

A System for Biodegrading Biopolymer Packaging and a Method of Biodegrading Biopolymer Packaging

Field of Invention

[0001] The present invention relates to a system for biodegrading a biopolymer packaging and a method of biodegrading the same.

Background

[0002] The following discussion of the background is intended to facilitate an understanding of the present disclosure only. It should be appreciated that the discussion is not an acknowledgement or admission that any of the material referred to was published, known or is part of the common general knowledge of the person skilled in the art in any jurisdiction as of the priority date of the invention.

[0003] Plastic, Styrofoam and paper packaging have been used widely in the food and beverage industry due to their properties. However, their uses and disposal have caused great environmental concerns such as shrinkage of biodiversity, marine life ingesting plastic packaging and bags, deforestation, climate and environmental changes, global warming, contribute greatly to the debris in the Great Pacific Garbage Patch, toxic waste and presence of toxic waste in seafood.

[0004] Plastics are non-biodegradable and thus contribute to pollution. The usual biodegradable packaging will also not biodegrade in a landfill and contaminates plastic recycling streams. In view of such critical environmental concerns, food packaging manufacturers have also produced pseudo biodegradable packaging such as using oxo-biodegradable materials which are essentially conventional plastics mixed with bio-based additives. Such packaging is then marked and promoted as being eco-friendly. However, the polymers in such packaging will be fragmented into microplastics which causes ecological and health concerns. This also results in an increase in the presence of microplastics in the environment.

[0005] Such pseudo biodegradable packaging aggravates the problem of plastic pollution. Existing biodegradable systems have been unable to degrade biodegradable packaging due to its thickness. It has been found in many research and studies that biodegradable plastic cannot be degraded regardless of the environment. This is because, unlike paper, which can be decomposed easily, biodegradable plastic has at least a plastic lining the food packaging.

[0006] While paper may be fully biodegradable, it simply cannot replace plastic for practical reasons in food packaging. Paper is not waterproof and cannot withstand food that is heavier. Paper on its own, is flimsy and cannot be designed to stack multiple food packaging boxes. Hence, paper-based food packaging boxes must be lined with Polyethylene (PE) plastic. Such packaging is often contaminated and thus are unacceptable for recycling and thus contaminating recycling paper bins as the users are unaware of the plastic content in the food packaging. Hence, such paper-based food packaging is basically a plastic packaging since the plastic lining cannot be separated from the paper after it is manufactured. The waste and residue for such single use packaging creates hazards and health or life risks for all living things and the environment over the next ten years. Plastic is in great demand and if there is no suitable substitute for it, there will be increased manufacturing of such plastic packaging, and which will result in increased irreversible pollution and damage to the earth.

[0007] Biodegradable packaging requires very specific conditions for biodegradation and the current known processes take a very long time and have residual microplastics therein since such packaging are typically mixed with plastic polymers. Many biodegradable plastics are labelled as biodegradable and compostable when in fact, they contain a significant percentage of non-biodegradable plastics such as Polypropylene (PP). If a user discards such packaging into a plastic recycling stream (such as a designated plastic recycling bin), it will contaminate and interfere with the plastic waste recycling process. If a user discards such packaging into a normal trash bin, it will end up at the landfill and in such case, the packaging will not biodegrade but pollute the environment.

[0008] It is thus contemplated to provide a food packaging manufactured from biopolymers that are 100% biodegradable. There is also a need for a biodegradation system and method to alleviate one or more of the abovementioned problems.

Summary of Invention

[0009] The disclosure was conceptualized to provide a system for biodegrading a biopolymer packaging. The biopolymer packaging is 100% biodegradable and may have a composition of polylactic acid (PLA), polyhydroxyalkanoates (PHS) and polybutylene succinct (PBS) starch blends. A method of biodegrading such a biopolymer packaging is also disclosed. Since the specific % composition down to the carbon and nitrogen makeup of the biopolymer packaging is known, a suitable environment can be provided to ensure fast and complete biodegradation of the biopolymer packaging can be achieved through the disclosed methods and utilizing the disclosed system. Further, the system and method disclosed herein allows a user to achieve carbon neutrality and reduce greenhouse gases with the circular production and degradation of biopolymer packaging.

[0010] In an aspect of the invention, there is provided a system for biodegrading a biopolymer packaging having a composition of polylactic acid, polyhydroxyalkanoates and polybutylene succinct starch blends. The system comprises a crusher that is adapted to crush and compact the biopolymer packaging into one or more portions and a chamber configured to receive the one or more portions from the crusher. The chamber may have a heat source. The system also comprises an air source arranged to supply oxygen into the chamber, a first inlet arranged to supply water into the chamber, and a second inlet arranged to feed one or more microorganisms into the chamber. There is one or more mixing members disposed within the chamber. The heat source is configured to maintain the temperature in the chamber at a range of 40°C to 70°C and the first inlet is configured to maintain the humidity in the chamber at a range of 43 to 58 %. A pH level of the chamber is maintained at a range of 5 to 8. The one or more mixing members is adapted to mix the one or more portions continuously with the oxygen, water and the one or more microorganisms such that the one or more portions undergoes a combination of thermal, chemical and biotic degradation in the chamber to form an output matter.

[0011] In some embodiments, the system comprises a tank arranged to receive the output matter from the chamber.

[0012] In some embodiments, the one or more portions is mixed in the chamber for a period of up to 105 days.

