

Description

Title of Invention: BIOBASED AND COMPOSTABLE COMPOSITIONS COMPRISING AN AMORPHOUS PHA AND METHODS OF USE

Technical Field

- [1] The present disclosure relates to a composition comprising an amorphous polyhydroxyalkanoate (PHA).

Background Art

- [2] In recent years, as concerns about environmental problems increase, research on the treatment and recycling of various household wastes is being actively conducted. Specifically, although polymer materials, which are inexpensive and have excellent processability, are widely used to manufacture various products such as paper, films, fibers, packaging materials, bottles, and containers, when the lifespan of these products is over, harmful substances may be discharged when they are incinerated, and it takes hundreds of years depending on their types to completely decompose naturally.
- [3] Therefore, research on biodegradable polymers continues, which can be decomposed within a short period of time to enhance environmental friendliness, while enhancing mechanical properties such as flexibility and strength, productivity, and processability, and increasing the lifespan of products themselves, thereby reducing the amount of waste or enhancing their recyclability.
- [4] Polyhydroxyalkanoates (PHAs) are biodegradable polymers produced in nature by various microorganisms, such as bacteria, algae, and fungi, through bacterial fermentation of sugars or lipids, and stored within cells of the microorganisms as energy storage materials. PHAs are composed of several types of hydroxyl carboxylic acids produced by numerous microorganisms and used as intracellular storage materials. Polyhydroxyalkanoates have physical properties similar to those of conventional petroleum-derived synthetic polymers such as polybutylene adipate terephthalate (PBAT), polybutylene succinate (PBS), polybutylene succinate terephthalate (PBST), and polybutylene succinate adipate (PBSA), exhibit complete biodegradability, and are excellent in biocompatibility. Due to their biocompatibility and biodegradability, PHAs are a sustainable and eco-friendly alternative to synthetic plastics and have a wide range of applications in various industries such as tissue engineering, drug delivery, surgery and wound dressing.

Disclosure of Invention

Technical Problem

- [5] Microporous polymer films are used for various purposes. Those skilled in the art generally understand that microporous films have a microporous morphology with some ability to allow the passage of air or water vapor. Such microporous polymer films are generally formed from non-biodegradable polymers such as polyolefins. Various attempts have been made to form microporous films from biodegradable polymers. Problems have been encountered, however, in forming microporous biodegradable films with high breathability and high puncture toughness and impact/tear strength.

Solution to Problem

- [6] In one aspect, the present disclosure relates to biobased compositions comprising an amorphous polyhydroxyalkanoate(s) (PHA), a polyester and a pore-forming agent, and use thereof. Embodiments of the present embodiments are not limited to the compositions mentioned above and may be variously extended in the scope of the technical ideas included in the present disclosure.
- [7] The PHA may be environmentally friendly by virtue of its excellent biodegradability and biocompatibility, and the PHA may be capable of providing increased or no change in biobased carbon content, high impact toughness, and improved flexibility.
- [8] The biobased composition comprising an amorphous PHA, a polyester and a pore-forming agent according to the present disclosure may exhibit a reduced density of the biobased composition or a biobased porous film without negatively impacting biocarbon content and compostability and provides a microporous film having an improved puncture toughness and an increased biobased carbon content compared with conventional films such as polyolefin film. For example, in some embodiments, the film comprising the biobased composition of the present disclosure provides breathable films having desirable processability, stiffness, and/or toughness used for various applications.
- [9] The embodiments of the present disclosure are further illustrated by the following detailed description and drawings.

Brief Description of Drawings

- [10] The accompanying drawings, which are incorporated in and constitute a part of this disclosure, illustrate exemplary embodiments and, together with the description, serve to explain the disclosed principles.
- [11] FIGURE 1 is a scanning electron microscope (SEM) micrograph of the microporous film of Example 1, which was stretched 3.3 times in a machine direction orientation (MDO). Voids in the microporous film elongated along the machine direction are clearly visible in the SEM. These voids add breathability and softness to the films.

Best Mode for Carrying out the Invention

- [12] Hereinafter, the present disclosure will be described in more detail to help the understanding of the present disclosure.
- [13] As used herein and unless otherwise indicated, "wt%" refers to a weight percent based on a total weight of a reference unless otherwise explained.
- [14] When the term "about" is used, it is used to mean a certain effect or result can be obtained within a certain tolerance, and the skilled person knows how to obtain the tolerance. When the term "about" is used in describing a value or an end-point of a range, the disclosure should be understood to include the specific value or end-point referred to. In one aspect, the term "about" means plus or minus 20, 19, 18, 17, 16, 15, 14, 13, 12, 11, 10, 9, 8, 7, 6, 5, 4, 3, 2, or 1% of the numerical value of the number with which it is being used.
- [15] As used herein, the terms "comprises," "comprising," "includes," "including," "has," "having" or any other variation thereof, are intended to cover a non-exclusive inclusion. For example, a process, method, article, or apparatus that comprises a list of elements is not necessarily limited to only those elements but can include other elements not expressly listed or inherent to such process, method, article, or apparatus.
- [16] The transitional phrase "consisting of" excludes any element, step, or ingredient not specified in the claim, closing the claim to the inclusion of materials other than those recited except for impurities ordinarily associated therewith. When the phrase "consists of" appears in a clause of the body of a claim, rather than immediately following the preamble, it limits only the element set forth in that clause; other elements are not excluded from the claim as a whole.
- [17] The transitional phrase "consisting essentially of" limits the scope of a claim to the specified materials or steps and those that do not materially affect the basic and novel characteristic(s) of the claimed embodiment. A "consisting essentially of" claim occupies a middle ground between closed claims that are written in a "consisting of" format and fully open claims that are drafted in a "comprising" format. Optional additives as defined herein, at a level that is appropriate for such additives, and minor impurities are not excluded from a composition by the term "consisting essentially of".
- [18] Further, unless expressly stated to the contrary, "or" and "and/or" refers to an inclusive and not to an exclusive. For example, a condition A or B, or A and/or B, is satisfied by any one of the following: A is true (or present) and B is false (or not present), A is false (or not present) and B is true (or present), and both A and B are true (or present).
- [19] The use of "a" or "an" to describe the various elements and components herein is merely for convenience and to give a general sense of the disclosure. This description should be read to include one or at least one and the singular also includes the plural unless it is obvious that it is meant otherwise.

- [20] In the present disclosure, the glass transition temperature (T_g) and melting temperature (T_m) may be measured using a differential scanning calorimeter (DSC). Specifically, the glass transition temperature (T_g) and melting temperature (T_m) may be measured by conducting a first scan or a second scan in a differential scanning calorimetry (DSC) mode, and they can be confirmed from a heat flow curve obtained by these scans. More specifically, the glass transition temperature (T_g) and melting temperature (T_m) may be confirmed from a heat flow curve obtained by raising the temperature from 40°C to 180°C at a rate of 10°C/minute and then cooling it -50°C at a rate of 10°C/minute.
- [21] As used herein and unless otherwise indicated, the term "biobased carbon" refers to carbon present in carbon containing materials obtained from biological source (naturally derived materials) as opposed to materials obtained from ancient carbon such as petroleum, fossil oil and coal.
- [22] As used herein and unless otherwise indicated, the term "blown film" refers to a film forming process in which a film is produced from a thermoplastic polymer by the blown extrusion process.
- [23] As used herein and unless otherwise indicated, the term "cast film" refers to a film forming process in which a film is produced from a thermoplastic polymer by casting in a film or sheet structure but is not oriented by substantial stretching in either the machine or transverse direction after crystallization.
- [24] As used herein and unless otherwise indicated, the term "oriented film" refers to a film forming process in which a film is produced from a thermoplastic polymer, for example, by using a cast or blown film process; this film may be subsequently oriented in one or more common directions usually at temperatures below the melting point of the polymer.
- [25] As used herein and unless otherwise indicated, the term "machine direction orientation (MDO)" refers to a film manufacturing process by stretching in a particular direction in which a material is extruded. The MDO may include drawing a film or sheet between rolls rotating at a particular speed, annealing and/or cooling steps.
- [26] For convenience, many elements of the present embodiments are discussed separately, lists of options may be provided and numerical values may be in ranges; however, for the purposes of the present disclosure, that should not be considered as a limitation on the scope of the disclosure or support of the present disclosure for any claim of any combination of any such separate components, list items or ranges. Unless stated otherwise, each and every combination possible with the present disclosure should be considered as explicitly disclosed for all purposes.
- [27] The present disclosure relates to a biobased composition comprising an amorphous polyhydroxyalkanoate (PHA), a polyester, and a pore-forming agent. In some

embodiment, a biobased composition comprising an amorphous polyhydroxyalkanoate (PHA), a polylactic acid (PLA) and a pore-forming agent. In some embodiments, the polymer composition is a mixture of the amorphous polyhydroxyalkanoate (PHA), and the polylactic acid (PLA) and the pore-forming agent. In some embodiments, the polymer composition is a mixture of the amorphous polyhydroxyalkanoate (PHA), and the polylactic acid (PLA) and the pore-forming agent.

- [28] In some embodiments, the puncture toughness of the biobased composition may decrease by about 10, 9, 8, 7, 6, 5, 4, 3, 2 or 1 % or less, stay the same, or increase upon reduction of a density of the biobased composition at least by about 5, 10, 15, 20, 25, 30, 35, 40, or 45% and about 50, 45, 40, 35, 30, 25, 20, 15, 10% or less. In additional embodiments, the puncture toughness of the biobased composition may decrease by 10, 9, 8, 7, 6, 5, 4, 3, 2 or 1% or less. In additional embodiments, the puncture toughness of the biobased composition may stay the same. In additional embodiments, the puncture toughness of the biobased composition may increase. In additional embodiments, the puncture toughness of the biobased composition may increase at least by about 10, 20, 30, 40, 50, or 60% and less than about 65, 60, 40, 30, or 20%.
- [29] In some embodiments, the density of the biobased composition may be decreased by stretching in a machine direction orientation (MDO) by a stretch ratio of about 0.5 or more. In some embodiments, the puncture toughness of the biobased composition may decrease by about 10, 9, 8, 7, 6, 5, 4, 3, 2 or 1% or less, stay the same, or increase upon reduction of a density of the biobased composition at least by about 5, 10, 15, 20, 25, 30, 35, 40, or 45% and about 50, 45, 40, 35, 30, 25, 20, 15, 10% or less by stretching in a machine direction orientation (MDO) by a stretch ratio of about 0.5, 0.6, 0.7, 0.8, 0.9, 1.0, 1.5, 2.0, 2.5, 3.0, 3.5, 4.0 or 4.5 or more and about 5.0, 4.5, 4.0, 3.5, 3.0, 2.5, 2.0, 1.5, 1.0, 0.9, 0.8, 0.7, 0.6 or less.
- [30] In some embodiments, the biobased composition may be in a form of film having a thickness of about 1, 2, 3, 4, 5, 10, 20, 30, 40, 50, 60, 70, 80, 90, 100, 150, 200, 250, 300, 350, 400 or 450 μm or more and about 500, 450, 400, 350, 300, 250, 200, 150, 100, 50, 40, 30, 20, 10, 5, 4, 3, or 2 μm or less.
- [31] As used herein and unless otherwise indicated, the term "puncture toughness" or "puncture strength" means the resistance of a film/sheet against external object or the strength required to penetrate. The "puncture toughness" or "puncture strength" can be measured by spencer impact test and/or ASTM D3420.
- [32] In some embodiments, a biobased carbon content of the biobased composition of the present disclosure as measured according to ASTM D6866 may be at least about 75, 80, 85, 90, 95, 99 or 100% and about 100, 99, 95, 90, 85, 80% or less.

