SUMMARY

The present disclosure provides a process for enriching the enantiomeric purity of lactic acid obtained, for example, from lactic acid fermentation of organic waste and/or PLA waste chemical recycling. The present disclosure further provides a process for obtaining L-lactate salt with enriched enantiomeric purity.

The present disclosure is based, in part, on the unexpected finding that the enantiomeric purity of L-lactic acid can be enhanced by selective precipitation of L-lactate salt from an enantiomeric mixture containing D- and L-lactic acid. The present disclosure therefore enables the recycling of waste from various sources including waste that contains endogenous D-lactic acid monomers while obviating the need for D-lactic acid-utilizing bacteria or enzymes to eliminate D-lactic acid. The present disclosure advantageously produces L-lactate salt in enantiomeric purity of over 98% which can be used for the commercial production of PLA with no additional processing for isomer separation.

Disclosed herein for the first time is the selective precipitation of L-lactate salt from an enantiomeric mixture of D- and L- lactic acid originated from organic waste. The selective precipitation results in enrichment in L-lactic acid/lactate monomers for subsequent use.

The present disclosure provides a process for enriching L-lactic acid enantiomer or salt thereof, the process comprising the steps of:

(a) obtaining decomposed organic waste comprising an enantiomeric mixture of D- and L-lactic acid at a concentration of about 100 to about 1,100 g/L, wherein the enantiomeric mixture comprises 10% D-lactic acid or less;

(b) contacting the enantiomeric mixture with an alkaline substance comprising divalent cations in an amount of about 50 to about 120 equivalent % based on the number of carboxyl groups present in the enantiomeric mixture; and

(c) precipitating L-lactate salt with said divalent cations thereby obtaining L-lactate salt with enriched enantiomeric purity as compared to the initial enantiomeric mixture,

wherein step (b) and/or (c) are performed at a temperature in the range of about 40°C to about 100°C, including each value within the specified ranges.

The present disclosure provides a process for producing

enantiomerically enriched L-lactate salt, the process comprising the steps of:

(a) obtaining decomposed organic waste comprising an enantiomeric mixture of D- and L-lactic acid at a concentration of about 100 to about 1,100 g/L, wherein the enantiomeric mixture comprises 10% D-lactic acid or less;

(b) contacting the enantiomeric mixture with an alkaline substance comprising divalent cations in an amount of about 50 to about 120 equivalent % based on the number of carboxyl groups present in the enantiomeric mixture; and

(c) precipitating L-lactate salt with said divalent cations thereby obtaining L-lactate salt with enriched enantiomeric purity as compared to the initial enantiomeric mixture,

wherein step (b) and/or (c) are performed at a temperature in the range of about 40°C to about 100°C, including each value within the specified ranges.

In one aspect, the present disclosure provides a process for enriching L-lactic acid enantiomer or salt thereof or for producing enantiomerically enriched L-lactate salt, the process comprising the steps of:

(a) obtaining decomposed organic waste comprising an enantiomeric mixture of D- and L-lactic acid at a concentration of about 100 to about 1,100 g/L, wherein the enantiomeric mixture comprises 10% D-lactic acid or less;

(b) contacting the enantiomeric mixture with an alkaline substance comprising divalent cations in an amount of about 50 to about 120 equivalent % based on the number of carboxyl groups present in the enantiomeric mixture; and

(c) precipitating L-lactate salt with said divalent cations thereby obtaining L-lactate salt with enriched enantiomeric purity as compared to the initial enantiomeric mixture,

wherein step (b) and/or (c) are performed at a temperature in the range of about 40°C to about 100°C.

In some examples, the enantiomeric mixture comprises 9% D-lactic acid or less. In other examples, the enantiomeric mixture comprises 8% D-lactic acid or less. In yet other examples, the enantiomeric mixture comprises 7% D-lactic acid or less. In additional examples, the enantiomeric mixture comprises 6% D-lactic acid or less. In further examples, the enantiomeric mixture comprises 5% D-lactic acid or less. In various examples, the enantiomeric mixture comprises 4% D-lactic acid or less. In particular examples, the enantiomeric mixture comprises 3% D-lactic acid or less. In certain examples, the enantiomeric mixture comprises 3% D-lactic acid or more. In several examples, the enantiomeric mixture comprises 4% D-lactic acid or more. In exemplary examples, the enantiomeric mixture comprises 5% D-lactic acid or more.

