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(54) **MULTI-STEP METHOD FOR PRODUCING ALGAE PRODUCTS**

MEHRSTUFIGES VERFAHREN FÜR DIE HERSTELLUNG VON ALGENPRODUKTEN

PROCÉDÉ À PLUSIEURS ÉTAPES POUR PRODUIRE DES PRODUITS À BASE D'ALGUE

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Description

[0001] This application claims priority to a provisional patent application having serial number 61/018,957, filed on January 4, 2008.

TECHNICAL FIELD

[0002] Provided is a process for producing useful algae products from media comprising organic materials and/or microorganisms. More particularly, provided is a multi-step process for producing algae and/or algae products from media comprising organic materials and/or microorganisms.

BACKGROUND

[0003] Algae can produce a wide variety of commercially and industrially valuable products. Algae can also treat, break-down, convert, process, or otherwise eliminate many kinds of waste products. In certain situations, algae can produce commercially and industrially valuable products directly or indirectly from waste products or other growth media..

[0004] Algae are useful for producing products including, but not limited to, food, fertilizers, pharmaceuticals, dyes, bio-plastics, lipids, feedstock for chemical production, and feedstock for energy production.. Lipids can be used to produce valuable products such as biodiesel.

[0005] Sustainable biodiesel production is dependent upon development of renewable feedstock. Presently, the renewable feedstock is provided by edible oils such as soybean oil, palm oil, and rapeseed oil. It is of interest to develop additional types of renewable feedstock such as lipids from algae.

[0006] One factor making algae interesting as a source of renewable feedstock is that algae may be grown under conditions or in places not suitable to other sources of renewable feedstock. Accordingly, algae may be grown and used in ways that do not significantly compete with food sources or agriculturally productive land.

[0007] An additional factor making algae of interest is the availability of material to convert to biodiesel or other fuel. Some algae have a lipid content on the order of 50% to 70% of their dry weight. By way of comparison, the lipid content in dry soybeans is approximately 20%. Algal lipids have a similar composition to vegetable oil and are readily adaptable as feedstock to existing biodiesel manufacturing processes. The remaining algal biomass may be converted to bio-ethanol, converted to biodiesel, converted to methane, burned, or used as food for other organisms.

[0008] Waste water treatment is an essential and costly requirement of modern society.

[0009] In some applications the purpose of biological waste water treatment is to remove organics and nitrogen-containing and/or phosphorous-containing materials. In some applications the purpose of biological waste

water treatment is to remove harmful materials such as heavy metals or other materials. Algae can treat, break-down, convert, or process waste water effectively in many waste water treatment applications.

5 [0010] In addition to the desired end of treated waste water, treating waste water or any waste product with algae creates an opportunity to use the waste product as medium for the growth of desirable algae and the end of desirable algae products including, but not limited to, 10 food, fertilizers, pharmaceuticals, dyes, bio-plastics, lipids, feedstock for chemical production, and feedstock for energy production..

[0011] Existent waste water treatment processes have sought to minimize the production of microbial population or activated sludge because activated sludge disposal represents an additional cost and/or incurs environmental concerns.

[0012] US 3,955,318 discloses a system and a method for the removal of contaminants from an algae culture. 20 Specifically the system includes the incorporation of a contaminant removal system to remove the contaminants from the algae culture without substantially harming the primary algae type or removing a substantial portion of the primary algae type.

25 [0013] Improved methods, process conditions, and designs for the growth of algae in waste water continue to be of great interest. Improved methods for ensuring the establishment of desired algae species as a dominant population in a waste water treatment end product continue to be of great interest. Improved methods for production of algae products in many growth media continue to be of great interest.

SUMMARY

35 [0014] Provided is a multi-step method for producing an algae product comprising, a microorganism consumption step, another step, and an algae product collection step. The microorganism consumption step comprises, 40 combining a liquid growth medium comprising microorganisms with a phagotrophic algae capable of producing a desired algae product, consuming the microorganisms by the phagotrophic algae, and growing the phagotrophic algae. Another step comprises a microorganism growth 45 step . A microorganism growth step comprises providing a liquid growth medium comprising nutrients and microorganisms capable of the consuming the nutrients, consuming the nutrients by the microorganisms, and growing the microorganisms. An algae product collection step 50 comprises collecting a desired algae product from the phagotrophic algae.

[0015] Also provided is a multi-step method for producing an algae product from waste water treatment comprising a waste consumption step, a microorganism consumption step, and an algae product collection step. A waste consumption step comprises combining waste water comprising organic waste products with microorganisms capable of consuming the organic waste products

and treating the waste water by consuming the organic waste products by the microorganism and growing the microorganisms. A microorganism consumption step comprises combining the combined waste water and microorganisms with a phagotrophic algae capable of producing a desired algae product, consuming the microorganisms by the phagotrophic algae, and growing the phagotrophic algae. An algae product collection step comprises collecting a desired algae product from the phagotrophic algae.

[0016] Also provided is a multi-step method for producing lipids comprising a waste consumption step, a microorganism consumption step, and an algae product collection step. A waste consumption step comprises combining waste water comprising organic waste products with microorganisms capable of consuming organic waste products and treating said waste water by consuming said organic waste products by said microorganism and growing said microorganisms. A microorganism consumption step comprises combining said combined waste water and microorganisms with a phagotrophic algae capable of producing a desired lipid, consuming of microorganisms by said phagotrophic algae, and growing said phagotrophic algae. An algae product collection step comprises collecting said lipid from said phagotrophic algae.

BRIEF DESCRIPTION OF THE DRAWINGS

[0017]

FIG. 1 shows a phagotrophic algae and free bacteria.

FIG. 2 shows an embodiment of a multi-stage process for producing algae products.

FIG. 3 shows graphical results of the effects of pH on algal growth in one experiment.

DETAILED DESCRIPTION

[0018] There are many species of algae and other microorganisms. Some species of algae are desirable algae which are desirable to grow, cultivate or farm. Some desirable algae species can grow under phototrophic metabolism. Some desirable algae species can grow under heterotrophic metabolism. Some desired algae species can grow under heterotrophic metabolism or under mixotrophic, both phototrophic and heterotrophic, metabolism. Some desired algae species grow much faster under heterotrophic metabolism than under phototrophic metabolism. Some algae are capable of phagotrophy; algae capable of phagotrophy will be referred to herein as "phagotrophic algae". Referring to FIG. 1, phagotrophic algae (10) and bacteria (20) are shown. The phagotrophic algae (10) can consume the bacteria (20) as food. Shown in FIG. 1 is a food vacuole (12) containing ingested bacteria and a chromatophore (14) containing algae

products. Some desired algae species grow much faster under phagotrophic metabolism than do other non-algae phagotrophic organisms such as protozoa.

[0019] Microorganisms comprise microscopic organisms of all kinds. Microorganisms comprise bacteria, microalgae, yeast, and fungi.

