outlet has been sealed).

After gasses emitted from the heated biomass feedstock pass into and are combusted within the combustion chamber, such gasses may continue to be combusted therein until pyrolysis of the biomass feedstock to form biochar is complete. Burning such gasses as fuel for heating the furnace chamber may advantageously prevent any additional external fuel needing to be burned to heat the furnace chamber after the gas released from the release outlet is found to be combustible.

In some embodiments, the method may comprise the additional step of opening the release outlet if the temperature in the furnace chamber exceeds a threshold temperature. This may release gasses from the furnace chamber, diverting them from entering the combustion chamber and may thereby reduce the temperature of the furnace chamber. The threshold temperature above which the release outlet is opened may be 550°C, 575°C, 600°C, 625°C or 650°C.

The release outlet is preferably subsequently sealed (such that gasses from within the furnace chamber are redverted into the combustion chamber), preferably when the temperature of the furnace chamber subsequently falls below the threshold temperature or subsequently falls below a resealing threshold temperature which is preferably lower than the threshold temperature at which the release outlet is opened. The resealing threshold temperature may be 500°C, 525°C, 550°C, 575°C, 600°C or 625°C. The release outlet may then remain sealed until pyrolysis of the biomass feedstock to form biochar is complete or may be reopened when and if the temperature exceeds the threshold temperature again.
In some embodiments, the contents of the furnace chamber may continue to be heated until a period of time has elapsed (for example, a predetermined period of time since beginning heating the biomass feedstock, sealing the furnace chamber or initially sealing the release outlet). After this period has elapsed any ongoing heating may be stopped, for example by closing any air or oxygen inlets to the combustion chamber.

In other embodiments, the contents of the furnace chamber may continue to be heated until the supply of combustible gasses to the combustion chamber ceases. As the pyrolysis of the biomass feedstock is completed it will cease to produce syngas, therefore the combustion within the combustion chamber will cease due to a lack of supply of fuel gas.

After the furnace chamber ceases to be heated, the contents of the furnace chamber (and preferably the furnace chamber itself) are left to cool; for example, for a period of at least four hours, at least six hours, at least eight hours, at least ten hours, or at least twelve hours. After this cooling period has elapsed the furnace chamber may be unsealed or opened and the pyrolysed biomass feedstock (biochar) may be removed.

In some embodiments, the method comprises the additional steps of unsealing the furnace chamber and/or removing the pyrolysed biomass feedstock (biochar) therefrom. For example, in embodiments wherein the furnace comprises a sealable opening in its top, the opening may be unsealed, and the contents of the furnace chamber may be removed by tilting or tipping the furnace (for example, by using a forklift rotating attachment).

In some embodiments, the method comprises the additional step of mixing the pyrolysed biomass feedstock (biochar) with a mixture of a diluted fertiliser tonic. The ratio of pyrolysed material (biochar) to the diluted fertiliser tonic mixture is preferably greater than 3:2 or greater than 7:4 and is preferably less than 5:2 or less than 9:4. In preferred embodiments the ratio of pyrolysed material (biochar) to the diluted fertiliser tonic mixture is 2:1. The fertiliser tonic is preferably diluted with water and the ratio of fertiliser tonic to water in the diluted fertiliser tonic is preferably greater than 8:1 or greater than 9:1, and is preferably less than 12:1 or less than 11:1. In
preferred embodiments the ratio of fertiliser tonic to water in the diluted fertiliser tonic is 10:1. The fertiliser tonic may be made from seaweed.

In such embodiments, the method preferably comprises the additional step of breaking the mixture of pyrolysed biomass feedstock and diluted fertiliser into smaller pieces, for example by crushing them. In preferred embodiments the mixture is broken into pieces which do not exceed 3mm, 2.5mm, 2mm or 1.5 mm in any dimension. Breaking the mixture into smaller pieces may advantageously facilitate saturation of the pyrolysed biomass feedstock with the diluted fertiliser tonic.

