technologies use autotrophic algae, bacteria, yeast or cyanobacteria to produce oil from sugar.

Summary

In one aspect, the present invention refers to a thermoplastic composition comprising a covalently modified microalgal biomass from a heterotrophically cultivated microalgae the composition further comprising soybean hulls. In one ~~aspect~~example, the ~~invention~~ disclosure provides thermoplastic compositions or thermoset compositions. In some ~~embodiments~~examples, the thermoplastic compositions or thermoset compositions comprise one or more of a covalently modified microbial biomass from an oleaginous microbe and a non-covalently modified biomass from a heterotrophically cultivated microbe, wherein the microbial biomass optionally comprises from 0.25% to 90% triglyceride by dry cell weight. In some examples~~embodiments~~, the microalgal biomass comprises from 0.25% to 20% triglyceride by dry cell weight. In some examples~~embodiments~~, the fatty acid profile of the triglyceride comprises at least 60% C18:1; at least 50% combined total amount of C10, C12, and C14; or at least 70% combined total amount of C16:0 and C18:1. The thermoplastic composition may optionally further comprise one or more plant polymers. Suitable plant polymers include, *e.g.*, switchgrass, rice straw, sugar beet pulp, corn starch, potato starch, cassava starch, sugar cane bagasse, soybean hulls, dry rosemary, cellulose, corn stover, delipidated cake from soybean, canola, cottonseed, sunflower, jatropha seeds, paper pulp, and waste paper. In various examples~~embodiments~~, the microbe is an oleaginous microbe. In some examples~~embodiments~~, the microbe has been lysed. In some examples~~embodiments~~, the biomass is microalgal biomass. In some examples~~embodiments~~, the microalgal biomass is derived from cells having a mean diameter of between 1 micron and 50 microns. In various examples~~embodiments~~, the microalgal biomass comprises one or more plant polymers. In some examples~~embodiments~~, the covalently modified microalgal biomass has been covalently modified with a hydrophobic group, a hydrophilic group, an anionic group or a cationic group. In some examples~~embodiments~~, the covalently modified microalgal biomass is microalgal biomass that has been modified by one or more reactions selected from the group consisting of acylation, hydroxylation, epoxidation, isocyanization, and silylation. In a particular example~~embodiment~~, the acylation reaction is acetylation. In some examples~~embodiments~~, polysaccharide of the microalgal biomass is covalently modified. In some examples~~embodiment~~, the covalently modified algal biomass is characterized by a degree of substitution ("DS") value in the range of 0.25 to 3. In some examples~~embodiments~~, the microalgal biomass is unbleached. In various examples~~embodiments~~, the microalgal biomass comprises less than 5000 ppm color generating compounds

(*e.g.*, chlorophyll). In various examplesembodiments, the microalgal biomass comprises less than 3000 ppm chlorophyll. In some examplesembodiments, the biomass is of microalgae that are heterotrophs, and optionally obligate heterotrophs. In some examplesembodiments, the microalgae are of the class Trebouxiophyceae. In some examplesembodiments, the microalgae are of the genus *Chlorella* or the genus *Prototheca*. In a particular examplembodiment, the microalgae are *Prototheca moriformis*. In some examplesembodiments, the thermoplastic composition further comprises a plasticizer. Suitable plasticizers include, *e.g.*, glycerol, sorbitol, triacetin, triethyl citrate, acetyl triethyl citrate, tributyl cirtate, acetyl tributyl citrate, trioctyl citrate, acetyl trioctyl citrate, trihexyl citrate, butyryl trihexyl citrate, trimethyl citrate, alkyl sulphonic acid phenyl ester, and 1,2-cyclohexane dicarboxylic acid diisononyl ester. In some examplesembodiments, the composition further comprises a surfactant. Suitable surfactants include, *e.g.*, glyceryl monostearate, ethoxylated dimethylsiloxane, polyoxyethylene, propylene oxide, an organic sulfate, an organic sulfonate, an alkyl polyglycoside, and a polyolefin glycol. In various examplesembodiments, the microbial biomass is a fraction that is insoluble in an aqueous solvent, said insoluble fraction produced by removing components soluble in an aqueous solvent from microbial biomass. In various examplesembodiments, the microbial biomass is insoluble in an aqueous solvent. In various examplesembodiments, the composition has been formed through extruding, molding, blowing, coating, or calendering. In various examplesembodiments, the composition is a film.

In a further examplaspect, the ~~invention~~ disclosure provides blended compositions. In various examplesembodiments, the blended compositions comprise a thermoplastic composition as described above and herein, and a second thermoplastic composition. In some examplesembodiments, the second thermoplastic composition is present in the range of 5 to 95% by mass. Suitable second thermoplastic compositions include, *e.g.*, polylactic acid, polycaprolactone, polyesteramide, polyhydroxybutyrate, polyhydroxybutyrate-co-valerate, polyhydroxyalkanoate, polyethylene, polypropylene, polyethylene terephthalate, and polycarbonate. In some examplesembodiments, the second thermoplastic composition is a derivative of polyethylene. In some examplesembodiments, the second thermoplastic composition is a derivative of polypropylene. In some examplesembodiments, the second thermoplastic composition is of biological origin. In some examplesembodiments, the thermoplastic composition has one or more of the following characteristics:

(a) a Young's modulus of 300-3000 MPa;

(b) a tensile strength of 5-70 MPa;

(c) a tensile strength at maximum load of 5-50MPa; and/or

(d) an ultimate elongation of 1-400%.

In a related ~~aspect~~example, the ~~invention~~ disclosure provides absorbent compositions. In various examples~~embodiments~~, the absorbent compositions comprise thermoplastic compositions or thermoset compositions as described above and herein. In various examples~~embodiments~~, the absorbent compositions comprise microbial biomass from a microbe covalently modified with a hydrophilic moiety. In some examples~~embodiments~~, the absorbent composition is cross-linked. In various examples~~embodiments~~, the microbe is an oleaginous microbe. In some examples~~embodiments~~, the microbe has been lysed. In some examples~~embodiments~~, the microbe is a microalga. In some examples~~embodiments~~, the microalga cell has a mean diameter of between approximately 1 micron and approximately 50 microns. In various examples~~embodiments~~, the hydrophilic moiety is anionic, cationic, zwitterionic, or neutral. In some examples~~embodiments~~, the anionic moiety is a carboxylate, a sulfate, a sulfonate, or a phosphate. In some examples~~embodiments~~, the cationic moiety is an amine or a substituted amine. In some examples~~embodiments~~, the neutral moiety is an hydroxyl or acyl. In a particular example~~embodiment~~, the anionic group is a carboxylate group, and the covalently modified biomass is formed by modifying the biomass with a carboxymethyl group. In some examples~~embodiments~~, the modified biomass is characterized by a degree of substitution ("DS") value of 0.25 to 3. In some examples~~embodiments~~, the covalently modified biomass comprises polysaccharide. In some examples~~embodiments~~, the absorbent compositions further comprise a cross-linking agent. Suitable cross-linking agents include, *e.g.*, aldehydes, C2-C8 dialdehydes, C2-C9 polycarboxylic acids, epichlorhydrin, divinyl sulphone, ethylenediamine, cystamine dihydrochloride, acrylic acid, sorbitan monolaurate, polyethylene glycol, sodium zirconium lactate, sodium borate, genipin, and sodium stearate. In a particular example~~embodiment~~, the dialdehyde is glyoxal. In various examples~~embodiments~~, the absorbent composition is included in a structural material. In some examples~~embodiments~~, the fatty acid composition of the microbial biomass comprises at least 60% C18:1; at least 50% combined total amount of C10, C12, and C14; or at least 70% combined total amount of C16:0 and C18:1. In some examples~~embodiments~~, the microbial biomass is a biomass fraction that is insoluble in an aqueous solvent, said insoluble fraction produced by removing components soluble in an aqueous solvent from microbial biomass. In some examples~~embodiments~~, the microbial