[0020] Provided are processes for algal growth comprising the use of materials in a growth medium as nutrients. A growth medium is a medium comprising nutrients usable to support the growth of microorganisms and/or algae. A growth medium may comprise waste materials such as, without limitation, waste water, sewage, raw sewage, liquefied solid waste, washing water, grey water, drainage, black water, industrial effluvia, residential effluvia, commercial effluvia, other waste, or combinations thereof. A growth medium may also comprise non-waste materials, such as, without limitation, food processing by-products, sugar solutions, starch solutions, wort, mash, malt, grist, and agar. Nutrients may comprise, without limitation, organics, nitrogen-containing materials, and/or phosphorous-containing materials.

[0021] In certain of the provided processes, microorganisms consume organics, nitrogen-containing materials, phosphorous-containing materials, and/or other nutrients for their growth and the microorganisms are, in turn, consumed by phagotrophic algae; thereby growing phagotrophic algae and promoting the production of algae products from the phagotrophic algae. In certain of the provided processes, desirable algae consume organics, nitrogen-containing materials, phosphorous-containing materials, and/or other nutrients for their growth; thereby growing algae and promoting the production of algae products.

[0022] Production of algae products is a function of multiple factors affecting algae growth including growth medium composition, weather, other microorganisms, and microbial interactions. Growth medium composition can vary due to input, age, and in some embodiments, location. Weather is known to vary with location and time. Variable growth medium composition and growth competition between desired algal species and other organisms can reduce the output of desirable algae and reduce the production of desirable algae products. Certain of the provided processes employ selection pressures to promote the establishment of desirable algae species as a predominant population in the end culture.

[0023] In certain embodiments, processes use operating conditions and process designs to apply selection pressures favorable to the growth of the desired algae species over the growth of other microorganisms present in the growth environment. A selection pressure can be any condition, ability, or trait which favors the growth of or survival of certain species over that of other species. In certain embodiments, the selection pressure favors the growth of a single algae species over that of other species

[0024] In certain embodiments the selection pressure comprises pH conditions. Election of any pH which favors

the growth of or survival of a selected species over that of other species is a selection pressure comprising pH conditions. In certain embodiments a selected species will be a species of algae that is capable of producing a valuable algae product. Algal species are known to grow well in a much wider range of pH than other common microorganisms. Referring to FIG. 3., the graph shows the dry cell weight of the algae in g/L on the vertical axis of the graph as grown at the pH indicated on the horizontal axis of the graph. The algae grow and produce valuable algae products well even at pH levels that slow, inhibit, or substantially prevent the growth of competing organisms. By way of a non-limiting example, common bacteria that grow rapidly near neutral pH, pH near 7, cannot grow fast at low pH such as 3-4. As shown, the algae grow well and produce valuable algae products even at a pH levels as low as 3 and as high as 8. Because algal species are more tolerant of pH extremes than other common microorganisms, inducing pH extremes can favor the growth of algae species over the growth of other microorganisms. In certain embodiments pH conditions may range from a pH of 3 to a pH of 8.

[0025] In certain embodiments the selection pressure comprises impoverished or depleted conditions wherein nutrient sources in the growth medium are substantially depleted or rarified. Certain algae species are able to survive and grow phototrophically in the absence of organics or inorganics as an energy source. Algae can grow in, or at least tolerate and survive, organic depleted conditions. Under organic depleted conditions, other heterotrophic organisms will tend to die off from starvation. Organic depleted conditions can be created by encouraging consumption of the existing organic materials. In certain embodiments, conditions can be created to have a culture of microorganisms grow under heterotrophic metabolism and then switch to lighted and depleted organic conditions or lighted and no organic conditions.

[0026] In certain embodiments the selection pressure comprises the ability of some mixotrophic algae to grow by ingesting other microorganisms directly as food. In certain processes, this ability to grow by ingesting other microorganisms directly as food can be used to increase the ratio of desired algae in the microorganism population by allowing the algae to grow by ingesting other microorganisms and/or the nutrients released from the lysis of other microorganisms.

[0027] In certain embodiments, the method for growth of algae comprises multiple steps or stages. Each step or stage may comprise different conditions or different selection pressures to promote the growth of different microorganisms or to modify the medium conditions by the action of the microorganisms, or both. For example, and without limitation, establishing conditions which favor the growth of a particular microorganism that consume organic materials will tend to modify the medium conditions by increasing the amount of that particular microorganism and will tend to diminish the organic materials that are consumed by that particular microorganism.

In certain embodiments, steps or stages are combined such that the end conditions produced by one step or stage are the desired starting conditions for a subsequent stage or step.

[0028] In certain multiple step embodiments, the first step can comprise conditions that encourage the growth of microorganisms using growth medium that contains some non-zero concentration of organic materials usable by the microorganisms as nutrients. Growth of microorganisms promotes the consumption or depletion of materials usable by the microorganisms as nutrients. During the first step of certain embodiments, materials usable by the microorganisms as nutrients are reduced by consumption. Without limitation, in embodiments wherein the growth medium is a waste product, the consumption of nutrients may also act as treatment of the waste product. In the second step of certain embodiments, the growth medium and the microorganism population therein is combined with a population of microorganism-consuming algae. In certain embodiments this is done by combining an algae culture with the growth medium. If the organic materials usable by the microorganisms as nutrients remain in a substantial concentration the faster-growing heterotrophic microorganisms will grow to dominate the growth region. In certain embodiments, the faster-growing heterotrophic microorganisms are bacteria. Domination of the growth region by bacteria can block light penetration in the growth region and deny organic food for maintaining the population of other organisms.

[0029] In certain multiple step embodiments, the first step can comprise conditions that encourage the growth of microorganisms using growth medium that contains a high concentration of organic materials usable by the microorganisms as nutrients. Growth of microorganisms promotes the consumption or depletion of organic materials usable by the microorganisms as nutrients. During the first step of certain embodiments organic materials usable by the microorganisms as nutrients are substantially eliminated or rarified by consumption. In the second step of certain embodiments, the growth medium and the microorganism population therein is combined with a population of microorganism-consuming algae. Because the organic materials usable by the microorganisms as nutrients are substantially eliminated or rarified, the microorganism-consuming algae will develop by eating the other microorganisms while the other microorganisms will develop to a lesser degree because of the lack of usable nutrients; accordingly the microorganism-consuming algae will tend to develop as the dominant population. In certain multiple step embodiments a third stage exists in which the algae-dominated culture from stage two is subjected to lighted and depleted organic conditions or lighted and no organic conditions.

[0030] FIG. 2 shows a non-limiting embodiment of a multi-step method for producing an algae product. Illustrated is a multi-step process (50) for production of an algae product. In a first stage (60), a growth medium (62) is introduced to a first growth region (64). Also introduced

to the grown region (64) are microorganisms (not shown). The microorganisms (not shown) consume nutrients (not shown) from the growth medium (62) and grow. The first stage (60) continues at least until the nutrients (not shown) from the growth medium (62) are substantially depleted by consumption by the microorganisms (not shown).