- [33] In some embodiments, the biobased carbon content of the biobased composition of the present disclosure may satisfy compostability test according to ASTM D6400.
- [34] In some embodiments, the biobased carbon content of the biobased composition of the present disclosure may comprise an amorphous polyhydroxyalkanoate (PHA), a polyester, and a pore-forming agent, and the pore-forming agent may comprise a mineral selected from the group consisting of calcium carbonate (CaCO_3), talc, wallstonite (CaSiO_3), aluminum oxide (Al_2O_3), and combinations thereof. In some embodiments, the mineral may comprise inorganic particles having a particle diameters in a range from about 0.1, 0.5, 1, 1.5, 2, 2.5, 3, 3.5, 4, 4.5, 5, 5.5, 6, 6.5, 7, 7.5, 8, 8.5, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18 or $19\mu\text{m}$ to 20, 19, 18, 17, 16, 15, 14, 13, 12, 11, 10, 9, 8.5, 8, 7.5, 7, 6.5, 6, 5.5, 5, 4.5, 4, 3.5, 3, 2.5, 2, 1.5, 1 or $0.5\mu\text{m}$. In some embodiments, the biobased carbon content of the biobased composition of the present disclosure may comprise an amorphous polyhydroxyalkanoate (PHA), a polyester, and a pore-forming agent, and the pore-forming agent may comprise organic or inorganic particles having a particle diameters in a range from about 0.1, 0.5, 1, 1.5, 2, 2.5, 3, 3.5, 4, 4.5, 5, 5.5, 6, 6.5, 7, 7.5, 8, 8.5, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18 or $19\mu\text{m}$ to 20, 19, 18, 17, 16, 15, 14, 13, 12, 11, 10, 9, 8.5, 8, 7.5, 7, 6.5, 6, 5.5, 5, 4.5, 4, 3.5, 3, 2.5, 2, 1.5, 1 or $0.5\mu\text{m}$.
- [35] In some embodiments, the biobased composition of the present disclosure may include the pore-forming agent in an amount from about 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 15, 20, 25, 30, 35, 40 or 45wt% to about 50, 45, 40, 35, 30, 25, 20, 15, 10, 9, 8, 7, 6, 5, 4, 3, or 2wt%.
- [36] In some embodiments, the biobased composition according to the present disclosure may include the amorphous PHA, a polyester and a pore-forming agent. As used herein and unless otherwise indicated, the term "polyester" means a polymer comprising ester functional groups in its main chain. In some embodiments, the polyester may include polylactide (PLA). As used herein and unless otherwise indicated, the term "polylactide" or "polylactic acid" refers to a polymer containing a repeating lactic acid unit derived from L-lactic acid and/or D-lactic acid as a main component. The polylactide (PLA) may be made from plant-derived starch. In some embodiments, the PLA may include either L-lactic acid or D-lactic acid units in an amount from about 50, 60, 70, 80, 90 or 99wt% to about 100, 99, 90, 80, 70, 60wt% or less. In some embodiments, the polyester or PLA may include a polylactic resin including other than a polylactic resin.
- [37] In some embodiments, the biobased composition described herein may include a polyester or PLA in an amount from about 55, 56, 57, 58, 59, 60, 61, 62, 63, 64, 65, 66, 67, 68, 69, 70, 71, 72, 73, 74, 75, 76, 77, 78, 79, 80, 81, 82, 83, 84, 85, 86, 87, 88, 89, 90, 91, 92, 93, 94, 95, 96, 97, 98wt% or more, and/or about 99, 98, 97, 96, 95, 94,

93, 92, 91, 90, 89, 88, 87, 86, 85, 84, 83, 82, 81, 80, 79, 78, 77, 76, 75, 74, 73, 72, 71, 70, 69, 68, 67, 66, 65, 64, 63, 62, 61, 60, 59, 58, 57, 56wt% or less with respect to a total amount of the polymer composition.

- [38] In certain embodiments, PLA may be 100% biobased, as measured using ASTM D6866. In some embodiment, PLA may have a biobased carbon content, as measured using ASTM D6866, of about 10, 15, 20, 25, 30, 35, 40, 45, 50, 55, 60, 65, 70, 75, 80, 85, 90, 91, 92, 93, 94, 95, 96, 97, 98, or 99% or more, and/or about 100, 95, 90, 85, 80, 75, 70, 65, 60, 55, 50, 45, 40, 35, 30, 25, 20, 15, or 10% or less. In certain embodiments, the biobased compositions comprising an amorphous PHA, a polyester and a pore-forming agent may be at least 50, 55, 60, 65, 70, 75, 80, 85, 90, 91, 92, 93, 94, 95, 96, 97, 98 or 99% biobased.
- [39] In some embodiments, the biobased composition described herein may include a polyester or PLA having a weight-average molecular weight (Mw) in a range from about 10,000, 20,000, 30,000, 40,000, 50,000, 60,000, 70,000, 80,000, 90,000, 100,000, 150,000, 200,000, 250,000, 300,000 g/mol or 350,000 to about 400,000, 350,000, 300,000, 250,000, 200,000, 150,000, 100,000, 90,000, 80,000, 70,000, 60,000, 50,000, 40,000, 30,000, or 20,000 g/mol.
- [40] In some embodiments, the biobased composition according to the present disclosure may include the amorphous polyhydroxyalkanoate (PHA), a polyester and a pore-forming agent, and PHA may be a natural thermoplastic polyester polymer that accumulates in microbial cells. Since it may be a biodegradable material, it may be composted and finally decomposed into carbon dioxide, water, and organic waste without generating toxic waste. Since PHA may be biodegradable even in soil and sea, when the biodegradable resin composition and the biodegradable fiber or biodegradable nonwoven fabric prepared using the same comprise a PHA resin, it may have environmentally friendly characteristics. Thus, the biodegradable resin composition and the biodegradable nonwoven fabric prepared using the same may have a great advantage in that it may be used in various fields since it may be biodegradable and environmentally friendly.
- [41] In addition, PHA may have physical properties similar to those of conventional petroleum-derived synthetic polymers such as polybutylene adipate terephthalate (PBAT), polybutylene succinate (PBS), polybutylene succinate terephthalate (PBST), and polybutylene succinate adipate (PBSA), may exhibit complete biodegradability, and may be excellent in biocompatibility.
- [42] Unlike other environmentally friendly plastic materials such as polybutylene succinate (PBS), polylactic acid (PLA), and polytrimethylene terephthalate (PTT), PHA may be synthesized from more than 150 types of monomers, so that hundreds of types of PHAs may be prepared depending on the types of monomers. Hundreds of

different types of PHAs depending on the types of monomers may have completely different structures and properties.

- [43] In some embodiments, an amorphous PHA disclosed herein may exclude a PHA having a single monomer repeating unit. In some embodiments, an amorphous PHA disclosed herein may be formed by polymerizing two or more monomer repeat units. In some embodiments, the amorphous PHA may exclude a homopolyhydroxyalkanoate resin. In some embodiments, the amorphous PHA may comprise a copolymerized polyhydroxyalkanoate resin. In some embodiments, the amorphous PHA may comprise a copolymer in which different repeat units may be randomly distributed in the polymer chain.
- [44] In some embodiments, a total crystallinity of the amorphous PHA disclosed herein may be less than about 5, 4, 3, 2, 1, 0.5 or 0.1%. In certain embodiments, a total crystallinity of the amorphous PHA disclosed herein may be about 0, 0.1, 0.2, 0.3, 0.4, 0.5, 0.6, 0.7, 0.8, 0.9, 1, 2, 3, or 4% or more. As used herein and unless otherwise indicated, the term "crystallinity" refers to a polymer having a primary transition point or crystal melting point (T_m) determined by differential scanning calorimetry (DSC) or equivalent techniques.
- [45] In some embodiments, the amorphous PHA may comprise a copolymer including 3-hydroxybutyrate (3-HB). In some embodiments, the amorphous PHA may comprise a copolymer including 4-hydroxybutyrate (4-HB). In certain embodiments, the amorphous PHA may comprise a copolymer including 3-hydroxypropionate (3-HP). In certain embodiments, the amorphous PHA may comprise a copolymer including 3-hydroxyhexanoate (3-HH). In certain embodiments, the amorphous PHA may comprise a copolymer including 3-hydroxyoctanoate (3-HO). In certain embodiments, the amorphous PHA may comprise a copolymer including 3-hydroxy valerate (3-HV). In certain embodiments, the amorphous PHA may comprise a copolymer including 4-hydroxyvalerate (4-HV). In certain embodiments, the amorphous PHA may comprise a copolymer including 5-hydroxyvalerate (5-HV). In certain embodiments, the amorphous PHA may comprise a copolymer including 6-hydroxyhexanoate (6-HH).
- [46] In some embodiments, the amorphous PHA comprise a copolymer of 3-hydroxybutyrate (3-HB) and 4-hydroxybutyrate (4-HB), and a content of 4-HB is in a range from about 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39, 40, 41, 42, 43 or 44wt% to about 45, 44, 43, 42, 41, 40, 39, 38, 37, 36, 35, 34, 33, 32, 31, 30, 29, 28, 27 or 26wt% with respect to a total amount of the amorphous PHA. In certain embodiments, the amorphous PHA may comprise a copolymer of 3-hydroxybutyrate (3-HB) and 3-hydroxypropionate (3-HP), and a content of 3-HP is in a range from about 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39, 40, 41, 42, 43 or 44wt% to about 45, 44, 43, 42, 41, 40, 39, 38, 37, 36, 35, 34, 33, 32, 31, 30, 29, 28, 27 or

26wt% with respect to a total amount of the amorphous PHA. In certain embodiments, the amorphous PHA may comprise a copolymer of 3-hydroxybutyrate (3-HB) and 3-hydroxyhexanoate (3-HH), a content of 3-HH is in a range from about 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39, 40, 41, 42, 43 or 44wt% to about 45, 44, 43, 42, 41, 40, 39, 38, 37, 36, 35, 34, 33, 32, 31, 30, 29, 28, 27 or 26wt% with respect to a total amount of the amorphous PHA. In some embodiments, the amorphous PHA may comprise a copolymer of 3-hydroxybutyrate (3-HB) and 3-hydroxyoctanoate (3-HO), a content of 3-HO is in a range from about 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39, 40, 41, 42, 43 or 44wt% to about 45, 44, 43, 42, 41, 40, 39, 38, 37, 36, 35, 34, 33, 32, 31, 30, 29, 28, 27 or 26wt% with respect to a total amount of the amorphous PHA. In some embodiments, the amorphous PHA may comprise a copolymer of 3-hydroxybutyrate (3-HB) and 3-hydroxy valerate (3-HV), a content of 3-HV is in a range from about 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39, 40, 41, 42, 43 or 44wt% to about 45, 44, 43, 42, 41, 40, 39, 38, 37, 36, 35, 34, 33, 32, 31, 30, 29, 28, 27 or 26wt% with respect to a total amount of the amorphous PHA. In some embodiments, the amorphous PHA may comprise a copolymer of 3-hydroxybutyrate (3-HB) and 4-hydroxyvalerate (4-HV), a content of 4-HV in a range from about 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39, 40, 41, 42, 43 or 44wt% and about 45, 44, 43, 42, 41, 40, 39, 38, 37, 36, 35, 34, 33, 32, 31, 30, 29, 28, 27 or 26wt% with respect to a total amount of the amorphous PHA. In some embodiments, the amorphous PHA may comprise a copolymer of 3-hydroxybutyrate (3-HB) and 5-hydroxyvalerate (5-HV), a content of 5-HV is in a range from about 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39, 40, 41, 42, 43 or 44wt% to about 45, 44, 43, 42, 41, 40, 39, 38, 37, 36, 35, 34, 33, 32, 31, 30, 29, 28, 27 or 26wt% with respect to a total amount of the amorphous PHA. In some embodiments, the amorphous PHA may comprise a copolymer of 3-hydroxybutyrate (3-HB) and 6-hydroxyhexanoate (6-HH), a content of 6-HH is in a range from about 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39, 40, 41, 42, 43 or 44wt% and about 45, 44, 43, 42, 41, 40, 39, 38, 37, 36, 35, 34, 33, 32, 31, 30, 29, 28, 27 or 26wt% with respect to a total amount of the amorphous PHA. In some embodiments, the amorphous PHA may comprise a copolymer including at least one selected from the group consisting of 4-hydroxybutyrate (4-HB), 3-hydroxypropionate (3-HP), 3-hydroxyhexanoate (3-HH), 3-hydroxyoctanoate (3-HO), 3-hydroxyvalerate (3-HV), 4-hydroxyvalerate (4-HV), 5-hydroxyvalerate (5-HV), and 6-hydroxyhexanoate (6-HH), wherein the at least one is at a concentration from about 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39, 40, 41, 42, 43 or 44wt% to about 45, 44, 43, 42, 41, 40, 39, 38, 37, 36, 35, 34, 33, 32, 31, 30, 29, 28, 27 or 26wt% with respect to a total amount of the amorphous PHA.