biomass is insoluble in an aqueous solvent. In various examplesembodiments, the composition absorbs at least 5 times its weight in liquid. In some examplesembodiments, the composition absorbs at least 5 times its weight in liquid after immersion in liquid for 4 hrs. In various examplesembodiments, the composition absorbs at least 10 times its weight in liquid. In some examplesembodiments, the composition absorbs at least 10 times its weight in liquid after immersion in liquid for 4 hrs. In various examplesembodiments, the composition absorbs at least 20 times its weight in liquid. In some examplesembodiments, the composition absorbs at least 20 times its weight in liquid after immersion in liquid for 4 hrs. In various examplesembodiments, the composition absorbs at least 50 times its weight in liquid. In some examplesembodiments, the composition absorbs at least 50 times its weight in liquid after immersion in liquid for 4 hrs. In various examplesembodiments, the composition absorbs at least 100 times its weight in liquid. In some examplesembodiments, the composition absorbs at least 100 times its weight in liquid after immersion in liquid for 4 hrs. In various examplesembodiments, the liquid is water, saline, oil, urine, or blood. In some examplesembodiments, the biomass is of microalgae that are heterotrophs, and *Chlorella* or the genus *Prototheca*. In a particular exampleembodiment, the microalgae are *Prototheca moriformis*. In various examplesembodiments, the absorbent composition further comprises a plant polymer. Suitable plant polymers include, *e.g.*, switchgrass, rice straw, sugar beet pulp, sugar cane bagasse, soybean hulls, corn starch, potato starch, cassava starch, dry rosemary, cellulose, corn stover, delipidated cake from soybean, canola, cottonseed, sunflower, jatropha seeds, paper pulp, and waste paper. In some examplesembodiments, the composition further comprises a second absorbent composition. Suitable second absorbent compositions include, *e.g.*, polyacrylate, polyacrylamide, polyvinyl alcohol, starch, starch-g-polyacrylonitrile, cellulose, carboxymethyl cellulose, and hydroxyethyl cellulose. optionally obligate heterotrophs. In some examplesembodiments, the microalgae are of the class Trebouxiophyceae. In some examplesembodiments, the microalgae are of the genus

In another aspectexample, the invention disclosure provides methods of making an adsorbent material, wherein the method comprises the steps of: a) preparing biomass from a microbe; and b) hydrothermally carbonizing the biomass, thereby making the adsorbent material. In various examplesembodiments, the microbe is an oleaginous microbe. In some examplesembodiments, the microbe has been lysed. In some examplesembodiments, the microbe is microalga. In some examplesembodiments, the microalgal biomass is prepared

from microalgal cells having a mean diameter between approximately 1 micron and approximately 50 microns. In some examplesembodiments, the biomass is of microalgae that are heterotrophs, and optionally obligate heterotrophs. In some examplesembodiments, the microalgae are of the class Trebouxiophyceae. In some examplesembodiments, the microalgae are of the genus *Chlorella* or the genus *Prototheca*. In some examplesembodiments, the microalgae are *Prototheca moriformis*. In some examplesembodiments, microalgal biomass is carbonized in the presence of an acidic catalyst. In various examplesembodiments, the amount of acidic catalyst is in the range of 0.01 grams to 0.6 grams per gram of microalgal biomass. In various examplesembodiments, the microalgal biomass is hydrothermally carbonized by heating to between about 180°C to 350°C in the presence of water from 60 minutes to 180 minutes. In some examplesembodiments, the fatty acid composition of the biomass comprises at least 60% C18:1; at least 50% combined total amount of C10, C12, and C14; or at least 70% combined total amount of C16:0 and C18:1. In some examplesembodiments, the biomass is a biomass fraction that is insoluble in an aqueous solvent, said insoluble fraction produced by removing components soluble in an aqueous solvent from oleaginous microbial biomass. In some examplesembodiments, the adsorbent material further comprises a plant polymer. Suitable plant polymers include, *e.g.*, switchgrass, rice straw, sugar beet pulp, sugar cane bagasse, soybean hulls, dry rosemary, corn starch, potato starch, cassava starch, cellulose, corn stover, delipidated cake from soybean, canola, cottonseed, sunflower, jatropha seeds, paper pulp, and waste paper. In some examplesembodiments, the methods further comprise the step of recovering and optionally using one or more nutrient from the biomass. Suitable nutrients include, *e.g.*, phosphorus, nitrogen, and potassium. In various examplesembodiments using is recycling the one or more nutrient to support the cultivation of additional microbial cells or using the one or more nutrient as a fertilizer to support plant growth.

In a related aspectexample, the invention disclosure provides paper products. In various examplesembodiments, the paper products comprise thermoplastic compositions or thermoset compositions as described above and herein. In various examplesembodiments, the paper products comprise 0.1% to 50% biomass from heterotrophically cultivated microbes. In some examplesembodiments, the microbe is an oleaginous microbe. In some examplesembodiments, the microbe has been lysed. In some embodiments, the microbe is a microalga. In some examplesembodiments, the microalgal biomass is derived from microalgal cells having a