The biochar may be mixed with diluted fertiliser tonic and/or broken up into smaller pieces after removing it from the furnace chamber. In alternative embodiments, the biochar may be mixed with diluted fertiliser tonic and/or broken up into smaller pieces within the furnace chamber; for example, after the furnace chamber is unsealed. In some such embodiments the biochar may be broken up by moving or rotating solid objects (such as the one or more freestanding elongate ducts) within the furnace chamber, or may be broken up by a user reaching into the furnace chamber with one or more tools or implements (such as a long handled hammer) manipulating them therein to break up the biochar.

The broken-up mixture of pyrolysed biomass feedstock (biochar) and diluted fertiliser tonic is then preferably left for a period of 2, 3, 4, or more days. This may advantageously ensure that the pyrolysed biomass feedstock material is saturated with the diluted fertiliser tonic. The saturated biochar may then be mixed with soil in order to improve its physical properties. The ratio of soil to saturated biochar is preferably 10:1.

According to a second aspect of the present invention there is provided a furnace for using in the method of the first aspect of the invention described above, the furnace comprising: a furnace chamber for biomass feedstock to be heated within, a sealable release outlet for releasing gasses from within the furnace chamber and a combustion chamber for burning gas to heat the furnace chamber wherein gasses are able to pass from the furnace chamber to the combustion chamber.

The furnace may additionally comprise one or more sealable openings between the furnace chamber and the exterior of the furnace; an opening, passage or conduit for gasses to pass from the furnace chamber to the combustion chamber; one or more
flues for exhaust gasses from the combustion chamber; insulation; and/or one or more elongate ducts with a plurality of lateral openings along their lengths for inserting into the furnace chamber and/or materials being heated therein.

In some embodiments the furnace is generally or substantially cylindrical. The furnace may comprise an insulated outer wall which preferably surrounds the furnace chamber and the combustion chamber. The combustion chamber is preferably beneath the furnace chamber and may be located at the base of the furnace. The release outlet is preferably through the upper surface or top of the furnace.

The furnace preferably comprises one or more sealable openings between the furnace chamber and the exterior of the furnace. Such an opening may be provided at the top of the furnace with a displaceable lid for sealing it. In use biomass feedstock (and optionally the one or more elongate ducts) may be inserted into the furnace chamber through such an opening and biochar may be removed from the furnace chamber through such an opening after pyrolysis is complete.

The furnace preferably comprises one or more flues extending from the combustion chamber through which smoke and other waste gasses from the burning of fuel within the combustion box may escape. The one or more flues preferably extend generally vertically and in preferred embodiments extend through the and/or across the furnace chamber. The flues may thereby convey heat from the combustion box to the interior of the furnace chamber.

The furnace preferably comprises a passage or conduit for gasses to pass through from furnace chamber to the combustion chamber. The passage or conduit preferably extends from an upper portion of the furnace chamber, preferably near the top of the furnace chamber and/or near the interior opening of the release outlet to, the combustion chamber. A valve or pump may be comprised by or associated with the conduit or passage and may regulate the passage of gasses from the furnace chamber to the combustion chamber.

The furnace preferably comprises one or more elongate ducts with a plurality of lateral openings along their lengths for inserting into the furnace chamber and/or materials being heated therein. The one or more ducts are preferably freestanding and may be inserted into the furnace chamber and/or the biomass feedstock therein...
in use. As the biomass feedstock is heated, gasses (such as steam and syngas) emitted from the biomass feedstock are able to enter the one or more ducts through the lateral openings and to rise along the ducts to above the biomass feedstock. This may prevent steam emitted from lower pieces of biomass feedstock from increasing the moisture content of higher pieces of biomass feedstock.

The furnace may be a retort or chamber thereof. A retort is an airtight chemical industrial vessel within which substances are heated in order to cause them to undergo a chemical reaction producing one or more gasses to be collected.

The furnace according to the second aspect of the invention may comprise any of the furnace features with reference to the method of the first aspect of the invention and the method of the first aspect of the invention may be characterised in that it is performed using a furnace comprising any of the features of the second aspect of the invention described above.

According to a third aspect of the present invention there is provided biochar produced by the method of the first aspect of the invention described above.