In additional examples, step (b) and/or (c) are performed at a temperature in the range of about 45°C to about 100°C, including each value within the specified range. In other examples, step (b) and/or (c) are performed at a temperature in the range of about 50°C to about 100°C, including each value within the specified range.

The present disclosure provides a process for enriching L-lactic acid enantiomer or salt thereof, the process comprising the steps of:

(a) obtaining decomposed organic waste comprising an enantiomeric mixture of D- and L-lactic acid at a concentration of about 100 to about 1,100 g/L, wherein the enantiomeric mixture comprises 6% D-lactic acid or less;

(b) contacting the enantiomeric mixture with an alkaline substance comprising

divalent cations; and

(c) precipitating L-lactate salt with said divalent cations thereby obtaining L-lactate salt with enriched enantiomeric purity as compared to the initial enantiomeric mixture,

wherein step (b) and/or (c) are performed at a temperature in the range of about 50°C to about 100°C, including each value within the specified ranges.

The present disclosure provides a process for producing enantiomerically enriched L-lactate salt, the process comprising the steps of:

(a) obtaining decomposed organic waste comprising an enantiomeric mixture of D- and L-lactic acid at a concentration of about 100 to about 1,100 g/L, wherein the enantiomeric mixture comprises 6% D-lactic acid or less;

(b) contacting the enantiomeric mixture with an alkaline substance comprising divalent cations; and

(c) precipitating L-lactate salt with said divalent cations thereby obtaining L-lactate salt with enriched enantiomeric purity as compared to the initial enantiomeric mixture,

wherein step (b) and/or (c) are performed at a temperature in the range of about 50°C to about 100°C, including each value within the specified ranges.

In another aspect, the present disclosure provides a process for enriching L-lactic acid enantiomer or salt thereof or for producing enantiomerically enriched L-lactate salt, the process comprising the steps of:

(a) obtaining decomposed organic waste comprising an enantiomeric mixture of D- and L-lactic acid at a concentration of about 100 to about 1,100 g/L, wherein the enantiomeric mixture comprises 6% D-lactic acid or less;

(b) contacting the enantiomeric mixture with an alkaline substance comprising divalent cations; and

(c) precipitating L-lactate salt with said divalent cations thereby obtaining L-lactate salt with enriched enantiomeric purity as compared to the initial enantiomeric mixture,

wherein step (b) and/or (c) are performed at a temperature in the range of about 50°C to about 100°C.

In various examples, the processes disclosed herein provide enrichment of L-lactic acid enantiomer or salt thereof by 1% or more. In another example, the processes provide enrichment of L-lactic acid enantiomer or salt thereof by 5% or more. In yet another example, the processes provide enrichment of L-lactic acid enantiomer or salt thereof by 10% or more. In particular examples, the processes provide enrichment of L-lactic acid enantiomer or salt thereof of up to 10%. In other examples, the processes provide reduction in D-lactic acid enantiomer or salt thereof of 10% or more. In yet other examples, the processes provide reduction of D-lactic acid enantiomer or salt thereof of 20% or more. In additional examples, the processes provide reduction of D-lactic acid enantiomer or salt thereof of 30% or more. In certain examples, the processes provide reduction of D-lactic acid enantiomer or salt thereof of 40% or more. In additional examples, the processes provide reduction of D-lactic acid enantiomer or salt thereof of 50% or more. In further examples, the processes provide reduction of D-lactic acid enantiomer or salt thereof of 60% or more. In

exemplary examples, the processes provide reduction of D-lactic acid enantiomer or salt thereof of 70% or more. In particular examples, the processes provide reduction of D-lactic acid enantiomer or salt thereof of 80% or more. In several examples, the processes provide reduction of D-lactic acid enantiomer or salt thereof of 90% or more. In specific examples, the processes provide reduction of D-lactic acid enantiomer or salt thereof of up to 95%.

