SUMMARY

[006a] In one aspect, the present disclosure refers to a biodegradable tubular article, wherein the tubular article is profile extrusion molded from a polymer resin comprising at least 25 weight percent of at least one biodegradable polymer,

wherein the at least one biodegradable polymer comprises a reaction product formed from reactive extrusion of polyhydroxyalkanoates and a second biodegradable polymer and

wherein the polyhydroxyalkanoates comprise from about 65 to about 99.5 mole percent hydroxybutyrate moieties and from about 0.5 to about 35 mole percent hydroxyhexanoate moieties.

[006b] In another aspect, the present disclosure refers to a method for making a biodegradable tubular article, the method comprising the steps of:

providing a polymer resin comprising at least 25 weight percent of at least one biodegradable polymer;

heating a charge of the polymer resin, in an extruder, to a temperature at or above the melting point of the polymer resin; and

profile extruding the polymer resin charge through a die to form a tubular article,

wherein the at least one biodegradable polymer in the polymer resin charge comprises polyhydroxyalkanoates and a second biodegradable polymer and

wherein the tubular article comprises a reaction product formed from reactive extrusion of the polyhydroxyalkanoates and the second biodegradable polymer, and

wherein the polyhydroxyalkanoates comprise from about 65 to about 99.5 mole percent hydroxybutyrate moieties and from about 0.5 to about 35 mole percent hydroxyhexanoate moieties.

[006c] In a further aspect, the present disclosure refers to a method for making a biodegradable food service item, the method comprising the steps of:

providing a polymer resin comprising at least 25 weight percent of a first and a second biodegradable polymer;

heating a charge of the polymer resin to a temperature at or above the melting point of the polymer resin; and

molding a food service item from the polymer resin charge,

wherein the at least one biodegradable polymer in the polymer resin charge comprises polyhydroxyalkanoates and a second biodegradable polymer,

wherein the food service item comprises a reaction product formed from reactive extrusion of the polyhydroxyalkanoates and the second biodegradable polymer, and

wherein the polyhydroxyalkanoates comprise from about 65 to about 99.5 mole percent hydroxybutyrate moieties and from about 0.5 to about 35 mole percent hydroxyhexanoate moieties.

[007] The above and other needs are met by a biodegradable tubular article. According to one example, this biodegradable tubular article is profile extrusion molded from a polymer resin which is made up of at least 25 weight percent of at least one biodegradable polymer.

[008] In some examples, the biodegradable tubular article is preferably selected from the group consisting of medical tubing, gas tubing, laboratory tubing, automotive tubing, drinking straws, and beverage stirrers.

[009] According to certain examples, the polymer resin is preferably made up of at least one biodegradable polymer selected from the group consisting of polyhydroxyalkanoates, polycaprolactone, polylactic acid, polybutylene succinate, polybutylene succinate-co-butylene adipate, polybutylene adipate terephthalate, blends of two or more of the aforementioned polymers, and reaction products of two or more of the aforementioned polymers.

[010] In certain examples, the at least one biodegradable polymer preferably includes polyhydroxyalkanoates, and the polyhydroxyalkanoates are made up of from about 65 (preferably about 70) to about 99.5 mole percent hydroxybutyrate moieties and from about 0.5 to about 30 (preferably about 35) mole percent hydroxyhexanoate moieties. In some instances, the polyhydroxyalkanoates may be a terpolymer. For example, the

polyhydroxyalkanoates may be made up of monomer residues of 3-hydoxybutyrate, monomer residues of 3-hydoxyvalerate, and monomer residues of 3-hydoxyhexanoate.

[011] According to certain examples, the at least one biodegradable polymer preferably includes polyhydroxyalkanoates having a weight average molecular weight from about 1000 Daltons to about 2.5 million Daltons. According to other examples, the at least one biodegradable polymer preferably includes polyhydroxyalkanoates having a weight average molecular weight from about 10,000 Daltons to about 7.5 million Daltons.

