

IMPROVED BIOLOGICAL PRODUCTION OF HYDROGEN AND CO-PRODUCTION OF METHANE

Field of the Invention

[0001] The present invention relates to a process for the production of biogas from biological waste streams. In particular, this invention relates to the improved production of hydrogen gas and methane gas from biological waste streams.

Background of the Invention

[0002] The use of hydrogen as an alternative fuel source has been receiving wide attention recently with increase in research and development into electric automobiles and the development of clean fuels. There have been many studies done on the efficient and feasible production of hydrogen gas. One method that has generated more interest lately is the biological production of hydrogen gas using anaerobic bacteria. The method utilizes anaerobic bacteria for fermentation of biological waste streams to produce hydrogen. These biological waste streams may comprise of municipal wastewater treatment plants having organic residues or waste streams of food and beverage processing industries. Use of anaerobic bacteria is subject to isolating the right bacteria to add to the biological waste streams and providing the right environment and conditions before the bacteria are effective in degrading the biological waste streams and producing hydrogen. Further, present methods of producing hydrogen have produced unsatisfactory results in the yield of hydrogen from biological waste streams containing insoluble solid waste residues, amounting to about 1 – 5% by weight. Typically, the hydrogen yield has been in the range of 0.08 mmol-H₂/g-DS(dried solids) as disclosed in the publication by Huang et. al. (2000) “The preliminary studies of hydrogen production from anaerobic digestion with different substrates and cultivations”, at “The 25th Wastewater Tech. Conference, Yulin, Taiwan”.

[0003] Another biogas generated during treatment of biological waste streams is methane. Methane has long been recognized as a potential means for energy recovery especially during biological waste treatment. Again the concern with methane is that of a sufficient yield and of efficient recovery.

[0004] There have been considerable efforts to improve hydrogen and methane production and recovery from degradation of biological waste streams using enzymes, controlling of environment characteristics e.g. temperature and pH levels as well as the addition of various chemical catalysts. However, there is still a lack of a simple and efficient method for the improved production of hydrogen and co-production of methane from biological waste streams containing insoluble particulate phases such as biological sludges.

Summary of the Invention

[0005] The present invention seeks to provide a system and method for the co-production of hydrogen and methane.

[0006] Accordingly, in one aspect, the present invention provides, a system for producing hydrogen and co-producing methane comprising: a pre-processor and a processor; wherein the pre-processor for receiving a biological waste stream and for producing at least one pre-processed output, the processor for receiving the at least one pre-processed output for production of hydrogen and co-production of methane.

[0007] In another aspect, the present invention provides, a system for producing hydrogen and co-producing methane comprising: a pre-processor, the pre-processor further comprising a pre-treatment module and a first solid-liquid separator; and a processor comprising a hydrogen fermenter and a methane digester; wherein the pre-processor for receiving a biological waste stream and for producing at least one

pre-processed output, the processor for receiving the at least one pre-processed output for production of hydrogen and co-production of methane.

[0008] In a further aspect, the present invention provides, a method for producing hydrogen and co-producing methane, the method comprising the steps: subjecting a biological waste stream to pre-treatment; subjecting a pretreated waste stream to solid-liquid separation; hydrogen production; and methane production.

Brief Description of the Drawings

[0009] A preferred embodiment of the present invention will now be more fully described, with reference to the drawings of which:

[0010] FIG.1 illustrates a general block diagram of the system in accordance with the present invention.

[0011] FIG.2 illustrates a functional block diagram in accordance with FIG.1;

[0012] FIG.3 illustrates a flowchart of the method in accordance with the present invention;

[0013] FIG.4 illustrates a flowchart of hydrogen production of Fig.3 in accordance with the present invention; and

[0014] FIG.5 illustrates a flowchart of methane production of Fig. 3 in accordance with the present invention.