In one example, the decomposed organic waste comprises lactic acid derived from a low-pH lactic acid fermentation process.

In certain examples, the organic waste comprises a carbohydrate source. In other examples, the organic waste is selected from food waste, municipal food waste, residential food waste, agricultural waste, industrial food waste from food and beverages processing facilities, commercial food waste (from hospitals, restaurants, shopping centers, airports etc.), and a mixture or combination thereof. Each possibility represents a separate example.

In further examples, the decomposed organic waste is pre-treated prior to step (a). In particular examples, pretreatment comprises removal of non-lactic acid-containing impurities.

In additional examples, the low-pH lactic acid fermentation process is performed at a pH of about 2 to about 5.5, including each value within the specified range.

In one example, the decomposed organic waste comprises lactic acid derived from decomposition of polylactic acid in an acidic medium.

In certain examples, decomposition of polylactic acid in an acidic medium comprises the hydrolysis of polylactic acid in the presence of an acid selected from the group consisting of hydrochloric acid, hydrobromic acid, nitric acid, sulfuric acid, phosphoric acid, and combinations thereof. Each possibility represents a separate example.

In further examples, the decomposed organic waste comprises lactic acid by-product that is derived from an industrial production of polylactic acid. In other examples, the decomposed organic waste comprises lactic acid by-product that is derived from industrial purification of lactic acid. In yet other examples, the decomposed organic waste comprises lactic acid obtained from hydrolyzing lactide by-product from an industrial production of polylactic acid.

In some examples, the alkaline substance comprising divalent cations comprises a hydroxide. In another example, the alkaline substance comprising divalent cations is selected from the group consisting of magnesium hydroxide, calcium hydroxide, and a mixture thereof. Each possibility represents a separate example. In one example, the alkaline substance comprising divalent cations is magnesium hydroxide. In further examples, the alkaline substance comprising divalent cations comprises a carbonate or a bicarbonate. Each possibility represents a separate example. In further examples, the alkaline substance comprising divalent cations is selected from the group consisting of magnesium bicarbonate, magnesium carbonate, calcium bicarbonate, calcium carbonate, and a mixture thereof. Each possibility represents a separate example.

In certain examples, the alkaline substance is added in solid form. In alternative examples, the alkaline substance is added as an aqueous solution or suspension. In further examples, the alkaline substance is gradually added. In other examples, the alkaline substance is added as an aqueous solution at a concentration of about 50 to about 500 g/L, including each value within the specified range.

In various examples, step (b) and/or (c) are performed at a temperature in the range of about 55°C to about 100°C, including each value within the specified range. In exemplary examples, step (b) and/or (c) are performed at a temperature in the range of about 60°C to about 100°C, including each value within the specified range. In particular examples, step (b) and/or (c) are performed at a temperature in the range of about 70°C to about 100°C, including each value within the specified range. In yet additional examples, step (b) and/or (c) are performed at a temperature in the range of about 80°C to about 100°C, including each value within the specified range.

In further examples, step (b) and/or (c) are performed at a pressure of about 100 to about 1,000 mbar, including each value within the specified range. In other examples, step (b) and/or (c) are performed at a mixing speed of about 200 to about 1,000 rounds per minute (RPM), including each value within the specified range.

In some examples, precipitation of L-lactate salt in step (c) is performed in a period of time ranging from 10 minutes to 1 day, including each value within the specified range. In additional examples, precipitation of L-lactate salt in step (c) is performed in a period of time ranging from 1 hour to 1 day, including each value within the specified

range.

In further examples, precipitation of L-lactate salt in step (c) is performed at a pH range of about 3 to about 10, including each value within the specified range. In specific examples, precipitation of L-lactate salt in step (c) is performed at a pH range of about 4 to about 9, including each value within the specified range. In some examples, precipitation of L-lactate salt in step (c) is performed at a pH range of about 5 to about 8, including each value within the specified range. In further examples, precipitation of L-lactate salt in step (c) is performed at a pH range of about 6 to about 7, including each value within the specified range.