[0013] In some embodiments, the chamber comprises a first section and a second section adjacent to the first section, the first section and the second section each having a mixing member.

[0014] In some embodiments, the air source, the first and the second inlets are arranged to supply oxygen, water and one or more microorganisms respectively into the first section, and the mixing member in the first section is configured to mix the one or more portions continuously with the oxygen, water and the one or more microorganisms for a predetermined period to form a first section mixture before directing the first section mixture to the second section.

[0015] In some embodiments, the heat source is configured to maintain the temperature in the first section at a range of 40°C to 60°C and more preferably, at a range of 43°C to 57°C.

[0016] In some embodiments, the chamber comprises a third section adjacent to the second section, the third section having a mixing member configured to mix the first section mixture for the duration of the predetermined period to form a second section mixture before directing the second section mixture to the third section.

[0017] In some embodiments, the heat source is configured to maintain the temperature in the second section at a range of 50°C to 70°C and more preferably, at a range of 53°C to 62°C.

[0018] In some embodiments, the mixing member in the third section mixes the second section mixture for the predetermined period to form the output matter.

[0019] In some embodiments, the predetermined period is at a range of 25 to 35 days, and more preferably at a range of 28 to 32 days.

[0020] In some embodiments, the heat source is configured to maintain the temperature in the third section at a range of 50°C to 70°C and more preferably, at a range of 53°C to 68°C.

[0021] In some embodiments, the chamber comprises an actuator operable to open a door to transmit the output matter to the tank. This enables a user to be able to verify that the mixture has been biodegraded to a satisfactory state before activating the actuator to transmit the output matter to the tank.

[0022] In some embodiments, each of the first, second and the third sections has a window. This allows a user to view the mixing content of the chamber at various periods. For example, if the user determines that there are contaminants in the chamber, or the mixing content have not biodegraded suitably, the window may be opened to remove such contaminants or redirect such mixing content to a previous section.

[0023] In some embodiments, a composition of 1 – 5% urea is added to the chamber.

[0024] In some embodiments, the chamber has at least one of a pH sensor, a humidity sensor or a temperature sensor. These sensors allow the user to monitor the pH and humidity levels and the temperature in the chamber. Once the sensors detect an abnormality (such as the pH, humidity and temperature falling outside of the prescribed range), the user may be alerted to change the factors (for example, adding more water).

[0025] In some embodiments, the tank has an outlet adapted to allow one or more gases in the output matter to be released. The outlet allows waste gases that are produced during the biodegradation process to escape to the atmosphere.

[0026] In some embodiments, the output matter in the tank is arranged to be cooled for a period of 1 to 12 months. Cooling the output matter allows the output matter to be converted into useful matter as will be described later.

[0027] In some embodiments, the chamber has an Ultraviolet (UV) light source configured to direct UV radiation to the one or more portions. The UV light source aids in speeding up the biodegradation process and serves as a disinfectant

[0028] According to another aspect of the disclosure, there is provided a method of degrading a biopolymer packaging having a composition of polylactic acid, polyhydroxyalkanoates and polybutylene succinct starch blends. The method comprises the steps of crushing and compacting the biopolymer packaging into one or more portions by a crusher, mixing the one or more portions in a chamber having a heat source and adding one or more microorganism adapted for biotic degradation of the one or more portions to the chamber to form a mixture. Water and oxygen are supplied to the chamber via one or more inlets. The mixture undergoes a combination of thermal, chemical and biotic degradation in the chamber at a humidity at a range of 40-60%, a pH level at a range of 5-8 and at a temperature at a range of 43°C to 57°C for a first predetermined period, at a temperature at a range of 53°C to 62°C for a second predetermined period, and at a temperature range of 53°C to 68°C for a third predetermined period to form an output matter.

[0029] In some embodiments, a composition of 1-5% urea is supplied to the mixture.

[0030] In some embodiments, the mixture is mixed in the chamber for a total period of up to 105 days.

[0031] In some embodiments, each of the first, second and third predetermined periods has a range of 5 to 15 days, and more preferably a range of 15 to 25 days, and most preferably a range of 25 to 35 days.

[0032] In some embodiments, each of the first, second and third predetermined periods has a range of 8 to 12 days, more preferably a range of 18 to 22 days, and most preferably a range of 28 to 32 days.

[0033] In some embodiments, the mixture is maintained at a temperature at a range of 40°C to 60°C and more preferably, at a range of 43°C to 57°C during the first predetermined period.

[0034] In some embodiments, the mixture is maintained at a temperature at a range of 50°C to 70°C and more preferably, at a range of 53°C to 62°C during the second predetermined period.

[0035] In some embodiments, the mixture is maintained at a temperature at a range of 50°C to 70°C and more preferably, at a range of 53°C to 68°C during the third predetermined period.

[0036] In some embodiments, the output matter is cooled to form an organic compound having a formula of $C_{204}H_{325}O_{85}N_{77}S$.

[0037] In some embodiments, a surface layer of non-biodegradable contaminant is removed from the output matter.

[0038] In some embodiments, a portion of the output matter that is partially degraded is redirected back into the chamber or crusher for further thermal, chemical and biotic degradation.

[0039] In some embodiments, the moisture content of the mixture is maintained at 45 to 55%.

[0040] In some embodiments, the pH level of the mixture is maintained at 5.3 to 8.