mean diameter between approximately 1 micron and approximately 50 microns. In some examplesembodiments, the biomass is of microalgae that are obligate heterotrophs. In some examplesembodiments, the microalgae are of the class Trebouxiophyceae. In some examplesembodiments, the microalgae are of the genus *Chlorella* or the genus *Prototheca*. In a particular exampleembodiment, the microalgae are *Prototheca moriformis*. In some examplesembodiments, the biomass is a biomass fraction that is insoluble in an aqueous solvent, said insoluble fraction produced by removing components soluble in an aqueous solvent from microalgal biomass. In some examplesembodiments, the biomass is insoluble in an aqueous solvent. In various examplesembodiments, the biomass is a biomass fraction that is insoluble in an aqueous solvent, said insoluble fraction produced by removing components soluble in an aqueous solvent from oleaginous microbial biomass. In some examplesembodiments, triglyceride has been removed from the microalgal cells. For example, in various embodimentsIn some examples, the amount of triglyceride removed from the cells is more than 10% of the dry weight of the microalgal cells. In some examplesembodiments, one or more cationic retention aids have been added to the biomass. Suitable cationic retention aids include, *e.g.*, polydiallyldimethylammonium chlorides, branched polyacrylamides, polyamines having a molar mass of more than 50,000, modified polyamines grafted with ethylenimine, crosslinked polyetheramides, polyvinylimidazoles, polyvinylpyrrolidines, polyvinylimidazolines, polyvinyltetrahydropyrines, poly(dialkylaminoalkylvinylethers), poly(diakylaminoalkyl(meth)acrylates) in protonated or quaternized form, polyamidoamines obtained from a dicarboxylic acid, polyalkylenepolymines grafted with ethylenimine and crosslinked with polyethylene glycol dichlorohydrin ether, polyamidoamines reacted with epichlorohydrin to give water-soluble condensates, cationic starches, alum, polyaluminum chloride, and combinations thereof. In various examplesembodiments, the paper products further comprise a flocculating agent. In various examplesembodiments, the fatty acid composition of biomass comprises at least 60% C18:1; at least 50% combined total amount of C10, C12, and C14; or at least 70% combined total amount of C16:0 and C18:1. In various examplesembodiments, one or more additional papermaking fiber has been added to the biomass. Suitable papermaking fibers include, *e.g.*, cotton, straw, flax, jute hemp, bagasse, eucalyptus, maple, birch, aspen, pine, bamboo, rayon, polyester, fibers from recycled paper products and mixtures thereof. In some examplesembodiments, the paper product further comprises a plant polymer. Suitable plant polymers include, *e.g.*, switchgrass, rice straw, sugar beet pulp, sugar

cane bagasse, soybean hulls, dry rosemary, corn starch, potato starch, cassava starch, cellulose, corn stover, delipidated cake from soybean, canola, cottonseed, sunflower, jatropha seeds, paper pulp, and waste paper.

In another ~~aspect~~example, the ~~invention~~ disclosure provides methods of making a thermoplastic composition or a thermoset composition. In some examples~~embodiments~~, methods comprise the steps of: a) providing biomass from heterotrophically cultivated microbes; b) acylating the polysaccharides within the biomass, wherein the acylating is optionally acetylating; c) adding one or more of a plasticizer, an additional polymer, a filler, or a cross-linking agent. In various examples~~embodiments~~, the methods further comprise the step d) adding one or more plant polymers. Suitable plant polymers include, *e.g.*, switchgrass, rice straw, sugar beet pulp, sugar cane bagasse, soybean hulls, dry rosemary, corn starch, potato starch, cassava starch, cellulose, corn stover, delipidated cake from soybean, canola, cottonseed, sunflower, jatropha seeds, paper pulp, and waste paper. In some examples~~embodiments~~, the microbe is an oleaginous microbe. In some examples~~embodiments~~, the microbe has been lysed. In some examples~~embodiments~~, the acylating comprises acetylating using acetic anhydride or acetyl chloride as an acetylating agent. In some examples~~embodiments~~, the additional polymer is biodegradable. In some examples~~embodiments~~, the microbe is a microalga. In some examples~~embodiments~~, microalgal biomass is derived from microalgal cells having a mean diameter between approximately 1 micron and approximately 50 microns. In some examples~~embodiments~~, the biomass is of microalgae that are heterotrophs, and optionally obligate heterotrophs. In some examples~~embodiments~~, the microalgae are of the class Trebouxiophyceae. In some examples~~embodiments~~, the microalgae are of the genus *Chlorella* or the genus *Prototheca*. In a particular example~~embodiment~~, the microalgae are *Prototheca moriformis*. In some example~~embodiment~~, triglyceride has been removed from the microalgal cells, and wherein the amount of triglyceride removed from the microalgal cells is more than 10% of the dry weight of the microalgal cells. In some examples~~embodiments~~, the fatty acid composition of the biomass comprises at least 60% C18:1; at least 50% combined total amount of C10, C12, and C14; or at least 70% combined total amount of C16:0 and C18:1. Suitable plasticizers include, *e.g.*, one or more of: glycerol, sorbitol, triacetin, triethyl citrate, acetyl triethyl citrate, tributyl cirtate, acetyl tributyl citrate, trioctyl citrate, acetyl trioctyl citrate, trihexyl citrate, butyryl trihexyl citrate, trimethyl citrate, alkyl sulphonic acid phenyl ester, and 1,2-cyclohexane dicarboxylic acid diisononyl ester.

Suitable additional polymers include, *e.g.*, of one or more of: polylactic acid, polycaprolactone, polyesteramide, polyhydroxybutyrate, polyhydroxybutyrate-co-valerate, polyhydroxyalkanoate, polyethylene, polypropylene, polyethylene terephthalate, and polycarbonate. In some examples~~embodiments~~, the biomass is insoluble in an aqueous solvent, said insoluble fraction produced by removing components soluble in an aqueous solvent from oleaginous microbial biomass. In some examples~~embodiments~~, the biomass is a biomass fraction that is insoluble in an aqueous solvent. In some examples~~embodiments~~, the methods further comprise the step of forming the thermoplastic through one or more steps selected from extruding, molding, blowing, coating, and calendering.

In one example~~embodiment~~, a thermoset composition ~~of the invention~~disclosed herein is made by covalently modifying biomass with a phenolic moiety, an isocyanate moiety, an epoxide moiety, or an imide moiety. Phenolized biomass can be prepared by reacting the biomass with a phenol containing reactant in the presence an acidic catalyst, for example, sulfuric acid. The phenolization reaction is typically carried out at temperatures of 50° C to 200°C. One exemplary phenol containing reactant is benzyl alcohol. Biomass can be covalently modified with isocyanate moieties by reacting the biomass with a compound that contains one or more isocyanate moieties. The reaction is typically carried out at temperatures of 50° C to 200°C. Exemplary compounds that contain one or more isocyanate moieties include methylene diphenyl diisocyanate (MDI), toluene diisocyanate (TDI), (HDI),isophorone diisocyanate (IPDI), and methyl isocyanate (MIC). The covalently modified isocyanate biomass is then reacted with a polyol to form the thermoset composition. Biomass can be covalently modified to comprise epoxides by reacting the biomass with peroxide containing reactants. The peroxide containing biomass is then subsequently cured to form the thermoset composition. Covalently modified biomass that contains imides can be prepared by reacting the biomass with for example, N,N-dimethylacetamide (DMAc) or N-methylpyrrolidinone (NMP), pyromellitic dianhydride (PMDA), and/or 4-4'oxydianiline.