[0031] In a second stage (70), the nutrient depleted growth medium (72) is introduced to a second growth region (74). Also introduced to the second growth region (74) are the microorganisms (not shown) grown in the first stage. Also introduced to the second growth region (74) are phagotrophic algae (not shown). The phagotrophic algae (not shown) grow by ingesting the microorganisms (not shown) grown in the first stage (60). Without limitation, in the embodiment shown in FIG. 2, the phagotrophic algae (not shown) have the capability to grow photosynthetically. The second stage (70) may optionally include natural or artificial lighting (76). The second stage (70) may optionally include mechanical mixing or aeration (78). The second stage (70) may optionally include a selection pressure to favor the growth of the phagotrophic algae (not shown) over the growth of the microorganisms (not shown). In certain embodiments, the second stage (70) continues at least until the microorganisms (not shown) grown in the first stage (60) are substantially depleted by consumption by the phagotrophic algae (not shown).

[0032] In an optional third stage (80), the nutrient depleted growth medium (72) is introduced to a third growth region (84). Also introduced to the third growth region (84) are the phagotrophic algae (not shown) grown in the second stage (70). The third stage (80) includes natural or artificial lighting (76). The third growth region (84) is shallow to allow for light penetration throughout the growth region from the natural or artificial lighting (76). The third stage (80) may optionally include mechanical mixing or aeration (88). The third stage (80) may optionally include the addition of carbon dioxide. The third stage (80) may optionally include a selection pressure to favor the growth of the phagotrophic algae (not shown) over the growth of any remaining microorganisms (not shown). In the low nutrient environment of the third stage (80), the phagotrophic algae can grow photosynthetically to dominate the population of organisms in the growth medium. In certain embodiments, at the end of the third stage there are no significant amounts of any organisms remaining other than the phagotrophic algae (not shown) that produce the algae products.

[0033] FIG. 2 shows an optional fourth stage, a clarifier stage (90), included in the process to accept output from the third stage (80). The clarifier separates, at least partially, phagotrophic algae (not shown) that produce the algae products from nutrient depleted growth medium (72). The clarifier routes phagotrophic algae (not shown) to a phagotrophic algae output (92) and routes nutrient depleted growth medium (72) to a nutrient depleted growth medium output (94).

[0034] In certain multiple step embodiments, the microorganisms in the first stage are selected for their ability to consume, break-down, convert, or process particular materials in the growth medium. Microorganisms may include, without limitation, enteric bacteria and pseudomonads.

[0035] In embodiments involving the treatment of waste materials, sufficient waste material treatment, the removal of most organics, nitrogen-containing materials, and/or phosphorous-containing materials can be achieved by a two or three stage method for growth of algae. If necessary or desired, additional stages for polishing or otherwise treating the treated waste material can be performed.

[0036] In certain embodiments, the algae grown comprise members selected from the group consisting of Dinobryon chrysomonads, Chrysosphaerella chrysomonads, Uroglena chrysomonads, Catenochrysis chrysomonads, Ochromonas chrysomonads, Chromulina chrysomonads, Chrysococcus chrysomonads, Chrysochromulina prymnesiophytes, Coccolithus pelagicus coccolithophorids, Chlorochromonas xanthophytes, Phaeaster chrysophytes, Chrysamoeba chrysophytes, Pedinella chrysophytes, Ceratium hirundinella, and Cryptomonas ovata.

[0037] The produced algae may be harvested by any acceptable means. In certain embodiments algae are harvested by means selected from the group consisting of settling, microscreening, centrifugation, flocculation, froth flotation, and combinations thereof.

[0038] Algae products including, but not limited to, food, fertilizers, pharmaceuticals, dyes, bio-plastics, lipids, feedstock for chemical production, and feedstock for energy production, may be collected by any acceptable means. In certain embodiments algae products are collected by means selected from the group comprising mechanical pressing, use of chemical solvents, enzymatic extraction, precipitation, chromatography, adsorption, electrophoresis, crystallization, binding, foam fractionation, osmotic shock, and combinations thereof.

[0039] While the multi-step method for producing algae products has been described above in connection with the certain embodiments, it is to be understood that other embodiments may be used or modifications and additions may be made to the described embodiments for performing the same function of the multi-step method for producing algae products without deviating therefrom. Further, all embodiments disclosed are not necessarily in the alternative, as various embodiments may be combined to provide the desired characteristics. Variations can be made by one having ordinary skill in the art without departing from the scope of the multi-step method for producing algae products. Therefore, the multi-step method for producing algae products should not be limited to any single embodiment, but rather construed in breadth and scope in accordance with the recitation of the attached claims.

Claims

1. A multi-step method for producing an algae product comprising:

a microorganism consumption step comprising,

combining a liquid growth medium comprising microorganisms with a phagotrophic algae capable of producing a desired algae product, consuming said microorganisms by said phagotrophic algae, and growing said phagotrophic algae; and

another step comprising,

a microorganism growth step comprising

providing a liquid growth medium comprising nutrients and microorganisms capable of consuming said nutrients, consuming said nutrients by said microorganisms, and growing said microorganisms; and

an algae product collection step comprising,

collecting a desired algae product from said phagotrophic algae.

2. The multi-step method for producing an algae product of claim 1, wherein said liquid growth medium comprises a member of the group consisting of waste water, a prepared medium, and combinations thereof.

3. The multi-step method for producing an algae product of claim 2, wherein said liquid medium is waste water.

4. The multi-step method for producing an algae product of claim 2, wherein said desired algae products comprise a member of the group consisting of food, fertilizers, pharmaceuticals, dyes, bio-plastics, lipids, feedstock for chemical production, and feedstock for energy production.

5. The multi-step method for producing an algae product of claim 3, wherein said desired algae products comprise lipids.

6. The multi-step method for producing an algae product of claim 4, wherein said microorganism consumption step further comprises, application of a selection pressure favorable to the growth of a phagotrophic algae species over the growth of other microorganisms present in the growth environment

7. The multi-step method for producing an algae product of claim 6, wherein said selection pressure comprises establishing a pH favorable to the growth of a phagotrophic algae species over the growth of other microorganisms present in the growth environment.

8. The multi-step method for producing an algae product of claim 6, wherein said selection pressure comprises substantial depletion or rarification of organic nutrient sources usable by the microorganisms.

9. The multi-step method for producing an algae product of claim 6, wherein said phagotrophic algae comprise members selected from the group consisting of Dinobryon chrysomonads, Chrysosphaerella chrysomonads, Uroglena chrysomonads, Catenochrysis chrysomonads, Ochromonas chrysomonads, Chromulina chrysomonads, Chrysococcus chrysomonads, Chrysochromulina prymnesiophytes, Coccolithus pelagicus coccolithophorids, Chlorochromonas xanthophytes, Phaeaster chrysophytes, Chrysamoeba chrysophytes, Pedinella chrysophytes, Ceratium hirundinella, and Cryptomonas ovata.

10. The multi-step method for producing an algae product of claim 9, wherein said microorganisms comprise enteric bacteria and pseudomonads.