- [47] In certain embodiments, the amorphous PHA may have a crystallinity of less than 5% by weight and may comprise a copolymer of 3-hydroxybutyrate (3-HB) and 3-hydroxypropionate (3-HP). In certain embodiments, the amorphous PHA may have a crystallinity of less than 5% by weight and may comprise a copolymer of 3-hydroxybutyrate (3-HB) and 3-hydroxyhexanoate (3-HH). In certain embodiments, the amorphous PHA may have a crystallinity of less than 5% by weight and may comprise a copolymer of 3-hydroxybutyrate (3-HB) and 3-hydroxyoctanoate (3-HO). In certain embodiments, the amorphous PHA may have a crystallinity of less than 5% by weight and may comprise a copolymer of 3-hydroxybutyrate (3-HB) and 3-hydroxy valerate (3-HV).
- [48] In certain embodiments, the biobased composition described herein may have a PHA content in a range from about 1 to about 45wt%, from about 1 to about 40wt%, from about 1 to about 35wt%, from about 1 to about 30wt%, from about 1 to about 25wt%, from about 1 to about 20wt%, from about 5 to about 45wt%, from about 5 to about 40wt%, from about 5 to about 35wt%, from about 5 to about 30wt%, from about 5 to about 25wt%, from about 5 to about 20wt%, from about 10 to about 45wt%, from about 10 to about 40wt%, from about 10 to about 35wt%, from about 10 to about 30wt%, from about 10 to about 25wt% with respect to a total amount of the polymer composition. In some embodiments, the PHA content may be about 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39, 40, 41, 42, 43 or 44 wt% or more, and/or about 45, 44, 43, 42, 41, 40, 39, 38, 37, 36, 35, 34, 33, 32, 31, 30, 29, 28, 27, 26, 25, 24, 23, 22, 21, 20, 19, 18, 17, 16, 15, 14, 13, 12, 11, 10, 9, 8, 7, 6, 5, 4, 3, or 2wt% or less with respect to a total amount of the polymer composition.
- [49] In certain embodiments, the biobased composition described herein may have an amorphous PHA content in a range from about 1 to about 45wt%, from about 1 to about 40wt%, from about 1 to about 35wt%, from about 1 to about 30wt%, from about 1 to about 25wt%, from about 1 to about 20wt%, from about 5 to about 45wt%, from about 5 to about 40wt%, from about 5 to about 35wt%, from about 5 to about 30wt%, from about 5 to about 25wt%, from about 5 to about 20wt%, from about 10 to about 45wt%, from about 10 to about 40wt%, from about 10 to about 35wt%, from about 10 to about 30wt%, from about 10 to about 25wt% with respect to a total amount of the polymer composition. In some embodiments, the PHA content may be about 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39, 40, 41, 42, 43 or 44wt% or more, and/or about 45, 44, 43, 42, 41, 40, 39, 38, 37, 36, 35, 34, 33, 32, 31, 30, 29, 28, 27, 26, 25, 24, 23, 22, 21, 20, 19, 18, 17, 16, 15, 14, 13, 12, 11, 10, 9, 8, 7, 6, 5, 4, 3, or 2wt% or less with respect to a total amount of the polymer composition.

- [50] Examples of repeat units that may be contained in the amorphous PHA include 2-hydroxybutyrate, lactic acid, glycolic acid, 3-hydroxybutyrate (hereinafter, referred to as 3-HB), 3-hydroxypropionate (hereinafter, referred to as 3-HP), 3-hydroxyvalerate (hereinafter, referred to as 3-HV), 3-hydroxyhexanoate (hereinafter, referred to as 3-HH), 3-hydroxyheptanoate (hereinafter, referred to as 3-HHep), 3-hydroxyoctanoate (hereinafter, referred to as 3-HO), 3-hydroxynonanoate (hereinafter, referred to as 3-HN), 3-hydroxydecanoate (hereinafter, referred to as 3-HD), 3-hydroxydodecanoate (hereinafter, referred to as 3-HDD), 4-hydroxybutyrate (hereinafter, referred to as 4-HB), 4-hydroxyvalerate (hereinafter, referred to as 4-HV), 5-hydroxyvalerate (hereinafter, referred to as 5-HV), and 6-hydroxyhexanoate (hereinafter, referred to as 6-HH). The amorphous PHA may contain one, two, three, four or more repeat units selected from the above.
- [51] The amorphous PHA may comprise one, two, three, four or more repeat units selected from the group consisting of 3-HB, 4-HB, 3-HP, 3-HH, 3-HV, 4-HV, 5-HV, and 6-HH.
- [52] In addition, the amorphous PHA may comprise isomers. The amorphous PHA may comprise structural isomers, enantiomers, or geometric isomers. Specifically, the amorphous PHA may comprise structural isomers.
- [53] The amorphous PHA may comprise a copolymerized amorphous PHA resin that comprises at least one repeat unit selected from the group consisting of 3-hydroxybutyrate (3-HB), 4-hydroxybutyrate (4-HB), 3-hydroxypropionate (3-HP), 3-hydroxyhexanoate (3-HH), 3-hydroxyoctanoate (3-HO), 3-hydroxyvalerate (3-HV), 4-hydroxyvalerate (4-HV), 5-hydroxyvalerate (5-HV), and 6-hydroxyhexanoate (6-HH).
- [54] The copolymerized amorphous PHA resin may comprise a 4-HB repeat unit and further comprises one or more repeat units selected from the group consisting of a 3-HB repeat unit, a 3-HP repeat unit, a 3-HH repeat unit, a 3-HV repeat unit, a 4-HV repeat unit, a 5-HV repeat unit, and a 6-HH repeat unit. The amorphous PHA resin may comprise a 4-HB repeat unit and a 3-HB repeat unit.
- [55] In certain embodiments, the amorphous PHA may comprise: a copolymer comprising or consisting of 3-hydroxybutyrate (3-HB) and 4-hydroxybutyrate (4-HB); a copolymer comprising or consisting of 3-hydroxybutyrate (3-HB) and 3-hydroxypropionate (3-HP); a copolymer comprising or consisting of 3-hydroxybutyrate (3-HB) and 3-hydroxyhexanoate (6-HH); a copolymer comprising or consisting of 3-hydroxybutyrate (3-HB) and 3-hydroxyoctanoate (3-HO); or a copolymer comprising or consisting of 3-hydroxybutyrate (3-HB) and 3-hydroxyvalerate (3-HV).
- [56] In certain embodiments, the amorphous PHA may comprise 3-hydroxybutyrate (3-HB). In certain embodiments, the amorphous PHA may comprise a copolymer

including 3-hydroxybutyrate (3-HB). In certain embodiments, the amorphous PHA may comprise 4-hydroxybutyrate (4-HB). In certain embodiments, the amorphous PHA may comprise a copolymer including 4-hydroxybutyrate (4-HB). In certain embodiments, the amorphous PHA comprises a copolymer including at least one selected from the group consisting of 4-hydroxybutyrate (4-HB), 3-hydroxypropionate (3-HP), 3-hydroxyhexanoate (3-HH), 3-hydroxyoctanoate (3-HO), 3-hydroxyvalerate (3-HV), 4-hydroxyvalerate (4-HV), 5-hydroxyvalerate (5-HV), and 6-hydroxyhexanoate (6-HH), wherein the at least one is at a concentration from 25 to 45 wt% with respect to a total amount of the amorphous PHA.

[57] In certain embodiments, the amorphous PHA may have a 3-HB content in a range from about 55 to about 75wt%, from about 55 to about 73wt%, from about 55 to about 70wt%, from about 55 to about 65wt%, from about 58 to about 79wt%, from about 58 to about 70wt%, from about 60 to about 75wt%, from about 60 to about 71wt%, from about 65 to about 75wt%, from about 65 to about 70wt%, from about 68 to about 75wt%, from about 68 to about 70wt%, from about 69 to about 75wt%, from about 70 to about 75wt% with respect to a total amount of the amorphous PHA. In some embodiments, the 3-HB content may be about 5, 10, 15, 20, 25, 30, 45, 50, 51, 52, 53, 54, 55, 56, 57, 58, 59, 60, 61, 62, 63, 64, 65, 66, 67, 68 or 69wt% or more, and/or about 80, 79, 78, 77, 76, 75, 74, 73, 72, 71, 70, 69, 68, 67, 66, 65, 64, 63, 62, 61, 60, 59, or 58wt% or less with respect to a total amount of the amorphous PHA.

[58] In certain embodiments, the amorphous PHA may have a 4-HB content in a range from about 25 to about 45wt%, from about 26 to about 44wt%, from about 27 to about 43wt%, from about 28 to about 42wt%, from about 29 to about 41wt%, from about 30 to about 40wt%, from about 30 to about 41wt%, from about 30 to about 42wt%, from about 30 to about 43wt%, from about 30 to about 44wt%, from about 30 to about 45wt%, from about 31 to about 39wt%, from about 31 to about 40wt%, from about 31 to about 41wt%, from about 31 to about 42wt%, from about 31 to about 43wt%, from about 31 to about 44wt%, from about 31 to about 45wt%, from about 32 to about 38wt%, from about 32 to about 39wt%, from about 32 to about 40wt%, from about 32 to about 41wt%, from about 32 to about 42wt%, from about 32 to about 43wt%, from about 32 to about 44wt%, from about 32 to about 45wt%, from about 33 to about 37wt%, from about 33 to about 38wt%, from about 33 to about 39wt%, from about 33 to about 40wt%, from about 33 to about 41wt%, 33 to about 42wt%, 33 to about 43wt%, 33 to about 44wt%, 33 to about 45wt%, from about 34 to about 36wt%, from about 34 to about 37wt%, from about 34 to about 38wt%, from about 34 to about 39wt%, from about 34 to about 40wt%, from about 34 to about 41wt%, from about 34 to about 42wt%, from about 34 to about 43wt%, from about 34 to about 44wt%, or from about 34 to about 45wt% with respect to a total amount of the amorphous PHA. In some

embodiments, the 4-HB content may be about 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39, 40, 41, 42, 43, 44, 45 wt% or more, and/or about 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39, 40, 41, 42, 43, 44, or 45wt% or less with respect to a total amount of the amorphous PHA.

[59] In certain embodiments, the amorphous PHA may have a 3-HP content in a range from about 25 to about 45wt%, from about 26 to about 44wt%, from about 27 to about 43wt%, from about 28 to about 42wt%, from about 29 to about 41wt%, from about 30 to about 40wt%, from about 30 to about 41wt%, from about 30 to about 42wt%, from about 30 to about 43wt%, from about 30 to about 44wt%, from about 30 to about 45wt%, from about 31 to about 39wt%, from about 31 to about 40wt%, from about 31 to about 41wt%, from about 31 to about 42wt%, from about 31 to about 43wt%, from about 31 to about 44wt%, from about 31 to about 45wt%, from about 32 to about 38wt%, from about 32 to about 39wt%, from about 32 to about 40wt%, from about 32 to about 41wt%, from about 32 to about 42wt%, from about 32 to about 43wt%, from about 32 to about 44wt%, from about 32 to about 45wt%, from about 33 to about 37wt%, from about 33 to about 38wt%, from about 33 to about 39wt%, from about 33 to about 40wt%, from about 33 to about 41wt%, 33 to about 42wt%, 33 to about 43wt%, 33 to about 44wt%, 33 to about 45wt%, from about 34 to about 36wt%, from about 34 to about 37wt%, from about 34 to about 38wt%, from about 34 to about 39wt%, from about 34 to about 40wt%, from about 34 to about 41wt%, from about 34 to about 42wt%, from about 34 to about 43wt%, from about 34 to about 44wt%, or from about 34 to about 45wt% with respect to a total amount of the amorphous PHA. In some embodiments, the 3-HP content may be about 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39, 40, 41, 42, 43, 44, 45 wt% or more, and/or about 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39, 40, 41, 42, 43, 44, or 45wt% or less with respect to a total amount of the amorphous PHA.