The biochar may be broken up and/or mixed with a diluted fertiliser tonic as described above. The biochar may be produced by the pyrolysis of an invasive weed biomass feedstock such as a knotweed biomass feedstock.

Preferred embodiments of the invention will now be described by way of example, with reference to the Figures.

**Brief Description of the Figures**

Figure 1 is a flow chart showing the steps of a method according to the first aspect of the invention; and

Figure 2 is a cross sectional view of a furnace for use in the method of Figure 1.

**Detailed Description of the Figures**

Figure 1 shows the steps of an example of a method 100 according to the first aspect of the invention. The method 100 is for producing biochar by the pyrolysis of a biomass feedstock 4. The method 100 may be used to produce biochar from plant material and in particular from invasive weeds such as knotweed.
The first step of the method 102 is to dry the biomass feedstock 4; for example, in ambient air. The biomass feedstock 4 is preferably dried until its water content is around 10% by weight. The second step 104 is to cut the dried biomass feedstock 4 into a plurality of pieces, typically by cutting the feedstock 4 such that no piece exceeds 100mm in any direction. After the dried feedstock 4 is cut any foreign matter such as soil is removed from the feedstock 4.

The third step of the method 106 is to arrange the dried and cut biomass feedstock 4 within a furnace chamber of a furnace 10 as shown in Figure 2. The feedstock 4 is inserted into the furnace chamber 4 by inserting it through an open upper opening of the furnace chamber. The fourth step 108 is to insert one or more elongate ducts 9 with a plurality of lateral openings along their lengths into the biomass feedstock 4. The ducts 9 are arranged generally or substantially vertically within the furnace chamber with upper ends protruding above the biomass feedstock 4.

In alternative embodiments of the method, the elongate ducts 9 may be arranged substantially vertically within the furnace chamber 4 before the biomass feedstock 4 is arranged within the furnace chamber 4 around the ducts 9.

The fifth step 110 is to heat the furnace chamber by burning fuel within a combustion chamber 3 of the furnace 10. As the fuel is burnt the furnace chamber and the biomass feedstock 4 will be heated. The remaining water content within the biomass feedstock 4 will be evaporated and released from the feedstock as steam. Steam released from lower pieces of biomass feedstock 4 will enter the one or more ducts 9 via the lateral openings through the walls of the duct 9 and will then rise through the duct 9 out of the biomass feedstock 4. Smoke from the burning of the fuel within the combustion chamber 3 will rise through flues 5 which extend through the combustion chamber, thereby transferring heat thereto.

The sixth step 112 of the method is to seal the furnace chamber by closing the opening through which the biomass feedstock was inserted, by closing it with a lid 8. After the furnace chamber is sealed gas within the furnace chamber will only be able to escape the interior of the furnace chamber through the release outlet 7 of the furnace chamber or through the conduit 2 from the furnace chamber to the combustion chamber 3.
The seventh step 114 is to periodically release gasses from the interior of the furnace chamber through the release outlet 7 of the furnace. When the release outlet 7 is opened, the gasses from the interior of the furnace chamber will driven out through the release outlet 7 by the pressure differential between the furnace chamber and the exterior of the furnace 10. While the release outlet 7 is open hot gasses from within the furnace chamber will escape therethrough in preference to passing through the conduit 2 as the combustion chamber 3 is below the furnace chamber.

The released gasses are tested to determine whether they are combustible (which will depend upon the relative concentrations of steam and syngas released by the heated biomass feedstock as they are heated). The released gasses may be tested by exposing them to an open flame.

The seventh step 114 is continued with periodic releases of gasses through the release outlet 7 until the released gasses are combustible. When the released gasses are found to be combustible the release outlet 7 is sealed in the eighth step 116.

When the release outlet 7 is sealed, gasses within the furnace chamber will only be able to escape via the conduit 2 to the combustion chamber 3. As more gasses are emitted by the heated biomass feedstock 4 and the pressure within the furnace chamber increases, the combustible gasses will be driven through the conduit 2 to the combustion chamber 3 where they will be burned as fuel. After this step no additional fuel other than the gasses from the furnace chamber will need to be added to the combustion chamber 3.