Detailed description of the Drawings

[0015] Referring to FIG.1, a system 100 for improved production of hydrogen 15 and co-production methane 20 is shown. The system 100 comprises a pre-

processor 5 and a processor 10. The pre-processor 5 for receiving at least one input of a biological waste stream 2. The biological waste stream 2 may comprise waste water having dissolved organic substances with insoluble solid waste residues amounting to about 1 – 5% by weight. Examples of such biological waste streams are waste streams from food and beverage processing industries, from industries generating biological wastes and from municipal wastewater treatment plants. The pre-processor 5 pre-processes the biological waste stream 2 and produces at least one pre-processed output for the processor 10. The processor 10 is adapted for receiving the at least one pre-processed output from the pre-processor 5 and for producing of hydrogen 15 and co-producing of methane 20.

[0016] Referring to FIG.2, the system 100 of FIG.1 is shown in more detail. The pre-processor 5 further comprises a pre-treatment module 35 and a first solid-liquid separator 40. The at least one pre-processed output from the pre-processor 5 comprises a liquid phase 6 and a solid phase 7. The at least one input of the biological waste stream 2 undergoes pre-treatment in the pre-treatment module 35 and produces a pre-treated waste stream 36. The pre-treatment module 35 further utilizes the methods of pasteurization and “Freezing and Thawing”.

[0017] The pre-treatment effectively hydrolyzes or releases insoluble organic substances into the water of the biological waste stream 2. The method of pasteurization involves maintaining the biological waste stream 2 at a temperature of 121°C and at a pressure of 1.2 kgf/cm² for about 30 minutes.

[0018] The method of “Freezing and Thawing” first requires that the biological waste stream 2 undergoes complete freezing to about –17°C. The frozen biological waste stream 2 is then thawed. This “Freezing and Thawing” method releases considerable amounts of insoluble organic substances from the solid waste residues of the biological waste stream 2 into the waste water.

[0019] The pre-treated waste stream 36 from the pre-treatment module 35 is then sent to the first solid-liquid separator 40 where the pre-treated waste stream 36 is

separated into the solid phase 7 and the liquid phase 6. The solid phase 7 comprises substantially of the solid waste residues and any insoluble organic substances from the pre-treated waste stream 36. The liquid phase 6 comprises substantially of wastewater having dissolved organic substances with negligible insoluble solid waste residues amounting to less than 0.1% by weight. The solid phase 7 and the liquid phase 6 are then sent to the processor 10 for processing.

[0020] The first solid-liquid separator 40 may utilize a variety separating means. Some examples of such separating means are by way of mechanical separation using shakers and sieves/screens, centrifuges and drum separators. The first solid-liquid separator 40 may also be a holding tank for standing the pre-treated waste stream 36 and allowing the solid waste residues to either sink to the bottom of the holding tank or to float to the surface of the pre-treated waste stream 36.

[0021] The processor 10 further comprises a hydrogen fermenter 45 and a methane digester 50. The hydrogen fermenter 45 is adapted to receive the liquid phase 6 from the solid-liquid separator 40 and also adapted to receive a first inoculum dose 46. The hydrogen fermenter 45 may be an anaerobic reactor and may further be a batch, semi-batch or continuous anaerobic reactor. The hydrogen fermenter 45 may further be provided with stirrers or agitators and may also be provided with a temperature regulating means to regulate the temperature within the hydrogen fermenter 45.

[0022] The first inoculum dose 46 comprises bacteria isolated from the biological waste stream that has been identified and predetermined to be the desired bacteria for the degradation of the organic residues or wastes found in the biological waste streams that would result in the optimum production of hydrogen 15. The bacteria strain that has proved to produce the best results is from the Clostridium strain, particularly Clostridium bifermentans.

[0023] Even though the strain of bacteria is known in the art, commercially available strains of these bacteria are not as effective as the same strain of bacteria

isolated from the biological waste stream to be used as the first inoculum 46 for the system 100. Studies have indicated that commercially available strains of *Clostridium* required incubation periods of up to more than sixty hours before becoming active in degrading organic residues and producing hydrogen 15. However, bacteria isolated from the biological waste streams 2 begin to be active once they are introduced into the hydrogen fermenter 45 as the first inoculum dose 46 and are dosed into the liquid phase 6. Upon fermentation of the liquid phase 6, hydrogen 15 is produced.