[60] In certain embodiments, the amorphous PHA may have a 6-HH content in a range from about 25 to about 45 wt%, from about 26 to about 44 wt%, from about 27 to about 43 wt%, from about 28 to about 42 wt%, from about 29 to about 41 wt%, from about 30 to about 40 wt%, from about 30 to about 41 wt%, from about 30 to about 42 wt%, from about 30 to about 43 wt%, from about 30 to about 44 wt%, from about 30 to about 45 wt%, from about 31 to about 39 wt%, from about 31 to about 40 wt%, from about 31 to about 41 wt%, from about 31 to about 42 wt%, from about 31 to about 43 wt%, from about 31 to about 44 wt%, from about 31 to about 45 wt%, from about 32 to about 38 wt%, from about 32 to about 39 wt%, from about 32 to about 40 wt%, from about 32 to about 41 wt%, from about 32 to about 42 wt%, from about 32 to about 43 wt%, from about 32 to about 44 wt%, from about 32 to about 45 wt%, from about 33 to about 37 wt%, from about 33 to about 38 wt%, from about 33 to

about 39 wt%, from about 33 to about 40 wt%, from about 33 to about 41 wt%, 33 to about 42 wt%, 33 to about 43 wt%, 33 to about 44 wt%, 33 to about 45 wt%, from about 34 to about 36 wt%, from about 34 to about 37 wt%, from about 34 to about 38 wt%, from about 34 to about 39 wt%, from about 34 to about 40 wt%, from about 34 to about 41 wt%, from about 34 to about 42 wt%, from about 34 to about 43 wt%, from about 34 to about 44 wt%, or from about 34 to about 45 wt% with respect to a total amount of the amorphous PHA. In some embodiments, the 6-HH content may be about 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39, 40, 41, 42, 43, 44, 45 wt% or more, and/or about 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39, 40, 41, 42, 43, 44, or 45 wt% or less with respect to a total amount of the amorphous PHA.

[61] In certain embodiments, the amorphous PHA may have a 3-HO content in a range from about 25 to about 45 wt%, from about 26 to about 44 wt%, from about 27 to about 43 wt%, from about 28 to about 42 wt%, from about 29 to about 41 wt%, from about 30 to about 40 wt%, from about 30 to about 41 wt%, from about 30 to about 42 wt%, from about 30 to about 43 wt%, from about 30 to about 44 wt%, from about 30 to about 45 wt%, from about 31 to about 39 wt%, from about 31 to about 40 wt%, from about 31 to about 41 wt%, from about 31 to about 42 wt%, from about 31 to about 43 wt%, from about 31 to about 44 wt%, from about 31 to about 45 wt%, from about 32 to about 38 wt%, from about 32 to about 39 wt%, from about 32 to about 40 wt%, from about 32 to about 41 wt%, from about 32 to about 42 wt%, from about 32 to about 43 wt%, from about 32 to about 44 wt%, from about 32 to about 45 wt%, from about 33 to about 37 wt%, from about 33 to about 38 wt%, from about 33 to about 39 wt%, from about 33 to about 40 wt%, from about 33 to about 41 wt%, 33 to about 42 wt%, 33 to about 43 wt%, 33 to about 44 wt%, 33 to about 45 wt%, from about 34 to about 36 wt%, from about 34 to about 37 wt%, from about 34 to about 38 wt%, from about 34 to about 39 wt%, from about 34 to about 40 wt%, from about 34 to about 41 wt%, from about 34 to about 42 wt%, from about 34 to about 43 wt%, from about 34 to about 44 wt%, or from about 34 to about 45 wt% with respect to a total amount of the amorphous PHA. In some embodiments, the 3-HO content may be about 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39, 40, 41, 42, 43, 44, 45 wt% or more, and/or about 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39, 40, 41, 42, 43, 44, or 45 wt% or less with respect to a total amount of the amorphous PHA.

[62] In certain embodiments, the amorphous PHA may have a 3-HV content in a range from about 25 to about 45 wt%, from about 26 to about 44 wt%, from about 27 to about 43 wt%, from about 28 to about 42 wt%, from about 29 to about 41 wt%, from about 30 to about 40 wt%, from about 30 to about 41 wt%, from about 30 to about 42 wt%, from about 30 to about 43 wt%, from about 30 to about 44 wt%, from about 30 to about 45 wt%, from about 31 to about 39 wt%, from about 31 to about 40 wt%

%, from about 31 to about 41 wt%, from about 31 to about 42 wt%, from about 31 to about 43 wt%, from about 31 to about 44 wt%, from about 31 to about 45 wt%, from about 32 to about 38 wt%, from about 32 to about 39 wt%, from about 32 to about 40 wt%, from about 32 to about 41 wt%, from about 32 to about 42 wt%, from about 32 to about 43 wt%, from about 32 to about 44 wt%, from about 32 to about 45 wt%, from about 33 to about 37 wt%, from about 33 to about 38 wt%, from about 33 to about 39 wt%, from about 33 to about 40 wt%, from about 33 to about 41 wt%, 33 to about 42 wt%, 33 to about 43 wt%, 33 to about 44 wt%, 33 to about 45 wt%, from about 34 to about 36 wt%, from about 34 to about 37 wt%, from about 34 to about 38 wt%, from about 34 to about 39 wt%, from about 34 to about 40 wt%, from about 34 to about 41 wt%, from about 34 to about 42 wt%, from about 34 to about 43 wt%, from about 34 to about 44 wt%, or from about 34 to about 45 wt% with respect to a total amount of the amorphous PHA. In some embodiments, the 3-HV content may be about 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39, 40, 41, 42, 43, 44, 45 wt% or more, and/or about 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39, 40, 41, 42, 43, 44, or 45 wt% or less with respect to a total amount of the amorphous PHA.

[63] In certain embodiments, the amorphous PHA may have a 3-HH content in a range from about 25 to about 45 wt%, from about 26 to about 44 wt%, from about 27 to about 43 wt%, from about 28 to about 42 wt%, from about 29 to about 41 wt%, from about 30 to about 40 wt%, from about 30 to about 41 wt%, from about 30 to about 42 wt%, from about 30 to about 43 wt%, from about 30 to about 44 wt%, from about 30 to about 45 wt%, from about 31 to about 39 wt%, from about 31 to about 40 wt%, from about 31 to about 41 wt%, from about 31 to about 42 wt%, from about 31 to about 43 wt%, from about 31 to about 44 wt%, from about 31 to about 45 wt%, from about 32 to about 38 wt%, from about 32 to about 39 wt%, from about 32 to about 40 wt%, from about 32 to about 41 wt%, from about 32 to about 42 wt%, from about 32 to about 43 wt%, from about 32 to about 44 wt%, from about 32 to about 45 wt%, from about 33 to about 37 wt%, from about 33 to about 38 wt%, from about 33 to about 39 wt%, from about 33 to about 40 wt%, from about 33 to about 41 wt%, 33 to about 42 wt%, 33 to about 43 wt%, 33 to about 44 wt%, 33 to about 45 wt%, from about 34 to about 36 wt%, from about 34 to about 37 wt%, from about 34 to about 38 wt%, from about 34 to about 39 wt%, from about 34 to about 40 wt%, from about 34 to about 41 wt%, from about 34 to about 42 wt%, from about 34 to about 43 wt%, from about 34 to about 44 wt%, or from about 34 to about 45 wt% with respect to a total amount of the amorphous PHA. In some embodiments, the 3-HV content may be about 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39, 40, 41, 42, 43, 44, 45 wt% or more, and/or about 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39, 40, 41, 42, 43, 44, or 45 wt% or less with respect to a total amount of the amorphous PHA.

- [64] In certain embodiments, the amorphous PHA may have a 4-HV content in a range from about 25 to about 45 wt%, from about 26 to about 44 wt%, from about 27 to about 43 wt%, from about 28 to about 42 wt%, from about 29 to about 41 wt%, from about 30 to about 40 wt%, from about 30 to about 41 wt%, from about 30 to about 42 wt%, from about 30 to about 43 wt%, from about 30 to about 44 wt%, from about 30 to about 45 wt%, from about 31 to about 39 wt%, from about 31 to about 40 wt%, from about 31 to about 41 wt%, from about 31 to about 42 wt%, from about 31 to about 43 wt%, from about 31 to about 44 wt%, from about 31 to about 45 wt%, from about 32 to about 38 wt%, from about 32 to about 39 wt%, from about 32 to about 40 wt%, from about 32 to about 41 wt%, from about 32 to about 42 wt%, from about 32 to about 43 wt%, from about 32 to about 44 wt%, from about 32 to about 45 wt%, from about 33 to about 37 wt%, from about 33 to about 38 wt%, from about 33 to about 39 wt%, from about 33 to about 40 wt%, from about 33 to about 41 wt%, 33 to about 42 wt%, 33 to about 43 wt%, 33 to about 44 wt%, 33 to about 45 wt%, from about 34 to about 36 wt%, from about 34 to about 37 wt%, from about 34 to about 38 wt%, from about 34 to about 39 wt%, from about 34 to about 40 wt%, from about 34 to about 41 wt%, from about 34 to about 42 wt%, from about 34 to about 43 wt%, from about 34 to about 44 wt%, or from about 34 to about 45 wt% with respect to a total amount of the amorphous PHA. In some embodiments, the 3-HV content may be about 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39, 40, 41, 42, 43, 44, 45 wt% or more, and/or about 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39, 40, 41, 42, 43, 44, or 45 wt% or less with respect to a total amount of the amorphous PHA.
- [65] In certain embodiments, the amorphous PHA may have a 5-HH content in a range from about 25 to about 45 wt%, from about 26 to about 44 wt%, from about 27 to about 43 wt%, from about 28 to about 42 wt%, from about 29 to about 41 wt%, from about 30 to about 40 wt%, from about 30 to about 41 wt%, from about 30 to about 42 wt%, from about 30 to about 43 wt%, from about 30 to about 44 wt%, from about 30 to about 45 wt%, from about 31 to about 39 wt%, from about 31 to about 40 wt%, from about 31 to about 41 wt%, from about 31 to about 42 wt%, from about 31 to about 43 wt%, from about 31 to about 44 wt%, from about 31 to about 45 wt%, from about 32 to about 38 wt%, from about 32 to about 39 wt%, from about 32 to about 40 wt%, from about 32 to about 41 wt%, from about 32 to about 42 wt%, from about 32 to about 43 wt%, from about 32 to about 44 wt%, from about 32 to about 45 wt%, from about 33 to about 37 wt%, from about 33 to about 38 wt%, from about 33 to about 39 wt%, from about 33 to about 40 wt%, from about 33 to about 41 wt%, 33 to about 42 wt%, 33 to about 43 wt%, 33 to about 44 wt%, 33 to about 45 wt%, from about 34 to about 36 wt%, from about 34 to about 37 wt%, from about 34 to about 38 wt%, from about 34 to about 39 wt%, from about 34 to about 40 wt%, from about

34 to about 41 wt%, from about 34 to about 42 wt%, from about 34 to about 43 wt%, from about 34 to about 44 wt%, or from about 34 to about 45 wt% with respect to a total amount of the amorphous PHA. In some embodiments, the 3-HV content may be about 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39, 40, 41, 42, 43, 44, 45 wt % or more, and/or about 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39, 40, 41, 42, 43, 44, or 45 wt% or less with respect to a total amount of the amorphous PHA.

[66] In certain embodiments, the amorphous PHA may comprise a copolymer of 3-hydroxybutyrate (3-HB) and 4-hydroxybutyrate (4-HB). In certain embodiments, the amorphous PHA may comprise a copolymer of 3-hydroxybutyrate (3-HB) and 3-hydroxypropionate (3-HP). In certain embodiments, the amorphous PHA may comprise a copolymer of 3-hydroxybutyrate (3-HB) and 3-hydroxyhexanoate (3-HH). In certain embodiments, the amorphous PHA may comprise a copolymer of 3-hydroxybutyrate (3-HB) and 6-hydroxyhexanoate (6-HH). In certain embodiments, the amorphous PHA may comprise a copolymer of 3-hydroxybutyrate (3-HB) and 3-hydroxyoctanoate (3-HO). In certain embodiments, the amorphous PHA may comprise a copolymer of 3-hydroxybutyrate (3-HB) and 3-hydroxy valerate (3-HV).