11. A multi-step method for producing an algae product from waste water treatment comprising:

a waste consumption step comprising,

combining waste water comprising organic waste products with microorganisms capable of consuming said organic waste products, and treating said waste water by,

consuming said organic waste products by said microorganism, and growing said microorganisms; and

a microorganism consumption step comprising,

combining said combined waste water and microorganisms with a phagotrophic algae capable of producing a desired algae product, consuming said microorganisms by said phagotrophic algae, and growing said phagotrophic algae; and

an algae product collection step comprising

collecting a desired algae product from said

- phagotrophic algae.
12. A multi-step method for producing an algae product from waste water treatment of claim 11, wherein said desired algae product comprises a member of the group consisting of food, fertilizers, pharmaceuticals, dyes, bio-plastics, lipids, feedstock for chemical production, and feedstock for energy production.
13. The multi-step method for producing an algae product of claim 12, wherein said desired algae products comprise lipids.
14. The multi-step method for producing an algae product of claim 12, wherein said microorganism consumption step further comprises application of a selection pressure favorable to the growth of a phagotrophic algae species over the growth of other microorganisms present in the growth environment, said selection pressure comprising
- establishing a pH favorable to the growth of a phagotrophic algae species over the growth of other microorganisms present in the growth environment; or
- substantial depletion or ratification of organic nutrient sources usable by the microorganisms.
15. The multi-step method for producing an algae product of claim 14, wherein said phagotrophic algae comprise members selected from the group consisting of Dinobryon chrysomonads, Chrysphaerella chrysomonads, Uroglena chrysomonads, Catenochrysis chrysomonads, Ochromonas chrysomonads, Chromulina chrysomonads, Chrysococcus chrysomonads, Chrysochromulina prymnesiophytes, Coccolithus pelagicus coccolithophorids, Chlorochromonas xanthophytes, Phaeaster chrysophytes, Chrysamoeba chrysophytes, Pedinella chrysophytes, Ceratium hirundinella, and Cryptomonas ovata.
16. A multi-step method for producing lipids comprising:
- a waste consumption step comprising,
- combining waste water comprising organic waste products with microorganisms capable of consuming organic waste products, and
- treating said waste water by,
- consuming said organic waste products by said microorganism, and
- growing said microorganisms; and
- a microorganism consumption step comprising,

- combining said combined waste water and microorganisms with a phagotrophic algae capable of producing a desired lipid, consuming of microorganisms by said phagotrophic algae, and growing said phagotrophic algae; and
- an algae product collection step comprising,
- collecting said lipid from said phagotrophic algae.
17. The multi-step method for producing lipids of claim 16, wherein said microorganism consumption step further comprises application of a pH selection pressure, said pH selection pressure comprising establishing a pH favorable to the growth of a phagotrophic algae species over the growth of other microorganisms present in the growth environment
18. The multi-step method for producing lipids of claim 17, wherein said microorganism consumption step further comprises application of an organic nutrient selection pressure, said organic nutrient selection pressure comprising substantial depletion or rarification of organic nutrient sources usable by the microorganisms.
19. The multi-step method for producing lipids of claim 18, wherein said pH selection pressure comprises establishing a pH in the range of about 3 to about 8.
20. The multi-step method for producing lipids of claim 19, wherein said phagotrophic algae comprise members selected from the group consisting of Dinobryon chrysomonads, Chrysphaerella chrysomonads, Uroglena chrysomonads, Catenochrysis chrysomonads, Ochromonas chrysomonads, Chromulina chrysomonads, Chrysococcus chrysomonads, Chrysochromulina prymnesiophytes, Coccolithus pelagicus coccolithophorids, Chlorochromonas xanthophytes, Phaeaster chrysophytes, Chrysamoeba chrysophytes, Pedinella chrysophytes, Ceratium hirundinella, and Cryptomonas ovata.

Patentansprüche

1. Mehrschrittiges Verfahren für die Herstellung eines Algenprodukts, umfassend:
- einen Mikroorganismen aufbrauchenden Schritt, umfassend
- Kombinieren eines flüssigen Wachstumsmediums, das Mikroorganismen umfasst, mit einer phagotrophen Alge, die ein gewünschtes Algenprodukt herstellen kann,

- wobei die Mikroorganismen durch die phagotrophen Algen aufgebraucht werden, und die phagotrophen Algen wachsen; und
- einen weiteren Schritt, umfassend 5
- einen Schritt zum Wachstum von Mikroorganismen, umfassend
- Bereitstellen eines flüssigen Wachstumsmediums, das Nährstoffe und Mikroorganismen umfasst, die die Nährstoffe aufbrauchen können, 10
- Aufbrauchen der Nährstoffe durch die Mikroorganismen, und 15
- Wachsen der Mikroorganismen;
- einen Schritt zur Sammlung des Algenprodukts, umfassend 20
- Sammeln eines gewünschten Algenprodukts aus der phagotrophen Alge.
2. Mehrschrittiges Verfahren für die Herstellung eines Algenprodukts nach Anspruch 1, wobei das flüssige Wachstumsmedium ein Element der Gruppe bestehend aus Abwasser, einem aufbereiteten Medium und einer Kombination daraus umfasst. 25
3. Mehrschrittiges Verfahren für die Herstellung eines Algenprodukts nach Anspruch 2, wobei das flüssige Medium Abwasser ist. 30
4. Mehrschrittiges Verfahren für die Herstellung eines Algenprodukts nach Anspruch 2, wobei die gewünschten Algenprodukte ein Mitglied der Gruppe bestehend aus Nahrungsmitteln, Düngemitteln, Pharmazeutika, Farbstoffen, Bio-Kunststoffen, Lipiden, Rohstoffen für die chemische Produktion und Rohstoffen für die Energieerzeugung umfassen. 35 40
5. Mehrschrittiges Verfahren für die Herstellung eines Algenprodukts nach Anspruch 3, wobei die gewünschten Algenprodukte Lipide umfassen. 45
6. Mehrschrittiges Verfahren für die Herstellung eines Algenprodukts nach Anspruch 4, wobei der Mikroorganismen aufbrauchende Schritt weiterhin Folgendes umfasst: 50
- Anwendung eines Selektionsdrucks, der für das Wachstum einer phagotrophen Algenspezies vorteilhafter ist als für das Wachstum anderer Mikroorganismen, die in der Wachstumsumgebung vorhanden sind. 55
7. Mehrschrittiges Verfahren für die Herstellung eines Algenprodukts nach Anspruch 6, wobei der Selektionsdruck Folgendes umfasst:
- Herstellen eines pH-Werts, der für das Wachstum einer phagotrophen Algenspezies vorteilhafter ist als für das Wachstum anderer Mikroorganismen, die in der Wachstumsumgebung vorhanden sind.
8. Mehrschrittiges Verfahren für die Herstellung eines Algenprodukts nach Anspruch 6, wobei der Selektionsdruck Folgendes umfasst:
- eine wesentliche Verringerung oder Verknappung von organischen Nährstoffquellen, die von den Mikroorganismen verwertet werden können.
9. Mehrschrittiges Verfahren für die Herstellung eines Algenprodukts nach Anspruch 6, wobei die phagotrophe Algen Mitglieder ausgewählt aus der Gruppe bestehend aus Dinobryon chrysomonads, Chrysophaerella chrysomonads, Uroglena chrysomonads, Catenochrysis chrysomonads, Ochromonas chrysomonads, Chromulina chrysomonads, Chrysococcus chrysomonads, Chrysochromulina prymnesiophytes, Coccolithus pelagicus coccolithophorids, Chlorochromonas xanthophytes, Phaeaster chrysophytes, Chrysamoeba chrysophytes, Pedinella chrysophytes, Ceratium hirundinella und Cryptomonas ovata umfassen.
10. Mehrschrittiges Verfahren für die Herstellung eines Algenprodukts nach Anspruch 9, wobei die Mikroorganismen enterische Bakterien und Pseudomonaden umfassen.
11. Mehrschrittiges Verfahren für die Herstellung eines Algenprodukts bei der Abwasserbehandlung, umfassend:
- einen Abfall aufbrauchenden Schritt, umfassend
- Kombinieren von Abwasser, das organische Abfallprodukte mit Mikroorganismen umfasst, die organische Abfallprodukte aufbrauchen können, und
- Behandeln des Abwassers durch
- Aufbrauchen der organischen Abfallprodukte durch die Mikroorganismen, und
- Wachsen der Mikroorganismen; und
- einen Mikroorganismen aufbrauchenden Schritt, umfassend
- Kombinieren des kombinierten Abwassers