In other examples, the obtained L-lactate salt is separated by filtration or centrifugation. In further examples, the obtained L-lactate salt is subjected to subsequent purification. In other examples, subsequent purification comprises at least one of crystallization, recrystallization, partitioning, silica gel chromatography, preparative HPLC, and combinations thereof. Each possibility represents a separate example.

In particular examples, subsequent purification comprises washing the obtained L-lactate salt, for example using purified water. In other examples, subsequent purification comprises dissolving and recrystallizing the obtained L-lactate salt.

In one example, the obtained L-lactate salt comprises less than 6% D-lactate. In another example, the obtained L-lactate salt comprises less than 5% D-lactate. In another example, the obtained L-lactate salt comprises less than 4% D-lactate. In another example, the obtained L-lactate salt comprises less than 3% D-lactate. In another example, the obtained L-lactate salt comprises less than 2% D-lactate. In another example, the obtained L-lactate salt comprises less than 1.5% D-lactate. In specific examples, the obtained L-lactate salt comprises less than 1% D-lactate.

In further examples, the obtained L-lactate salt is a crystalline L-lactate salt.

In other examples, the obtained L-lactate salt is acidified to form L-lactic acid by at least one of hydrochloric acid, hydrobromic acid, nitric acid, sulfuric acid, phosphoric acid, and combinations thereof. Each possibility represents a separate example. In particular examples, the L-lactic acid is used for subsequent polylactic acid formation.

Other objects, features and advantages of the present disclosure will become clear

CLAIMS

1. A process for enriching L-lactic acid enantiomer or salt thereof or for producing enantiomerically enriched L-lactate salt, the process comprising the steps of:
   (a) obtaining decomposed organic waste comprising an enantiomeric mixture of D- and L-lactic acid at a concentration of about 100 to about 1,100 g/L, wherein the enantiomeric mixture comprises 10% D-lactic acid or less;
   (b) contacting the enantiomeric mixture with an alkaline substance comprising divalent cations in an amount of about 50 to about 120 equivalent % based on the number of carboxyl groups present in the enantiomeric mixture; and
   (c) precipitating L-lactate salt with said divalent cations thereby obtaining L-lactate salt with enriched enantiomeric purity as compared to the initial enantiomeric mixture,

   wherein step (b) and/or (c) are performed at a temperature in the range of about 40°C to about 100°C.

2. The process of claim 1 comprising enrichment of L-lactic acid enantiomer or salt thereof by 5% or more, or comprising enrichment of L-lactic acid enantiomer or salt thereof of up to 10%.

3. The process of any one of claims 1 to 2, wherein the decomposed organic waste comprises lactic acid derived from a low-pH lactic acid fermentation process; or wherein the decomposed organic waste comprises lactic acid derived from decomposition of polylactic acid in an acidic medium; or wherein the decomposed organic waste comprises lactic acid by-product that is derived from an industrial production of polylactic acid; or wherein the decomposed organic waste comprises lactic acid by-product that is derived from industrial purification of lactic acid; or wherein the decomposed organic waste comprises lactic acid obtained from hydrolyzing lactide by-product from an industrial production of polylactic acid.

4. The process of any one of claims 1 to 3, wherein the alkaline substance comprises a hydroxide selected from the group consisting of magnesium

hydroxide, calcium hydroxide, and a mixture thereof; or wherein the alkaline substance comprises a carbonate or a bicarbonate selected from the group consisting of magnesium bicarbonate, magnesium carbonate, calcium bicarbonate, calcium carbonate, and a mixture thereof.

5. The process of any one of claims 1 to 4, wherein the alkaline substance is added in solid form; or wherein the alkaline substance is added as an aqueous solution or suspension, preferably wherein the alkaline substance is added as an aqueous solution at a concentration of about 50 to about 500 g/L.

6. The process of any one of claims 1 to 5, wherein step (b) and/or (c) are performed at a pressure of about 100 to about 1,000 mbar; or wherein step (b) and/or (c) are performed at a mixing speed of about 200 to about 1,000 rounds per minute (RPM).