[67] In certain embodiments, the amorphous PHA may comprise a copolymer of 3-hydroxybutyrate (3-HB) and 4-hydroxybutyrate (4-HB), with a 4-HB content in a range from 25 to 45%. In certain embodiments, the amorphous PHA comprises a copolymer of 3-hydroxybutyrate (3-HB) and 3-hydroxypropionate (3-HP), a content of 3-HP is in a range from 25 to 45%. In certain embodiments, the amorphous PHA comprises a copolymer of 3-hydroxybutyrate (3-HB) and 3-hydroxyhexanoate (3-HH), a content of 3-HH is in a range from 25 to 45%. In certain embodiments, the amorphous PHA comprises a copolymer of 3-hydroxybutyrate (3-HB) and 3-hydroxyoctanoate (3-HO), a content of 3-HO is in a range from 25 to 45%. In certain embodiments, the amorphous PHA comprises a copolymer of 3-hydroxybutyrate (3-HB) and 3-hydroxy valerate (3-HV), a content of 3-HV is in a range from 25 to 45%. In certain embodiments, the amorphous PHA comprises a copolymer of 3-hydroxybutyrate (3-HB) and 4-hydroxyvalerate (4-HV), a content of 4-HV is in a range from 25 to 45%. In certain embodiments, the amorphous PHA comprises a copolymer of 3-hydroxybutyrate (3-HB) and 5-hydroxyvalerate (5-HV), a content of 5-HV is in a range from 25 to 45%. In certain embodiments, the amorphous PHA comprises a copolymer of 3-hydroxybutyrate (3-HB) and 6-hydroxyhexanoate (6-HH), a content of 6-HH is in a range from 25 to 45%.

[68] The glass transition temperature (T_g) of the amorphous PHA may be in a range from about -45°C to about -10°C, from about -44°C to about -11°C, from about -43°C to about -12°C, from about -42°C to about -13°C, from about -41°C to about -14°C, from about -40°C to about -15°C, from about -39°C to about -16°C, from about -38°C

to about -17°C, from about -37°C to about -18°C, from about -36°C to about -19°C, from about -35°C to about -20°C, from about -35°C to about -19°C, from about -35°C to about -18°C, from about -35°C to about -17°C, from about -35°C to about -16°C, from about -35°C to about -15°C, from about -34°C to about -16°C, from about -33°C to about -17°C, from about -32°C to about -18°C, from about -31°C to about -19°C, or from about -30°C to about -20°C. In some the glass transition temperature (T_g) of the amorphous PHA may be about -45, -44, -43, -42, -41, -40, -39, -38, -37, -36, -35, -34, -33, -32, -31, -30, -29, -28, -27, -26, -25, -24, -23, -22, -21, -20, -19, -18, -17, -16, -15, -14, -13, -12, -11, -10 °C or more, and/or about -10, -11, -12, -13, -14, -15, -16, -17, -18, -19, -20, -21, -22, -23, -24, -25, -26, -27, -28, -29, -30, -31, -32, -33, -34, -35, -36, -37, -38, -39, -40, -41, -42, -43, -44, -45 °C or less.

[69] The amorphous PHA may have a melt flow index (MFI) of in a range from about 0.1 to about 100 g/10 minutes measured at 165°C and 5 kg according to ASTM D1238. The melt flow index (MFI) of the first PHA resin measured at 165°C and 5 kg according to ASTM D1238 may be in a range from about 0.1 to about 15 g/10 minutes, in a range from about 0.1 to about 12 g/10 minutes, in a range from about 0.1 to about 10 g/10 minutes, in a range from about 0.1 to about 8 g/10 minutes, in a range from about 0.1 to about 6 g/10 minutes, in a range from about 0.1 to about 5.5 g/10 minutes, in a range from about 0.5 to about 10 g/10 minutes, in a range from about 1 to about 10 g/10 minutes, in a range from about 2 to about 8 g/10 minutes, in a range from about 3 to about 6 g/10 minutes, or in a range from about 3 to about 5.5 g/10 minutes. In some the melt flow index (MFI) of the amorphous PHA measured at 165°C and 5 kg according to ASTM D1238 may be about 0.1, 0.5, 1, 1.5, 2, 2.5, 3, 3.5, 4, 4.5, 5, 5.5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, or 20 g/10 minutes or more, and/or about 20, 19, 18, 17, 16, 15, 14, 13, 12, 11, 10, 9, 8, 7, 6, 5.5, 5, 4.5, 4, 3.5, 3, 2.5, 2, 1.5, 1, 0.5, or 0.1 g/10 minutes or less.

[70] The amorphous PHA may have a weight average molecular weight of in a range from about 10,000 to about 1,200,000 g/mole, in a range from about 10,000 to about 1,000,000 g/mole, in a range from about 10,000 to about 100,000 g/mole, in a range from about 10,000 to about 90,000 g/mole, in a range from about 50,000 to about 1,000,000 g/mole, in a range from about 200,000 to about 1,200,000 g/mole, in a range from about 250,000 to about 1,000,000 g/mole, in range from about 100,000 to about 900,000 g/mole, in range from about 500,000 to about 900,000 g/mole, in a range from about 200,000 to about 800,000 g/mole, or in a range from about 200,000 to about 500,000 g/mole. In some embodiments, the amorphous PHA may have a weight average molecular weight of about 10,000, 20,000, 30,000, 40,000, 50,000, 60,000, 70,000, 80,000, 90,000, 100,000, 150,000, 200,000, 250,000, 500,000, 800,000, 900,000, 1,000,000, 1,100,000, 1,200,000 g/mole or more, and/or about

1,200,000, 1,100,000, 1,000,000, 900,000, 800,000, 500,000, 250,000, 200,000, 150,000, 100,000, 90,000, 80,000, 70,000, 60,000, 50,000, 40,000, 30,000, 20,000, or 10,000 g/mole or more.

- [71] In some embodiments, the biobased composition may exclude plasticizer for increasing tensile elongation, impact strength or tear strength of a film comprising the biobased composition.
- [72] In some embodiments, the biobased composition according to the present disclosure may comprise the amorphous PHA less than about 70, 65, 60, 55, 50, 45, or 40 wt% with respect to a total weight of the biobased composition.
- [73] In certain embodiments, the amorphous PHA may be at least 75% or 100% biobased, as measured using ASTM D6866. In some embodiment, the amorphous PHA maybe, as measured using ASTM D6866, at least about 10, 15, 20, 25, 30, 35, 40, 45, 50, 55, 60, 65, 70, 75, 80, 85, 90, 91, 92, 93, 94, 95, 96, 97, 98, or 99% or more, and/or about 100, 95, 90, 85, 80, 75, 70, 65, 60, 55, 50, 45, 40, 35, 30, 25, 20, 15, or 10% or less biobased.
- [74] In certain embodiments, a weight ratio of the amorphous PHA to PLA in the biobased composition may be 1:99, 5:95, 10:90, 15:85, 20:80, 25:75, 30:70, 35:65, 40:60, 45:55, 50:50, 55:45, 60:40, 65:35, 70:30, 75:25, 80:20, 85:15, 90:10, 95:5 or 99:1. In certain embodiments, a weight ratio of the amorphous PHA to the pore-forming agent in the biobased composition may be 1:99, 5:95, 10:90, 15:85, 20:80, 25:75, 30:70, 35:65, 40:60, 45:55, 50:50, 55:45, 60:40, 65:35, 70:30, 75:25, 80:20, 85:15, 90:10, 95:5 or 99:1. In certain embodiments, a weight ratio of PLA to the pore-forming agent in the biobased composition may be 1:99, 5:95, 10:90, 15:85, 20:80, 25:75, 30:70, 35:65, 40:60, 45:55, 50:50, 55:45, 60:40, 65:35, 70:30, 75:25, 80:20, 85:15, 90:10, 95:5 or 99:1.
- [75] In certain embodiments, a biobased composition comprising an amorphous PHA, a polyester and a pore-forming agent may be injection molded, extrusion molded, a blown film extrusion, thermoformed, compression molded, blow molded into an article or a film. In certain embodiments, a biobased composition comprising an amorphous PHA, a polyester and a pore-forming agent may be formed into a film or an oriented film by a blown film extrusion, a cast film extrusion, oriented film extrusion, a blown film extrusion or combinations thereof.
- [76] In certain embodiments, a biobased composition comprising an amorphous PHA, a polyester and a pore-forming agent may be used as film. In some embodiments, a film of the present disclosure may include an amorphous PHA, a polyester and a pore-forming agent. In certain embodiments, a film comprising the biobased composition of the present disclosure may have an impact strength of about 5, 10, 20, 30, 40, 50, 60, 70, 80, 90, 100, 110, 120, 130, 140, 150, 160, 170, 180 or 190 kJ/m² or more and/

or about 200, 190, 180, 170, 160, 150, 140, 130, 120, 110, 100, 90, 80, 70, 60, 50, 40, 30, 20 or 10 or less kJ/m². In certain embodiments, a film comprising the biobased composition of the present disclosure may have a tear strength of about 10, 20, 30, 40, 50, 60, 70, 80, 90, 100, 150, 200, 250, 300, 350, 400 or 450 kN/m² or more and/or 500, 450, 400, 350, 300, 250, 200, 150, 100, 90, 80, 70, 60, 50, 40, 30 or 10 kN/m² or less.

[77] In certain embodiments, a film comprising the biobased composition may be a monolayer or multiple layers. In certain embodiments, a film comprising the biobased composition of the present disclosure may include at least two layers, three layers, four layers, or five layers each of which includes the amorphous (PHA), the polyester, and the pore-forming agent. In certain embodiments, each and every layer in a film may comprise the biobased composition of the present disclosure. In some embodiments, the film comprising the biobased composition of the present disclosure may include a biobased film or a microporous film and may be a biaxially oriented film. In some embodiments, the film comprising the biobased composition of the present disclosure may be prepared by blown film extrusion of the biobased composition. In certain embodiments, the present disclosure is related to a product or an article comprising a biobased composition comprising an amorphous PHA, a polyester and a pore-forming agent, and the product or the article may be produced by using a blown or cast film process followed by subsequent orientation in one or two directions. In some embodiments, the product comprising the biobased composition of the present disclosure may be produced by a blown film process that is subsequently stretched in one direction only (MDO). In some embodiments, the product comprising the biobased composition of the present disclosure may be produced by a cast film process that is subsequently stretched in one direction only (MDO). In some embodiments, the product comprising the biobased composition of the present disclosure may be produced by making a blown film that is subsequently stretched in two directions (MD & TD) either simultaneously or in sequence. In some embodiments, the product comprising the biobased composition of the present disclosure may be produced by making a cast film that is subsequently stretched in two directions (MD & TD) either simultaneously or in sequence.

[78] In some embodiments, the product comprising the biobased composition of the present disclosure may have a density reduction of at least about 10, 15, 20, 25, 30, 35, 40, 45 or 50% relative to the non-porous un-oriented baseline film.

[79] The biobased composition comprising amorphous PHA, a polyester and a pore-forming agent according to the present disclosure may provide a film which exhibits high durability and puncture toughness or strength along with lower density, larger surface area and high permeability, and improved flexibility. The present disclosure

relates to method of producing a stretched film, the method comprising stretching a film comprising the biobased composition in a stretch ratio of 10, 9.5, 9, 8.5, 8, 7.5, 7, 6.5, 6, 5.5, 5, 4.5, 4, 3.5, 3, 2.5, 2, 1.5, 1, or 0.5 or less. In some embodiments, the method of producing the stretched film of the present disclosure may comprise extruding by a blown film extrusion, injection molding, thermoforming or a cast film extrusion the biobased composition before stretching the film. In some embodiments, the method of producing the stretched film of the present disclosure may comprise stretching a film in one direction only. In some embodiments, the method of producing the stretched film of the present disclosure may comprise stretching a film at least in two directions comprising a machine direction (MD) and a traverse direction (TD) simultaneously or in sequence.

- [80] Hereinafter, the present disclosure will be described in more detail with reference to the following examples. But the following Examples are intended to illustrate the present embodiments, and the scope of the Examples is not limited thereto only.

Mode for the Invention

- [81] **Example 1**

[82] CJ Biomaterials CA1270PF was used in the blown film experiment. CA1270PF is a blend of PLA (Ingeo 4043D), an amorphous PHA (PHACT A1000P) and Calcium Carbonate (~ 15% CaCO_3), which was subject to blown film processing followed by orientation along the machine direction (MDO).

[83] The blown film extrusion system employed for this experiment is a 3-extruder, 3-layer A/B/C film construction. CA1270PF was run through all 3 extruders at a 25/50/25 split. The blown film extruder was set at the following temperature profile: 165/180/180/185 ($^{\circ}\text{C}$) while all die zones were set at 185 $^{\circ}\text{C}$; the transfer lines were set at 190 $^{\circ}\text{C}$. Extruders A and C were run at 74 rpm, while extruder B was run at 46 rpm (total output rate was ~ 46 kgs/hr). Melt pressures for A/B/C were 1722/843/2398 psi. The die diameter was 120 mm, blow-up ratio was approximately 2.5 for all blown films and the die gap was 1.5 mm. Initial blown film thickness was approximately 64 microns prior to stretching.

