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Description

Title of The Invention

HYDROTHERMAL TREATMENT DEVICE AND HYDROTHERMAL
TREATMENT SYSTEM

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Field of The Invention

[0001]

The present invention relates to a hydrothermal treatment device which treats waste containing organic matter, and a hydrothermal treatment system which produces gas by utilizing the hydrothermal treatment device.

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Background of The Invention

[0002]

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Systems which perform hydrothermal treatment by using high-temperature and high-pressure steam to react and solubilize waste containing organic matter such as municipal solid waste which is comprised of kitchen waste (food waste) from households, paper and plant matter waste, livestock manure, and sludge; and the gas production employing hydrothermally treated waste containing organic matter (slurry) by microorganisms and bacteria, e.g., methane fermentation, have been developed (e.g., Patent Documents 1, 2).

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Patent Document 1 discloses a hydrothermal treatment device where the waste containing organic matter is hydrothermally treated in a stirred-vessel with an airtight feature. Patent Document 1 states that if the temperature inside the vessel is less than 180°C, hard substances such as biological bones cannot be sufficiently solubilized, therefore hydrothermal treatment at 180°C and 1.0 MPa is performed.

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[0003]

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However, as described in Patent Document 2, performing hydrothermal treatment at a temperature of 150°C or higher promotes the Maillard reaction between sugars and proteins contained in the organic waste and leads to the production of a large amount of melanoidins, which are nitrogen-containing antioxidant substances and act as an inhibitor during the gas production process. Therefore, Patent Document 2 discloses a system consisting of two hydrothermal treatment devices in order to reduce the amount of melanoidins.

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First of all, a first hydrothermal treatment device performs hydrothermal treatment at a low temperature (e.g., 120°C) which can suppress the Maillard reaction. Next, by means of solid-liquid separation, a liquid product from the first hydrothermal treatment device (referred to as “hydrothermal treatment

liquid 1”) is recovered and the remaining solid product is then transferred into the second hydrothermal treatment device which performs the hydrothermal treatment at a high temperature (e.g., 220°C). A liquid product obtained from the second hydrothermal treatment device (referred to as “hydrothermal treatment liquid 2”) and the previously obtained hydrothermal treatment liquid 1 are transferred into a fermentation device and subject to the methane fermentation.

In principle, since the hydrothermal treatment liquid 1 is produced by means of hydrothermal treatment at a low temperature which suppresses the Maillard reaction, it contains a very small amount of melanoidins. Meanwhile, after separating the hydrothermal treatment liquid 1, the amount of nitrogen compounds in the solid product transferred into the second hydrothermal treatment device decreases. Thus, even though the hydrothermal treatment is performed at a high temperature at which the Maillard reaction is promoted, the production of the melanoidins is reduced. Therefore, compared with the system which only employs the second hydrothermal treatment device, the system which employs the first and second hydrothermal treatment devices can reduce the total amount of melanoidins contained in the hydrothermal treatment liquid 1 and hydrothermal treatment liquid 2, and as a result, the inhibition during methane fermentation can be reduced.

References Cited

Patent Literatures

[0004]

Patent Document 1: JP 2009-119378 A

Patent Document 2: JP 2020-163280 A

Summary of The Invention

Technical Problem

[0005]

For example, in the case of utilizing waste containing organic matter collected by a garbage truck or waste containing organic matter stored in the waste pit of a garbage incineration plant for gas production by using microorganisms and bacteria, it is preferable to perform the hydrothermal treatment selectively for the kitchen waste, paper waste, and plant matter.

However, in general, even though kitchen waste, paper waste, and plant matter are selectively extracted from the waste containing organic matter, some organic matters that do not contribute to or hardly contribute to gas production

are not completely extracted and still remain in kitchen waste, paper waste, and plant matter fractions. Inorganic matter such as metals, and organic matter such as plastics, are examples of the matters that do not contribute or hardly contribute to gas production by using microorganisms or others. Therefore, for example, after performing the hydrothermal treatment, inorganic matter such as metals, and organic matter such as plastics which are larger than 6 mm in diameter are removed by solid-liquid separation (e.g., a screen with an aperture size of 6 mm).