~~In certain embodiments, a further aspect of the invention includes~~Also disclosed herein is a process for producing triglyceride that entails (a) heterotrophically cultivating microalgal cells in a culture medium including crop-derived sugar so as to produce triglyceride inside the cells; (b) removing the triglyceride from the cells to produce an oil and a residual

biomass; (c) hydrothermally carbonizing a water soluble fraction and/or water insoluble fraction of the biomass to produce a carbonized product and a nutrient-rich aqueous solution; and (d) repeating the process with recycling of the nutrients of the nutrient-rich aqueous solution to step (a) to support the cultivation of additional microalgal cells or using the nutrients of the nutrient-rich aqueous solution in the growing of crops. In particular examplesembodiments, the microalgal cells have a mean diameter between approximately 1 micron and approximately 50 microns. In some examplesembodiments, the microalgal cells are obligate heterotrophs. In certain examplesembodiments, removed triglyceride accounts for more than 10% of the dry weight of the microalgal cells. In certain examplesembodiments, the biomass is carbonized in the presence of an acidic catalyst. For example, the biomass can be hydrothermally carbonized by heating it in the presence of water to between about 180-350°C for between 60 to 180 minutes. In such examplesembodiments, the amount of acidic catalyst can be in the range of 0.01grams to 0.6 grams per gram of biomass. Suitable acidic catalysts include, *e.g.*, citric acid and acrylic acid. In certain examplesembodiments, the fatty acid composition of the biomass includes at least 60% C18:1; at least 50% combined total amount of C10, C12, and C14; or at least 70% combined total amount of C16:0 and C18:1.

In certain examplesembodiments, provided is a composition comprising a blend of a moldable polymer, a microalgal biomass, and optionally a lipid selected from a triacylglyceride, a fatty acid, a fatty acid salt, a fatty acid ester, and one or more combinations thereof, wherein the microalgal biomass is optionally covalently modified and is obtained from a heterotrophic oleaginous microalgae. In certain examplesembodiments, provided is a composition comprising a blend of a moldable polymer, a microalgal biomass, and optionally a lipid selected from a triacylglyceride, a fatty acid, a fatty acid salt, a fatty acid ester, and one or more combinations thereof, wherein the microalgal biomass is optionally covalently modified and is obtained from a heterotrophic oleaginous microalgae that is an obligate heterotroph.

In certain examplesembodiments, provided is a film comprising a composition provided herein.

In certain examplesembodiments, provided is an injection molded article comprising a composition provided herein.

In one examplesembodiment, the compositions provided herein do not contain a plant polymer.

These and other aspects and embodiments are further described in the drawings and detailed descriptions below.

Brief Description of the Drawings

The foregoing features of the invention will be more readily understood by reference to the following detailed description, taken with reference to the accompanying drawing, in which:

Fig. 1 shows a flow diagram depicting a method for preprocessing biomass in connection with some embodiments of the present invention.

Fig. 2 shows scanning electron microscopy (SEM) morphology of selected hydrothermal treated microalgal samples made with an embodiment of the compositions as illustrated in Example 5.

Fig. 3 shows Fourier transform infrared (FTIR) spectra of selected carbon samples made with an embodiment of the compositions as illustrated in Example 5.

Fig. 4 shows a graph of charge densities of the crosslinked, anionized biomass made with an embodiment of the compositions as illustrated in Example 7.

Fig. 5A-B show the retention results of filtration studies conducted on paper preparations made with biomass in an embodiment of the compositions as illustrated in Example 12.

Detailed Description

Definitions:

"About" refers to the stated value $\pm$ 10%.

"Acylation" refers to a reaction between a reactant having a hydroxy group and a reactant having activated carbonyl group to produce an ester linkage. Activated carbonyl groups include anhydrides, esters, acids, and acyl groups having a leaving group such as a halide attached to the carbonyl carbon. "Acetylation" refers to an ester producing reaction where one of the reactants has an acetyl ($CH_3C=O$-) group.

Claims

What is claimed is:

1. A thermoplastic composition or thermoset composition comprising one or more of a covalently modified microbial biomass from an oleaginous microbe and a non-covalently modified biomass from a heterotrophically cultivated microbe, wherein the microbial biomass optionally comprises from 0.25% to 90% triglyceride by dry cell weight; the thermoplastic composition optionally further comprising one or more plant polymers.

2. The composition according to claim 1, wherein the microbe is an oleaginous microbe.

3. The composition according to claim 1 or 2, wherein the microbe has been lysed.

4. The composition according to any of claims 1 to 3, wherein the biomass is microalgal biomass.

5. The composition according to claim 4, wherein the microalgal biomass is derived from cells having a mean diameter of between 1 micron and 50 microns.

6. The composition according to claims 4 or 5, wherein the microalgal biomass comprises from 0.25% to 20% triglyceride by dry cell weight.

7. The composition according to any of claims 1 to 6, further comprising one or more plant polymers.

8. The composition according to any of claims 4 to 7, wherein the covalently modified microalgal biomass has been covalently modified with a hydrophobic group, a hydrophilic group, an anionic group or a cationic group.

9. The composition of claim 8, wherein the covalently modified microalgal biomass is microalgal biomass that has been modified by one or more

reactions selected from the group consisting of acylation, hydroxylation, epoxidation, isocyanization, and silylation.

10. The composition of claim 9, wherein the acylation reaction is acetylation.

11. The composition of any of claims 8 to 10, wherein polysaccharide of the microalgal biomass is covalently modified.

12. The composition according to any of claims 9 to 11, wherein the covalently modified algal biomass is characterized by a DS value of 0.25 to 3.

13. The composition according to any of claims 4 to 12, wherein the microalgal biomass is unbleached.

14. The composition according to any of claims 4 to 13, wherein the microalgal biomass comprises less than 5000 ppm color generating compounds.

15. The composition according to any of claims 4 to 14, wherein the microalgal biomass comprises less than 3000 ppm chlorophyll.

16. The composition according to any of claims 4 to 15, wherein the biomass is of microalgae that are heterotrophs, and optionally obligate heterotrophs.

17. The composition according to any of claims 4 to 16, wherein the microalgae are of the class Trebouxiophyceae.

18. The composition according to claim 17, wherein the microalgae are of the genus *Chlorella* or the genus *Prototheca*.

19. The composition according to claim 18, wherein the microalgae are *Prototheca moriformis*.

20. The composition according to any of claims 4 to 19, wherein the thermoplastic composition further comprises a plasticizer.

21. The composition according to claim 20, wherein the plasticizer is selected from a group consisting of one or more of: glycerol, sorbitol, triacetin, triethyl citrate, acetyl triethyl citrate, tributyl cirtate, acetyl tributyl citrate, trioctyl citrate, acetyl trioctyl citrate, trihexyl citrate, butyryl trihexyl citrate, trimethyl

citrate, alkyl sulphonic acid phenyl ester, and 1,2-cyclohexane dicarboxylic acid diisononyl ester.

22. The composition according to any of claims 1 to 21, wherein the composition further comprises a surfactant.

23. The composition according to claim 22, wherein the surfactant is selected from the group consisting of glyceryl monostearate, ethoxylated dimethylsiloxane, polyoxyethylene, propylene oxide, an organic sulfate, an organic sulfonate, an alkyl polyglycoside, and a polyolefin glycol.