[0041] In some embodiments, the one or more microorganisms is selected from a group comprising: methylotrophs, actinobacteria, and proteobacteria.

[0042] In some embodiments, additives selected from a group comprising: dextran, levan, gellan and xanthan is added to the mixture.

[0043] Other aspects and features of the present invention will become apparent to those of ordinary skill in the art upon review of the following description of specific embodiments of the invention in conjunction with the accompanying figures.

Brief Description of the Drawings

[0044] The present invention will now be described, by way of example only, with reference to the accompanying drawings, in which:

[0045] FIG.1 is a schematic diagram of the system for biodegrading a biopolymer packaging in accordance with a first preferred embodiment;

[0046] FIG. 2 is a schematic diagram of the system for biodegrading a biopolymer packaging in accordance with a second preferred embodiment;

[0047] FIG. 3 is a schematic diagram of the system for biodegrading a biopolymer packaging in accordance with a third preferred embodiment; and

[0048] FIG. 4 is a schematic diagram of the system for biodegrading a biopolymer packaging illustrating the various processes of the system.

Description of Embodiments

[0049] In order to illustrate the technical solution(s) to the embodiments of the present disclosure, embodiments of the present disclosure are described with reference to the drawings. It is appreciable that the drawings referred to are some examples or embodiments of the present disclosure. A person having ordinary skill in the art, without further creative efforts, may apply the present disclosure to other scenarios according to these drawings. For example, although the disclosure relates to a system for biodegrading biopolymer packaging having up to three sections in the chamber, a person having ordinary skill in the art would be able to apply the present disclosure to more sections in the chamber, depending on the load and sizing requirements.

[0050] In various embodiments of the invention, there is disclosed a system for biodegrading a biopolymer packaging having a composition of polylactic acid, polyhydroxyalkanoates and polybutylene succinct starch blends. The system comprises a crusher that is adapted to crush and compact the biopolymer packaging into one or more portions and a chamber configured to receive the one or more portions from the crusher. The chamber may have a heat source. The system also comprises an air source arranged to supply oxygen into the chamber, a first inlet arranged to supply water into the chamber, and a second inlet arranged to feed one or more microorganisms into the chamber. There is one or more mixing members disposed within the chamber. The heat source is configured to maintain the temperature in the chamber at a range of 40°C to 70°C and the first inlet is configured to maintain the humidity in the chamber at a range of 43 to 58 %. A pH level of the chamber is maintained at a range of 5 to 8, and more preferably, at a range of 5.3 to 8. The one or more mixing members is adapted to mix the one or more portions continuously with the oxygen, water and the one or more microorganisms such that the one or more portions undergoes a combination of thermal, chemical and biotic degradation in the chamber to form an output matter. It will be appreciated that the system disclosed allows a complete biodegradation of biopolymer packaging via through a combination of crushing, heat, molecular and enzymic processes. A useful product will be output at the end of the cooling period and greenhouses gases are eliminated from the output.

[0051] FIG. 1 shows a schematic diagram of the system for biodegrading a biopolymer packaging in accordance with a first preferred embodiment. The biopolymer packaging comprises a composition of polylactic acid (PLA), polyhydroxyalkanoates (PHA) and polybutylene succinct starch blends. It may also comprise thermoplastic starch, polycaprolactone (PCL) and/ or corn cellulose. The term “biopolymer packaging” as used herein, includes, but is not limited to food packaging boxes, box covers, utensils and cutlery such as forks, spoons, sporks, chopstick, straws, skewers, plates, bowls, cups, sauce dishes, coasters, carriers and bags for carrying the food packaging boxes.

[0052] The system 10 of the present invention, generally comprises a crusher 14, a chamber 16, and a tank 30. The crusher 14 crushes and compacts the biopolymer

packaging into smaller portions before sending such smaller portions to the chamber 16. The chamber 16 is subjected to heat, molecular and enzymic processes for a predetermined period to biodegrade the biopolymer packaging. The tank 30 receives the output from the chamber 16 after the biodegradation process is completed. The system 10 may comprise a hopper 11 configured to receive the biopolymer packaging. The hopper 11 is then configured to send the biopolymer packaging to a pre-screening station 12. At the pre-screening station 12, a user may check the biopolymer packaging for any residual food waste such as bones or scraps, or presence of other plastic waste which may have been thrown into the hopper 11 by accident. Such food or plastic waste will be removed at the pre-screening station 12.

[0053] From the pre-screening station 12, the rest of the biopolymer packaging that has been screened will be directed to the crusher 14. The crusher 14 may be provided with one or more jaws (not shown) adapted to exert mechanical pressure, tensional and compressional forces and stresses on the biopolymer packaging to crush, break down and compact the biopolymer packaging into one or more smaller portions. These actions also help to increase the surface area for biotic and enzymic reactions. The crusher 14 may be any suitable mechanical instrument that is capable of crushing thicker packaging into at least 2 x 2 mm sized smaller portions. The crushed one or more portions may then be deposited into the chamber 16.

[0054] The chamber 16 may be sized and shaped to receive a predetermined load such that the system 10 may be used at home, in offices or industrially. The chamber 16 may have an air source 18 adapted to draw air from the surrounding and supply oxygen into the chamber 16. The air source 18 may be a blower or an air valve, for example. The system 10 also has a first inlet 20 adapted to supply water into the chamber 16. The first inlet 20 may be a port which may be opened to allow water to be added to the chamber. The first inlet 20 may be a sprayer or connected to a hose which is in turn connected to a water source.