However, in this case, there is a risk that due to the hydrothermal treatment, plastic breaks apart into fine particles (6 mm or less) and a liquid which is recovered by solid-liquid separation after performing the hydrothermal treatment (hereinafter referred to “hydrothermal treatment liquid”) contains these fine particles of plastic, and they are transferred altogether into a gas production device which produces gas by utilizing microorganisms and bacteria (e.g., a fermentation device).

Since the hydrothermal treatment liquid to be fed into the gas production device is in a specific prescribed amount (constant amount), the more fine the particles of plastic contained in the hydrothermal treatment liquid is, the more the ratio of plastic to the prescribed amount becomes, and the lower gas production efficiency becomes. Accordingly, the fine particles of plastic do not contribute to gas production or hinder gas production produced by microorganisms and so forth, but since they reduce the amount gas produced per amount of feed (i.e., a prescribed amount of hydrothermal treatment liquid), the fine particles of plastic can be considered as an inhibitor during gas production.

An experiment conducted by the present inventor found that when the hydrothermal treatment is performed at a constant temperature of 180°C for 60 minutes, about 65% of the plastic contained in the waste containing organic matter breaks apart into a size of 6 mm or less. Therefore, due to this fragmentation of plastic during hydrothermal treatment, when solid-liquid separation is performed by using a screen with an aperture size of 6 mm, most of the plastic contained in the waste containing organic matter is transferred to the gas production device. This configuration may cause inefficient gas production, therefore, improvement is required.

[0006]

Herein, one idea for the improvement is to perform hydrothermal treatment at a low temperature. The reason for this is that the production of fine particles of plastic trend is similar to that of melanoidins, in which the higher

5 the hydrothermal reaction temperature is, the more amount of fine particles of plastic is produced. But, in this case, according to Patent Document 1, the waste containing organic matter is not sufficiently solubilized, less organic matter is dissolved in the hydrothermal treatment liquid, and there is also a risk of inefficient gas production.

10 In the technique of Patent Document 2, although the production amount of melanoidins can be reduced, the amount of fine particles of plastic still cannot be reduced. Moreover, since two hydrothermal treatment devices are used, an increase in the cost of the system is unavoidable.

[0007]

15 Herein, the objective of the present invention is to provide a hydrothermal treatment device and a hydrothermal treatment system which only employ one hydrothermal treatment device which is capable to solubilize waste containing organic matter and to reduce the production amount of two inhibitors during gas production which are the melanoidins and fine particles of plastic.

Solution to The Problem

[0008]

25 A hydrothermal treatment device, according to the present invention, includes: a sealable vessel including an inlet and an outlet and into which waste containing organic matter is fed; a temperature measurement device configured to measure an internal temperature of the sealable vessel; an introduction pipe through which steam is introduced into the sealable vessel; a solenoid valve that is configured in the introduction pipe, opens to introduce the steam into the sealable vessel, and closes to stop introducing the steam; a depressurization device configured to decrease pressure inside the sealable vessel into which the steam is introduced, by releasing the steam from the sealable vessel; and a control device configured to perform a hydrothermal reaction of the waste containing organic matter in the sealable vessel and to control the solenoid valve and the depressurization device based on the internal temperature measured by the temperature measurement device.

35 The control device, during the hydrothermal reaction, introduces the steam into the sealable vessel to increase the internal temperature to a first temperature which is equal to or higher than a temperature which promotes Maillard reaction, and then maintains the first temperature for a first length of time, immediately after the first length of time elapses, decreases the internal temperature from the first temperature by decreasing the pressure, decreases the

5 internal temperature from the first temperature to a second temperature which
 is approximately equal to or higher than a lower limit temperature of
 hydrothermal reaction by means of the abovementioned temperature
 decreasing, and then maintains the second temperature for a second length of
 time which is approximately equal to the first length of time or longer than the
 10 first length of time, immediately after the second length of time elapses,
 increases the internal temperature to a third temperature which is
 approximately equal to the first temperature, and then maintains the third
 temperature for a third length of time which is approximately equal to the first
 length of time, and immediately after the third length of time elapses, decreases
 15 the internal temperature from the third temperature by decreasing the pressure.
 [0009]