24. A blended composition comprising a thermoplastic composition according to any of claims 1 to 23, and a second thermoplastic composition.

25. The blended composition according to claim 24, wherein the second thermoplastic composition is present in the range of 5 to 95% by mass.

26. The blended composition according to claim 24, wherein the second thermoplastic composition is selected from a group consisting of polylactic acid, polycaprolactone, polyesteramide, polyhydroxybutyrate, polyhydroxybutyrate-co-valerate, polyhydroxyalkanoate, polyethylene, very low density polyethylene, low density polyethylene, linear low density polyethylene, medium density polyethylene, high density polyethylene, ultra high molecular weight polyethylene, polypropylene, polyethylene terephthalate, and polycarbonate.

27. The blended composition of any of claims 24 to 26, wherein the second thermoplastic composition is of biological origin.

28. The composition according to any of claims 1 to 27, wherein the thermoplastic composition has one or more of the following characteristics: (a) a Young's modulus of 300-3000 MPa; (b) a tensile strength of 5-70 MPa; (c) a tensile strength at maximum load of 5-50MPa; or (d) an ultimate elongation of 1-400%.

29. The composition according to any of claims 1 to 28, wherein the fatty acid profile of the triglyceride comprises at least 60% C18:1; at least 50%

combined total amount of C10, C12, and C14; or at least 70% combined total amount of C16:0 and C18:1.

30. The composition according to any of claims 1 to 29, wherein the microbial biomass is a fraction that is insoluble in an aqueous solvent, said insoluble fraction produced by removing components soluble in an aqueous solvent from microbial biomass.

31. The composition according to any of claims 1 to 29, wherein the composition has been formed through extruding, molding, blowing, coating, calendering, or spinning.

32. The thermoplastic composition according to any of claims 1 to 30, wherein the composition is a film or a fiber.

33. The thermoplastic composition according to any of claims 1 to 32, wherein the one or more plant polymers is from the group consisting of switchgrass, rice straw, sugar beet pulp, corn starch, potato starch, cassava starch, sugar cane bagasse, soybean hulls, dry rosemary, cellulose, corn stover, delipidated cake from soybean, canola, cottonseed, sunflower, jatropha seeds, paper pulp, and waste paper.

34. An absorbent composition comprising microbial biomass from a microbe covalently modified with a hydrophilic moiety and wherein the composition is optionally cross-linked.

35. The absorbent composition according to claim 34, wherein the microbe is an oleaginous microbe.

36. The absorbent composition according to claim 34 or 35, wherein the microbe has been lysed.

37. The absorbent composition according to any of claims 34 to 36, wherein the microbe is a microalga.

38. The absorbent composition according to claim 37, wherein the microalga cell has a mean diameter of between approximately 1 micron and approximately 50 microns.

39. The absorbent composition according to any of claims 34 to 38, wherein the hydrophilic moiety is anionic, cationic, zwitterionic, or neutral.

40. The absorbent composition according to claim 39, wherein the anionic moiety is a carboxylate, a sulfate, a sulfonate, or a phosphate.

41. The absorbent composition according to claim 39, wherein the cationic moiety is an amine or a substituted amine.

42. The absorbent composition according to claim 39, wherein the neutral moiety is an hydroxyl or acyl.

43. The absorbent composition according to claim 39, wherein the anionic group is a carboxylate group, and wherein the covalently modified biomass is formed by modifying the biomass with a carboxymethyl group.

44. The absorbent composition according to any of claims 34 to 43, wherein the modified biomass is characterized by a DS value of 0.25 to 3.

45. The absorbent composition according to any of claims 34 to 44, wherein the covalently modified biomass comprises polysaccharide.

46. The absorbent composition according to any of claims 34 to 45, further comprising a cross-linking agent, optionally selected from the group consisting of aldehydes, C2-C8 dialdehydes, C2-C9 polycarboxylic acids, epichlorhydrin, divinyl sulphone, ethylenediamine, cystamine dihydrochloride, acrylic acid, sorbitan monolaurate, polyethylene glycol, sodium zirconium lactate, sodium borate, genipin, and sodium stearate.

47. The absorbent composition of claim 46, wherein the dialdehyde is glyoxal.

48. The absorbent composition according to any of claims 34 to 47, wherein the composition is included in a structural material.

49. The absorbent composition according to any of claims 34 to 48, wherein the fatty acid composition of the microbial biomass comprises at least 60% C18:1; at least 50% combined total amount of C10, C12, and C14; or at least 70% combined total amount of C16:0 and C18:1.

50. The absorbent composition according to any of claims 34 to 49, wherein the microbial biomass is a biomass fraction that is insoluble in an aqueous solvent, said insoluble fraction produced by removing components soluble in an aqueous solvent from microbial biomass.

51. The absorbent composition according to any of claims 34 to 50, wherein the composition absorbs at least 5 times its weight in liquid.

52. The absorbent composition according to claim 51, wherein the composition absorbs at least 5 times its weight in liquid after immersion in liquid for 4 hrs.

53. The absorbent composition according to any of claims 34 to 50, wherein the composition absorbs at least 10 times its weight in liquid.

54. The absorbent composition according to claim 53, wherein the composition absorbs at least 10 times its weight in liquid after immersion in liquid for 4 hrs.

55. The absorbent composition according to any of claims 34 to 50, wherein the composition absorbs at least 20 times its weight in liquid.

56. The absorbent composition according to claim 55, wherein the composition absorbs at least 20 times its weight in liquid after immersion in liquid for 4 hrs.

57. The absorbent composition according to any of claims 34 to 50, wherein the composition absorbs at least 50 times its weight in liquid.

58. The absorbent composition according to claim 57, wherein the composition absorbs at least 50 times its weight in liquid after immersion in liquid for 4 hrs.

59. The absorbent composition according to any of claims 34 to 50, wherein the composition absorbs at least 100 times its weight in liquid.

60. The absorbent composition according to claim 59, wherein the composition absorbs at least 100 times its weight in liquid after immersion in liquid for 4 hrs.

61. The absorbent composition according to any of claims 51 to 60, wherein the liquid is water, saline, oil, urine, or blood.

62. The absorbent composition according to any of claims 34 to 61, wherein the biomass is of microalgae that are heterotrophs, and optionally obligate heterotrophs.

63. The absorbent composition according to any of claims 34 to 62, wherein the microalgae are of the class Trebouxiophyceae.

64. The composition according to claim 63, wherein the microalgae are of the genus *Chlorella* or the genus *Prototheca*.

65. The composition according to claim 64, wherein the microalgae are *Prototheca moriformis*.

66. The absorbent composition according to any of claims 34 to 65, wherein the absorbent composition further comprises a plant polymer.

67. The absorbent composition according to claim 66, wherein the plant polymer is from the group consisting of switchgrass, rice straw, sugar beet pulp, sugar cane bagasse, soybean hulls, corn starch, potato starch, cassava starch, dry rosemary, cellulose, corn stover, delipidated cake from soybean, canola, cottonseed, sunflower, jatropha seeds, paper pulp, and waste paper.