- und der Mikroorganismen mit einer phagotrophen Alge, die ein gewünschtes Algenprodukt herstellen kann,
 Aufbrauchen der Mikroorganismen durch die phagotrophen Algen, und
 Wachsen der phagotrophen Algen; und
 einen Schritt zur Sammlung des Algenprodukts, umfassend
 Sammeln eines gewünschten Algenprodukts aus den phagotrophen Algen.
12. Mehrschrittiges Verfahren für die Herstellung eines Algenprodukts bei der Abwasserbehandlung nach Anspruch 11, wobei das gewünschte Algenprodukt ein Mitglied der Gruppe bestehend aus Nahrungsmitteln, Düngemitteln, Pharmazeutika, Farbstoffen, Bio-Kunststoffen, Lipiden, Rohstoffen für die chemische Produktion und Rohstoffen für die Energieerzeugung umfasst.
13. Mehrschrittiges Verfahren für die Herstellung eines Algenprodukts nach Anspruch 12, wobei die gewünschten Algenprodukte Lipide umfassen.
14. Mehrschrittiges Verfahren für die Herstellung eines Algenprodukts nach Anspruch 12, wobei der Mikroorganismen aufbrauchende Schritt weiterhin die Anwendung eines Selektionsdrucks umfasst, der für das Wachstum einer phagotrophen Algenspezies vorteilhafter ist als für das Wachstum anderer Mikroorganismen, die in der Wachstums Umgebung vorhanden sind, wobei der Selektionsdruck Folgendes umfasst:
 Herstellen eines pH-Werts, der für das Wachstum einer phagotrophen Algenspezies vorteilhafter ist als für das Wachstum anderer Mikroorganismen, die in der Wachstums Umgebung vorhanden sind; oder
 wesentlicher Verringerung oder Verknappung der organischen Nährstoffquellen, die von den Mikroorganismen verwertet werden können.
15. Mehrschrittiges Verfahren für die Herstellung eines Algenprodukts nach Anspruch 14, wobei die phagotrophe Algen Mitglieder ausgewählt aus der Gruppe bestehend aus Dinobryon chrysomonads, Chrysopharella chrysomonads, Uroglena chrysomonads, Catenochrysis chrysomonads, Ochromonas chrysomonads, Chromulina chrysomonads, Chrysococcus chrysomonads, Chrysochromulina prymnesiophytes, Coccolithus pelagicus coccolithophorids, Chlorochromonas xanthophytes, Phaeaster chrysophytes, Chrysamoeba chrysophytes, Pedinella chrysophytes, Ceratium hirundinella und Cryptomonas ovata umfassen.
16. Mehrschrittiges Verfahren für die Herstellung von Lipiden, umfassend:
 einen Abfall aufbrauchenden Schritt, umfassend
 Kombinieren von Abwasser, das organische Abfallprodukte umfasst, mit Mikroorganismen, die organische Abfallprodukte aufbrauchen können, und
 Behandeln des Abwassers durch
 Aufbrauchen der organischen Abfallprodukte durch die Mikroorganismen, und
 Wachsen der Mikroorganismen; und
 einen Mikroorganismen aufbrauchenden Schritt, umfassend
 Kombinieren des kombinierten Abwassers und der Mikroorganismen mit einer phagotrophen Alge, die ein gewünschtes Lipid herstellen kann,
 Aufbrauchen der Mikroorganismen durch die phagotrophe Alge, und
 Wachsen der phagotrophen Algen; und
 einen Schritt zur Sammlung des Algenprodukts, umfassend Sammeln des Lipids aus der phagotrophen Alge.
17. Mehrschrittiges Verfahren für die Herstellung von Lipiden nach Anspruch 16, wobei der Mikroorganismen aufbrauchende Schritt weiterhin die Anwendung eines pH-Selektionsdrucks umfasst, wobei der pH-Selektionsdruck die Herstellung eines pH-Werts umfasst, der für das Wachstum einer phagotrophen Algenspezies vorteilhafter ist als für das Wachstum anderer Mikroorganismen, die in der Wachstums Umgebung vorhanden sind.
18. Mehrschrittiges Verfahren für die Herstellung von Lipiden nach Anspruch 17, wobei der Mikroorganismen aufbrauchende Schritt weiterhin die Anwendung eines Selektionsdrucks für organische Nährstoffe umfasst, wobei der Selektionsdruck für organische Nährstoffe eine wesentliche Verringerung oder Verknappung der organischen Nährstoffquellen, die von den Mikroorganismen verwertet werden können, umfasst.
19. Mehrschrittiges Verfahren für die Herstellung von Lipiden nach Anspruch 18, wobei der pH-Selektionsdruck die Herstellung eines pH-Werts im Bereich von etwa 3 bis etwa 8 umfasst.
20. Mehrschrittiges Verfahren für die Herstellung von Li-

piden nach Anspruch 19, wobei die phagotrophe Algen Mitglieder ausgewählt aus der Gruppe bestehend aus Dinobryon chrysomonads, Chrysopharella chrysomonads, Uroglena chrysomonads, Catenochrysis chrysomonads, Ochromonas chrysomonads, Chromulina chrysomonads, Chrysococcus chrysomonads, Chrysochromulina prymnesiophytes, Coccolithus pelagicus coccolithophorids, Chlorochromonas xanthophytes, Phaeaster chrysophytes, Chrysamoeba chrysophytes, Pedinella chrysophytes, Ceratium hirundinella und Cryptomonas ovata umfassen.

