In summary, current known technologies of PHAs production have several disadvantages including: (1) the need to use aseptic culture of selected or genetically modified strains that requires high expenses for sterilization of equipment and medium, as well as maintenance of aseptic conditions during biosynthesis of PHA; 2) the need to use relatively expensive nutrients such as pure mineral salts and glucose or other pure sources of carbon and energy; 3) the need to use selection techniques which are limited to batch processes and which may adversely disrupt the normal cellular behavior of PHAs producing micro-organisms and 4) the need to use expensive, flammable and toxic organic solvents or energy-consuming methods for extraction of PHAs from bacterial cells.

Furthermore, known methods of PHAs synthesis and extraction suffer from high cost or environmental pollution, and are difficult to be industrialized. Accordingly, there is a need to provide a method for the production of PHAs that overcomes, or at least ameliorates, the disadvantages mentioned above. There is also a need to provide a method for selecting PHAs producing microorganisms that overcomes or at least ameliorates, the disadvantages mentioned above. There is also a need to provide a method for extracting PHAs from PHAs producing microorganism that overcomes or at least ameliorates, the disadvantages mentioned above.

Summary

According to an aspect, there is provided a process for producing polyhydroxyalkanoate (PHA) comprising the steps of:

culturing a biomass containing PHA-producing microbes accumulating PHAs in a culture media containing supplied hydrogen gas and volatile organic compounds; and

hydrolyzing said PHAs-producing microbes using microorganisms selected from the PHAs-containing microbes.

According to an embodiment~~a first aspect~~, there is provided a process for producing polyhydroxyalkanoate (PHA) comprising the steps of culturing a biomass containing PHA-producing microbes in a culture media and hydrolyzing said PHAs-producing microbes using microorganisms

fermentation zone for the production of volatile organic compounds and hydrogen include but are not limited to the species of the genera *Acetobacter, Bacteroides, Clostridium, Citrobacter, Enterobacter, Moorella, Propionibacterium, Ruminococcus, Thermoanaerobium.*

In one embodiment, the microbial fermentation zone is maintained at substantially anaerobic conditions. In one embodiment, the process comprises the step of producing hydrogen gas in said microbial fermentation zone. Advantageously, the hydrogen produced can used for injection into the culture medium as described above.

In one embodiment, said fermentation zone comprises of a liquid phase and a vapor phase. In another embodiment, the process comprises the step of obtaining the volatile organic compounds from said microbial fermentation zone. In one embodiment, the obtaining step comprises the step of removing a vapor phase adjacent to or above said fermentation zone. Advantageously, the volatile organic compounds produced can be used for injection into the culture medium as described above.The microbial fermentation zone may be maintained at a pH in the range of 5 to 8. The microbial fermentation zone may also be maintained at a reduction potential of from -50 mV to - 400 mV.

According to an embodiment~~a second aspect~~, there is provided a method of increasing the proportion of PHAs-producing microbes relative to non-PHAs producing microbes in a culture media containing both PHAs-producing microbes and non-PHAs producing microbes, the method comprising the step of (a2) incubating said culture media in a selection zone under conditions to enable faster propagation of the PHAs-producing microbes relative to the non-PHAs producing microbes for a period of time to produce a culture media having more PHAs microbes relative to non-

This step allows the "positively selected" PHAs-producing microbes to assimilate carbon source rapidly in the presence of a carbon source, thereby overall producing an increased amount of PHAs. Preferably, the steps (a1), (a2) and (a3) take place continuously. Advantageously, this enables the cycling of the culture media between the providing step and incubating step continuously allowing rapid "positive selection" as well as the production of PHAs to take place rapidly. More advantageously, this method can be incorporated into a continuous process and is not limited for use in a batch process, thereby increasing the overall throughput.