[012] In some examples, the at least one biodegradable polymer preferably includes a reaction product formed from reactive extrusion of polyhydroxyalkanoates and a second biodegradable polymer.

[013] According to certain examples, the at least one biodegradable polymer preferably includes polycaprolactone and/or polylactic acid having a weight average molecular weight from 10,000 Daltons to about 300,000 Daltons.

[014] In certain examples, the polymer resin preferably at least one biodegradable polymer selected from the group consisting polylactic acid, polybutylene succinate, polybutylene succinate-co-butylene adipate, polybutylene adipate terephthalate, and mixtures thereof.

[015] In some examples, it is preferred that the polymer resin also includes from about 1 to about 50 weight percent of at least one filler selected from the group consisting of clays, calcium carbonate, talc, kaolinite, montmorillonite, bentonite, silica, chitin, titanium dioxide, nano clay, nanocellulose, mica and mixtures thereof.

[016] In some instances, it is preferred that the polymer resin also includes from about 0.5 to about 20 weight percent of at least one nucleating agent selected from the group consisting of polyester waxes, behenamide, crodamide, stearamide, erucamide, pentaerythritol, dipentaerythritol, sulfur and mixtures thereof.

[017] According to certain examples, it is preferred that the polymer resin also includes from about 1.0 to about 25 weight percent of at least one polysaccharide.

[018] In certain examples, it is preferred that the polymer resin also includes from about 0.5 to about 15 weight percent of at least one plasticizer selected from the group consisting of sebacates, citrates, fatty esters of adipic acid, fatty esters of succinic acid, fatty esters of glucaric acid, lactates, alkyl diesters, alkyl methyl esters, dibenzoates, propylene carbonate, caprolactone diols having a weight average molecular weight from about 200 to about 10,000 g/mol, polyethylene glycols having a weight average molecular weight from about 400 to about 10,000 g/mol, esters of vegetable oils, long chain alkyl acids, adipates, glycerol, isosorbide derivatives, and mixtures thereof.

[019] In certain examples, it is preferred that the polymer resin also includes from about 15 to about 35 weight percent of at least one filler, from about 1.0 to about 5 weight percent of at least one nucleating agent, and from about 0.01 (preferably 0.05) to about 2 of at least one polymerization catalyst or initiator.

[020] In a second example, the present disclosure provides a method for making a biodegradable tubular article. According to one example, the method includes an initial step of providing a polymer resin which is made of at least 25 weight percent of at least one biodegradable polymer. A charge of this polymer resin is heated, in an extruder, to a temperature at or above the melting point of the polymer resin. The heated the polymer resin charge is then profile extruded through a die to form a tubular article.

[021] In some examples, the biodegradable tubular article is preferably selected from the group consisting of medical tubing, gas tubing, laboratory tubing, automotive tubing, drinking straws, and beverage stirrers.

[022] In some examples, the polymer resin is preferably made up of at least one biodegradable polymer selected from the group consisting of polyhydroxyalkanoates, polycaprolactone, polylactic acid, polybutylene succinate, polybutylene succinate-co-butylene adipate, polybutylene adipate terephthalate, blends of two or more of the aforementioned polymers, and reaction products of two or more of the aforementioned polymers.

[023] According to certain examples, the at least one biodegradable polymer preferably includes polyhydroxyalkanoates, and the polyhydroxyalkanoates are made up of from about 65 (preferably about 70) to about 99.5 mole percent hydroxybutyrate moieties and from about 0.5 to about 30 (preferably about 35) mole percent hydroxyhexanoate moieties. In some instances, the polyhydroxyalkanoates may be a terpolymer. For example, the polyhydroxyalkanoates may be made up of monomer residues of 3-hydoxybutyrate, monomer residues of 3-hydoxyvalerate, and monomer residues of 3-hydoxyhexanoate.