Revendications

1. Procédé à plusieurs étapes pour produire un produit d'algue comprenant :

une étape de consommation de micro-organismes comprenant,

la combinaison d'un milieu de croissance liquide comprenant des micro-organismes avec une algue phagotrophe capable de produire un produit d'algue souhaité, la consommation desdits micro-organismes par ladite algue phagotrophe, et la croissance de ladite algue phagotrophe ; et

une autre étape comprenant,

une étape de croissance des micro-organismes comprenant

la fourniture d'un milieu de croissance liquide comprenant des nutriments et des micro-organismes capables de consommer lesdits nutriments, la consommation desdits nutriments par lesdits micro-organismes, et la croissance desdits micro-organismes ; et

une étape de recueil du produit d'algue comprenant,

le recueil d'un produit algue souhaité à partir de ladite algue phagotrophe.

2. Procédé à plusieurs étapes pour produire un produit d'algue selon la revendication 1, dans lequel ledit milieu de croissance liquide comprend un membre du groupe constitué d'eaux usées, d'un milieu préparé, et de leurs combinaisons.

3. Procédé à plusieurs étapes pour produire un produit

d'algue selon la revendication 2, dans lequel ledit milieu liquide consiste en des eaux usées.

4. Procédé à plusieurs étapes pour produire un produit d'algue selon la revendication 2, dans lequel lesdits produits d'algue souhaités comprennent un membre du groupe constitué d'aliments, de fertilisants, d'agents pharmaceutiques, de colorants, de bioplastiques, de lipides, de matières premières pour la production d'agents chimiques, et de matières premières pour la production d'énergie.

5. Procédé à plusieurs étapes pour produire un produit d'algue selon la revendication 3, dans lequel lesdits produits d'algue souhaités comprennent des lipides.

6. Procédé à plusieurs étapes pour produire un produit d'algue selon la revendication 4, dans lequel ladite étape de consommation de micro-organismes comprend en outre, l'application d'une pression de sélection favorable à la croissance d'une espèce d'algue phagotrophe par rapport à la croissance d'autres micro-organismes présents dans l'environnement de croissance.

7. Procédé à plusieurs étapes pour produire un produit d'algue selon la revendication 6, dans lequel ladite pression de sélection comprend l'établissement d'un pH favorable à la croissance d'une espèce d'algue phagotrophe par rapport à la croissance d'autres micro-organismes présents dans l'environnement de croissance.

8. Procédé à plusieurs étapes pour produire un produit d'algue selon la revendication 6, dans lequel ladite pression de sélection comprend un appauvrissement substantiel ou une raréfaction des sources de nutriments organiques utilisables par les micro-organismes.

9. Procédé à plusieurs étapes pour produire un produit d'algue selon la revendication 6, dans lequel lesdites algues phagotrophes comprennent des membres choisis dans le groupe constitué des chrysomonades Dynobryon, des chrysomonades Chrysopharella, des chrysomonades Uroglena, des chrysomonades Catenochrysis, des chrysomonades Ochromonas, des chrysomonades Chromulina, des chrysomonades Chrysococcus, des prymnésiphytes Chrysochromulina, des coccolithophoridés Coccolithus pelagicus, des xanthophytes Chlorochromonas, des chrysophytes Phaeaster, des chrysophytes Chrysamoeba, des chrysophytes Pedinella, de Ceratium hirundinella, et de Cryptomonas ovata.

10. Procédé à plusieurs étapes pour produire un produit d'algue selon la revendication 9, dans lequel lesdits organismes comprennent des bactéries entériques

et des pseudomonades.

- 11.** Procédé à plusieurs étapes pour produire un produit d'algue à partir d'un traitement d'eaux usées comprenant :

une étape de consommation de déchets comprenant,

la combinaison d'eaux usées comprenant des produits de déchets organiques avec des micro-organismes capables de consommer lesdits produits de déchets organiques, et

le traitement desdites eaux usées par,

la consommation desdits produits de déchets organiques par lesdits micro-organismes, et
la croissance desdits micro-organismes ; et

une étape de consommation de micro-organismes comprenant,

la combinaison desdites eaux usées et micro-organismes combinés avec une algue phagotrophe capable de produire un produit d'algue souhaité,

la consommation desdits micro-organismes par ladite algue phagotrophe, et
la croissance de ladite algue phagotrophe ; et

une étape de recueil du produit d'algue comprenant,

le recueil d'un produit algue souhaité à partir de ladite algue phagotrophe.

- 12.** Procédé à plusieurs étapes pour produire un produit d'algue à partir d'un traitement d'eaux usées selon la revendication 11, dans lequel ledit produit d'algue souhaité comprend un membre du groupe constitué d'aliments, de fertilisants, d'agents pharmaceutiques, de colorants, de bioplastiques, de lipides, de matières premières pour la production d'agents chimiques, et de matières premières pour la production d'énergie.

- 13.** Procédé à plusieurs étapes pour produire un produit d'algue selon la revendication 12, dans lequel lesdits produits d'algue souhaités comprennent des lipides.

- 14.** Procédé à plusieurs étapes pour produire un produit d'algue selon la revendication 12, dans lequel ladite étape de consommation de micro-organismes comprend en outre l'application d'une pression de sélection

favorable à la croissance d'une espèce d'algue phagotrophe par rapport à la croissance d'autres micro-organismes présents dans l'environnement de croissance, ladite pression de sélection comprenant

l'établissement d'un pH favorable à la croissance d'une espèce d'algue phagotrophe par rapport à la croissance d'autres micro-organismes présents dans l'environnement de croissance ; ou
un appauvrissement substantiel ou une raréfaction des sources de nutriments organiques utilisables par les micro-organismes.

- 15.** Procédé à plusieurs étapes pour produire un produit d'algue selon la revendication 14, dans lequel lesdites algues phagotrophes comprennent des membres choisis dans le groupe constitué des chrysomonades Dynobryon, des chrysomonades Chrysophaerella, des chrysomonades Uroglena, des chrysomonades Catenochrysis, des chrysomonades Ochromonas, des chrysomonades Chromulina, des chrysomonades Chrysococcus, des prymnésiophytes Chrysochromulina, des coccolithophoridés Coccolithus pelagicus, des xanthophytes Chlorochromonas, des chrysophytes Phaeaster, des chrysophytes Chrysamoeba, des chrysophytes Pedinella, de Ceratium hirundinella, et de Cryptomonas ovata.

- 16.** Procédé à plusieurs étapes pour produire des lipides comprenant :

une étape de consommation de déchets comprenant,

la combinaison d'eaux usées comprenant des produits de déchets organiques avec des micro-organismes capables de consommer des produits de déchets organiques, et

le traitement desdites eaux usées par,

la consommation desdits produits de déchets organiques par lesdits micro-organismes, et
la croissance desdits micro-organismes ; et

une étape de consommation de micro-organismes comprenant,

la combinaison desdites eaux usées et micro-organismes combinés avec une algue phagotrophe capable de produire un lipide souhaité,
la consommation de micro-organismes par ladite algue phagotrophe, et

la croissance de ladite algue
phagotrophe ; et

une étape de recueil du produit d'algue
comprenant, 5

le recueil dudit lipide à partir de ladite
algue phagotrophe.