A hydrothermal treatment system of the present invention includes: the
 hydrothermal treatment device of the present invention; a solid-liquid
 separation device configured to separate hydrothermally reacted waste
 20 containing organic matter which is treated by the hydrothermal treatment
 device into a hydrothermal treatment liquid and a residue; and a gas production
 device configured to produce gas by microorganisms or bacteria, by utilizing
 the hydrothermal treatment liquid which is separated by the solid-liquid
 separation device as a feedstock.
 25 [0010]

In the hydrothermal treatment device of the present invention, after
 waste containing organic matter is fed into a sealable vessel, the hydrothermal
 treatment device increases the temperature in the sealable vessel to a first
 temperature which is equal to or higher than the temperature which promotes
 30 Maillard reaction and maintains the first temperature for a first length of time,
 immediately after that, decreases the temperature to a second temperature
 which is lower than the first temperature (however, the temperature is equal to
 or higher than the lower limit temperature of hydrothermal reaction) and
 maintains the second temperature for a second length of time, after that,
 35 increases again the temperature to a third temperature and maintains the third
 temperature for a third length of time, and immediately after that, decreases the
 temperature from the third temperature. Namely, when the hydrothermal
 treatment device is started, the temperature change is expressed as follows:
 "→" indicating the elapsed time, "low (normal temperature: when starting the
 40 device)" → "high (hydrothermal reaction at a temperature equal to or higher
 than the temperature which promotes Maillard reaction)" → "low
 (hydrothermal reaction at a temperature equal to or higher than the lower limit

5 temperature of hydrothermal reaction)" → "high (hydrothermal reaction at a
temperature equal to or higher than the temperature which promotes Maillard
reaction)" → "low".

In other words, the internal temperature of the sealable vessel is first
increased to the first temperature which is equal to or higher than the
10 temperature which promotes Maillard reaction to smoothly start the
hydrothermal reaction of the waste containing organic matter, and after the first
length of time elapses, the temperature is immediately decreased, after that, the
temperature is increased again to the third temperature which is approximately
equal to the first temperature, and then the temperature is decreased. Because
15 the organic matter in the waste is subjected to a temperature change in the
middle of the hydrothermal reaction, the cell wall is inflicted by multiple
thermal shocks, thus, the solubilization of the organic matter is promoted. In
other words, in the waste containing organic matter having been subjected to a
hydrothermal reaction by the hydrothermal treatment device of the present
20 invention, the cell wall of the organic matter is partially destroyed by the
thermal shock applied during the hydrothermal reaction, and thus, the
solubilization of the waste containing organic matter is much more even in a
region of the second temperature in the present invention as compared with a
case of the hydrothermal reaction only at a constant value of the second
25 temperature.

[0011]

Since the second length of time, in which hydrothermal treatment is
performed at the second temperature (which is lower than the first
temperature), is approximately equal to or longer than the first length of time,
30 both the amount of melanoidins and the amount of fine particles of plastic are
reduced as compared with a case of performing the hydrothermal treatment
only at a constant temperature of the first temperature.

Therefore, the hydrothermal treatment liquid produced by the
hydrothermal treatment device of the present invention contains a large amount
35 of organic matter, and compared with the conventional case, it contains a
smaller amount of melanoidins and fine particles of plastic which are inhibitors
during gas production.

Furthermore, since the hydrothermal treatment device system of the
present invention performs gas production utilizing the hydrothermal treatment
40 liquid produced by the hydrothermal treatment device of the present invention,
it is possible to efficiently produce gas.

Advantageous Effects of The Invention

[0012]

According to the hydrothermal treatment device of the present invention, even a single hydrothermal treatment device can solubilize waste containing organic matter and reduce the production amount of melanoidins and fine particles of plastic which are inhibitors during gas production by utilizing microorganisms and bacteria.

According to the hydrothermal treatment system of the present invention, since gas production is performed by utilizing a hydrothermal treatment liquid containing a smaller amount of these two inhibitors, gas can be efficiently produced.

Brief Description of The Drawings

[0013]

FIG. 1 is a schematic diagram illustrating a hydrothermal treatment system according to an embodiment.

FIG. 2 is a schematic diagram illustrating a hydrothermal treatment device according to the embodiment.