[0024] The methane digester 50 is adapted to receive the solid phase 7 from the first solid-liquid separator 40 and also adapted to receive the remaining liquid phase 47 from the hydrogen fermenter 45. The methane digester 50 is further adapted to receive a second inoculum dose 51. The methane digester 50 may be an anaerobic reactor and may further be a batch, semi-batch or continuous anaerobic reactor. The methane digester 50 may further be provided with stirrers or agitators and may also be provided with a temperature regulating means to regulate the temperature within the methane digester 50.

[0025] The second inoculum dose 51 comprises common methagenic bacteria that could degrade organic matter into methane. The remaining liquid phase 47 from the hydrogen fermenter 45, the solid phase 7 and the second inoculum 51 together undergoes digestion in the methane digester and thus produces methane 20.

[0026] After digestion in the methane digester 50, remaining bio-sludge 52 from the methane digester 50 can further be sent to a second solid-liquid separator 55, where solid residues referred to as cake 57 is separated from processed liquid 56. The processed liquid 56 and the cake 57 can then be further disposed of.

[0027] Referring to FIG.2 and FIG.3, a method 300 of producing hydrogen 15 and co-producing of methane 20 is shown. The method 300 comprising the steps: subjecting the biological waste stream 2 to pre-treatment 310, subjecting pre-treated waste stream 36 to solid-liquid separation 315, hydrogen production 320

and methane production 325. The step of pre-treatment 310 may further comprise the methods of pasteurization and "Freezing and Thawing" as discussed earlier. The pre-treated waste stream 36 is then subjected to solid-liquid separation 315 by the first solid-liquid separator 40. The liquid phase 6 and the solid phase 7 from the solid-liquid separation 315 step is then used in the steps of hydrogen production. 320 and methane production 325.

[0028] Referring to FIG.4, the steps in hydrogen production 320 in FIG 3 starts 405 with sending 410 the liquid phase 6 from the first solid-liquid separator 40 to the hydrogen fermenter 45. The liquid phase 6 comprises substantially of waste water having dissolved organic substances with insoluble solid waste residues amounting to less than 0.1% by weight.

[0029] Next, the step of adding 415 the first inoculum dose 46 into the hydrogen fermenter 45 followed by the fermenting 420 of the liquid phase to produce hydrogen 15. Following which, the produced hydrogen 15 is extracted 425 and the remaining liquid phase 47 is sent 430 to the methane digester 50. Studies by the inventors have shown that hydrogen production 320 using the liquid phase 6 as a substrate have yielded results of up to 0.9 mmol-H₂/g-DS(dried solids). This is a vast improvement over current methods producing only about 0.08 mmol-H₂/g-DS(dried solids). This is attributed to the low amounts of insoluble solid waste residues in the liquid phase 6 which is used as the substrate for the fermentation to produce hydrogen 15. The high yield is also further attributed to the pre-treatment of the biological waste stream 2 thereby hydrolyzing or releasing insoluble organic substances into the water of the biological waste stream 2. The pre-treatment comprises the methods of pasteurization or "Freezing and Thawing".

[0030] Referring to FIG.5, the steps in methane production 325 starts 505 with sending 510 the solid phase 7 to the methane digester. Next, the second inoculum dose 51 is added 515 into the methane digester 50. The remaining liquid phase 47 from the hydrogen fermenter 45 is sent 520 to the methane digester 50. Following which, the step of digesting 525 of the solid phase 7 and the remaining liquid phase

12 FEB 2007

8

47 to produce methane 20 occurs and followed by the extracting 530 of the produced methane 20.

[0031] It will be appreciated that various modifications and improvements can be made by a person skilled in the art without departing from the scope of the present invention.

Claims

1. A system for producing hydrogen and co-producing methane comprising:
a pre-processor and a processor;
said pre-processor for receiving a biological waste stream and for producing at least one pre-processed output, said processor for receiving said at least one pre-processed output for production of hydrogen and co-production of methane;
wherein said pre-processor further comprises a pre-treatment module and a solid-liquid separator; and
further wherein said pre-treatment module is adapted to utilize the methods of pasteurisation.
2. A system for producing hydrogen and co-producing methane comprising:
a pre-processor and a processor;
said pre-processor for receiving a biological waste stream and for producing at least one pre-processed output, said processor for receiving said at least one pre-processed output for production of hydrogen and co-production of methane;
wherein said pre-processor further comprises a pre-treatment module and a solid-liquid separator; and
further wherein said pre-treatment module is adapted to utilize the methods of freezing and thawing.
3. A system in accordance to claim 1 or 2, wherein said solid-liquid separator is adapted to produce a solid phase and a liquid phase.
4. A system in accordance to claim 3, wherein said liquid phase comprises water having dissolved organic substances with solid waste residues amounting to less than 0.1% by weight.
5. A system in accordance to claim 1 or 2, wherein said processor further comprises a hydrogen fermenter and a methane digester.