In the ninth step 118, heating of the biomass feedstock within the furnace chamber is continued by burning gasses within the combustion chamber 3. This step will continue until the biomass feedstock 4 is nearly or completely pyrolysed and ceases to produce syngas to further fuel the heating of the furnace chamber.

When the biomass feedstock 4 ceases to produce syngas the burning within the combustion chamber will cease due to lack of fuel. After this occurs the furnace chamber and its contents are allowed to cool in the tenth step 120, for example, overnight.
In the eleventh step 122 the furnace chamber is unsealed by removing the lid 8 and opening the upper opening of the furnace 10. The biochar produced by the pyrolysis of the biomass feedstock is then removed from the furnace, for example by tipping the furnace using a forklift rotation attachment.

In the twelfth step 124 the biochar is mixed with a diluted fertiliser tonic. The diluted tonic being made by mixing 1 part of a seaweed-based fertiliser tonic with 10 parts water. Preferably by mixing 2 parts biochar to 1 part diluted fertiliser tonic. In the thirteenth step 126 the mixture of biochar and diluted fertiliser tonic is ground to break it up into pieces of less than 2mm in any dimension. The ground mixture is then preferably left for three days to allow the biochar to become saturated with the diluted fertiliser tonic.

The saturated biochar may then be added to soil to improve its qualities, typically at the rate of 1 part biochar to 10 parts soil.

Figure 2 is a cross sectional view of a furnace 10 according to the second aspect of the invention for performing the method of the first aspect of the invention.

The furnace 10 is in the form of a vertically extending cylinder which is supported by a plurality of feet 1 at its lower end. The furnace 10 comprises a large upper furnace chamber for containing material to be heated and a lower smaller combustion chamber 3 for fuel to be burnt within to provide heating. The furnace chamber and the combustion chamber 3 are contained within an insulated wall 6 of the furnace 10.

A pair of flues 5 extend generally vertically from the combustion chamber 3 through and across the interior of the furnace chamber and through the upper end of the furnace. As fuel is burned within the combustion chamber 3, smoke rises through the flues and transfers heat to the contents of the furnace chamber.

A central sealable opening is provided through the upper end wall of the furnace chamber. The opening is sealable with an air tight lid 8. A release outlet 7 is also formed through the upper end wall of the furnace chamber for releasing gasses from the furnace chamber.

A conduit 2 extends from near the upper end of the furnace chamber and near the interior opening of the release outlet to the combustion chamber 3. The conduit
allowing gasses to pass from the upper end of the release chamber to the combustion chamber 3 to be burned as fuel.

The furnace further comprises a freestanding elongate duct 9 with a plurality of lateral openings along its lengths. In use the duct 9 may be arranged within the furnace chamber and/or inserted into materials being heated therein. As biomass feedstock 4 into which the duct is inserted is heated, gasses (such as steam and syngas) emitted from the biomass feedstock 4 are able to enter the one or more ducts through the lateral openings and to rise along the ducts to above the biomass feedstock. This may prevent steam emitted from lower pieces of biomass feedstock from increasing the moisture content of higher pieces of biomass feedstock.

The invention has been described by way of example only and it will be appreciated that variation may be made to the above-mentioned embodiments without departing from the scope of the invention as defined by the claims. For example, in the seventh step 114 gas may be released and tested continuously instead of periodically.
Claims

1. A method of producing biochar by pyrolysis of biomass feedstock, the method comprising the steps of:
   heating the biomass feedstock within a furnace chamber;
   sealing the furnace chamber such that oxygen cannot enter the furnace chamber and gasses can only exit the furnace chamber via a release outlet or to a combustion chamber;
   subsequently releasing gas from the furnace chamber through the release outlet and testing whether the released gas is combustible;
   when the released gas is combustible sealing the release outlet;
   gasses emitted from the furnace chamber subsequently passing to the combustion chamber where they are combusted to further heat the furnace chamber; and
   subsequently allowing the contents of the furnace chamber to cool.

2. A method according to claim 1 wherein the biomass feedstock is invasive weeds.

3. A method according to claim 1 or claim 2 comprising the additional step of drying the biomass feedstock before heating the biomass feedstock within the furnace chamber.