[024] In certain examples, the at least one biodegradable polymer preferably includes polyhydroxyalkanoates having a weight average molecular weight from about 1000 Daltons to about 2.5 million Daltons. According to other examples, the at least one biodegradable polymer preferably includes polyhydroxyalkanoates having a weight average molecular weight from about 10,000 Daltons to about 7.5 million Daltons.

[025] According to certain examples the at least one biodegradable polymer preferably includes a reaction product formed from reactive extrusion of polyhydroxyalkanoates and a second biodegradable polymer.

[026] In some examples, wherein the at least one biodegradable polymer preferably includes polycaprolactone and/or polylactic acid having a weight average molecular weight from about 10,000 Daltons to about 300,000 Daltons.

[027] In some instances, the polymer resin preferably includes at least one biodegradable polymer selected from the group consisting polylactic acid, polybutylene succinate, polybutylene succinate-co-butylene adipate, polybutylene adipate terephthalate, and mixtures thereof.

[028] In certain examples, it is preferred that the polymer resin also includes from about 1 to about 50 weight percent of at least one filler selected from the group consisting of clays, calcium carbonate, talc, kaolinite, montomorillonite, bentonite, silica, chitin, titanium dioxide, nano clay, nanocellulose, mica and mixtures thereof.

[029] In certain examples, it is preferred that the polymer resin also includes from about 0.5 to about 20 weight percent of at least one nucleating agent selected from the group consisting of polyester waxes, behenamide, crodamide, stearamide, erucamide, pentaerythritol, dipentaerythritol, sulfur and mixtures thereof.

[030] In some example, it is preferred that the polymer resin also includes from about 1.0 to about 25 weight percent of at least one polysaccharide.

[031] In some examples it is preferred that the polymer resin also includes from about 0.5 to about 15 weight percent of at least one plasticizer selected from the group consisting of sebacates, citrates, fatty esters of adipic acid, fatty esters of succinic acid, fatty esters of glucaric acid, lactates, alkyl diesters, alkyl methyl esters, dibenzoates, propylene carbonate, caprolactone diols having a weight average molecular weight from about 200 to about 10,000 g/mol, polyethylene glycols having a weight average molecular weight from about 400 to about 10,000 g/mol, esters of vegetable oils, long chain alkyl acids, adipates, glycerol, isosorbide derivatives, and mixtures thereof.

[032] In some examples, it is preferred that the polymer resin also includes from about 15 to about 35 weight percent of at least one filler, from about 1.0 to about 5.0 weight percent of at least one nucleating agent, and from about 0.01 (preferably 0.05) to about 2 weight percent of at least one polymerization catalyst or initiator.

[033] In still another example, the present disclosure method for making a biodegradable food service item. According to one example, the method includes an initial step of providing a polymer resin which is made of at least 25 weight percent of a first and a second biodegradable polymer. A charge of this polymer resin is heated to a temperature at or above the melting point of the polymer resin. The food service item is molded from the polymer resin charge.

[034] In certain example, it is preferred that the biodegradable food service time comprises an eating utensil, beverage splash stick, cocktail pick, or toothpick.

[035] In certain examples, it is preferred that the at least one biodegradable polymer in the polymer resin charge is made up of a reaction product formed from reactive extrusion of the first and the second biodegradable polymers.

WHAT IS CLAIMED IS:

Claim 1. A biodegradable tubular article, wherein the tubular article is profile extrusion molded from a polymer resin comprising at least 25 weight percent of at least one biodegradable polymer,

wherein the at least one biodegradable polymer comprises a reaction product formed from reactive extrusion of polyhydroxyalkanoates and a second biodegradable polymer and

wherein the polyhydroxyalkanoates comprise from about 65 to about 99.5 mole percent hydroxybutyrate moieties and from about 0.5 to about 35 mole percent hydroxyhexanoate moieties.