7. The process of any one of claims 1 to 6, wherein the obtained L-lactate salt is separated by filtration or centrifugation; and/or wherein the obtained L-lactate salt is subjected to subsequent purification, preferably wherein subsequent purification comprises at least one of crystallization, recrystallization, partitioning, silica gel chromatography, and preparative HPLC, or wherein subsequent purification comprises washing the obtained L-lactate salt with purified water.

8. The process of any one of claims 1 to 7, wherein the obtained L-lactate salt comprises less than 6% D-lactate; and/or wherein the obtained L-lactate salt is acidified to form L-lactic acid by at least one of hydrochloric acid, hydrobromic acid, nitric acid, phosphoric acid, sulfuric acid, and combinations thereof and used for subsequent polylactic acid formation.

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9. A process for enriching L-lactic acid enantiomer or salt thereof or for producing enantiomerically enriched L-lactate salt, the process comprising the steps of:

(a) obtaining decomposed organic waste comprising an enantiomeric mixture of

D- and L-lactic acid at a concentration of about 100 to about 1,100 g/L, wherein the enantiomeric mixture comprises 6% D-lactic acid or less;

(b) contacting the enantiomeric mixture with an alkaline substance comprising divalent cations; and

(c) precipitating L-lactate salt with said divalent cations thereby obtaining L-lactate salt with enriched enantiomeric purity as compared to the initial enantiomeric mixture,

wherein step (b) and/or (c) are performed at a temperature in the range of about 50°C to about 100°C.

10. The process of claim 9 comprising enrichment of L-lactic acid enantiomer or salt thereof by 5% or more, or comprising enrichment of L-lactic acid enantiomer or salt thereof of up to 10%.

11. The process of any one of claims 9 to 10, wherein the decomposed organic waste comprises lactic acid derived from a low-pH lactic acid fermentation process; or wherein the decomposed organic waste comprises lactic acid derived from decomposition of polylactic acid in an acidic medium; or wherein the decomposed organic waste comprises lactic acid by-product that is derived from an industrial production of polylactic acid; or wherein the decomposed organic waste comprises lactic acid by-product that is derived from industrial purification of lactic acid; or wherein the decomposed organic waste comprises lactic acid obtained from hydrolyzing lactide by-product from an industrial production of polylactic acid.

12. The process of any one of claims 9 to 11, wherein the alkaline substance comprises a hydroxide selected from the group consisting of magnesium hydroxide, calcium hydroxide, and a mixture thereof; or wherein the alkaline substance comprises a carbonate or a bicarbonate selected from the group consisting of magnesium bicarbonate, magnesium carbonate, calcium bicarbonate, calcium carbonate, and a mixture thereof.

13. The process of any one of claims 9 to 12, wherein the alkaline substance is added in solid form; or wherein the alkaline substance is added as an aqueous solution or suspension, preferably wherein the alkaline substance is added as an aqueous solution at a concentration of about 50 to about 500 g/L.

14. The process of any one of claims 9 to 13, wherein step (b) and/or (c) are performed at a pressure of about 100 to about 1,000 mbar, or wherein step (b) and/or (c) are performed at a mixing speed of about 200 to about 1,000 rounds per minute (RPM).

15. The process of any one of claims 9 to 14, wherein the obtained L-lactate salt is separated by filtration or centrifugation; or wherein the obtained L-lactate salt is subjected to subsequent purification, preferably wherein subsequent purification comprises at least one of crystallization, recrystallization, partitioning, silica gel chromatography, and preparative HPLC, or wherein subsequent purification comprises washing the obtained L-lactate salt with purified water.

16. The process of any one of claims 9 to 15, wherein the obtained L-lactate salt comprises less than 3% D-lactate; and/or wherein the obtained L-lactate salt is acidified to form L-lactic acid by at least one of hydrochloric acid, hydrobromic acid, nitric acid, phosphoric acid, sulfuric acid, and combinations thereof and used for subsequent polylactic acid formation.

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