FIG. 3 is a graph for explaining internal temperature control and agitation control of the sealable vessel performed in the hydrothermal treatment device according to the embodiment.

Description of The Embodiments

[0014]

Hereinafter, a hydrothermal treatment device as an embodiment and a hydrothermal treatment system including the same will be described with reference to the drawings. The configurations and so forth described below are merely examples, and there is no intention to exclude various modifications and applications of technologies which are not explicitly described. The configuration and so forth described below can be variously modified and implemented without deviating from the essential constituent elements and the essence of the present invention.

[0015]

FIG. 1 shows a schematic diagram illustrating a hydrothermal treatment system 1 of the present embodiment. The hydrothermal treatment system 1 includes a hydrothermal treatment device 10 configured to hydrothermally react and solubilize waste containing organic matter with high-temperature and high-pressure steam, a solid-liquid separation device 20 configured to separate the

hydrothermally reacted waste containing organic matter (hereinafter, referred to as hydrothermal treatment product), which is treated by the hydrothermal treatment device 10, into a hydrothermal treatment liquid and a residue, and a gas production device 30 (for example, a methane fermentation device which performs methane fermentation) configured to produce gas by microorganisms or bacteria, by utilizing the hydrothermal treatment liquid which is separated by the solid-liquid separation device 20 as a feedstock.

Examples of the waste containing organic matter fed into the hydrothermal treatment device 10 may include: food waste discharged from households, paper and plant matter waste, livestock manure, and sludge. The waste containing organic matter collected by the garbage truck and the waste containing organic matter stored in the waste pit of the garbage incineration plant may be directly fed to the hydrothermal treatment device 10, or may be fed to the hydrothermal treatment device 10 after extracting the inorganic matters from the waste containing organic matter. Of course, kitchen waste, paper waste, and plant matter may be selectively extracted from the waste containing organic matter, and then the extracted kitchen waste, paper waste, or plant matter may be fed into the hydrothermal treatment device 10. However, in any case, in general, plastic, which is an organic matter that does not contribute to or hardly contributes to gas production by using microorganisms, bacteria, and so forth cannot be completely removed from the waste containing organic matter.

The configuration and control of the hydrothermal treatment device 10 will be described later with reference to FIGS. 2 and 3.

[0016]

The solid-liquid separation device 20 is a device which retains a solid having a particle size equal to or more than a certain particle size while allowing a liquid having a particle size less than the certain particle size to flow; and a screen, a screw press, or another having a predetermined aperture size (e.g., aperture size of 6 mm) can be used. A large amount of organic matter from the waste containing organic matter is dissolved in the hydrothermal treatment liquid, and this serves as a feedstock for gas production in the gas production device 30 which will be described later.

The residue discharged from the solid-liquid separation device 20 is disposed or incinerated.

[0017]

The gas production device 30 is, for example a device which produces methane gas by methane fermentation. Since the hydrothermal treatment system

5 1 can reduce the amount of melanoidins and fine particles of plastic in the hydrothermal treatment device 10, which will be described later, efficient gas production is possible.

The gas production device 30 may be a device which produces a gas such as hydrogen as long as it is a device which produces a gas by utilizing
 10 microorganisms or bacteria with the hydrothermal treatment liquid as a feedstock.
 [0018]

FIG. 2 is a schematic diagram illustrating the hydrothermal treatment device 10 of the present embodiment. The hydrothermal treatment device 10
 15 includes a sealable vessel 11 that can be airtightly sealed, an introduction pipe 14 for introducing steam into the sealable vessel 11, a solenoid valve 15 configured in the introduction pipe 14, a temperature sensor 18 (temperature measurement device) configured to measure an internal temperature of the sealable vessel 11, a depressurization device 17 configured to decrease an
 20 internal pressure of the sealable vessel 11 into which steam is introduced, an agitation device 16 which agitates the waste containing organic matter fed into the sealable vessel 11, and a control device 19 configured to control the solenoid valve 15, the depressurization device 17, and the agitation device 16 based on the internal temperature measured by the temperature sensor 18.
 25 [0019]

The sealable vessel 11 includes an inlet 12 and an outlet 13. The waste containing organic matter to be subjected to the hydrothermal reaction is fed into the sealable vessel 11 from the inlet 12. At the time of the hydrothermal treatment, the inlet 12 and the outlet 13 are closed, and the sealable vessel 11 is
 30 sealed. The hydrothermally treated waste containing organic matter (hydrothermal treatment product) is discharged to the outside of the sealable vessel 11 by opening the outlet 13 and transferred to the solid-liquid separation device 20, for example, by a conveyor or another. Since the waste containing organic matter is solubilized due to the hydrothermal treatment, the
 35 hydrothermal treatment product is often in a slurry state.