[0055] The chamber 16 may also comprise a second inlet 22. The second inlet 22 is adapted to feed one or more microorganisms into the chamber 16. The microorganisms may be any suitable microorganisms for biodegradation of

biopolymers. For example, the microorganisms may be selected from the group comprising methylotrophs, actinobacteria or proteobacteria.

[0056] The system 10 may also comprise a heat source 24 configured to heat the contents of the chamber 16. The heat source 24 may be any suitable heat source, for example, a heating coil, etc. The heat source 24 is configured to supply heat to the chamber 16 at a range of 35°C to 70°C. More preferably, the heat source is configured to supply heat to the chamber 16 at a range of 42°C to 68°C. The chamber 16 may also have a moisture source 26. The moisture source 26 is configured to supply moisture to the chamber 16 and to maintain the humidity in the chamber 16 at a range of 40 to 60%. More preferably, the moisture source 26 is configured to supply moisture to the chamber 16 and maintain the humidity in the chamber 16 at a range of 43 to 58%. Alternatively, the first inlet 20 which is adapted to supply water into the chamber 16, may also function as the moisture source. A pH level of the chamber is maintained at a range of 5 to 8, and more preferably, at a range of 5.3 to 8.

[0057] The chamber 16 may have a mixing member 17 adapted to mix the contents in the chamber continuously. The mixing member 17 may be any suitable member, such as a stirrer that can operate to mix or swirl the mixture constantly and preferably, uniformly. The mixing member 17 ensures that the contents in the chamber 16 are mixed constantly and not allowed to settle as sediments or clumps. It will be appreciated that the mixing of the contents increases surface area to facilitate the combination of thermal, chemical and biotic degradation. The chamber 16 may have an Ultraviolet (UV) light source 27. The UV light source 27 is arranged in the chamber to direct UV radiation to the contents in the chamber 16. The UV radiation helps to speed up the biodegradation process in the chamber 16 and also serves as a disinfectant. A composition of 1 – 5 % urea is also added to the chamber 16. One or more additives selected from a group comprising: dextran, levan, gellan and xanthan may also be added into the chamber 16 through the second inlet 22.

[0058] The chamber 16 may comprise a pH sensor 23 adapted to measure and monitor a pH level of the contents in the chamber 16, a moisture sensor 21 operable to measure the humidity level of the chamber 16 and a temperature control means 25

adapted to measure and monitor the temperature of the chamber. The pH sensor 23, moisture sensor 21 and temperature control means 25 may be configured to send the readings to be displayed on a LCD display 29 (see FIG. 4).

[0059] In an embodiment, the chamber 16 is supplied with oxygen from the air source 18, water from the first inlet 20, one or more microorganisms from the second inlet 22, and moisture from the moisture source 26. The heat source 24 supplies heat at a range of 35°C to 70°C, and more preferably, a range of 42°C to 68°C, and most preferably, at a range of 43°C to 57°C. The moisture source 26 maintains the humidity in the chamber at a range of 40 to 60 %, and more preferably at a range of 43 to 58%. Alternatively, the first inlet 20 which is adapted to supply water into the chamber 16, may also function as the moisture source. A pH level of the chamber is maintained at a range of 5 to 8, and more preferably, at a range of 5.3 to 8. The mixing member 17 mixes the contents (collectively, oxygen, water, urea and one or more microorganisms) continuously for a predetermined period of up to 35 days. Preferably, the contents in the chamber 16 are mixed for a period of at least 28 to 32 days. Under the aforesaid conditions, a combination of thermal, chemical and biotic degradation occurs in the chamber 16 to form an output matter (not shown).

[0060] The chamber 16 may have one or more windows 15. The one or more windows 15 may be adapted to be opened by the user at any time to observe the biodegradation process. The one or more windows 15 may preferably be transparent or at least translucent so that the user is able to view the contents without having to open the one or more windows 15. At the end of the predetermined period, the user may open the one or more windows 15 in the chamber 16, to inspect and verify that the output matter has indeed been biodegraded fully, or at least 80 – 99.9% degraded. If there is matter which have not been fully biodegraded or at least to a satisfactory level, the user may then separate such matter and redirect such matter to the crusher 14, so that such matter can repeat the degradation process. If there are contaminants or food scraps, such contaminants or food scraps may be removed from the chamber 16 and disposed at a scrap contamination disposal 50. For the output matter which have been fully biodegraded or at least to a satisfactory level, such output matter may then be directed to the tank 30.

[0061] Optionally, all the output matter may be directed to the tank 30 at the end of the predetermined period. Visual checks and verification may alternatively be carried out at the tank 30, instead of the chamber 16, and contaminants and food scraps may be removed from the tank 30 and directed to the scrap contamination disposal 50. Output matter which has not been fully degraded or at least to a satisfactory level may be redirected from the tank 30 to the crusher 14 or chamber 16.

[0062] Following the combination of thermal, chemical and biotic degradation processes in the chamber 16, waste gases are also produced alongside the output matter. For example, carbon dioxide, water vapor, NO_3 and phosphate may be produced in the output. The tank 30 may have an outlet 31 adapted to allow waste gases directed to the tank 30 to escape to the atmosphere. The outlet 31 have be fitted or designed with a filter (not shown). The filter may be adapted to minimize the odor and prevent other gases from escaping. The filter may also be designed to filter dust, mold, bacteria or other environmental contaminants from escaping into the environment. In some embodiments, the filter may be a carbon filter.