Claim 2. The biodegradable tubular article of Claim 1, wherein the tubular article is selected from the group consisting of medical tubing, gas tubing, laboratory tubing, automotive tubing, drinking straws, and beverage stirrers.

Claim 3. The biodegradable tubular article of Claim 1, wherein the polymer resin comprises at least one biodegradable polymer selected from the group consisting of polyhydroxyalkanoates, polycaprolactone, polylactic acid, polybutylene succinate, polybutylene succinate-co-butylene adipate, polybutylene adipate terephthalate, blends of two or more of the aforementioned polymers, and reaction products of two or more of the aforementioned polymers.

Claim 4. The biodegradable tubular article of Claim 1, wherein the at least one biodegradable polymer comprises polyhydroxyalkanoates having a weight average molecular weight from about 100,00 Daltons to about 7.5 million Daltons.

Claim 5. The biodegradable tubular article of Claim 1, wherein the at least one biodegradable polymer comprises polycaprolactone and/or polylactic acid having a weight average molecular weight from about 10,000 Daltons to about 300,000 Daltons.

Claim 6. The biodegradable tubular article of Claim 1, wherein the polymer resin comprises at least one biodegradable polymer selected from the group consisting polylactic acid, polybutylene succinate, polybutylene succinate adipate, polybutylene adipate terephthalate, and mixtures thereof.

Claim 7. The biodegradable tubular article of Claim 1, wherein the polymer resin further comprises from about 1 to about 50 weight percent of at least one filler selected from the group

consisting of clays, calcium carbonate, talc, kaolinite, montomorillonite, bentonite, silica, chitin, titanium dioxide, nano clay, nanocellulose, mica and mixtures thereof.

Claim 8. The biodegradable tubular article of Claim 1, wherein the polymer resin further comprises from about 0.01 to about 20 weight percent of at least one nucleating agent selected from the group consisting of polyester waxes, behenamide, crodamide, stearamide, erucamide, pentaerythritol, sulfur, dipentaerythritol and mixtures thereof.

Claim 9. The biodegradable tubular article of Claim 1, wherein the polymer resin further comprises from about 1.0 to about 25 weight percent of at least one polysaccharide.

Claim 10. The biodegradable tubular article of Claim 1, wherein the polymer resin further comprises from about 0.5 to about 15 weight percent of at least one plasticizer selected from the group consisting of sebacates, citrates, fatty esters of adipic acid, fatty esters of succinic acid, fatty esters of glucaric acid, lactates, alkyl diesters, alkyl methyl esters, dibenzoates, propylene carbonate, caprolactone diols having a weight average molecular weight from about 200 to about 10,000 g/mol, polyethylene glycols having a weight average molecular weight from about 400 to about 10,000 g/mol, esters of vegetable oils, long chain alkyl acids, adipates, glycerol, isosorbide derivatives, and mixtures thereof.

Claim 11. The biodegradable tubular article of Claim 1, wherein the polymer resin further comprises from about 15 to about 35 weight percent of at least one filler, from about 1.0 to about 5.0 weight percent of at least one nucleating agent, and from about 0.01 to about 2 of at least one polymerization catalyst or initiator.

Claim 12. A method for making a biodegradable tubular article, the method comprising the steps of:

providing a polymer resin comprising at least 25 weight percent of at least one biodegradable polymer;

heating a charge of the polymer resin, in an extruder, to a temperature at or above the melting point of the polymer resin; and

profile extruding the polymer resin charge through a die to form a tubular article,

wherein the at least one biodegradable polymer in the polymer resin charge comprises polyhydroxyalkanoates and a second biodegradable polymer and

wherein the tubular article comprises a reaction product formed from reactive extrusion of the polyhydroxyalkanoates and the second biodegradable polymer, and

wherein the polyhydroxyalkanoates comprise from about 65 to about 99.5 mole percent hydroxybutyrate moieties and from about 0.5 to about 35 mole percent hydroxyhexanoate moieties.