68. The absorbent composition according to any of claims 34 to 67, wherein the composition further comprises a second absorbent composition.

69. The absorbent composition of claim 68, the second absorbent composition selected from the group consisting of polyacrylate, polyacrylamide, polyvinyl

alcohol, starch, starch-g-polyacrylonitrile, cellulose, carboxymethyl cellulose, and hydroxyethyl cellulose.

70. A method of making an adsorbent material, wherein the method comprises the steps of:

a) preparing biomass from a microbe;

b) hydrothermally carbonizing the biomass, thereby making the adsorbent material.

71. The method according to claim 70, wherein the microbe is an oleaginous microbe.

72. The method according to claim 70 or 71, wherein the microbe has been lysed.

73. The method according to any of claims 70 to 72, wherein the microbe is microalga.

74. The method according to any of claim 71 to 73, wherein the microalgal biomass is prepared from microalgal cells having a mean diameter between approximately 1 micron and approximately 50 microns.

75. The method according to any of claims 70 to 74, wherein the biomass is of microalgae that are heterotrophs, and optionally obligate heterotrophs.

76. The method according to any of claims 70 to 75, wherein the microalgae are of the class Trebouxiophyceae.

77. The method according to claim 76, wherein the microalgae are of the genus *Chlorella* or the genus *Prototheca*.

78. The method according to claim 77, wherein the microalgae are *Prototheca moriformis*.

79. The method according to any of claims 70 to 78, wherein microalgal biomass is carbonized in the presence of an acidic catalyst.

80. The method according to claim 79, wherein the amount of acidic catalyst is in the range of 0.01 grams to 0.6 grams per gram of microalgal biomass.

81. The method according to any of claims 71 to 80, wherein the microalgal biomass is hydrothermally carbonized by heating to between about 180°C to 350°C in the presence of water from 60 minutes to 180 minutes.

82. The method according to any of claims 70 to 81, wherein the fatty acid composition of the biomass comprises at least 60% C18:1; at least 60% combined total amount of C10, C12, and C14; or at least 70% combined total amount of C16:0 and C18:1.

83. The method according to any of claims 70 to 82, wherein the biomass is a biomass fraction that is insoluble in an aqueous solvent, said insoluble fraction produced by removing components soluble in an aqueous solvent from oleaginous microbial biomass.

84. The method according to any of claims 70 to 83, wherein the adsorbent material further comprises a plant polymer.

85. The method according to claim 84, wherein the plant polymer is from the group consisting of switchgrass, rice straw, sugar beet pulp, sugar cane bagasse, soybean hulls, dry rosemary, corn starch, potato starch, cassava starch, cellulose, corn stover, delipidated cake from soybean, canola, cottonseed, sunflower, jatropha seeds, paper pulp, and waste paper.

86. The method according to any of claims 70 to 85, further comprising recovering and optionally using one or more nutrient from the biomass wherein the nutrient is selected from the group of phosphorus, nitrogen, and potassium and wherein using is recycling the one or more nutrient to support the cultivation of additional microbial cells or using the one or more nutrient as a fertilizer to support plant growth.

87. A paper product comprising 0.1% to 50% biomass from heterotrophically cultivated microbes.

88. The paper product according to claim 87, wherein the microbe is an oleaginous microbe.

89. The paper product according to claim 87 or 88, wherein the microbe has been lysed.

90. The paper product according to any of claims 87 to 89, wherein the microbe is a microalga.

91. The paper product according to claim 90, wherein the microalgal biomass is derived from microalgal cells having a mean diameter between approximately 1 micron and approximately 50 microns.

92. The paper product according to claim 87 or 90, wherein the biomass is of microalgae that are obligate heterotrophs.

93. The paper product according to any of claims 87 to 92, wherein the microalgae are of the class Trebouxiophyceae.

94. The paper product according to claim 93, wherein the microalgae are of the genus *Chlorella* or the genus *Prototheca*.

95. The paper product according to claim 94, wherein the microalgae are *Prototheca moriformis*.

96. The paper product according to any of claims 87 to 95, wherein the biomass is a biomass fraction that is insoluble in an aqueous solvent, said insoluble fraction produced by removing components soluble in an aqueous solvent from microalgal biomass.

97. The paper product according to any of claims 90 to 96, wherein triglyceride has been removed from the microalgal cells, and wherein the amount of triglyceride removed from the cells is more than 10% of the dry weight of the microalgal cells.

98. The paper product according to any of claims 87 to 97, wherein one or more cationic retention aids have been added to the biomass.

99. The paper product according to claim 98, wherein the cationic retention aid is selected from a group consisting of: polydiallyldimethylammonium chlorides, branched polyacrylamides, polyamines having a molar mass of more than

50,000, modified polyamines grafted with ethylenimine, crosslinked polyetheramides, polyvinylimidazoles, polyvinylpyrrolidines, polyvinylimidazolines, polyvinyltetrahydropyrines, poly(dialkylaminoalkylvinylethers), poly(diakylaminoalkyl(meth)acrylates) in protonated or quaternized form, polyamidoamines obtained from a dicarboxylic acid, polyalkylenepolymines grafted with ethylenimine and crosslinked with polyethylene glycol dichlorohydrin ether, polyamidoamines reacted with epichlorohydrin to give water-soluble condensates, cationic starches, alum, polyaluminum chloride, and combinations thereof.

100. The paper product according to any of claims 87 to 99, further comprising a flocculating agent.

101. The paper product according to any of claims 87 to 100, wherein the fatty acid composition of biomass comprises at least 60% C18:1; at least 50% combined total amount of C10, C12, and C14; or at least 70% combined total amount of C16:0 and C18:1.

102. The paper product according to any of claims 87 to 101, wherein the biomass is a biomass fraction that is insoluble in an aqueous solvent, said insoluble fraction produced by removing components soluble in an aqueous solvent from oleaginous microbial biomass.

103. The paper product according to any of claims 87 to 102, wherein one or more additional papermaking fiber has been added to the biomass.

104. The paper product according to claim 103, wherein the one or more additional papermaking fiber is selected from the group consisting of cotton, straw, flax, jute hemp, bagasse, eucalyptus, maple, birch, aspen, pine, bamboo, rayon, polyester, and fibers from recycled paper products.

105. The paper product according to any of claims 87 to 104, wherein the product further comprises a plant polymer.

106. The paper product according to claim 105, wherein the plant polymer is from the group consisting of switchgrass, rice straw, sugar beet pulp, sugar cane

bagasse, soybean hulls, dry rosemary, corn starch, potato starch, cassava starch, cellulose, corn stover, delipidated cake from soybean, canola, cottonseed, sunflower, jatropha seeds, paper pulp, and waste paper.

107. A method of making a thermoplastic composition or a thermoset composition, the method comprising the steps of:
a) providing biomass from heterotrophically cultivated microbes;
b) acylating the polysaccharides within the biomass, wherein the acylating is optionally acetylating;
c) adding one or more of a plasticizer, an additional polymer, a filler, or a cross-linking agent
d) optionally adding one or more plant polymers.