[0063] The output matter that has completed the biodegradation process is fully biodegraded, or at least up to 80 – 99.9% biodegraded. There is no plastic residual waste at all. The system 10 has a cooling station 40. The cooling station 40 allows the output matter to be cooled at ambient conditions for a period of 1 to 12 months. At the end of the cooling period, a dark brown compost is produced. The dark brown compost is an organic compound with a chemical formula $\text{C}_{204}\text{H}_{325}\text{O}_{85}\text{N}_{77}\text{S}$. The organic compound formed is also rich in beneficial fungi. The organic compound is a viable output that may be sold to farms, gardens, parks or nurseries or be donated as useful organic matter beneficial the environment to grow corn and other crops. Hence, the present invention allows a complete biodegradation of biopolymer packaging and is also able to reduce the waste into useful compost. Also, no greenhouse gases are emitted.

[0064] In an embodiment as shown in FIG. 2, the chamber 16 comprises two sections, 16a and 16b. Both sections 16a and 16b are arranged adjacent to one another in the chamber 16. The chamber with two sections may be suitable for medium loads, for example up to 200kg. The air source 18 may be adapted to direct oxygen into the first

section 16a. The first inlet 20 may be adapted to supply water into the first section 16a while the second inlet 22 may be adapted to supply one or more microorganisms into the first section 16a. Similar to the previous embodiment, the chamber 16 has the same heat source 24, moisture source 26, UV light source 27.

[0065] The heat source 24 is configured to supply heat to the first section 16a at a range of 35°C to 70°C. More preferably, the heat source is configured to supply heat to the first section 16a at a range of 43°C to 57°C. The moisture source 26 is configured to supply moisture to the chamber 16 and to maintain the humidity in the chamber 16 at a range of 40 to 60%. More preferably, the moisture source 26 is configured to supply moisture to the chamber 16 and maintain the humidity in the chamber 16 at a range of 43 to 58%. Alternatively, the first inlet 20 which is adapted to supply water into the chamber 16, may also function as the moisture source. A pH level of the chamber is maintained at a range of 5 to 8, and more preferably, at a range of 5.3 to 8. A composition of 1 – 5 % urea is also added to the first section 16a.

[0066] The first section 16a may have a mixing member 17a adapted to mix the contents in the first section 16a continuously. The mixing member 17a ensures that the contents in the first section 16a are mixed constantly and not allowed to settle as sediments or clumps. It will be appreciated that the mixing of the mixture increases surface area to facilitate the combination of thermal, chemical and biotic degradation. The chamber 16 may have an Ultraviolet (UV) light source 27. The UV light source 27 is arranged in the chamber to direct UV radiation to the contents in the chamber 16. The UV radiation helps to speed up the biodegradation process in the chamber 16 and also serves as a disinfectant.

[0067] The first section 16a is supplied with oxygen from the air source 18, water from the first inlet 20, one or more microorganisms from the second inlet 22, and moisture from the moisture source 26. The heat source 24 supplies heat at a range of 35°C to 70°C, and more preferably, a range of 43°C to 57°C. The moisture source 26 maintains the humidity in the chamber at a range of 40 to 60 %, and more preferably at a range of 43 to 58%. Alternatively, the first inlet 20 which is adapted to supply water into the chamber 16, may also function as the moisture source. A pH level of the chamber is maintained at a range of 5 to 8, and more preferably, at a range of 5.3 to 8. The mixing

member 17a mixes the contents (collectively, oxygen, water, urea and one or more microorganisms) continuously for a predetermined period of up to 35 days. Preferably, the contents in the first section 16a are mixed for a period of at least 28 to 32 days. Under the aforesaid conditions, a combination of thermal, chemical and biotic degradation occurs in the first section 16a to form a first section matter.

[0068] At the end of the predetermined period, the first section matter is then transferred to the second section 16b. At the same time, the one or more portions from the crusher 14 may be directed to the first section 16a. This allows the biodegradation process to be continuous and the system's resources to be optimally utilized.

[0069] The second section 16b may have a mixing member 17b. The mixing member 17b is configured to mix the first section matter continuously for a predetermined period of up to 35 days. Preferably, the first section matter in the second section 16b is mixed for a period of at least 28 to 32 days. Under the aforesaid conditions, a combination of thermal, chemical and biotic degradation occurs in the second section 16b to form the output matter.

[0070] Each of the first section 16a and the second section 16b may have one or more windows 15. The one or more windows 15 may be adapted to be opened by the user at any time to observe the biodegradation process. The one or more windows 15 may preferably be transparent or at least translucent so that the user is able to view the contents without having to open the one or more windows 15. For instance, at the end of the predetermined period, the user may open the one or more windows 15 in the second section 16b, to inspect and verify that the output matter has indeed been biodegraded fully, or at least 80 – 99.9% degraded. If there is matter which have not been fully biodegraded or at least to a satisfactory level, the user may then separate such matter and redirect such matter to the crusher 14, so that such matter can repeat the degradation process. If there are contaminants or food scraps, such contaminants or food scraps may be removed from the chamber 16 and disposed at a scrap contamination disposal 50. For the output matter which have been fully biodegraded or at least to a satisfactory level, such output matter may then be directed to the tank 30. Furthermore, if upon inspection at the second section 16b, the user determines

that the first section matter in the second section is not fully degraded, the user may redirect such matter to the first section 16a.