The introduction pipe 14 is a pipe in which one of the ends connects with the sealable vessel 11 and into which high-temperature steam is introduced from the other end. As the steam, for example, steam coming from a post-power generation's turbine of a waste incinerator can be used. Since the steam from
 40 the post-power generation may exceed 200°C, which is a high temperature, the steam may be immediately introduced into the sealable vessel 11 as it is, or the steam may be appropriately cooled by natural cooling or a cooling device prior

5 to use, depending on the setting of a first temperature C1 which will be described later.

[0020]

The solenoid valve 15 opens to introduce steam into the sealable vessel 11 through the introduction pipe 14, and closes to stop introduction of steam.

10 Opening and closing of the solenoid valve 15 is controlled by the control device 19.

The temperature sensor (temperature measurement device) 18 measures the internal temperature of the sealable vessel 11 and transmits it to the control device 19.

15 The agitation device 16 agitates the waste containing organic matter in order to promote the hydrothermal reaction of the waste containing organic matter fed into the sealable vessel 11 and to prevent charring. The agitation device 16 may include, for example: an agitation blade installed in the sealable vessel 11 and may be a type of rotating agitation blade inside the fixed sealable
20 vessel 11; or the agitation is performed by rotating the sealable vessel 11 itself. The agitation speed of the agitation device 16 is controlled by the control device 19.

The depressurization device 17 decreases the internal pressure of the sealable vessel 11, into which the steam is introduced, by releasing a part of the
25 steam to the outside of the sealable vessel 11 during the hydrothermal treatment, or releasing all of the steam to the outside of the sealable vessel 11 at the end of the hydrothermal treatment. The degree of the depressurization is controlled by the control device 19.

During the hydrothermal treatment, the control device 19 opens or
30 closes the solenoid valve 15 based on the internal temperature measured by the temperature sensor 18, and controls the depressurization device 17 to appropriately decrease the pressure inside the sealable vessel 11, so that the internal temperature of the sealable vessel 11 can be controlled. The control device 19 controls the agitation device 16 based on the internal temperature
35 measured by the temperature sensor 18 to increase or decrease the agitation speed with respect to the waste containing organic matter fed into the sealable vessel 11.

[0021]

40 The control of the control device 19 will be described with reference to FIG. 3.

The waste containing organic matter is fed into the sealable vessel 11 and the sealable vessel 11 is sealed, and then the control device 19 opens the

5 solenoid valve 15 to introduce high-temperature steam into the sealable vessel 11 and increases the internal temperature of the sealable vessel 11 to the first temperature C1 which is equal to or higher than the temperature which promotes Maillard reaction. Thereafter, the control device 19 closes the solenoid valve 15, or appropriately repeats closing and opening to maintain the
10 first temperature C1 for a first length of time T1. At that time, the control device 19 controls the agitation device 16 to agitate the waste containing organic matter in the sealable vessel 11 at a first agitation speed R1. After starting the hydrothermal treatment, the hydrothermal reaction of the waste containing organic matter at a temperature equal to or higher than the
15 temperature which promotes Maillard reaction occurs, and this control makes the solubilization of the waste containing organic matter start smoothly.

As described above, according to Patent Document 2, the temperature which promotes Maillard reaction is 150°C or higher. In Patent Document 2, 120°C is set as a temperature which suppresses the Maillard reaction.
20 Therefore, the lower limit of the temperature which promotes the Maillard reaction can be said to be higher than 120°C and lower than 150°C. Therefore, 135°C, which is the midpoint between both temperature values, is assumed as the lower limit. Therefore, here, the temperature which promotes Maillard reaction is set to 135°C or higher, preferably 150°C or higher.