[84] The blown films were subsequently stretched along the machine direction using a MDO station. The stretching was performed at 70 $^{\circ}\text{C}$. The stretched films were subsequently relaxed at 55 $^{\circ}\text{C}$ prior to final collection. MDO stretch ratios of 0, 2.8 and 3.3 were achieved.

[85] The film with no MDO did not have any pores/voids in the film. The density of control film was about 1.47 g/cc. Relative to this control film, the film that was prepared at a MDO stretch of 2.8 displayed density of about 1.32 g/cc (representing

a 10% reduction in density) while the film that was prepared at a MDO stretch of 3.3 displayed a density of about 1.25 g/cc (representing a 15% reduction in density).

[86] Despite the 15% reduction in density as a result of the microvoids, no change in the puncture toughness of the film was observed. The Spencer impact toughness of the un-stretched film was 320 grams per 25 microns thickness, while the impact for the microporous film was 480 grams per 25 microns thickness. This observation of an increased puncture toughness in the microporous film is surprising and very likely enabled by the presence of amorphous PHA in the composition.

[87] The SEM micrograph (FIG. 1) shows the morphology of the film that was stretched to 3.3 times. Elongated voids shown in FIG. 1 are evident confirming the density reduction.

[88]

[89] **Example 2**

[90] This example demonstrates the processing of CJ Biomaterials CA1240PF, a blend of PLA, aPHA (A1000P), and Calcium Carbonate (~ 30% calcium carbonate), used a blown mono-layer film. The experiment was conducted using a Collins blown film extruder with a temperature profile of 25/170/175/175/180/180°C, and the die adaptor temperatures set to 190/190/185/180°C. The extruder was operated at 50 rpm with a melt pressure of 2160 psi and a melt temperature of 168°C. The die diameter was 30 mm, the blow-up ratio was approximately 2.3, and the die gap was 1.5 mm. The initial film thickness was approximately 40 microns.

[91] The blown films were stretched in the machine direction using an offline Bruckner MDO station. The stretching was performed at 75°C, with pre-treatment at 60°C and post-stretching relaxation at 65°C, using different stretch ratios of 1X, 2X, and 2.5X MDO. The non-MDO film, which acted as a baseline, did not have any pores. The density of the "control" unstretched film was about 1.69 g/cc. The densities of the stretched films were 1.34 g/cc, 1.30 g/cc and 1.31 g/cc for the 1X, 2X and 2.5X stretch ratios achieved.

[92] The MDO-stretched films exhibited a significant reduction in density, reaching 20% to 25% reduction or more (1.35 g/cc) relative to the non-oriented film. While the absolute magnitude of density reduction was noted across the range of stretch ratios, we did not observe a clear trend of density reduction with stretch ratio. Despite this reduction, the modulus of the cavitated films did not decrease and even showed an improvement of 70% and more, attributed to the orientation effect in the polymer chains.

[93]

[94] **Exemplary Embodiments**

- [95] Embodiment 1. A biobased composition comprising an amorphous polyhydroxyalkanoate (PHA), a polyester, and a pore-forming agent.
- [96] Embodiment 2. The biobased composition according to embodiment 1, wherein a puncture toughness of the biobased composition decreases by 10% or less, stays the same, or increases upon reduction of a density of the biobased composition at least by 5%.
- [97] Embodiment 3. The biobased composition according to embodiment 2, wherein the density is decreased by stretching in a machine direction orientation (MDO) by a stretch ratio of 0.5X or more.
- [98] Embodiment 4. The biobased composition according to embodiment 2, wherein the puncture toughness of the biobased composition decreases by 10% or less.
- [99] Embodiment 5. The biobased composition according to embodiment 2, wherein the puncture toughness of the biobased composition stays the same.
- [100] Embodiment 6. The biobased composition according to embodiment 2, wherein the puncture toughness of the biobased composition increases.
- [101] Embodiment 7. The biobased composition according to embodiment 2, wherein the puncture toughness of the biobased composition increases at least by 10%.
- [102] Embodiment 8. The biobased composition according to embodiment 2, wherein the puncture toughness of the biobased composition increases at least by 60%.
- [103] Embodiment 9. The biobased composition according to any one of the preceding embodiments, wherein a puncture toughness of the biobased composition decreases by 10% or less, stays the same, or increases upon reduction of a density of the biobased composition at least by 10%.
- [104] Embodiment 10. The biobased composition according to embodiment 9, wherein the density is decreased by stretching in a machine direction orientation (MDO) by a stretch ratio of 2.5 or more.
- [105] Embodiment 11. The biobased composition according to any one of the preceding embodiment, wherein a puncture toughness of the biobased composition decreases by 10% or less, stays the same, or increases upon reduction of a density of the biobased composition at least by 15%.
- [106] Embodiment 12. The biobased composition according to embodiment 10, the density is decreased by stretching in a machine direction orientation (MDO) by a stretch ratio of 3.0 or more.
- [107] Embodiment 13. The biobased composition according to any one of the preceding embodiments, wherein the biobased composition is in a form of film.
- [108] Embodiment 14. The biobased composition according to any one of the preceding embodiments, wherein the biobased composition is in a form of a film having a thickness of 1 to 400 μm or 15 μm to 100 μm .

- [109] Embodiment 15. The biobased composition according to any one of the preceding embodiments, wherein a puncture toughness of the biobased composition measured by spencer impact test decreases by 10% or less, stays the same, or increases upon reduction of a density of the biobased composition at least by 5%.
- [110] Embodiment 16. The biobased composition according to any one of the preceding embodiments, wherein a puncture toughness of the biobased composition measured by ASTM D3420 decreases by 10% or less, stays the same, or increases upon reduction of a density of the biobased composition at least by 5%.
- [111] Embodiment 17. The biobased composition according to any one of the preceding embodiments, wherein a biobased carbon content of the biobased composition as measured according to ASTM D6866 is at least 75%.
- [112] Embodiment 18. The biobased composition according to any one of the preceding embodiments, wherein a biobased carbon content of the biobased composition as measured according to ASTM D6866 is 100%.
- [113] Embodiment 19. The biobased composition according to any one of the preceding embodiments, wherein the biobased composition satisfies a compostability test according to ASTM D6400.
- [114] Embodiment 20. The biobased composition according to any one of the preceding embodiments, wherein the pore-forming agent comprises a mineral.
- [115] Embodiment 21. The biobased composition according to any one of the preceding embodiments, wherein the pore-forming agent comprises organic or inorganic particles.
- [116] Embodiment 22. The biobased composition according to any one of the preceding embodiments, wherein the pore-forming agent comprises organic or inorganic particles having particle diameters in a range from $0.1\mu\text{m}$ to $20\mu\text{m}$, or $1\mu\text{m}$ to $5\mu\text{m}$.
- [117] Embodiment 23. The biobased composition according to any one of the preceding embodiments, wherein the pore-forming agent comprises at least one selected from the group consisting of calcium carbonate (CaCO_3), talc, wallstonite (CaSiO_3), aluminum oxide (Al_2O_3), and combinations thereof.
- [118] Embodiment 24. The biobased composition according to any one of the preceding embodiments, wherein the biobased composition has the pore-forming agent at an amount from 1 to 50 wt% or from 5 to 30 wt%.
- [119] Embodiment 25. The biobased composition according to any one of the preceding embodiments, wherein the polyester comprises polylactide (PLA).
- [120] Embodiment 26. The biobased composition according to any one of the preceding embodiments, wherein the polyester comprises a polylactic resin having a lactic acid component.

- [121] Embodiment 27. The biobased composition according to any one of the preceding embodiments, wherein the polyester comprises a polylactic resin including L-lactic acid and/or D-lactic acid.
- [122] Embodiment 28. The biobased composition according to any one of the preceding embodiments, wherein the polyester comprises a polylactic resin including other than a polylactic resin.
- [123] Embodiment 29. The biobased composition according to any one of the preceding embodiments, wherein the composition has the polylactide (PLA) at an amount from 55 to 99 wt%.
- [124] Embodiment 30. The biobased composition according to any one of the preceding embodiments, wherein the composition has the amorphous PHA in an amount from 1 to 45 wt%.
- [125] Embodiment 31. The biobased composition according to any one of the preceding embodiments, wherein the amorphous PHA has a crystallinity of less than 5% by weight.
- [126] Embodiment 32. The biobased composition according to any one of the preceding embodiments, wherein the amorphous PHA comprises a copolymer including 3-hydroxybutyrate (3-HB).
- [127] Embodiment 33. The biobased composition according to any one of the preceding embodiments, wherein the amorphous PHA comprises a copolymer including 4-hydroxybutyrate (4-HB).
- [128] Embodiment 34. The biobased composition according to any one of the preceding embodiments, wherein the amorphous PHA comprises a copolymer including 3-hydroxypropionate (3-HP).
- [129] Embodiment 35. The biobased composition according to any one of the preceding embodiments, wherein the amorphous PHA comprises a copolymer including 3-hydroxyhexanoate (3-HH).
- [130] Embodiment 36. The biobased composition according to any one of the preceding embodiments, wherein the amorphous PHA comprises a copolymer including 3-hydroxyoctanoate (3-HO).
- [131] Embodiment 37. The biobased composition according to any one of the preceding embodiments, wherein the amorphous PHA comprises a copolymer including 3-hydroxy valerate (3-HV).
- [132] Embodiment 38. The biobased composition according to any one of the preceding embodiments, wherein the amorphous PHA comprises a copolymer including 4-hydroxyvalerate (4-HV).

- [133] Embodiment 39. The biobased composition according to any one of the preceding embodiments, wherein the amorphous PHA comprises a copolymer including 5-hydroxyvalerate (5-HV).
- [134] Embodiment 40. The biobased composition according to any one of the preceding embodiments, wherein the amorphous PHA comprises a copolymer including 6-hydroxyhexanoate (6-HH).
- [135] Embodiment 41. The biobased composition according to any one of the preceding embodiments, wherein the amorphous PHA comprises a copolymer of 3-hydroxybutyrate (3-HB) and 4-hydroxybutyrate (4-HB), and a content of 4-HB is in a range from 25 to 45% with respect to a total amount of the amorphous PHA.
- [136] Embodiment 42. The biobased composition according to any one of the preceding embodiments, wherein the amorphous PHA comprises a copolymer of 3-hydroxybutyrate (3-HB) and 3-hydroxypropionate (3-HP), and a content of 3-HP is in a range from 25 to 45% with respect to a total amount of the amorphous PHA.
- [137] Embodiment 43. The biobased composition according to any one of the preceding embodiments, wherein the amorphous PHA comprises a copolymer of 3-hydroxybutyrate (3-HB) and 3-hydroxyhexanoate (3-HH), and a content of 3-HH is in a range from 25 to 45% with respect to a total amount of the amorphous PHA.
- [138] Embodiment 44. The biobased composition according to any one of the preceding embodiments, wherein the amorphous PHA comprises a copolymer of 3-hydroxybutyrate (3-HB) and 3-hydroxyoctanoate (3-HO), and a content of 3-HO is in a range from 25 to 45% with respect to a total amount of the amorphous PHA.
- [139] Embodiment 45. The biobased composition according to any one of the preceding embodiments, wherein the amorphous PHA comprises a copolymer of 3-hydroxybutyrate (3-HB) and 3-hydroxy valerate (3-HV), a content of 3-HV is in a range from 25 to 45% with respect to a total amount of the amorphous PHA.
- [140] Embodiment 46. The biobased composition according to any one of the preceding embodiments, wherein the amorphous PHA comprises a copolymer of 3-hydroxybutyrate (3-HB) and 4-hydroxyvalerate (4-HV), a content of 4-HV is in a range from 25 to 45% with respect to a total amount of the amorphous PHA.
- [141] Embodiment 47. The biobased composition according to any one of the preceding embodiments, wherein the amorphous PHA comprises a copolymer of 3-hydroxybutyrate (3-HB) and 5-hydroxyvalerate (5-HV), a content of 5-HV is in a range from 25 to 45% with respect to a total amount of the amorphous PHA.
- [142] Embodiment 48. The biobased composition according to any one of the preceding embodiments, wherein the amorphous PHA comprises a copolymer of 3-hydroxybutyrate (3-HB) and 6-hydroxyhexanoate (6-HH), a content of 6-HH is in a range from 25 to 45% with respect to a total amount of the amorphous PHA.