[0071] Optionally, all the output matter may be directed to the tank 30 at the end of the predetermined period. In this embodiment with a chamber 16 having two sections 16a, 16b, the predetermined period is the sum of the mixing period in each section. In other words, the output matter may be directed to the tank 30 at the end of 56 to 64 days. Visual checks and verification may alternatively be carried out at the tank 30, instead of the second section 16b, and contaminants and food scraps may be removed from the tank 30 and directed to the scrap contamination disposal 50. Output matter which has not been fully degraded or at least to a satisfactory level may be redirected from the tank 30 to the crusher 14.

[0072] Following the combination of thermal, chemical and biotic degradation processes in the chamber 16, waste gases such as carbon dioxide, water vapor, nitrogen trioxide and phosphate may also be produced alongside the output matter. The tank 30 may have an outlet 31 adapted to allow waste gases directed to the tank 30 to escape to the atmosphere. The outlet 31 have be fitted or designed with a filter (not shown). The filter may be adapted to minimize the odor and prevent other gases from escaping. The filter may also be designed to filter dust, mold, bacteria or other environmental contaminants from escaping into the environment. In some embodiments, the filter may be a carbon filter.

[0073] The output matter that has completed the biodegradation process is fully biodegraded, or at least up to 80 – 99.9% biodegraded. There is no plastic residual at all. The cooling station 40 allows the output matter to be cooled at ambient conditions for a period of 1 to 12 months. At the end of the cooling period, a dark brown compost is produced. The dark brown compost has a chemical formula $C_{204}H_{325}O_{85}N_{77}S$. The organic compound formed is also rich in beneficial fungi. The organic compound is a viable output that may be sold to farms, gardens, parks or nurseries or be donated as useful organic matter beneficial the environment to grow corn and other crops. Hence, the present invention allows a complete biodegradation of biopolymer packaging and is also able to reduce the waste into useful compost. Also, no greenhouse gases are emitted.

[0074] In an embodiment as shown in FIG. 3, the chamber 16 comprises three sections, 16a, 16b, 16c. In addition to the two sections 16a, 16b as described above, the chamber 16 comprises a third section 16c arranged adjacent to the second section 16b, with the second section 16b sandwiched between the first section 16a and the third section 16c. The chamber with three sections may be suitable for larger loads and applicable for industrial purposes. The air source 18 may be adapted to direct oxygen into the first section 16a. The first inlet 20 may be adapted to supply water into the first section 16a while the second inlet 22 may be adapted to supply one or more microorganisms into the first section 16a. Similar to the previous embodiments, the chamber 16 has the same heat source 24, moisture source 26, UV light source 27.

[0075] The heat source 24 is configured to supply heat to the first section 16a at a range of 35°C to 70°C. More preferably, the heat source is configured to supply heat to the first section 16a at a range of 43°C to 57°C. The moisture source 26 is configured to supply moisture to the chamber 16 and to maintain the humidity in the chamber 16 at a range of 40 to 60%. More preferably, the moisture source 26 is configured to supply moisture to the chamber 16 and maintain the humidity in the chamber 16 at a range of 43 to 58%. Alternatively, the first inlet 20 which is adapted to supply water into the chamber 16, may also function as the moisture source. A pH level of the chamber is maintained at a range of 5 to 8, and more preferably, at a range of 5.3 to 8. A composition of 1 – 5 % urea is also added to the first section 16a.

[0076] The first section 16a may have a mixing member 17a adapted to mix the contents in the first section 16a continuously. The mixing member 17a ensures that the contents in the first section 16a are mixed constantly and not allowed to settle as sediments or clumps. It will be appreciated that the mixing of the mixture increases surface area to facilitate the combination of thermal, chemical and biotic degradation. The chamber 16 may have an Ultraviolet (UV) light source 27. The UV light source 27 is arranged in the chamber to direct UV radiation to the contents in the chamber 16. The UV radiation helps to speed up the biodegradation process in the chamber 16 and also serves as a disinfectant.

[0077] The first section 16a is supplied with oxygen from the air source 18, water from the first inlet 20, one or more microorganisms from the second inlet 22, and moisture from the moisture source 26. The heat source 24 supplies heat at a range of 35°C to 70°C, and more preferably, a range of 43°C to 57°C. The moisture source 26 maintains the humidity in the chamber at a range of 40 to 60 %, and more preferably at a range of 43 to 58%. Alternatively, the first inlet 20 which is adapted to supply water into the chamber 16, may also function as the moisture source. A pH level of the chamber is maintained at a range of 5 to 8, and more preferably, at a range of 5.3 to 8. The mixing member 17a mixes the contents (collectively, oxygen, water, urea and one or more microorganisms) continuously for a predetermined period of up to 35 days. Preferably, the contents in the first section 16a are mixed for a period of at least 28 to 32 days. Under the aforesaid conditions, a combination of thermal, chemical and biotic degradation occurs in the first section 16a to form a first section matter.

[0078] At the end of the predetermined period, the first section matter is then transferred to the second section 16b. At the same time, the one or more portions from the crusher 14 may be directed to the first section 16a. This allows the biodegradation process to be continuous and the system's resources to be optimally utilized.