17. Procédé à plusieurs étapes pour produire un produit 10
d'algue selon la revendication 16, dans lequel ladite
étape de consommation de micro-organismes com-
prend en outre l'application d'une pression de sélec-
tion par le pH, ladite pression de sélection par le pH
comprenant l'établissement d'un pH favorable à la 15
croissance d'une espèce d'algue phagotrophe par
rapport à la croissance d'autres micro-organismes
présents dans l'environnement de croissance.
18. Procédé à plusieurs étapes pour produire un produit 20
d'algue selon la revendication 17, dans lequel ladite
étape de consommation de micro-organismes com-
prend en outre l'application d'une pression de sélec-
tion par les nutriments organiques, ladite pression
de sélection par les nutriments organiques compren- 25
nant un appauvrissement substantiel ou une raré-
faction des sources de nutriments organiques utili-
sables par les micro-organismes.
19. Procédé à plusieurs étapes pour produire un produit 30
d'algue selon la revendication 18, dans lequel ladite
pression de sélection par le pH comprend l'établis-
sement d'un pH dans la plage d'environ 3 à environ 8.
20. Procédé à plusieurs étapes pour produire un produit 35
d'algue selon la revendication 19, dans lequel lesdi-
tes algues phagotrophes comprennent des mem-
bres choisis dans le groupe constitué des chryso-
monades Dynobryon, des chrysomonades Chryso-
phaerella, des chrysomonades Uroglena, des 40
chrysomonades Catenochrysis, des chrysomona-
des Ochromonas, des chrysomonades Chromulina,
des chrysomonades Chrysococcus, des prymnésio-
phytes Chrysochromulina, des coccolithophoridés
Coccolithus pelagicus, des xanthophytes Chloro- 45
chromonas, des chrysophytes Phaeaster, des
chrysophytes Chrysamoeba, des chrysophytes Pe-
dinella, de Ceratium hirundinella, et de Cryptomonas
ovata.

