

A DISTRIBUTED ALGAE MANUFACTURING ASSEMBLY

Technical Field

[0001] The present invention is broadly directed to a distributed algae manufacturing assembly. The invention is also generally directed to a method of producing algae typically as a source for protein and other food substances for consumption.

Summary of Invention

[0002] According to a first aspect of the present invention there is provided a distributed algae manufacturing assembly comprising:

an atmospheric carbon dioxide (CO₂) extractor sub-assembly configured for direct capture of CO₂ from air;

a bioreactor including:

- (a) a growth chamber adapted to contain algae within a liquid growth medium, said chamber arranged to cooperate with the atmospheric CO₂ extractor sub-assembly for enriching the liquid growth medium in the directly captured CO₂ which stimulates growth of the algae;
- (b) a light source associated with the growth chamber for exposing the algae within the growth chamber to light emitted from the light source thereby promoting growth of the algae within the bioreactor.

[0003] Preferably the distributed algae manufacturing assembly also comprises an algae processing sub-assembly arranged to cooperate with the bioreactor to separate the algae grown within the growth chamber from an algae mixture obtained from the bioreactor. More preferably said processing sub-assembly includes a centrifuge for separating an algae slurry including the grown algae from the algae mixture. Even more preferably said processing sub-assembly also includes a drying unit associated with the centrifuge for drying of the algae slurry to provide the grown algae in the form of an algae powder.

[0004] Preferably the distributed algae manufacturing assembly further comprises a liquid medium recovery sub-assembly associated with the algae processing sub-

assembly wherein liquid growth medium separated from the algae mixture and/or the algae slurry in said processing sub-assembly is returned to the growth chamber of the bioreactor. More preferably said recovery sub-assembly is associated with the centrifuge and/or the drying unit to recover liquid growth medium from either or both of said centrifuge and drying unit. Even more preferably the liquid growth medium is water-based.

[0005] Preferably the growth chamber includes one or more growth tubes formed in a spiral or serpentine arrangement within the bioreactor. More preferably each of said tubes is constructed from a transparent material thereby permitting exposure of the algae within the tube(s) to light emitted from the light source located outside of said tube(s).

[0006] Preferably the light source is an artificial light source including a plurality of LED light sources interposed between the growth tubes formed in the spiral or serpentine arrangement. More preferably the plurality of LED light sources are arranged in strips of LED lights.

[0007] Optionally or additionally the distributed algae manufacturing assembly also comprises a water capture generator operatively coupled to the bioreactor and designed for directly capturing water from atmosphere to provide the liquid growth medium in the form of liquid water for the growth chamber of the bioreactor. In this embodiment the directly captured liquid water from said water generator at least in part supplements the liquid growth medium within which the algae is grown within the growth chamber.

[0008] Preferably the atmospheric CO₂ extractor sub-assembly includes a metal-organic framework (MOF) lattice capable of directly adsorbing CO₂ from the air. More preferably said extractor sub-assembly also includes resistive heating means associated with the composite MOF lattice for resistive heating of said lattice whereby directly adsorbed CO₂ is desorbed from said lattice for delivery to the bioreactor for CO₂ enrichment of the liquid growth medium within the growth chamber.

[0009] According to a second aspect of the invention is provided a method of producing algae comprising the steps of:

directly capturing carbon dioxide (CO₂) from air;
containing algae and an associated liquid growth medium within a growth chamber;
exposing the growth medium to the directly captured CO₂ to enrich said growth medium to stimulate growth of the algae within the growth chamber;
exposing the algae within the growth chamber to light thereby promoting growth of the algae.

Brief Description of Drawings

[0010] In order to achieve a better understanding of the nature of the present invention a preferred embodiment of a distributed algae manufacturing assembly together with a method of producing algae of alternative aspects of the invention will now be described, by way of example only, with reference to the accompanying drawings in which:

Figure 1 is a perspective view of a preferred embodiment of a distributed algae manufacturing assembly according to a first aspect of the invention;

Figure 2 is a perspective view of the preferred embodiment of the distributed manufacturing assembly of figure 1 shown in its open configuration exposing its bioreactor and associated sub-assemblies;

Figure 3 is a front elevational view of the distributed manufacturing assembly of the preferred embodiment of figures 1 and 2 schematically depicting a preferred embodiment of a method of producing algae according to a second aspect of the invention.