[0079] The second section 16b may have a mixing member 17b. The mixing member 17b is configured to mix the first section matter continuously for a predetermined period of up to 35 days. Preferably, the first section matter in the second section 16b is mixed for a period of at least 28 to 32 days. Under the aforesaid conditions, a combination of thermal, chemical and biotic degradation occurs in the second section 16b to form the second section matter.

[0080] At the end of the predetermined period (in this case 56 to 64 days), the second section matter is then transferred to the third section 16c. At the same time, the one or more portions from the crusher 14 may be directed to the first section 16a. The third section 16c may have a mixing member 17c. The mixing member 17c is configured to mix the second section matter continuously for a predetermined period of up to 35 days. Preferably, the second section matter in the third section 16c is mixed for a period of at least 28 to 32 days. Under the aforesaid conditions, a combination of

thermal, chemical and biotic degradation occurs in the third section 16c to form the output matter.

[0081] Each of the first section 16a, the second section 16b and the third section 16c may have one or more windows 15. The one or more windows 15 may be adapted to be opened by the user at any time to observe the biodegradation process. The one or more windows 15 may preferably be transparent or at least translucent so that the user is able to view the contents without having to open the one or more windows 15. For instance, at the end of the predetermined period, the user may open the one or more windows 15 in the third section 16c, to inspect and verify that the output matter has indeed been biodegraded fully, or at least 80 – 99.9% degraded. If there is matter which have not been fully biodegraded or at least to a satisfactory level, the user may then separate such matter and redirect such matter to the crusher 14 or the first section 16a or the second section 16b, so that such matter can repeat the degradation process. If there are contaminants or food scraps, such contaminants or food scraps may be removed from the chamber 16 and disposed at a scrap contamination disposal 50. For the output matter which have been fully biodegraded or at least to a satisfactory level, such output matter may then be directed to the tank 30.

[0082] Optionally, all the output matter may be directed to the tank 30 at the end of the predetermined period. In this embodiment with a chamber 16 having three sections 16a, 16b, 16c, the predetermined period is the sum of the mixing period in each section. In other words, the output matter may be directed to the tank 30 at the end of 84 to 96 days. Visual checks and verification may alternatively be carried out at the tank 30, instead of the third section 16c, and contaminants and food scraps may be removed from the tank 30 and directed to the scrap contamination disposal 50. Output matter which has not been fully degraded or at least to a satisfactory level may be redirected from the tank 30 to the crusher 14.

[0083] Following the combination of thermal, chemical and biotic degradation processes in the chamber 16, waste gases such as carbon dioxide, water vapor, nitrogen trioxide and phosphate may also be produced alongside the output matter. The tank 30 may have an outlet 31 adapted to allow waste gases directed to the tank 30 to escape to the atmosphere. The outlet 31 have be fitted or designed with a filter

(not shown). The filter may be adapted to minimize the odor and prevent other gases from escaping. The filter may also be designed to filter dust, mold, bacteria or other environmental contaminants from escaping into the environment. In some embodiments, the filter may be a carbon filter.

[0084] The output matter that has completed the biodegradation process is fully biodegraded, or at least up to 80 – 99.9% biodegraded. There is no plastic residual at all. The cooling station 40 allows the output matter to be cooled at ambient conditions for a period of 1 to 12 months. At the end of the cooling period, a dark brown compost is produced. The dark brown compost has a chemical formula $C_{204}H_{325}O_{85}N_{77}S$, which can be used in farms, gardens, parks or nurseries. Hence, the present invention allows a complete biodegradation of biopolymer packaging and is also able to reduce the waste into useful compost. Also, no greenhouse gases are emitted.

[0085] While the drawings have illustrated a chamber with up to three sections, a skilled person upon reading this disclosure that four or more sections may also be utilized in the chamber for larger loads. While the air source 24, the first and second inlets 20, 22 have been described to supply oxygen, moisture and one or more microorganisms to the first section 16a, each of the second section 16b and third section 16c may also be provided with an air source, and a first and second inlets. For instance, when the pH sensor 23 in the chamber 16 detects and signals that the pH level in the second or third section 16b, 16c is outside of the range of 5 to 8, the user may then be prompted to increase the amount of water and oxygen in the second or third sections 16b, 16c.

[0086] The biopolymer packaging comprises a composition of polylactic acid (PLA), polyhydroxyalkanoates (PHA) and polybutylene succinct starch blends. It may also comprise thermoplastic starch, polycaprolactone (PCL) and/ or corn cellulose. Importantly, the biopolymer packaging comprises a high carbon content of 50 % and above and a high carbon to nitrogen (C/N) ratio, preferably with a C/N ratio of 30:1. Notwithstanding that term biopolymer packaging has used, other forms of suitable biopolymer, such as corn bags or cutleries, having the same or similar composition as described may be degraded by the system and method described herein.

[0087] A method of degrading a biopolymer packaging having a composition of polylactic acid, polyhydroxyalkanoates and polybutylene succinct starch blends will now be described with reference to FIG. 4. A user deposits the used biopolymer packaging into a hopper 11. From the hopper 11, the biopolymer packaging is directed to the crusher 14. The crusher 14 may be provided with a weight sensor (not shown) to detect the mass of the biopolymer packaging deposited therein. The crusher 14 then begins to crush and compact the biopolymer packaging into one or more smaller portions. The process of crushing breaks down and reduces the size of the biopolymer packaging to one or more smaller portions with an average size of 2 x 2mm or smaller. The crushed one or more portions are then deposited in the chamber 16.