6. A system in accordance to claim 3, wherein said hydrogen fermenter is adapted for receiving a first inoculum dose.
7. A system in accordance to claim 3, wherein said hydrogen fermenter is adapted for fermentation of said at least one pre-processed output from said pre-processor to produce hydrogen.
8. A system in accordance to claim 3, wherein said methane digester is adapted for receiving a second inoculum dose.
9. A system in accordance to claim 3, wherein said methane digester is adapted for digestion of said at least one pre-processed output from said pre-processor to produce methane.
10. A system for producing hydrogen and co-producing methane comprising:
a pre-processor, said pre-processor further comprising a pre-treatment module and a first solid-liquid separator; and
a processor comprising a hydrogen fermenter and a methane digester;
wherein said pre-processor for receiving a biological waste stream and for producing at least one pre-processed output, said processor for receiving said at least one pre-processed output for production of hydrogen and co-production of methane; and
further wherein said pre-treatment module is adapted to utilize the method of pasteurisation.
11. A system for producing hydrogen and co-producing methane comprising:
a pre-processor, said pre-processor further comprising a pre-treatment module and a first solid-liquid separator; and
a processor comprising a hydrogen fermenter and a methane digester;
wherein said pre-processor for receiving a biological waste stream and for producing at least one pre-processed output, said processor for receiving said at

least one pre-processed output for production of hydrogen and co-production of methane; and

further wherein said pre-treatment module is adapted to utilize the method of freezing and thawing.

12. A system in accordance to claim 10 or 11, wherein said first solid-liquid separator is adapted to produce a solid phase and a liquid phase.
13. A system in accordance to claim 12 wherein said hydrogen fermenter is adapted for receiving a first inoculum dose.
14. A system in accordance to claim 12, wherein said hydrogen fermenter is adapted for fermentation of said liquid phase from said solid-liquid separator to produce hydrogen.
15. A system in accordance to claim 12, wherein said methane digester is adapted for receiving a second inoculum dose.
16. A system in accordance to claim 12, wherein said methane digester is adapted for receiving a remaining liquid phase from said hydrogen fermenter.
17. A system in accordance to claim 16, wherein said methane digester is adapted for digestion of said solid phase from said pre-processor to produce methane.
18. A system in accordance to claim 15, further comprising a second solid-liquid separator.
19. A method for producing hydrogen and co-producing methane, said method comprising the steps:
subjecting a biological waste stream to pre-treatment;
subjecting a pretreated waste stream to solid-liquid separation;

hydrogen production; and

methane production;

wherein said pre-treatment utilizes the methods of pasteurisation.

20. A method for producing hydrogen and co-producing methane, said method comprising the steps:
 - subjecting a biological waste stream to pre-treatment;
 - subjecting a pretreated waste stream to solid-liquid separation;
 - hydrogen production; and
 - methane production;wherein said pre-treatment utilizes the method of freezing and thawing.
21. A method in accordance to claim 19 or 20, wherein said step of hydrogen production further comprises:
 - sending a liquid phase of said pre-treated waste stream to a hydrogen fermenter;
 - adding a first inoculum dose into said hydrogen fermenter;
 - fermenting said liquid phase of said separated waste stream to produce hydrogen;
 - and sending a remaining liquid phase from said hydrogen fermenter to a methane digester.
22. A method in accordance to claims 19 or 20, wherein said methane production further comprises:
 - sending a solid phase of said pre-treated waste stream to a methane digester;
 - adding a second inoculum dose into said methane digester;
 - receiving remaining liquid phase from said hydrogen fermenter to said methane digester; and
 - digesting said solid phase and said remaining liquid phase of said separated waste stream from said hydrogen fermenter to produce methane.