108. The method according to claim 107, wherein the microbe is an oleaginous microbe.

109. The method according to claim 107 or 108, wherein the microbe has been lysed.

110. The method according to any of claims 107 to 109, wherein the acylating is acetylating using acetic anhydride or acetyl chloride as an acetylating agent.

111. The method according to any of claims 107 to 110, wherein the additional polymer is biodegradable.

112. The method according to any of claims 107 to 111, wherein the microbe is a microalga.

113. The method according to claim 112, wherein microalgal biomass is derived from microalgal cells having a mean diameter between approximately 1 micron and approximately 50 microns.

114. The method according to the claim 112 or 113, wherein the biomass is of microalgae that are heterotrophs, and optionally obligate heterotrophs.

115. The method according to any of claims 112 to 114, wherein the microalgae are of the class Trebouxiophyceae.

116. The method according to claim 115, wherein the microalgae are of the genus *Chlorella* or the genus *Prototheca*.

117. The method according to claim 116, wherein the microalgae are *Prototheca moriformis*.

118. The method according to any of claims 112 to 117, wherein triglyceride has been removed from the microalgal cells, and wherein the amount of triglyceride removed from the microalgal cells is more than 10% of the dry weight of the microalgal cells.

119. The method according to any of claims 107 to 118, wherein the plasticizer is selected from the group consisting of one or more of: glycerol, sorbitol, triacetin, triethyl citrate, acetyl triethyl citrate, tributyl cirtate, acetyl tributyl citrate, trioctyl citrate, acetyl trioctyl citrate, trihexyl citrate, butyryl trihexyl citrate, trimethyl citrate, alkyl sulphonic acid phenyl ester, and 1,2-cyclohexane dicarboxylic acid diisononyl ester.

120. The method according to any of claims 107 to 119, wherein the additional polymer is selected from a group consisting of one or more of: polylactic acid, polycaprolactone, polyesteramide, polyhydroxybutyrate, polyhydroxybutyrate-co-valerate, polyhydroxyalkanoate, polyethylene, very low density polyethylene, low density polyethylene, linear low density polyethylene, medium density polyethylene, high density polyethylene, ultra high molecular weight polyethylene polypropylene, polyethylene terephthalate, and polycarbonate.

121. The method according to any of claims 107 to 120, wherein the fatty acid composition of the biomass comprises at least 60% C18:1; at least 50% combined total amount of C10, C12, and C14; or at least 70% combined total amount of C16:0 and C18:1.

122. The method according to any of claims 107 to 121, wherein the biomass is a biomass fraction that is insoluble in an aqueous solvent, said insoluble fraction produced by removing components soluble in an aqueous solvent from oleaginous microbial biomass.

123. The method according to any of claims 107 to 122, wherein the method further comprises forming said thermoplastic through one or more steps selected from extruding, molding, blowing, coating, and calendering.

124. The method according to any of claims 107 to 123, wherein the one or more plant polymers is from the group consisting of switchgrass, rice straw, sugar beet pulp, sugar cane bagasse, soybean hulls, dry rosemary, corn starch, potato starch, cassava starch, cellulose, corn stover, delipidated cake from soybean, canola, cottonseed, sunflower, jatropha seeds, paper pulp, and waste paper.

125. A process for producing triglyceride comprising (a) heterotrophically cultivating microalgal cells in a culture medium comprising crop-derived sugar so as to produce triglyceride inside the cells; (b) removing the triglyceride from the cells to produce an oil and a residual biomass; (c) hydrothermally carbonizing a water soluble fraction and/or water insoluble fraction of the biomass to produce a carbonized product and a nutrient-rich aqueous solution; and (d) repeating the process with recycling of the nutrients of the nutrient-rich aqueous solution to step (a) to support the cultivation of additional microalgal cells or using the nutrients of the nutrient-rich aqueous solution in the growing of crops.

126. The process according to claim 125, wherein the microalgae cells having a mean diameter between approximately 1 micron and approximately 50 microns.

127. The process according to claim 125 or claim 126, wherein the microalgal cells are obligate heterotrophs.

128. The process according to any of claims 125 to 127, wherein removed triglyceride accounts for more than 10% of the dry weight of the microalgal cells.

129. The process according to any of claims 125 to 128, wherein the biomass is carbonized in the presence of an acidic catalyst.

130. The process according to any of claims 125 to 129, wherein the biomass is hydrothermally carbonized by heating it in the presence of water to between about 180-350°C for between 60 to 180 minutes.

131. The process according to any of claims 125 to 130, wherein the acidic catalyst is included with the biomass in the range of 0.01 to 0.6 grams per gram of biomass.

132. The process according to any of claims 125 to 131, wherein the acidic catalyst is selected from a group consisting of citric acid and acrylic acid.

133. The process according to any of claims 125 to 132, wherein the fatty acid composition of the oleaginous microbial biomass comprises at least 60% C18:1; at least 50% combined total amount of C10, C12, and C14; or at least 70% combined total amount of C16:0 and C18:1.

134. A composition comprising a blend of a moldable polymer, a microalgal biomass, and optionally a lipid selected from a triacylglyceride, a fatty acid, a fatty acid salt, a fatty acid ester, and one or more combinations thereof, wherein the microalgal biomass is optionally covalently modified and is obtained from a heterotrophic oleaginous microalgae.

135. The composition of claim 134 wherein the microalgal biomass is obtained from microalgae cultivated with sugar from corn, sorghum, sugar cane, sugar beet, or molasses as a carbon source.

136. The composition of any one of claims 134 to 135, wherein the microalgal biomass is obtained from microalgae cultivated on sucrose.

137. The composition of any one of claims 134 to 136, wherein the microalgal biomass is obtained from *Parachlorella*, *Prototheca*, or *Chlorella* and strains having at least 85% nucleotide sequence identity in 23S rRNA sequences to a *Parachlorella, Prototheca,* or *Chlorella* strain.

138. The composition of any one of claims 134 to 137, wherein the oleaginous microalgae has a fatty acid profile of at least 60% C18:1; or at least 50%

combined total amount of C10, C12, and C14; or at least 70% combined total amount of C16:0 and C18:1.

139. The composition of any one of claims 134 to 138, wherein the microalgal biomass is obtained from heterotrophic oleaginous microalgae that is lysed.

140. The composition of any one of claims 134 to 139, wherein the lipid comprises 15% or less of the composition.

141. The composition of any one of claims 134 to 140, wherein the lipid comprises 10% or less of the composition.

142. The composition of any one of claims 134 to 141, wherein the lipid comprises 5% or less of the composition.

143. The composition of any one of claims 134 to 142, wherein the lipid comprises 2% or less of the composition.

144. The composition of any one of claims 134 to 143, wherein the lipid comprises a fatty acid salt.

145. The composition of claim 144 wherein the fatty acid salt is a calcium or magnesium salt.

146. The composition of claim 145 wherein the fatty acid salt is a calcium salt.

147. The composition of any one of claims 134 to 146, wherein the lipid has at least 60% C18:1; or at least 50% combined total amount of C10, C12, and C14; or at least 70% combined total amount of C16:0 and C18:1.