Detailed Description

[0011] As seen in figures 1 and 2, there is an embodiment of a first aspect of the invention broadly directed to a distributed algae manufacturing assembly 10 for producing algae typically as a source for protein for human consumption. It is to be understood that the invention extends to the distributed manufacture of algae and its various derivatives. The distributed assembly 10 may be of a portable benchtop design intended to be located indoors in food preparation and consumption areas at

home, business or community places. The benchtop assembly 10 for distributed manufacture is typically in the form of an appliance electrically powered by grid electricity via a conventional AC power point.

[0012] The distributed algae manufacturing assembly 10 broadly comprises:

1. an atmospheric carbon dioxide (CO₂) extractor sub-assembly 12 configured for direct capture of CO₂ from air;
2. a bioreactor 14 including (a) a growth chamber 16 arranged to cooperate with the CO₂ extractor sub-assembly 12 to stimulate growth of algae, and (b) a light source 18 associated with the growth chamber 16 to promote growth of the algae within the bioreactor 14.

[0013] In this embodiment the distributed manufacturing assembly or appliance 10 also comprises an algae processing sub-assembly 20 arranged to cooperate with the bioreactor 14. The processing sub-assembly 20 is designed to separate the algae grown within the growth chamber 16 from an algae mixture obtained from the bioreactor 14.

[0014] As best seen in figure 2, the growth chamber 16 of the bioreactor 14 of this example is adapted to contain algae within a liquid growth medium. The directly captured CO₂ from the CO₂ sub-assembly 12 enriches the growth medium within the growth chamber 16 to stimulate growth of the algae. The light source 18 of the bioreactor 14 exposes the algae within the growth chamber 16 to light emitted from said light source 16 thereby promoting growth of the algae.

[0015] In this embodiment the growth chamber 16 includes a growth tube 22 formed in a serpentine arrangement within the bioreactor 14. The growth tube 22 is constructed from a transparent material thereby facilitating exposure of the algae within the growth tube 22 to light emitted from the light source 18. In this case the light source 18 includes a plurality of LED light sources such as 24 interposed between banks of the growth tube 22. The LED light source 24 is in this example arranged in the form of a strip of LED lights. Although not illustrated, the bioreactor 14 may be configured for the addition of nutrients to the growth chamber 16.

[0016] In this embodiment the algae processing sub-assembly 20 includes a centrifuge 26 for separating an algae slurry from the algae mixtures obtained from the bioreactor 14. The algae slurry includes the grown algae from the growth chamber 16 of the bioreactor 14. The processing sub-assembly 20 also includes a drying unit or spray dryer 28 associated with the centrifuge 26 for drying of the algae slurry to provide the grown algae in the form of an algae powder. The processing sub-assembly 20 may also include a dispenser 30 associated with the spray dryer 28 for dispensing the dried algae powder.

[0017] In this embodiment and as schematically depicted in figure 3, the distributed algae manufacturing assembly or appliance 10 further comprises a liquid medium recovery sub-assembly depicted generally at 32. The liquid growth medium is typically water-based and the recovery sub-assembly 32 is associated with the algae processing sub-assembly 20 wherein said water-based growth medium separated from the algae mixture and/or the algae slurry in said processing sub-assembly 20 is returned to the growth chamber 16 of the bioreactor 14. In this example the water-based recovery sub-assembly 32 is associated with:

1. the centrifuge 26 to recover water-based growth medium from the algae mixture obtained from the bioreactor 14 for return of the recovered growth medium to the growth chamber 16 via a first recovery line at 34;
2. the drying unit or spray dryer 28 to recover water-based growth medium separated from the algae slurry obtained from the centrifuge 26, the recovered growth medium returned to the growth chamber 16 of the bioreactor 14 via a second recovery line at 36.

