CLAIMS

What is claimed is:

1. A food and/or feed additive product grown under chemoautotrophic conditions comprising:

a consortium of chemoautotrophic and photoautotrophic bacteria and heterotrophic microbes, the consortium including

chemoautotrophic bacteria from the genera *Cupriavidus,* or *Methylococcus*,

photoautotrophic bacteria from the genera *Rhodobacter, Rhodospirillum, Rhodopseudomonas, or Arthrospira*, and

heterotrophic microbes from the genera *Bacillus, Bacteroides, Bifidobacterium, Lactobacillus, Lactococcus, Leuconostoc, Paracoccus, Pediococcus*, *Propionibacterium or Streptococcus.*

2. A method for producing a food and/or feed additive product, the method comprising:

providing a consortium of chemoautotrophic and photoautotrophic bacteria and heterotrophic microbes within a system,

the system including

a fermentation vessel filled with an aqueous medium comprising the consortium,

the fermentation vessel having an input port into which gaseous substrates are introduced into the aqueous medium,

the fermentation vessel further having an exhaust port through which gases exit the fermentation vessel,

wherein the aqueous medium comprises inorganic anions and inorganic cations, and

wherein the aqueous medium contains a concentration of no more than 0.05% of each of added sugars, yeast extract, tryptone, and/or organic carbon compounds,

the consortium including

chemoautotrophic bacteria from the genera *Cupriavidus, Rhodococcus* or *Methylococcus*,

photoautotrophic bacteria from the genera *Rhodobacter*, *Rhodospirillum*, *Rhodopseudomonas*, or *Arthrospira*, and

heterotrophic microbes from the genera of *Bacillus, Bacteroides, Bifidobacterium, Lactobacillus, Lactococcus, Leuconostoc, Paracoccus, Pediococcus*, *Propionibacterium*, or *Streptococcus*;

introducing a first gaseous substrate into the input port, the first gaseous substrate including carbon predominantly in the form of single-carbon atom molecules;

introducing a second gaseous substrate into the aqueous medium, the second gaseous substrate including predominantly hydrogen gas (H_2) or methane gas (CH_4) or a mixture thereof, wherein either of the first or second substrates additionally includes oxygen gas (O_2); and

harvesting cells of the bacteria from the system to generate a biomass product that has enhanced nutritional value compared to the biomass that the same chemoautorophic microbes would produce if grown alone.

3. A product made by the method of claim 2.

4. The method of claim 2 or the product of claim 3,

wherein the inorganic anions comprise phosphate, nitrate, sulfate, carbonate, and/or ammonium, and/or

wherein the inorganic cations comprise iron, nickel, calcium, magnesium, manganese, and/or cobalt.

5. The method of claim 2 or 4 or the product of claim 3 or 4, wherein

the chemoautotrophic bacteria include one or more of the species *Cupriavidus necator, Cupriavidus basilensis, Methylococcus capsulatus,* and *Rhodococcus opacus*,

the photoautotrophic bacteria include one or more of the species *Rhodobacter capsulatus, Rhodospirillum rubrum, Rhodobacter sphaeroides, Rhodopseudomonas palustris*, and *Arthirospira platensis*, and

the heterotrophic microbes include one or more of the species , *Aspergillus niger, Aspergillus oryzae, Bacillus coagulans, Bacillus lentus, Bacillus licheniformis, Bacillus megaterium, Bacillus pumilus, Bacillus subtilis, Bacteroides amylophilus, Bacteroides capillosus, Bacteroides ruminocola, Bacteroides suis, Bifidobacterium adolescentis, Bifidobacterium animalis, Bifidobacterium bifidum, Bifidobacterium infantis, Bifidobacterium lactis, Bifidobacterium longum, Bifidobacterium thermophilum, Bifidobacterum breve, Brevibacterium linens, Chlorella emersonii, Chlorella protothecoides, Chlorella pyrenoidosa, Chlorella vulgaris, Dunaliella salina, Haematococcus pluvialis, Lactobacillus acidophilus,*