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FIG. 1

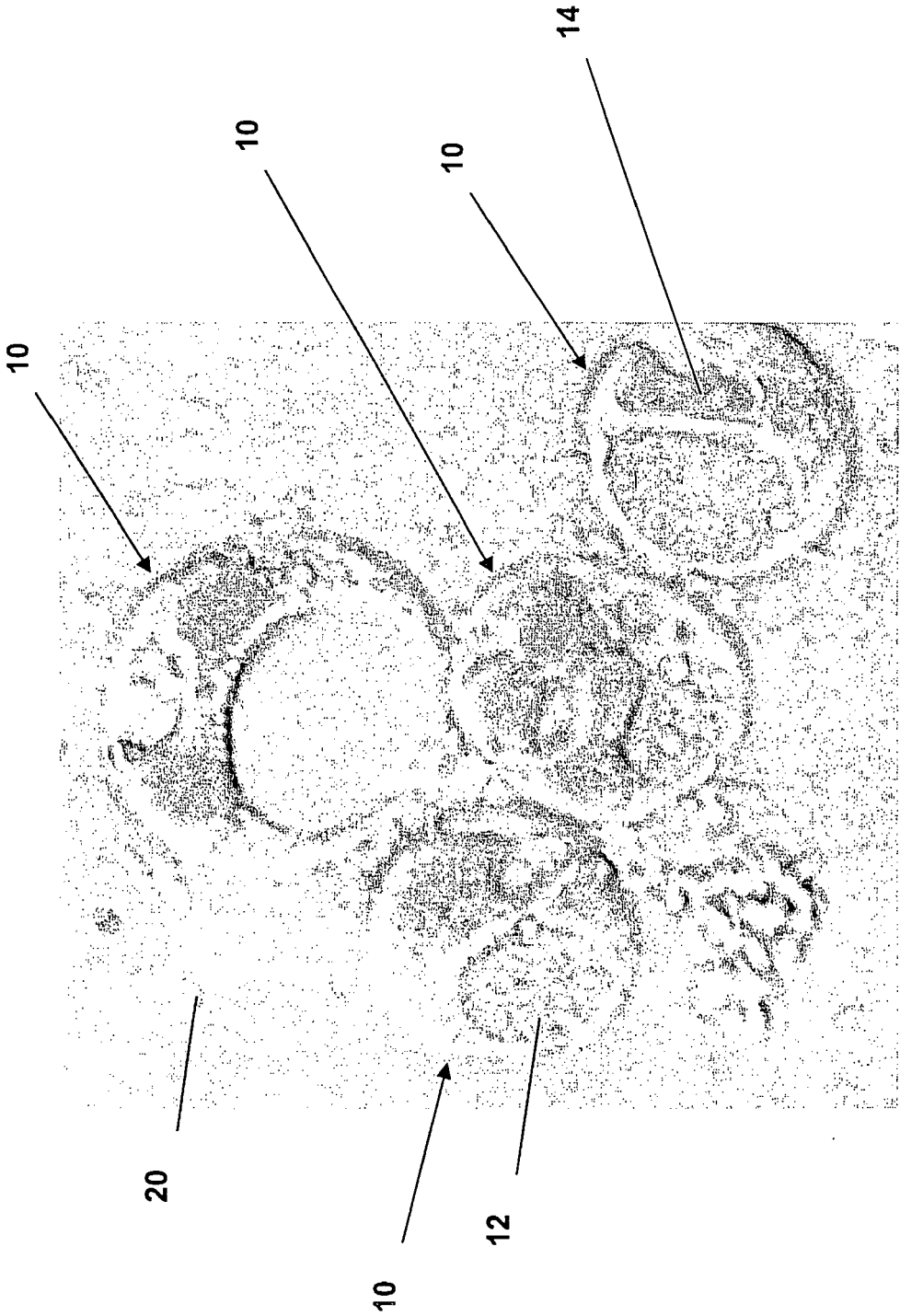


FIG. 2

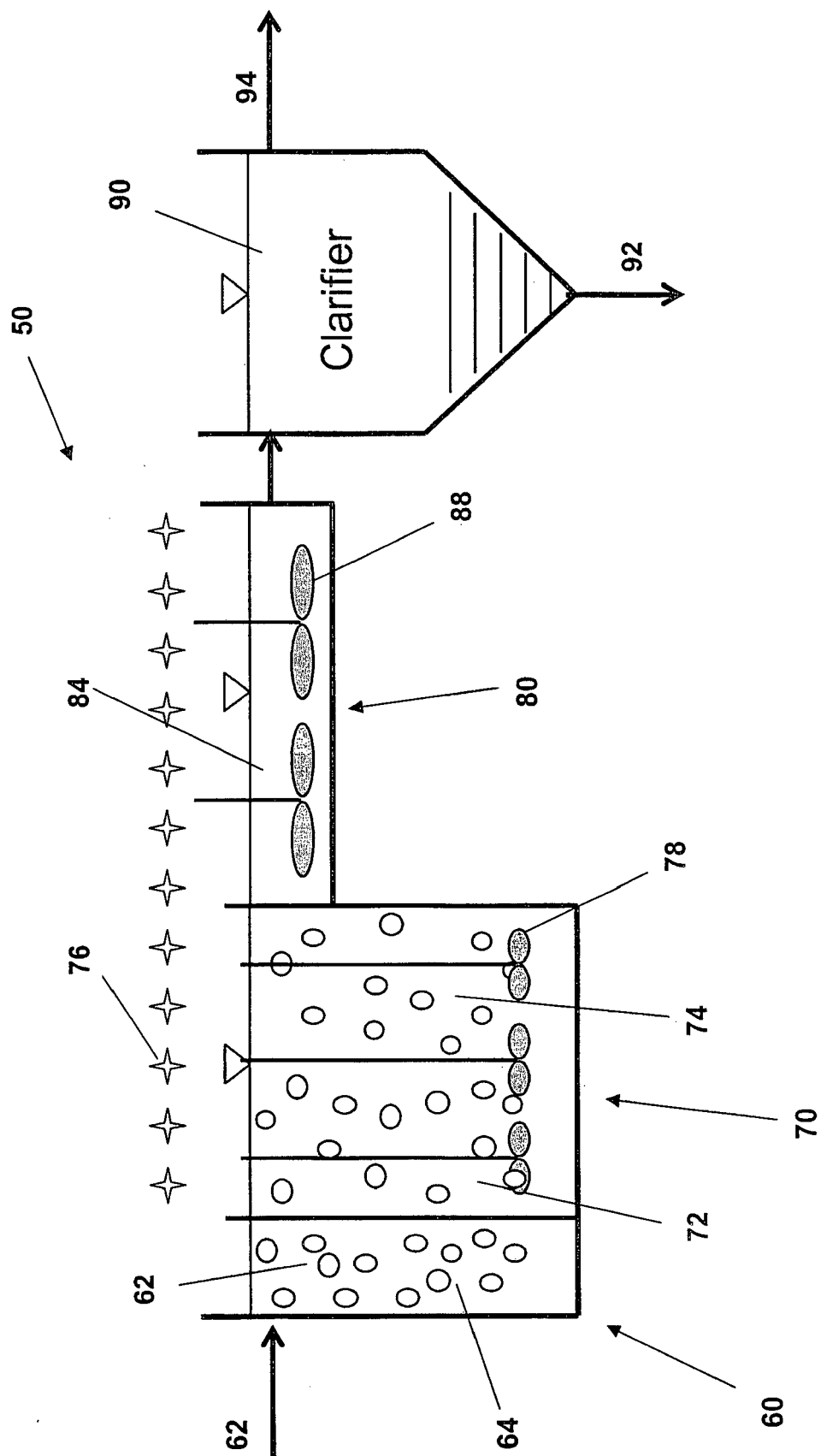
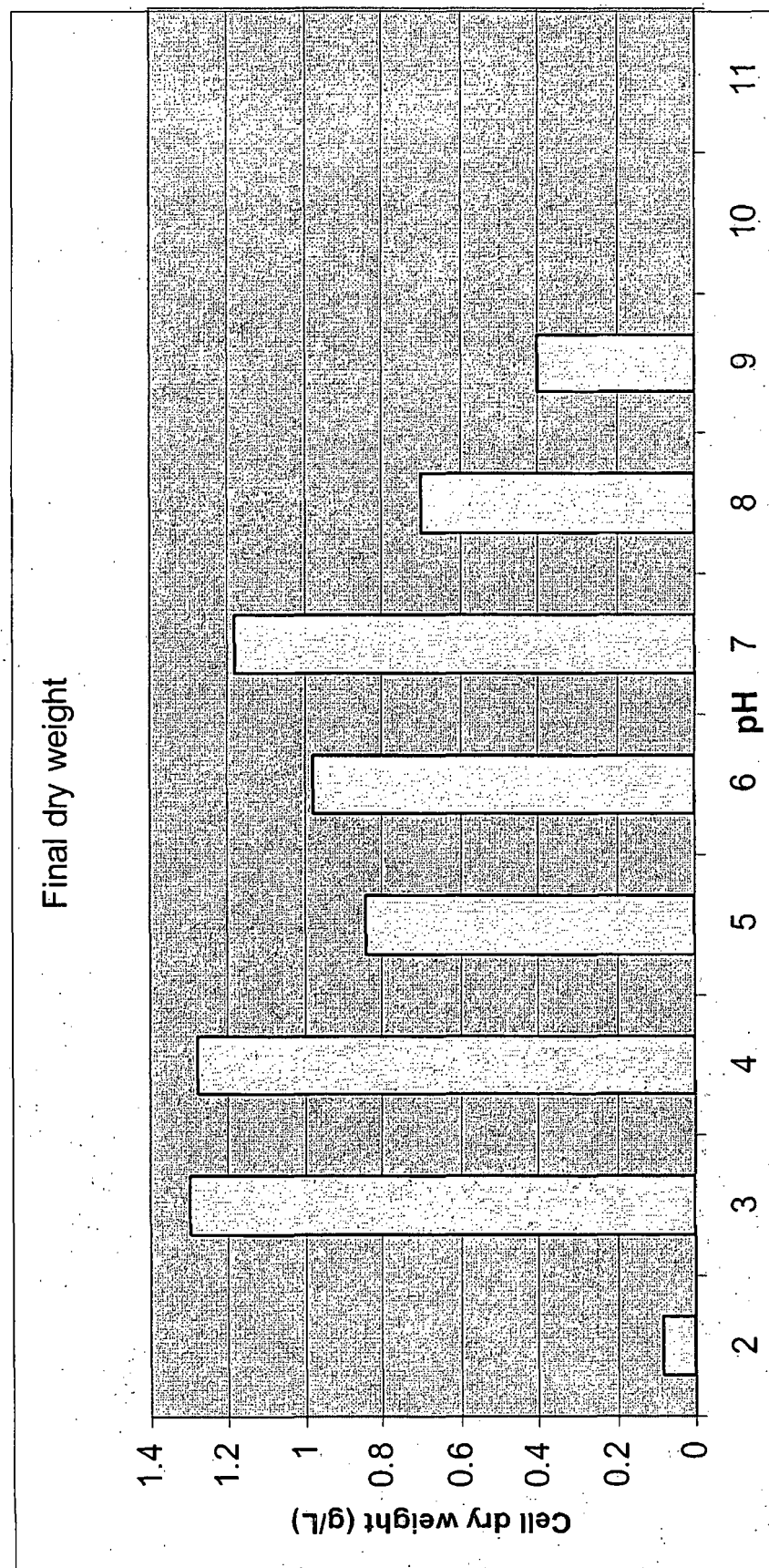


FIG. 3



REFERENCES CITED IN THE DESCRIPTION

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