[0018] It is to be understood that the liquid medium recovery sub-assembly 32 supplements or tops up the liquid growth medium which is initially supplied via tap water. The distributed manufacturing assembly or appliance 10 may also comprise a water capture generator (not shown) arranged to provide either the initial supply of liquid growth medium in the form of liquid water and/or top-up supplies for the growth chamber 16 of the bioreactor 14. The water capture generator is for this purpose operatively coupled to the bioreactor 14 and designed for directly capturing water from atmosphere. The water capture generator may be constructed in accordance

with the disclosures and teachings of the applicant's International patent application no. PCT/AU2019/05046 which although it is directed to a renewable methane production module is applicable in the context of this distributed algae manufacturing assembly. The disclosures of this International patent application are to be considered included herein by way of this reference.

[0019] Returning to figure 2, the atmospheric CO₂ extractor sub-assembly 12 includes:

1. a plurality of CO₂ cartridges 40a to 40d;
2. a plurality of CO₂ adsorption stations 42b to 42d configured to permit air to flow through select of the cartridges 40b to 40d for direct adsorption of CO₂ from air;
3. a CO₂ desorption station 42a arranged to contact a remaining one of the CO₂ extraction cartridges 40a for resistive heating whereby the directly adsorbed CO₂ is desorbed for extraction from the air.

[0020] In this example, each of the CO₂ extractor cartridges such as 40b includes a metal-organic framework (MOF) lattice such as 44b capable of directly adsorbing CO₂ from the air. The extractor sub-assembly 12 also includes resistive heating means associated with the composite MOF lattice 44a of the CO₂ extractor cartridge 40a at the CO₂ desorption station 42a. The resistive heating means (not shown) is effective in resistive heating of the MOF lattice 44a whereby directly adsorbed CO₂ is desorbed from said lattice 44a. In this embodiment, the desorbed CO₂ is delivered to the bioreactor 14 for CO₂ enrichment of the liquid growth medium within the growth chamber 16.

[0021] The CO₂ extractor sub-assembly 12 is otherwise constructed in accordance with the disclosures and teachings of the applicant's co-pending Australian provisional patent application nos. 2021900383 and 2021902305. The disclosures of the specification and drawings for each of these co-pending patent applications are to be considered included herein by way of these references.

[0022] In a second aspect of the invention there is a method of producing algae typically for human consumption as a protein-source. It is generally understood that

on average 40 to 50 grams of protein per day per person is a healthy level of consumption and the preferred method and distributed manufacturing assembly are sized accordingly. It is expected that the algae powder produced from the preferred manufacturing assembly and methodology will yield protein levels of greater than around 70 percent with the remainder containing other healthy components such as Omega 3. It is to be understood that some strains of algae inherently have high levels of Omega 3 which augment the nutritional value of the algae (and derivatives) powder produced by the present technology.

[0023] The method of this embodiment of the second aspect broadly comprises the steps of:

1. directly capturing carbon dioxide (CO₂) from air;
2. containing algae and an associated liquid growth medium within a growth chamber;
3. exposing the growth medium to the directly captured CO₂ to enrich it in CO₂ to stimulate growth of the algae within the growth chamber;
4. exposing the algae within the growth chamber to light thereby promoting growth of the algae.

[0024] Figure 3 schematically illustrates the preferred method for producing algae according to this aspect of the technology.

[0025] In step 1, carbon dioxide (CO₂) from the air at 50 is drawn into the CO₂ extractor sub-assembly 12. The CO₂ within the air 50 is directly adsorbed by the MOF lattice such as 44b of the corresponding CO₂ extractor cartridge 40b at an associated adsorption station 42b. It is to be understood that indoor levels of CO₂ are relatively high from exhaled human breath and/or ventilation with outside air which means that the distributed manufacturing assembly or appliance 10 lends itself to location indoors. The adsorbed CO₂ is desorbed from its associated MOF lattice such as 40a by heating it to release the directly adsorbed CO₂.