25 [0022]

Immediately after the first length of time T1 elapses, the control device 19 controls the depressurization device 17 to release a part of the steam in the sealable vessel 11 to the outside of the sealable vessel 11. Because of this, the control device 19 decreases the internal pressure of the sealable vessel 11 and
30 rapidly decreases the internal temperature of the sealable vessel 11 from the first temperature C1. At that time, it is desirable that the control device 19 closes the solenoid valve 15.

This control causes a thermal shock (first thermal shock) which is inflicted on the cell wall of the organic matter of the waste containing organic
35 matter in the middle of the hydrothermal reaction, thus, a part of the cell wall is destroyed. When the internal temperature is decreased from the first temperature C1, it is desirable to rapidly decrease the internal temperature in a short time (within 0 to 10 minutes, desirably about 0 to 5 minutes), and therefore to achieve this, the inside of the sealable vessel 11 may be forcibly
40 cooled down by a cooling device (not illustrated) in addition to the depressurization device 17.

Here, the plastic contained in the waste containing organic matter is also subject to thermal shock, but due to difference in the moisture content and the thermal conductivity between the cells of the organic matter and the plastic, the influence of the thermal shock on the plastic is smaller than that of the cells. Therefore, here, the fragmentation of plastic into the fine particles caused by the thermal shock almost does not occur.

[0023]

After the internal temperature of the sealable vessel 11 decreases from the first temperature C1 to a second temperature C2 which is equal to or higher than the lower limit temperature of hydrothermal reaction, the control device 19 maintains the second temperature C2 for a second length of time T2 which is approximately equal to the first length of time T1 or longer than the first length of time T1. At that time, the control device 19 controls the agitation device 16 to agitate the waste containing organic matter in the sealable vessel 11 at a second agitation speed R2 which is lower than the first agitation speed R1.

This control causes the hydrothermal reaction of the waste containing organic matter at the second temperature C2 for a relatively long time, but since a part of the cell walls has already been destroyed by the first thermal shock, the solubilization of the organic matter of the waste containing organic matter is much more promoted as compared with a case without the first thermal shock. Since the second temperature C2 is lower than the first temperature C1, production of melanoidins and fine particles of plastic which are inhibitors during gas production are suppressed as compared with the case where the hydrothermal treatment is performed only at the first temperature C1 which is higher than the second temperature C2. In addition, since the second agitation speed R2 is low, the production of fine particles of plastic can be further suppressed as compared with the case where the hydrothermal treatment is performed at the first agitation speed R1 which is higher than the second agitation speed R2.

Before the temperature reaches the second temperature C2 from the first temperature C1, the control device 19 stops the depressurization which is performed by the depressurization device 17. The control device 19 maintains the second temperature C2 for the second length of time T2 by closing the solenoid valve 15 or appropriately repeating closing and opening. Since steam is used in the hydrothermal reaction, here, the lower limit temperature of hydrothermal reaction is set to 100°C which is the temperature of steam at atmospheric pressure.

In FIG. 3, the second agitation speed R2 indicates a value more than 0 rpm. However, if the waste containing organic matter does not get charred, the second agitation speed R2 may be 0 rpm.

[0024]

Immediately after the second length of time T2 elapses, the control device 19 opens the solenoid valve 15 to introduce steam into the sealable vessel 11, and increases the internal temperature of the sealable vessel 11 to a third temperature C3 which is approximately equal to the first temperature C1. This control, furthermore, causes a thermal shock (second thermal shock) which is inflicted on the cell wall of the organic matter of the waste containing organic matter that has been insufficiently solubilized at the second length of time T2, thus, a part of the cell wall of the insufficiently solubilized organic matter is destroyed. For this reason, solubilization of an organic matter which is hard to solubilize such as a bone, is gradually promoted by the first and second thermal shocks (a multiple thermal shocks during the hydrothermal reaction).

Thereafter, the control device 19 closes the solenoid valve 15 or appropriately repeats closing and opening to maintain the third temperature C3 for a third length of time T3 which is approximately equal to the first length of time T1. At that time, the control device 19 controls the agitation device 16 to agitate the waste containing organic matter in the sealable vessel 11 at a third agitation speed R3 which is higher than the second agitation speed R2 and approximately equal to (or slightly lower than) the first agitation speed R1.