- [143] Embodiment 49. The biobased composition according to any one of the preceding embodiments, wherein the amorphous PHA comprises a copolymer including at least one selected from the group consisting of 4-hydroxybutyrate (4-HB), 3-hydroxypropionate (3-HP), 3-hydroxyhexanoate (3-HH), 3-hydroxyoctanoate (3-HO), 3-hydroxyvalerate (3-HV), 4-hydroxyvalerate (4-HV), 5-hydroxyvalerate (5-HV), and 6-hydroxyhexanoate (6-HH), wherein the at least one is at a concentration from 25 to 45 wt% with respect to a total amount of the amorphous PHA.
- [144] Embodiment 50. The biobased composition according to any one of the preceding embodiments, wherein the polylactide (PLA) is 100% biobased.
- [145] Embodiment 51. The biobased composition according to any one of the preceding embodiments, wherein the amorphous PHA is at least 75% biobased.
- [146] Embodiment 52. The biobased composition according to any one of the preceding embodiments, wherein the amorphous PHA is 100% biobased.
- [147] Embodiment 53. The biobased composition according to any one of the preceding embodiments, wherein the biobased composition excludes a plasticizer for increasing tensile elongation, impact strength or tear strength of a film comprising the biobased composition.
- [148] Embodiment 54. The biobased composition according to any one of the preceding embodiments, wherein the biobased composition includes the PLA less than 70 wt% with respect to a total weight of the biobased composition.
- [149] Embodiment 55. A film comprising the biobased composition of any one of the preceding embodiments.
- [150] Embodiment 56. The film according to embodiment 55, wherein the film has an impact strength of 500 to 200 kJ/m².
- [151] Embodiment 57. The film according to embodiments 55 or 56, wherein the film has a tear strength of 100 to 500 kN/m².
- [152] Embodiment 58. The film according to any one of embodiments 55 to 57, wherein the film is a monolayer.
- [153] Embodiment 59. The film according to any one of embodiments 55 to 58, wherein the film has multiple layers.
- [154] Embodiment 60. The film according to any one of embodiments 55 to 59, wherein the film comprises at least two layers, each of which includes the amorphous (PHA), the polyester, and the pore-forming agent.
- [155] Embodiment 61. The film according to any one of embodiments 55 to 60, wherein each and every layer in the biobased film includes the amorphous (PHA), the polyester, and the pore-forming agent.

- [156] Embodiment 62. The film according to any one of embodiments 55 to 61, wherein the biobased film comprises a machine-direction orientation (MDO) film.
- [157] Embodiment 63. The film according to any one of embodiments 55 to 62, wherein the biobased film is produced by a solid-state orientation of the biobased composition.
- [158] Embodiment 64. The film according to any one of embodiments 55 to 63, wherein the biobased film excludes a treatment layer disposed on a surface of the biobased film, wherein the treatment layer comprises a filler, calcium carbonate, or succinic anhydride.
- [159] Embodiment 65. The film according to any one of embodiments 55 to 64, wherein the biobased film is not a biaxially oriented film.
- [160] Embodiment 66. The film according to any one of embodiments 55 to 65, wherein the film is prepared by a blown film extrusion of the biobased composition.
- [161] Embodiment 67. The film according to any one of embodiments 55 to 66, wherein the film comprises a microporous film.
- [162] Embodiment 68. A product comprising the biobased composition according to any one of embodiments 1 to 54, wherein the product is produced by using a blown or cast film process followed by subsequent orientation in one or two directions.
- [163] Embodiment 69. The product according to embodiment 68, wherein the product has a density reduction of at least 10% relative to the non-porous un-oriented baseline film.
- [164] Embodiment 70. The product according to embodiments 68 or 69, wherein the product has a density reduction of at least 20% relative to the non-porous un-oriented baseline film.
- [165] Embodiment 71. The product according to any one of embodiments 68 to 70, wherein the product is produced by a blown film process that is subsequently stretched in one direction only (MDO).
- [166] Embodiment 72. The product according to any one of embodiments 68 to 71, wherein the product is produced by a cast film process that is subsequently stretched in one direction only (MDO).
- [167] Embodiment 73. The product according to any one of embodiments 68 to 72, wherein the product is produced by making a blown film that is subsequently stretched in two directions (MD & TD) either simultaneously or in sequence.
- [168] Embodiment 74. The product according to any one of embodiments 68 to 73, wherein the product is produced by making a cast film that is subsequently stretched in two directions (MD & TD) either simultaneously or in sequence.
- [169] Embodiment 75. A method of producing a stretched film, the method comprising stretching the biobased composition or the film of any one of the preceding embodiments in a stretch ratio of 10 or less to produce the stretched film.

- [170] Embodiment 76. The method according to embodiment 75, wherein the method further comprises, before the stretching, extruding by a blown film extrusion, injection molding, thermoforming the biobased composition.
- [171] Embodiment 77. The method according to embodiments 75 or 76, wherein the extruding comprises a cast film extrusion.
- [172] Embodiment 78. The method according to any one of embodiments 75 to 77, wherein the stretching is conducted in one direction only.
- [173] Embodiment 79. The method according to any one of embodiments 75 to 78, wherein the stretching is conducted at least in two directions comprising a machine direction (MD) and a traverse direction (TD) simultaneously or in sequence.
- [174] Embodiment 80. The product that is a blend of polylactide (PLA), a polyhydroxyalkanoate (PHA) copolymer, and a mineral.
- [175] Embodiment 81. The product of embodiment 80, wherein ultimate crystallinity of the PHA is less than 5%.
- [176] Embodiment 82. The product of embodiment 80, where the mineral can be calcium carbonate or talc or wallstonite or other.
- [177] Embodiment 83. The product of embodiment 80 that is at least 75% biobased (according to ASTM D6866).
- [178] Embodiment 84. The product of embodiment 80, where the PHA is a co-polymer of 3-hydroxybutanoic acid, and one selected from the group of 4-hydroxybutanoic acid, 3-hydroxypropionic acid, 3-hydroxyhexanoate, 3-hydroxyoctanoate, and 3-hydroxyvalerate.
- [179]
- [180] **Additional Exemplary Embodiments**
- [181] Embodiment 1. A microporous film that is 100% biobased (according to ASTM D6866) and is compostable under industrial compost conditions (as defined by ASTM D6400).
- [182] Embodiment 2. A product (microporous film) of embodiment 1 with a density reduction of at least 10% relative to the non-porous baseline achieved through a solid-state orientation process.
- [183] Embodiment 3. The product of embodiment 1 with a density reduction of at least 20% relative to the non-porous baseline achieved through a solid-state orientation process.
- [184] Embodiment 4. The product of embodiment 1 produced by using a compounded blend of compostable polymers.
- [185] Embodiment 5. The product of embodiment 1 produced by using a compounded blend of compostable polymers along with some mineral blended into the formulated product.

- [186] Embodiment 6. The product of embodiment 5, where the mineral can be calcium carbonate or talc or wallstonite or other.
- [187] Embodiment 7. The product of embodiment 1 that is a blend of polylactide (PLA) and a polyhydroxyalkanoate (PHA) copolymer, where ultimate crystallinity of the PHA is less than 5%.
- [188] Embodiment 8. The product of embodiment 1 that is a blend of polylactide (PLA), a polyhydroxyalkanoate (PHA) copolymer, and a mineral (any of the mineral choices mentioned in embodiment 6).
- [189] Embodiment 9. The product of embodiment 1 that is home compostable.
- [190] Embodiment 10. The product of embodiment 1 that displays a higher impact toughness relative to the non-porous control film.
- [191] Embodiment 11. The product of embodiment 1 that is composed of multiple layers.
- [192] Embodiment 12. The product of embodiment 1 that is at least 75% biobased (according to ASTM D6866).
- [193] Embodiment 13. The product of embodiment 1, achieved by making a blown film that is subsequently stretched in one direction only (MDO).
- [194] Embodiment 14. The product of embodiment 1 achieved by making a cast film that is subsequently stretched in one direction only (MDO).
- [195] Embodiment 15. The product of embodiment 1 achieved by making a cast film that is subsequently stretched in two directions (MD & TD) either simultaneously or in sequence.
- [196] Embodiment 16. The product of embodiment 1 where the amorphous PHA is a copolymer of -3HB and -4HB with -4HB content in the 25-45% range.
- [197] Embodiment 17. A composition of embodiment 1, where the amorphous PHA has a crystallinity of less than 5% by weight.
- [198] Embodiment 18. The composition of embodiment 1, where the amorphous PHA has a crystallinity of less than 5% by weight and is a copolymer of 3-hydroxybutanoic acid and 4-hydroxybutanoic acid.
- [199] Embodiment 19. The composition of embodiment 1, where the amorphous PHA has a crystallinity of less than 5% by weight and is a copolymer of 3-hydroxybutanoic acid and 3-hydroxypropionic acid.
- [200] Embodiment 20. The composition of embodiment 1, where the amorphous PHA has a crystallinity of less than 5% by weight and is a copolymer of 3-hydroxybutanoic acid and 3-hydroxyhexanoate.
- [201] Embodiment 21. The composition of embodiment 1, where the amorphous PHA has a crystallinity of less than 5% by weight and is a copolymer of 3-hydroxybutanoic acid and 3-hydroxyoctanoate.

[202] Embodiment 22. The composition of embodiment 1, where the amorphous PHA has a crystallinity of less than 5% by weight and is a copolymer of 3-hydroxybutanoic acid and 3-hydroxyvalerate.

Claims

- [Claim 1] A biobased composition comprising an amorphous polyhydroxyalkanoate (PHA), a polyester, and a pore-forming agent.
- [Claim 2] The biobased composition according to claim 1, wherein a puncture toughness of the biobased composition decreases by 10% or less, stays the same, or increases upon reduction of a density of the biobased composition at least by 5%.
- [Claim 3] The biobased composition according to claim 2, wherein the density is decreased by stretching in a machine direction orientation (MDO) by a stretch ratio of 0.5X or more.
- [Claim 4] The biobased composition according to claim 2, wherein the puncture toughness of the biobased composition decreases by 10% or less.
- [Claim 5] The biobased composition according to claim 2, wherein the puncture toughness of the biobased composition stays the same.
- [Claim 6] The biobased composition according to claim 2, wherein the puncture toughness of the biobased composition increases.
- [Claim 7] The biobased composition according to claim 2, wherein the puncture toughness of the biobased composition increases at least by 10%.
- [Claim 8] The biobased composition according to claim 2, wherein the puncture toughness of the biobased composition increases at least by 60%.
- [Claim 9] The biobased composition according to any one of the preceding claims 1 to 8, wherein a puncture toughness of the biobased composition decreases by 10% or less, stays the same, or increases upon reduction of a density of the biobased composition at least by 10%.
- [Claim 10] The biobased composition according to claim 9, wherein the density is decreased by stretching in a machine direction orientation (MDO) by a stretch ratio of 2.5 or more.
- [Claim 11] The biobased composition according to any one of the preceding claims 1 to 10, wherein a puncture toughness of the biobased composition decreases by 10% or less, stays the same, or increases upon reduction of a density of the biobased composition at least by 15%.