[0026] In step 2, the growth chamber such as 16 of the bioreactor 14 is seeded with microalgae for growth within a liquid growth medium, typically water. The water-based growth medium is provided via the water capture generator and/or tap water or

alternatively the distributed manufacturing assembly or appliance is plumbed to mains water for supply of the water-based growth medium.

[0027] In step 3, the growth medium within the growth chamber 16 of the bioreactor 14 is exposed to the directly captured CO₂ from the CO₂ extractor sub-assembly to enrich the growth medium in CO₂. In this case, the directly captured CO₂ is at 52 delivered to the growth tube 22 of the bioreactor 14 to enrich the growth medium with CO₂ to stimulate growth of the algae.

[0028] In step 4, the algae within the CO₂-enriched growth medium in the growth chamber 16 is at 54 exposed to light to promote growth of the algae. In this case the transparent tube 22 of the growth chamber 16 enables light exposure to the algae within said tube 22 via the light source such as the strip of LED lights 24.

[0029] In this embodiment the method of producing algae also comprises the steps of separating, drying and dispensing depicted broadly at 56. These algae processing steps are more specifically described in the context of the preferred embodiment of the distributed algae manufacturing assembly or appliance 10 of the first aspect of the invention.

[0030] As best seen in figure 2, both aspects of the technology in the preferred embodiment may comprise a food production unit depicted generally at 60. The food production unit 60 is in this example an additive manufacturing or 3D printing module associated with the algae processing sub-assembly 20. The 3D printing module 60 manually or automatically receives dried algae powder from the processing sub-assembly 20 for producing meat, fish, pasta and other food substitutes which may also involve the addition of various additives such as flavours, colours, binders and supplementary food nutrients.

[0031] As seen in figure 3, the distributed manufacturing assembly and method of both aspects are powered via an AC power point 70. It is to be understood that power delivered by the power point 70 could be sourced from grid or non-distributed power (purchased as renewably-derived power) and/or off-grid power such as that derived from rooftop solar PV. The manufacturing assembly or appliance such as 10 may be internet enabled (via a wireless web connection) with a touch screen display

seen at 62. It is to be understood that this embodiment of the manufacturing assembly or appliance 10 will be software-enabled with software updates being delivered via the internet. The distributed algae manufacturing assembly or appliance 10 would as such be configured for automatic operation with minimal skill required by an operator or other user.

[0032] It is to be understood that the present invention in both of its aspects provides a vehicle for trading carbon offsets *vis-a-vis* conventional and greenhouse gas intensive farming or growth practices for meat/fish as a protein source. This potential for selling reduced carbon associated with the present technology may assist in subsidising the cost of manufacturing the distributed algae production assembly. Furthermore, it is expected that distributed algae production based on atmospherically sourced CO₂ not only avoids the significant greenhouse gases, as well as water consumption and land use of meat/fish production, but also the cost and emissions and wastes from transportation and packaging of these products.

[0033] Now that a preferred embodiment of the alternative aspects of the invention have been described it will be apparent to those skilled in art that they have at least the following advantages:

1. the distributed manufacturing assembly provides efficient algae growth utilising CO₂ directly captured from air;
2. the manufacturing assembly effectively promotes growth of algae within a bioreactor by exposing the algae to artificial light from a light source;
3. the manufacturing assembly efficiently recovers liquid medium from the algae mixture obtained from the bioreactor and returns it to the growth chamber of said reactor;
4. the manufacturing assembly or appliance is typically of a standalone configuration powered via a conventional AC power point;
5. said assembly lends itself to the distributed manufacture of algae and its derivatives allowing end users to make for, example, their own protein powders.

[0034] Those skilled in the art will appreciate that the invention as described herein is susceptible to variations and modifications other than those specifically

described. For example, the growth chamber of the bioreactor may vary from the growth tube of the preferred embodiment where in a batch or semi-batch configuration the growth chamber is a growth tank. The CO₂ extractor sub-assembly may depart from the modular and relatively automated arrangement of the preferred embodiment provided it permits direct capture of CO₂ from air.