In one embodiment, the residence time of the culture media in the chamber where the providing step (a1) takes place is from 6 to 24 hours. The residence time of the culture media in the chamber where the incubating step (a2) takes place may be from 0.5 to 2 hours. In one embodiment, the ratio of the residence time of the culture media in the chamber where the providing step (a1) takes place to the residence time of the culture media in the chamber where the incubating step (a2) takes place is from 5 to 15. The dissolved oxygen in the incubating step (a2) may also be maintained at 1 mgL^{-1} to 10 mgL^{-1}. Advantageously, the above conditions contribute to the overall success and effectively of the method.

According to an aspect, there is provided a method of extracting PHAs from PHAs-containing microbes, the method comprising the steps of: hydrolyzing the cell walls of the PHAs-containing microbes to release PHAs from the PHAs-containing microbes; and separating said released PHAs from said microbes;

wherein the hydrolyzing step comprises the step of using microorganisms that release enzymes that hydrolyzes bacterial cell walls;

wherein the microorganisms that release enzymes that hydrolyzes bacterial cell walls are fungi selected from the group consisting of fungi from the genera Absidia, Agaricus, Aspergillus, Chaetomium, Fusarium, Neurospora, Penicillium, Phanerophaete, Phialophora, Pleurotus, Rhizoctonia and Trichoderma.

According to an embodiment~~a third aspect~~, there is provided a method of extracting PHAs from PHAs-containing microbes, the method comprising the steps of hydrolyzing the cell walls of the PHAs-containing microbes to release PHAs from the PHAs-containing microbes; and separating said released PHAs from said microbes. Advantageously, the method is a cost effective and efficient method of extracting the PHAs from PHAs-containing microbes.

In one embodiment, the hydrolyzing step comprises the step of using microorganisms that release enzymes that hydrolyzes bacterial cell walls. The microorganisms that release enzymes that hydrolyze bacterial cell walls may include fungi selected from the group consisting of fungi from the genera *Absidia*, *Agaricus*, *Aspergillus*, *Chaetomium*, *Fusarium*, *Neurospora*, *Penicillium*, *Phanerophaete*, *Phialophora*, *Pleurotus*, *Rhizoctonia* and *Trichoderma*.

In one embodiment, the hydrolysing step is performed simultaneously with the separating step to thereby reduce the time of contact between the hydrolytic enzymes and said released PHAs. Advantageously, this reduces the possibility of PHAs being undesirably hydrolysed by the hydrolytic enzymes. The separating step may comprise using at least one of flotative separation, centrifugation or membrane separation.

According to another aspect, there is provided a process for producing polyhydroxyalkanoate (PHA) comprising the steps of:

(a) incubating a culture media containing PHAs-producing microbes and non-PHAs producing microbes in a selection zone under conditions to enable faster propagation of the PHAs-producing microbes relative to the non-PHAs producing microbes, wherein said incubating is undertaken for a period of time to produce culture media having more PHA microbes relative to the non-PHA producing microbes;

b) providing said culture media produced in said incubating step (a) to a culturing zone to culture the PHA-producing microbes in a culture media containing hydrogen gas;

c) providing said PHA produced in said providing step (b) to an extraction zone in which said PHA producing microbes are hydrolyzed by microorganisms to release PHAs from the PHAs-containing microbes; and

d) isolating said PHAs from said culture media.

According to an embodiment~~a fourth aspect~~, there is provided a process for producing polyhydroxyalkanoates (PHAs) comprising the steps of (a) incubating a culture media containing PHAs-producing microbes and non-PHAs producing microbes in a selection zone under conditions to enable faster propagation of the PHAs-producing microbes relative to the non-PHAs producing microbes, wherein said incubating is undertaken for a period of time to produce culture media having more PHA microbes relative to the non-PHA producing microbes; (b) providing said culture media produced in said incubating step (a) to a culturing zone to culture the PHA-producing microbes in a culture media ; (c) providing said PHA produced in said providing step (a) to an extraction zone in which said PHA producing microbes are hydrolyzed by microorganisms to release PHAs from the PHAs-containing microbes; and (d) isolating said PHAs from said culture media.