148. The composition of any one of claims 134 to 147, wherein the microalgal biomass comprises 65-50 % of the composition.

149. The composition of any one of claims 134 to 147, wherein the microalgal biomass comprises 50-30 % of the composition.

150. The composition of any one of claims 134 to 147, wherein the microalgal biomass comprises 40-20 % of the composition.

151. The composition of any one of claims 134 to 147, wherein the microalgal biomass comprises 30-10 % of the composition.

152. The composition of any one of claims 134 to 147, wherein the microalgal biomass comprises 20-10 % of the composition.

153. The composition of any one of claims 134 to 147, wherein the microalgal biomass comprises 10-5 % of the composition.

154. The composition of any one of claims 134 to 153, wherein one or more of the bulk properties of the composition differ in comparison to the bulk properties of the moldable polymer alone by 25% or less.

155. The composition of claims 154 wherein one of the bulk properties is increased by 10% or less.

156. The composition of claims 154 wherein one of the bulk properties is decreased by 10% or less.

157. The composition of any one of claims 154 to 156, wherein one of the bulk properties is impact resistance.

158. The composition of any one of claims 154 to 157, wherein one of the bulk properties is tensile strength.

159. The composition of any one of claims 154 to 158, wherein one of the bulk properties is flexural strength.

160. The composition of any one of claims 154 to 159, wherein one of the bulk properties is seal strength.

161. The composition of any one of claims 154 to 160, wherein one of the bulk properties is melt flow index.

162. The composition of any one of claims 154 to 161, wherein one of the bulk properties is glass transition temperature.

163. The composition of any one of claims 154 to 162, wherein one of the bulk properties is density.

164. The composition of any one of claims 154 to 163, wherein one of the bulk properties is water vapor transition rate.

165. The composition of any one of claims 154 to 164, wherein the bulk property is selected from the group consisting of water absorption, porosity, thickness, color, brightness, opacity, light scattering, light absorption, and roughness.

166. The composition of any one of claims 134 to 165, wherein the polymer is a thermoplastic polymer.

167. The composition of any one of claims 134 to 166, wherein the polymer is a biodegradeable polymer.

168. The composition of any one of claims 134 to 167, wherein the polymer is selected from the group consisting of polylactic acid, polycaprolactone, polyesteramide, polyhydroxybutyrate, polyhydroxybutyrate-co-valerate, polyhydroxyalkanoate, polyethylene, very low density polyethylene, low density polyethylene, linear low density polyethylene, medium density polyethylene, high density polyethylene, ultra high molecular weight polyethylene, maleic anhydride polyethylene polypropylene, polyethylene terephthalate, and polycarbonate.

169. The composition of any one of claims 134 to 168, further comprising one more plasticizers independently selected from the group consisting of glycerol, sorbitol, triacetin, triethyl citrate, acetyl triethyl citrate, tributyl cirtate, acetyl tributyl citrate, trioctyl citrate, acetyl trioctyl citrate, trihexyl citrate, butyryl trihexyl citrate, trimethyl citrate, alkyl sulphonic acid phenyl ester, and 1,2-cyclohexane dicarboxylic acid diisononyl ester.

170. The composition of any one of claims 134 to 169, further comprising a plant polymer derived from the group consisting of switchgrass, rice straw, sugar beet pulp, sugar cane bagasse, soybean hulls, dry rosemary, corn starch, potato starch, cassava starch, cellulose, corn stover, delipidated cake from soybean, canola, cottonseed, sunflower, jatropha seeds, paper pulp, and waste paper.

171. The composition of any one of claims 134 to 170, wherein the covalent modification is acylation.

172. The composition of any one of claims 134 to 171, wherein the covalent modification is acetylation.

173. The composition of any one of claims 134 to 172, wherein the biomass is covalently linked to the polymer.

174. The composition of any one of claims 134 to 173, wherein the polymer is maleic anhydride grafted polyethylene, maleic anhydride grafted polypropylene, or maleic anhydride PLA.

175. The composition of any one of claims 134 to 174, wherein the biomass has a particle size of from 0.1 to 300 microns.

176. The composition of any one of claims 134 to 175, wherein the biomass has an average particle size about 5 microns.

177. A film comprising a composition of any one of claims 134 to 176.

178. An injection molded article comprising a composition of any one of claims 134 to 176.

Claims

What is claimed is:

1. A thermoplastic composition comprising a covalently modified microalgal biomass from a heterotrophically cultivated microalgae the composition further comprising soybean hulls.

2. The composition according to claim 1, wherein the microalgae has been lysed.

3. The composition according to claim 1, wherein the covalently modified microalgal biomass has been covalently modified with a hydrophobic group or an anionic group.

4. The composition of claim 3, wherein the microalgal biomass has been modified by acetylation.

5. The composition of claim 3, wherein polysaccharide of the microalgal biomass is covalently modified.

6. The composition according to claim 3, wherein the covalently modified algal biomass is characterized by a DS value of 1 to 3.

7. The composition according to claim 1, wherein the microalgal biomass is unbleached.

8. The composition according to claim 1, wherein the microalgal biomass is not colored due to the presence of chlorophyll.

9. The composition according to claim 1, wherein the biomass is of microalgae that are heterotrophs, and optionally obligate heterotrophs.

10. The composition according to claim 1, wherein the microalgae are of the genus Chlorella or the genus Prototheca.

11. The composition according to claim 10, wherein the microalgae are Prototheca moriformis.

12. The composition according to claim 1, wherein the thermoplastic composition further comprises a plasticizer.

13. The composition according to claim 12, wherein the plasticizer is selected from a group consisting of one or more of: glycerol, sorbitol, triacetin, triethyl citrate, acetyl triethyl citrate, tributyl cirtate, acetyl tributyl citrate, trioctyl citrate, acetyl trioctyl citrate, trihexyl citrate, butyryl trihexyl citrate, trimethyl citrate, alkyl sulphonic acid phenyl ester, and 1,2-cyclohexane dicarboxylic acid diisononyl ester.

14. The composition according to claim 1, wherein the thermoplastic composition has one or more of the following characteristics: (a) a Young's modulus of 300-3000 MPa; (b) a tensile strength of 5-70 MPa; (c) a tensile strength at maximum load of 5-50MPa; or (d) an ultimate elongation of 1-400%.

15. The composition according to claim 1, wherein the microalgal biomass is a fraction that is insoluble in an aqueous solvent, said insoluble fraction produced by removing components soluble in an aqueous solvent from microalgal biomass.

16. The composition according to claim 1, wherein the composition has been formed through extruding, molding, or blowing.

17. The thermoplastic composition according to claim 1, wherein the composition is a film.