Claim 13. The method of Claim 12, wherein the tubular article is selected from the group consisting of medical tubing, gas tubing, laboratory tubing, automotive tubing, drinking straws, and beverage stirrers.

Claim 14. The method of Claim 12, wherein the polymer resin comprises at least one biodegradable polymer selected from the group consisting of polyhydroxyalkanoates, polycaprolactone, polylactic acid, polybutylene succinate, polybutylene succinate-co-butylene adipate, polybutylene adipate terephthalate, blends of two or more of the aforementioned polymers, and reaction products of two or more of the aforementioned polymers.

Claim 15. The method of Claim 12, wherein the at least one biodegradable polymer comprises polyhydroxyalkanoates having a weight average molecular weight from about 10,000 Daltons to about 7.5 million Daltons.

Claim 16. The method of Claim 12, wherein the at least one biodegradable polymer comprises polycaprolactone and/or polylactic acid having a weight average molecular weight from about 10,000 Daltons to about 300,000 Daltons.

Claim 17. The method of Claim 12, wherein the polymer resin comprises at least one biodegradable polymer selected from the group consisting polylactic acid, polybutylene succinate, polybutylene succinate-co-butylene adipate, polybutylene adipate terephthalate, and mixtures thereof.

Claim 18. The method of Claim 12, wherein the polymer resin further comprises from about 1 to about 50 weight percent of at least one filler selected from the group consisting of clays, calcium carbonate, talc, kaolinite, montmorillonite, bentonite, silica, chitin, titanium dioxide, nano clay, nanocellulose, and mixtures thereof.

Claim 19. The method of Claim 12, wherein the polymer resin further comprises from about 0.5 to about 20 weight percent of at least one nucleating agent selected from the group consisting of polyester waxes, behenamide, crodamide, stearamide, erucamide, pentaerythritol, dipentaerythritol, sulfur and mixtures thereof.

Claim 20. The method of Claim 12, wherein the polymer resin further comprises from about 1.0 to about 25 weight percent of at least one polysaccharide.

Claim 21. The method of Claim 12, wherein the polymer resin further comprises from about 0.5 to about 15 weight percent of at least one plasticizer selected from the group consisting of sebacates, citrates, fatty esters of adipic acid, fatty esters of succinic acid, fatty esters of glucaric acid, lactates, alkyl diesters, alkyl methyl esters, dibenzoates, propylene carbonate, caprolactone diols having a weight average molecular weight from about 200 to about 10,000 g/mol, polyethylene glycols having a weight average molecular weight from about 400 to about 10,000 g/mol, esters of vegetable oils, long chain alkyl acids, adipates, glycerol, isosorbide derivatives, and mixtures thereof.

Claim 22. The method of Claim 12, wherein the polymer resin further comprises from about 15 to about 35 weight percent of at least one filler, from about 1.0 to about 5.0 weight percent of at least one nucleating agent, and from about 0.01 to about 2 of at least one polymerization catalyst or initiator.

Claim 23. A method for making a biodegradable food service item, the method comprising the steps of:

providing a polymer resin comprising at least 25 weight percent of a first and a second biodegradable polymer;

heating a charge of the polymer resin to a temperature at or above the melting point of the polymer resin; and

molding a food service item from the polymer resin charge,

wherein the at least one biodegradable polymer in the polymer resin charge comprises polyhydroxyalkanoates and a second biodegradable polymer,

wherein the food service item comprises a reaction product formed from reactive extrusion of the polyhydroxyalkanoates and the second biodegradable polymer, and

wherein the polyhydroxyalkanoates comprise from about 65 to about 99.5 mole percent hydroxybutyrate moieties and from about 0.5 to about 35 mole percent hydroxyhexanoate moieties.

Claim 24. The method of Claim 23, wherein the biodegradable food service item comprises an eating utensil, beverage splash stick, cocktail pick, or toothpick.