4. A method according to claim 3 wherein the biomass feedstock is dried until it has a water content of less than 12% by weight.

5. A method according to any preceding claim comprising the additional step of cutting the biomass feedstock into a plurality of pieces before heating the biomass feedstock within the furnace chamber.

6. A method according to claim 5 wherein the biomass feedstock is cut into pieces which are smaller than 120mm in any dimension.

7. A method according to any preceding claim comprising the additional step of inserting one or more elongate ducts with a plurality of lateral openings along their lengths generally vertically into the furnace chamber or the biomass feedstock therein.
8. A method according to any preceding claim wherein the biomass feedstock is heated for a period of time within the furnace chamber before the furnace chamber is sealed.

9. A method according to any preceding claim wherein whether the released gas is tested by exposing it to a flame.

10. A method according to any preceding claim wherein whether the released gas is tested by testing how much water vapour condenses from it.

11. A method according to any preceding claim wherein gasses from the furnace chamber pass to the combustion chamber through a conduit.

12. A method according to claim 11 wherein the conduit extends from an upper portion of the furnace chamber to the combustion chamber.

13. A method according to claim 11 or claim 12 wherein a valve regulates the passage of gas through the conduit.

14. A method according to any preceding claim wherein gasses are pumped from the furnace chamber to the combustion chamber after the release outlet is sealed.

15. A method according to any preceding claim comprising the additional step of opening the release outlet if the temperature in the furnace chamber exceeds a threshold temperature.

16. A method according to any preceding claim wherein after the released gasses are combustible, the contents of the furnace chamber continue to be heated until the supply of combustible gasses to the combustion chamber ceases.

17. A method according to any preceding claim comprising the additional step of removing the pyrolysed biomass feedstock from the furnace chamber and mixing it with diluted fertiliser tonic.

18. A method according to claim 17 comprising the additional step of grinding the mixture of pyrolysed biomass feedstock and diluted fertiliser tonic into smaller pieces.
19. A furnace for using in the method of any of claims 1 to 18, the furnace comprising: a furnace chamber for biomass feedstock to be heated within, a sealable release outlet for releasing gasses from within the furnace chamber and a combustion chamber for burning gas to heat the furnace chamber wherein gasses are able to pass from the furnace chamber to the combustion chamber.

20. A furnace according to claim 19 comprising one or more flues extending from the combustion chamber across the furnace chamber.

21. A furnace according to claim 19 or claim 20 comprising a conduit for gasses to pass from an upper portion of the furnace chamber to the combustion chamber.

22. A furnace according to any of claims 19 to 21 comprising one or more elongate ducts with a plurality of lateral openings along their lengths for arranged within the furnace chamber or inserting into materials being heated therein.

23. A furnace according to claim 22 wherein the one or more elongate ducts are freestanding.

24. Biochar produced by the method of any of claims 1 to 18.

25. Biochar produced by pyrolysis of a knotweed biomass feedstock using the method of claim 17 or claim 18, wherein the biochar is mixed with a diluted fertiliser tonic.
Patents Act 1977: Search Report under Section 17

Documents considered to be relevant:

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<th>Category</th>
<th>Relevant to claims</th>
<th>Identity of document and passage or figure of particular relevance</th>
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<td>Y</td>
<td>1-18</td>
<td>GB 2458951 A  Environet - see e.g. the claims and page 5 paragraph 1</td>
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<td>WO 2012/059113 A1  Mansour - see e.g. the abstract, the description and figure 1</td>
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<td>CN 109628117 A  Inst Soil Science - see WPI abstract number 2019-385783 and EPDOC abstract</td>
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Categories:

X Document indicating lack of novelty or inventive step
Y Document indicating lack of inventive step if combined with one or more other documents of same category.
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A Document indicating technological background and/or state of the art.
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Field of Search:

Search of GB, EP, WO & US patent documents classified in the following areas of the UKC

Worldwide search of patent documents classified in the following areas of the IPC
C10B, F27B

The following online and other databases have been used in the preparation of this search report
WPI, EPDOC, Patent Fulltext

International Classification:

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