Immediately after the third length of time T3 elapses, the control device 19 controls the depressurization device 17 to release the steam in the sealable vessel 11 to the outside of the sealable vessel 11. Because of this, the control device 19 decreases the internal pressure of the sealable vessel 11 and decreases the internal temperature of the sealable vessel 11 from the third temperature C3. At that time, the inside of the sealable vessel 11 may be forcibly cooled down by employing the cooling device as described above in addition to the depressurization device 17.

[0025]

FIG. 3 is a graph indicating that immediately after the third length of time T3 elapses, the hydrothermal treatment is ended and the hydrothermal treatment device 10 is stopped. Accordingly, immediately after the third length of time T3 elapses, the control device 19 controls the depressurization device 17 to release the entire steam in the sealable vessel 11 to the outside of the sealable vessel 11 and to decrease the internal pressure of the sealable vessel

11. Moreover, immediately after the third length of time T3 elapses, the control device 19 stops the agitation device 16. In other words, a reaction time “T” shown in FIG. 3 is a time from when the internal temperature reaches the first temperature C1, i.e., from the start point of the first length of time T1, maintained to the end of the third length of time T3.

However, FIG. 3 is merely an example, and the hydrothermal treatment may be maintained after the third length of time T3 elapses. In this case, the reaction time “T” presented in FIG. 3 becomes longer. The reaction time “T” is a time from the start point of the first length of time T1 to the end of the hydrothermal reaction performed in the hydrothermal treatment device 10.

For example, after the third length of time T3 in FIG. 3 elapses, the same control with those in the first length of time T1 and the second length of time T2, may be repeated again, i.e., the control of applying a similar thermal shock with the first and the second thermal shock may be performed again. In other words, control of applying multiple (2 or more) thermal shocks may be performed within the reaction time “T”, namely, during the hydrothermal reaction. Even though the second temperature C2 is a relatively low temperature, as the number of thermal shocks during the hydrothermal reaction is increased (three, four, or another), the solubilization effect of an organic matter which is not easily solubilized such as a bone, is enhanced.

In this case, immediately after the third length of time T3 elapses, the control device 19 controls the depressurization device 17 to release a part of (not entire) steam in the sealable vessel 11 to the outside of the sealable vessel 11, decreases the internal pressure of the sealable vessel 11, and decreases the internal temperature of the sealable vessel 11 from the third temperature C3. In this case, the control device 19 may maintain the agitation device 16 to agitate as it is needed.

[0026]

According to the present inventor, theoretically, the effects of the present invention can be obtained by the above configuration and the above control.

The present inventor has obtained an experimental result that the amount of fine particles of plastic (i.e., 6 mm or less in diameter) is about 45% of the total amount of plastic in the waste containing organic matter fed into the sealable vessel 11 when the following parameters were applied: the reaction time “T” is 60 minutes, the first temperature C1 is about 180°C, the second temperature C2 is about 165°C, the third temperature C3 is about 180°C, the first length of time T1 is 5 minutes to 10 minutes, the second length of time T2

5 is about 30 minutes, the third length of time T3 is 5 minutes to 10 minutes, the first agitation speed R1 is about 80 rpm, the second agitation speed R2 is almost 0 rpm (about 1 rpm), and the third agitation speed R3 is about 80 rpm.

On the other hand, as described above, when the hydrothermal treatment is performed at a constant internal temperature of the sealable vessel 11 of only 180°C, a constant reaction time of 60 minutes, and a constant agitation speed of only 30 rpm, the experimental result is that the amount of fine particles of plastic (i.e., 6 mm or less in diameter) was about 65% of the total amount of plastic in the waste containing organic matter fed into the sealable vessel 11.

Here, it can be said that, the comparison between these two experimental results suggests that even though a relatively less drastic temperature change over time and a rather small effect of thermal shock was applied to the former, the former had a better result (fine particles of plastic of about 45%) than the latter (fine particles of plastic of about 65%).