Lactobacillus brevis, Lactobacillus bulgaricus, Lactobacillus casei, Lactobacillus cellobiosus, Lactobacillus curvatus, Lactobacillus delbruekii, Lactobacillus fermentum, Lactobacillus helveticus, Lactobacillus johnsonii, Lactobacillus lactis, Lactobacillus paracasei, Lactobacillus parafarraginis, Lactobacillus plantarum, Lactobacillus reuterii, Lactobacillus rhamnosus, Lactobacillus salivarius, Lactobacillus sporogenes, Lactococcus lactis, Leuconostoc mesenteroides, Nannochloropsis gaditana, Nannochloropsis granulata, Nannochloropsis limnetica, Nannochloropsis oceanica, Nannochloropsis oculata, Nannochloropsis salina, Paracoccus zeaxanthinifaciens, Paracoccus carotinifaciens, Paracoccus marcusii,Paracoccus sp. Pediococcus acidilactici, Pediococcus cerevisiae, Pediococcus pentosaceus, Propionibacterium shermanii, Propionibacterium freudenreichii, Rhodotorula glutinis, Saccharomyces boulardii, Saccharomyces cerevisiae, Streptococcus cremoris, Streptococcus diacetylactis, Streptococcus faecium, Streptococcus intermedius, Streptococcus lactis, Streptococcus thermophiles, Xanthophyllomyces dendrorhous.

6. The method of claim 2, 4 or 5, or the product of an of claims 3 to 5, wherein the chemoautotrophic bacteria comprise *Cupriavidus necator* and/or *Rhodococcus opacus*.

7. The method of any of claims 2 or 4 to 6, or the product of any of claims 3 to 6, wherein the photoautotrophic bacteria comprise *Rhodobacter capsulatus*.

8. The method of any of claims 2 or 4 to 7 or the product of any of claims 3 to 7, wherein the heterotrophic microbes comprise:

Bifidobacterium animalis, and/or

Lactobacillus acidophilus and/or *Lactobacillus casei*, and/or

Bacillus megaterium, and/or

a yeast or fungus, wherein in particular yeast or fungi comprises a species of the genera, *Aspergillus, Saccharomyces, Xanthophyllomyces, or Rhodotorula.*

9. The method of any of claims 2 or 4 to 8, or the product of any of claims 3 to 8, wherein providing the consortium of chemoautotrophic, photoautotrophic, and heterotrophic microbes includes:

adding the chemoautotrophic bacteria into the fermentation vessel and then adding photoautotrophic and heterotrophic microbes to the fermentation vessel; or

adding the chemoautotrophic, photoautotrophic, and heterotrophic microbes into the fermentation vessel simultaneously.

10. The method of any of claims 2 or 4 to 9 or the product of any of claims 3 to 9, wherein a concentration of single-carbon atom molecules in the first gaseous substrate and a concentration of hydrogen gas in the second gaseous substrate are both higher concentrations than are found in the ambient atmosphere.

11. The method of any of claims 2 or 4 to 10 or the product of any of claims 3 to 10, wherein the single-carbon atom molecules comprise CO_2 and the first gaseous substrate includes a concentration of CO_2 and a concentration of CH_4, wherein the second substrate includes a

concentration of hydrogen gas, and wherein all three concentrations are higher concentrations than are found in the ambient atmosphere.

12. The method of any of claims 2 to 4 or 11 or the product of any of claims 3 to 11, wherein the single-carbon atom molecules comprise CH_4, CO, and CO_2,

wherein in particular the first gaseous substrate includes a concentration of CO_2, a concentration of CH_4, and a concentration of CO, wherein the second substrate includes a concentration of hydrogen gas, and wherein all four concentrations are higher concentrations than are found in the ambient atmosphere.

13. The method of any of claims 2 or 4 to 12 or the product of any of claims 3 to 12, wherein the single-carbon atom molecules comprise CO and CH_4 and the first gaseous substrate includes a concentration of CO and a concentration of CH_4,

wherein the second substrate includes a concentration of hydrogen gas, and wherein all three concentrations are higher concentrations than are found in the ambient atmosphere, and/or

wherein both concentrations are higher concentrations than are found in the ambient atmosphere.

14. The method of any of claims 2 or 4 to 13 or the product of any of claims 3 to 13, wherein one of the bacteria has been genetically modified.

15. The method of any of claims 2 or 4 to 14 or the product of any of claims 3 to 14, wherein one of the bacteria of the consortium produces:

a carotenoid, and/or

a lutein, and/or

a vitamin, and/or

a protein, and/or

an astaxanthin, and/or

a polyunsaturated fatty acid, and/or

an eicosapentaenoic acid, and/or

a docosahexaenoic acid, and/or

a protein including an essential amino acid.

16. The method of any of claims 2 or 4 to 15, or the product of any of claims 3 to 15, wherein the consortium creates an ecosystem in which the chemoautotrophic microbes form the base of a food chain on which the non-autotrophic microbes are capable of growing.