[0088] In the chamber 16, the one or more portions are mixed continuously with water, oxygen, urea and one or more microorganisms to form a mixture. The mixture undergoes a combination of thermal, chemical and biotic degradation in the chamber 16 at a moisture content at a range of 40-60%, a pH level at a range of 5-8 and at a temperature at a range of 43°C to 57°C for a first predetermined period, at a temperature at a range of 53°C to 62°C for a second predetermined period, and at a temperature range of 53°C to 68°C for a third predetermined period to form an output matter. The mixture may be mixed in the chamber 16 for a total period of up to 105 days.

[0089] It will be appreciated that the mixing of the mixture increases surface area to facilitate the combination of thermal, chemical and biotic degradation processes. The first, second and third predetermined periods may each have a range of 5 to 15 days, or a range of 15 to 25 days, or a range of 25 to 35 days.

[0090] Preferably, the first, second and third predetermined periods may each have a range of 8 to 12 days, more preferably a range of 18 to 22 days, and most preferably a range of 28 to 32 days.

[0091] The mixture may be maintained at a temperature at a range of 40°C to 60°C or more preferably, at a range of 43°C to 57°C during the first predetermined period. The mixture may be maintained at a temperature at a range of 50°C to 70°C or more preferably, at a range of 53°C to 62°C during the second predetermined period. The

mixture may be maintained at a temperature at a range of 50°C to 70°C or more preferably, at a range of 53°C to 68°C during the third predetermined period.

[0092] During the first predetermined period, rate of decomposition progressively increases. Rate of decomposition peaks during the second predetermined period. During the third predetermined period, rate of decomposition progressively decreases.

[0093] Oxygen supplied to the chamber 16 may be supplied as air in atmosphere in which the percentage of oxygen is 21%, or by other means of oxygen supply in which the percentage of oxygen is at least 10%. Advantageously, supply of and the presence of oxygen during mixing ensures that decomposition is aerobic.

[0094] The output matter may be cooled to form an organic compound having a formula of $C_{204}H_{325}O_{85}N_{77}S$. Cooling may be at ambient temperature, for example 20°C to 35°C, in which the output matter is kept moist and aerated. The cooling step can be from a period of one month, or longer than a year. Cooling for period of at least one to four months results in further breakdown of the output matter. The organic compound formed is also rich in beneficial fungi. The organic compound is a viable output that may be sold to farms, gardens, parks or nurseries or be donated as useful organic matter beneficial the environment to grow corn and other crops.

[0095] During the biodegradation process non-biodegradable contaminants may form on the surface of the output matter. A user may remove a surface layer of non-biodegradable contaminant from the output matter and dispose it at the scrap contamination disposal 50. A portion of the output matter that is partially degraded may be redirected back into the crusher 14 or chamber 16 for further thermal, chemical and biotic degradation.

[0096] The moisture content of the mixture is maintained at 45 to 55% while the pH level of the mixture is maintained at 5.3-8. For existing processes, during decomposition, organic acids are produced and would lead to decline in pH levels. This in turn promotes growth of the fungi population and with further breakdown of the organic acids, the decomposition turns anaerobic. Microbial activity is severely

reduced. The water may be deionised water, or any form of water that is free from, or effectively free from, agents such as pesticides or antimicrobials.

[0097] With the aforementioned disclosure, it will be apparent that the present invention provides a system and method that can fully biodegrade (from 80% to 99.9%) biopolymer packaging and at the same time reduce the waste into useful compost that may be used in farms, gardens, parks or nurseries. No greenhouse gases are emitted and hence is friendly to the environment. Moreover, the biodegradation process may be allowed to run continuously in a cycle and the system's resources are optimally utilized. No plastic waste is produced.

[0098] It will be apparent to those skilled in the art that various modifications, variations, substitutions, and equivalents exist for features of the system which do not materially depart from the scope of the invention.

[0099] It should be further appreciated by the person skilled in the art that variations and combinations of features described above, not being alternatives or substitutes, may be combined to form yet further embodiments falling within the intended scope of the invention.

Claims

1. A method of degrading a biopolymer packaging having a composition of polylactic acid, polyhydroxyalkanoates and polybutylene succinct starch blends, the method comprising the steps of:
 - crushing and compacting the biopolymer packaging into one or more portions by a crusher;
 - mixing the one or more portions in a chamber having a heat source;
 - adding one or more microorganism adapted for biotic degradation of the one or more portions to the chamber to form a mixture; and
 - supplying water and oxygen to the chamber via one or more inlets,
 wherein the mixture undergoes a combination of thermal, chemical and biotic degradation in the chamber at a humidity at a range of 40-60%, a pH level at a range of 5-8 and at a temperature at a range of 43°C to 57°C for a first predetermined period, at a temperature at a range of 53°C to 62°C for a second predetermined period, and at a temperature range of 53°C to 68°C for a third predetermined period to form an output matter.
2. The method of claim 1, further comprising supplying a composition of 1-5% urea to the mixture.
3. The method of claim 1 or 2, further comprising a step of cooling the output matter in a tank for a period of 1 to 12 months.
4. The method of any one of the preceding claims, wherein the first, second and third predetermined period each has a range of 8 to 12 days, more preferably a range of 18 to 22 days, and most preferably a range of 28 to 32 days.
5. The method of any one of the preceding claims, wherein the pH level in the chamber is at a range of 5.3-8.