In other words, according to the hydrothermal treatment device 10 of the present invention, by appropriately adjusting the first temperature C1, the second temperature C2, the third temperature C3, the first length of time T1, the second length of time T2, and the third length of time T3, the effect of the thermal shock can be increased by making the temperature change over time more drastic, and thus, as compared with the conventional case, the present invention can reduce the amount of fine particles of plastic (i.e., 6 mm or less in diameter) with respect to the total amount of plastic in the waste containing organic matter fed into the sealable vessel 11.

When methane fermentation is performed using a methane fermentation device, which is a type of gas production device, by utilizing the hydrothermal treatment liquid of the hydrothermal treatment device of the present invention as a feedstock, methane gas can be produced more efficiently than that in a conventional case.

[0027]

According to the above configuration and control, the hydrothermal treatment device of the present invention can solubilize waste containing organic matter, and can reduce not only the production amount of melanoidins, which is an inhibitor during gas production, but also the production amount of fine particles of plastic. Since the amounts of the two inhibitors can be reduced by only using one hydrothermal treatment device, it has better performance and lower cost.

- 5 Furthermore, according to the hydrothermal treatment system of the present invention using the hydrothermal treatment device of the present invention, gas can be efficiently produced.

Reference Signs List

- 10 [0028]
 1 Hydrothermal treatment system
 10 Hydrothermal treatment device
 11 Sealable vessel
 12 Inlet
15 13 Outlet
 14 Introduction pipe
 15 Solenoid valve
 16 Agitation device
 17 Depressurization device
20 18 Temperature sensor (temperature measurement device)
 19 Control device
 20 Solid-liquid separation device
 30 Gas production device (e.g., methane fermentation device)

Claims

[Claim 1]

A hydrothermal treatment device comprising:

a sealable vessel including an inlet and an outlet and into which waste containing organic matter is fed;

a temperature measurement device configured to measure an internal temperature of the sealable vessel;

an introduction pipe through which steam is introduced into the sealable vessel;

a solenoid valve that is configured in the introduction pipe, opens to introduce the steam into the sealable vessel, and closes to stop introducing the steam;

a depressurization device configured to decrease pressure inside the sealable vessel into which the steam is introduced, by releasing the steam from the sealable vessel; and

a control device configured to perform a hydrothermal reaction of the waste containing organic matter in the sealable vessel and to control the solenoid valve and the depressurization device based on the internal temperature measured by the temperature measurement device,

wherein the control device,

during the hydrothermal reaction, introduces the steam into the sealable vessel to increase the internal temperature to a first temperature which is equal to or higher than a temperature which promotes Maillard reaction, and then maintains the first temperature for a first length of time,

immediately after the first length of time elapses, decreases the internal temperature from the first temperature by decreasing the pressure,

decreases the internal temperature from the first temperature to a second temperature which is equal to or higher than a lower limit temperature of hydrothermal reaction by means of the abovementioned temperature decreasing, and then maintains the second temperature for a second length of time which is approximately equal to the first length of time or longer than the first length of time,

immediately after the second length of time elapses, increases the internal temperature to a third temperature which is approximately equal to the first temperature, and then maintains the third temperature for a third length of time which is approximately equal to the first length of time, and

immediately after the third length of time elapses, decreases the internal temperature from the third temperature by decreasing the pressure.

[Claim 2]

The hydrothermal treatment device according to claim 1, further comprising:

an agitation device configured to agitate a feedstock which is the waste containing organic matter inside the sealable vessel,

wherein the control device controls the agitation device to perform the agitation at a first agitation speed in the first length of time, to stop the agitation in the second length of time or to perform the agitation at a second agitation speed which is lower than the first agitation speed, and to perform the agitation at a third agitation speed which is approximately equal to the first agitation speed in the third length of time.

[Claim 3]

A hydrothermal treatment system comprising:

the hydrothermal treatment device according to claim 1 or 2;

a solid-liquid separation device configured to separate hydrothermally reacted waste containing organic matter which is treated by the hydrothermal treatment device into a hydrothermal treatment liquid and a residue; and

a gas production device configured to produce gas by microorganisms or bacteria, by utilizing the hydrothermal treatment liquid which is separated by the solid-liquid separation device as a feedstock.

[Claim 4]

The hydrothermal treatment system according to claim 3, wherein the gas production device is a methane fermentation device.