- [Claim 12] The biobased composition according to claim 10, the density is decreased by stretching in a machine direction orientation (MDO) by a stretch ratio of 3.0 or more.
- [Claim 13] The biobased composition according to any one of the preceding claims 1 to 12, wherein the biobased composition is in a form of film.
- [Claim 14] The biobased composition according to any one of the preceding claims 1 to 13, wherein the biobased composition is in a form of a film having a thickness of $1\mu\text{m}$ to $400\mu\text{m}$ or $15\mu\text{m}$ to $100\mu\text{m}$.
- [Claim 15] The biobased composition according to any one of the preceding claims 1 to 14, wherein a puncture toughness of the biobased composition measured by spencer impact test decreases by 10% or less, stays the same, or increases upon reduction of a density of the biobased composition at least by 5%.
- [Claim 16] The biobased composition according to any one of the preceding claims 1 to 15, wherein a puncture toughness of the biobased composition measured by ASTM D3420 decreases by 10% or less, stays the same, or increases upon reduction of a density of the biobased composition at least by 5%.
- [Claim 17] The biobased composition according to any one of the preceding claims 1 to 16, wherein a biobased carbon content of the biobased composition as measured according to ASTM D6866 is at least 75%.
- [Claim 18] The biobased composition according to any one of the preceding claims 1 to 17, wherein a biobased carbon content of the biobased composition as measured according to ASTM D6866 is 100%.
- [Claim 19] The biobased composition according to any one of the preceding claims 1 to 18, wherein the biobased composition satisfies a compostability test according to ASTM D6400.
- [Claim 20] The biobased composition according to any one of the preceding claims 1 to 19, wherein the pore-forming agent comprises a mineral.
- [Claim 21] The biobased composition according to any one of the preceding claims 1 to 20, wherein the pore-forming agent comprises organic or inorganic particles.
- [Claim 22] The biobased composition according to any one of the preceding claims 1 to 21, wherein the pore-forming agent comprises organic

or inorganic particles having particle diameters in a range from $0.1\mu\text{m}$ to $20\mu\text{m}$, or $1\mu\text{m}$ to $5\mu\text{m}$.

- [Claim 23] The biobased composition according to any one of the preceding claims 1 to 22, wherein the pore-forming agent comprises at least one selected from the group consisting of calcium carbonate (CaCO_3), talc, wallstonite (CaSiO_3), aluminum oxide (Al_2O_3), and combinations thereof.
- [Claim 24] The biobased composition according to any one of the preceding claims 1 to 23, wherein the biobased composition has the pore-forming agent at an amount from 1 to 50 wt% or from 5 to 30 wt%.
- [Claim 25] The biobased composition according to any one of the preceding claims 1 to 24, wherein the polyester comprises polylactide (PLA).
- [Claim 26] The biobased composition according to any one of the preceding claims 1 to 25, wherein the polyester comprises a polylactic resin having a lactic acid component.
- [Claim 27] The biobased composition according to any one of the preceding claims 1 to 26, wherein the polyester comprises a polylactic resin including L-lactic acid and/or D-lactic acid.
- [Claim 28] The biobased composition according to any one of the preceding claims 1 to 27, wherein the polyester comprises a polylactic resin including other than a polylactic resin.
- [Claim 29] The biobased composition according to any one of the preceding claims 1 to 28, wherein the composition has the polylactide (PLA) at an amount from 55 to 99 wt%.
- [Claim 30] The biobased composition according to any one of the preceding claims 1 to 29, wherein the composition has the amorphous PHA in an amount from 1 to 45 wt%.
- [Claim 31] The biobased composition according to any one of the preceding claims 1 to 30, wherein the amorphous PHA has a crystallinity of less than 5% by weight.
- [Claim 32] The biobased composition according to any one of the preceding claims 1 to 31, wherein the amorphous PHA comprises a copolymer including 3-hydroxybutyrate (3-HB).
- [Claim 33] The biobased composition according to any one of the preceding claims 1 to 32, wherein the amorphous PHA comprises a copolymer including 4-hydroxybutyrate (4-HB).

- [Claim 34] The biobased composition according to any one of the preceding claims 1 to 33, wherein the amorphous PHA comprises a copolymer including 3-hydroxypropionate (3-HP).
- [Claim 35] The biobased composition according to any one of the preceding claims 1 to 34, wherein the amorphous PHA comprises a copolymer including 3-hydroxyhexanoate (3-HH).
- [Claim 36] The biobased composition according to any one of the preceding claims 1 to 35, wherein the amorphous PHA comprises a copolymer including 3-hydroxyoctanoate (3-HO).
- [Claim 37] The biobased composition according to any one of the preceding claims 1 to 36, wherein the amorphous PHA comprises a copolymer including 3-hydroxy valerate (3-HV).
- [Claim 38] The biobased composition according to any one of the preceding claims 1 to 37, wherein the amorphous PHA comprises a copolymer including 4-hydroxyvalerate (4-HV).
- [Claim 39] The biobased composition according to any one of the preceding claims 1 to 38, wherein the amorphous PHA comprises a copolymer including 5-hydroxyvalerate (5-HV).
- [Claim 40] The biobased composition according to any one of the preceding claims 1 to 39, wherein the amorphous PHA comprises a copolymer including 6-hydroxyhexanoate (6-HH).
- [Claim 41] The biobased composition according to any one of the preceding claims 1 to 40, wherein the amorphous PHA comprises a copolymer of 3-hydroxybutyrate (3-HB) and 4-hydroxybutyrate (4-HB), and a content of 4-HB is in a range from 25 to 45% with respect to a total amount of the amorphous PHA.
- [Claim 42] The biobased composition according to any one of the preceding claims 1 to 41, wherein the amorphous PHA comprises a copolymer of 3-hydroxybutyrate (3-HB) and 3-hydroxypropionate (3-HP), and a content of 3-HP is in a range from 25 to 45% with respect to a total amount of the amorphous PHA.
- [Claim 43] The biobased composition according to any one of the preceding claims 1 to 42, wherein the amorphous PHA comprises a copolymer of 3-hydroxybutyrate (3-HB) and 3-hydroxyhexanoate (3-HH), and a content of 3-HH is in a range from 25 to 45% with respect to a total amount of the amorphous PHA.
- [Claim 44] The biobased composition according to any one of the preceding claims 1 to 43, wherein the amorphous PHA comprises a

- copolymer of 3-hydroxybutyrate (3-HB) and 3-hydroxyoctanoate (3-HO), and a content of 3-HO is in a range from 25 to 45% with respect to a total amount of the amorphous PHA.
- [Claim 45] The biobased composition according to any one of the preceding claims 1 to 44, wherein the amorphous PHA comprises a copolymer of 3-hydroxybutyrate (3-HB) and 3-hydroxy valerate (3-HV), a content of 3-HV is in a range from 25 to 45% with respect to a total amount of the amorphous PHA.
- [Claim 46] The biobased composition according to any one of the preceding claims 1 to 45, wherein the amorphous PHA comprises a copolymer of 3-hydroxybutyrate (3-HB) and 4-hydroxyvalerate (4-HV), a content of 4-HV is in a range from 25 to 45% with respect to a total amount of the amorphous PHA.
- [Claim 47] The biobased composition according to any one of the preceding claims 1 to 46, wherein the amorphous PHA comprises a copolymer of 3-hydroxybutyrate (3-HB) and 5-hydroxyvalerate (5-HV), a content of 5-HV is in a range from 25 to 45% with respect to a total amount of the amorphous PHA.
- [Claim 48] The biobased composition according to any one of the preceding claims 1 to 47, wherein the amorphous PHA comprises a copolymer of 3-hydroxybutyrate (3-HB) and 6-hydroxyhexanoate (6-HH), a content of 6-HH is in a range from 25 to 45% with respect to a total amount of the amorphous PHA.
- [Claim 49] The biobased composition according to any one of the preceding claims 1 to 48, wherein the amorphous PHA comprises a copolymer including at least one selected from the group consisting of 4-hydroxybutyrate (4-HB), 3-hydroxypropionate (3-HP), 3-hydroxyhexanoate (3-HH), 3-hydroxyoctanoate (3-HO), 3-hydroxyvalerate (3-HV), 4-hydroxyvalerate (4-HV), 5-hydroxyvalerate (5-HV), and 6-hydroxyhexanoate (6-HH), wherein the at least one is at a concentration from 25 to 45 wt% with respect to a total amount of the amorphous PHA.
- [Claim 50] The biobased composition according to any one of the preceding claims 1 to 49, wherein the polylactide (PLA) is 100% biobased.
- [Claim 51] The biobased composition according to any one of the preceding claims 1 to 50, wherein the amorphous PHA is at least 75% biobased.

- [Claim 52] The biobased composition according to any one of the preceding claims 1 to 51, wherein the amorphous PHA is 100% biobased.
- [Claim 53] The biobased composition according to any one of the preceding claims 1 to 52, wherein the biobased composition excludes a plasticizer for increasing tensile elongation, impact strength or tear strength of a film comprising the biobased composition.
- [Claim 54] The biobased composition according to any one of the preceding claims 1 to 53, wherein the biobased composition includes the PLA less than 70 wt% with respect to a total weight of the biobased composition.
- [Claim 55] A film comprising the biobased composition of any one of the preceding claims 1 to 54.
- [Claim 56] The film according to claim 55, wherein the film has an impact strength of 500 to 200 kJ/m².
- [Claim 57] The film according to claims 55 or 56, wherein the film has a tear strength of 100 to 500 kN/m².
- [Claim 58] The film according to any one of claims 55 to 57, wherein the film is a monolayer.
- [Claim 59] The film according to any one of claims 55 to 58, wherein the film has multiple layers.
- [Claim 60] The film according to any one of claims 55 to 59, wherein the film comprises at least two layers, each of which includes the amorphous (PHA), the polyester, and the pore-forming agent.
- [Claim 61] The film according to any one of claims 55 to 60, wherein each and every layer in the biobased film includes the amorphous (PHA), the polyester, and the pore-forming agent.
- [Claim 62] The film according to any one of claims 55 to 61, wherein the biobased film comprises a machine-direction orientation (MDO) film.
- [Claim 63] The film according to any one of claims 55 to 62, wherein the biobased film is produced by a solid-state orientation of the biobased composition.
- [Claim 64] The film according to any one of claims 55 to 63, wherein the biobased film excludes a treatment layer disposed on a surface of the biobased film, wherein the treatment layer comprises a filler, calcium carbonate, or succinic anhydride.

- [Claim 65] The film according to any one of claims 55 to 64, wherein the biobased film is not a biaxially oriented film.
- [Claim 66] The film according to any one of claims 55 to 65, wherein the film is prepared by a blown film extrusion of the biobased composition.
- [Claim 67] The film according to any one of claims 55 to 66, wherein the film comprises a microporous film.
- [Claim 68] A product comprising the biobased composition according to any one of claims 1 to 54, wherein the product is produced by using a blown or cast film process followed by subsequent orientation in one or two directions.
- [Claim 69] The product according to claim 68, wherein the product has a density reduction of at least 10% relative to the non-porous un-oriented baseline film.
- [Claim 70] The product according to claims 68 or 69, wherein the product has a density reduction of at least 20% relative to the non-porous un-oriented baseline film.
- [Claim 71] The product according to any one of claims 68 to 70, wherein the product is produced by a blown film process that is subsequently stretched in one direction only (MDO).
- [Claim 72] The product according to any one of claims 68 to 71, wherein the product is produced by a cast film process that is subsequently stretched in one direction only (MDO).
- [Claim 73] The product according to any one of claims 68 to 72, wherein the product is produced by making a blown film that is subsequently stretched in two directions (MD & TD) either simultaneously or in sequence.
- [Claim 74] The product according to any one of claims 68 to 73, wherein the product is produced by making a cast film that is subsequently stretched in two directions (MD & TD) either simultaneously or in sequence.
- [Claim 75] A method of producing a stretched film, the method comprising stretching the biobased composition or the film of any one of the preceding claims 1 to 67 in a stretch ratio of 10 or less to produce the stretched film.
- [Claim 76] The method according to claim 75, wherein the method further comprises, before the stretching, extruding by a blown film

- extrusion, injection molding, thermoforming the biobased composition.
- [Claim 77] The method according to claims 75 or 76, wherein the extruding comprises a cast film extrusion.
- [Claim 78] The method according to any one of claims 75 to 77, wherein the stretching is conducted in one direction only.
- [Claim 79] The method according to any one of claims 75 to 78, wherein the stretching is conducted at least in two directions comprising a machine direction (MD) and a traverse direction (TD) simultaneously or in sequence.
- [Claim 80] The product that is a blend of polylactide (PLA), a polyhydroxyalkanoate (PHA) copolymer, and a mineral.
- [Claim 81] The product of claim 80, wherein ultimate crystallinity of the PHA is less than 5%.
- [Claim 82] The product of claim 80, where the mineral can be calcium carbonate or talc or wallstonite or other.
- [Claim 83] The product of claim 80 that is at least 75% biobased (according to ASTM D6866).
- [Claim 84] The product of claim 80, where the PHA is a co-polymer of 3-hydroxybutanoic acid, and one selected from the group of 4-hydroxybutanoic acid, 3-hydroxypropionic acid, 3-hydroxyhexanoate, 3-hydroxyoctanoate, and 3-hydroxyvalerate.