[0035] All such variations and modifications are to be considered within the scope of the present invention the nature of which is to be determined from the foregoing description.

Claims

1. A distributed algae manufacturing assembly comprising:
an atmospheric carbon dioxide (CO₂) extractor sub-assembly configured for direct capture of CO₂ from air;
a bioreactor including:
 - (a) a growth chamber adapted to contain algae within a liquid growth medium, said chamber arranged to cooperate with the atmospheric CO₂ extractor sub-assembly for enriching the liquid growth medium in the directly captured CO₂ which stimulates growth of the algae;
 - (b) a light source associated with the growth chamber for exposing the algae within the growth chamber to light emitted from the light source thereby promoting growth of the algae within the bioreactor.
2. A distributed algae manufacturing assembly as claimed in claim 1 also comprising an algae processing sub-assembly arranged to cooperate with the bioreactor to separate the algae grown within the growth chamber from an algae mixture obtained from the bioreactor.
3. A distributed algae manufacturing assembly as claimed in claim 2 wherein said processing sub-assembly includes a centrifuge for separating an algae slurry including the grown algae from the algae mixture.
4. A distributed algae manufacturing assembly as claimed in claim 3 wherein said processing sub-assembly also includes a drying unit associated with the centrifuge for drying of the algae slurry to provide the grown algae in the form of an algae powder.
5. A distributed algae manufacturing assembly as claimed in claim 4 further comprising a liquid medium recovery sub-assembly associated with the algae processing sub-assembly wherein liquid growth medium separated from the algae mixture and/or the algae slurry in said processing sub-assembly is returned to the growth chamber of the bioreactor.

6. A distributed algae manufacturing assembly as claimed in claim 5 wherein said recovery sub-assembly is associated with the centrifuge and/or the drying unit to recover liquid growth medium from either or both of said centrifuge and drying unit.
7. A distributed algae manufacturing assembly as claimed in any one of claims 4 to 6 wherein the liquid growth medium is water-based.
8. A distributed algae manufacturing assembly as claimed in any one of the preceding claims wherein the growth chamber includes one or more growth tubes formed in a spiral or serpentine arrangement within the bioreactor.
9. A distributed algae manufacturing assembly as claimed in claim 8 wherein each of said tubes is constructed from a transparent material thereby permitting exposure of the algae within the tube(s) to light emitted from the light source located outside of said tube(s).
10. A distributed algae manufacturing assembly as claimed in either of claims 8 or 9 wherein the light source is an artificial light source including a plurality of LED light sources interposed between the growth tubes formed in the spiral or serpentine arrangement.
11. A distributed algae manufacturing assembly as claimed in claim 10 wherein the plurality of LED light sources are arranged in strips of LED lights.
12. A distributed algae manufacturing assembly as claimed in any one of the preceding claims also comprising a water capture generator operatively coupled to the bioreactor and designed for directly capturing water from atmosphere to provide the liquid growth medium in the form of liquid water for the growth chamber of the bioreactor.
13. A distributed algae manufacturing assembly as claimed in claim 12 wherein the directly captured liquid water from said water generator at least in part supplements the liquid growth medium within which the algae is grown within the growth chamber.

14. A distributed algae manufacturing assembly as claimed in any one of the preceding claims wherein the atmospheric CO₂ extractor sub-assembly includes a metal-organic framework (MOF) lattice capable of directly adsorbing CO₂ from the air.
15. A distributed algae manufacturing assembly as claimed in claim 14 wherein said extractor sub-assembly also includes resistive heating means associated with the composite MOF lattice for resistive heating of said lattice whereby directly adsorbed CO₂ is desorbed from said lattice for delivery to the bioreactor for CO₂ enrichment of the liquid growth medium within the growth chamber.
16. A method of producing algae comprising the steps of:
directly capturing carbon dioxide (CO₂) from air;
containing algae and an associated liquid growth medium within a growth chamber;
exposing the growth medium to the directly captured CO₂ to enrich said growth medium to stimulate growth of the algae within the growth chamber;
exposing the algae within the growth chamber to light thereby promoting growth of the algae.