CLAIMS

What is claimed is:

1. A method for producing a product of an enzymatic or chemical pathway from a starting substrate, the pathway comprising one or more conversion steps selected from the group consisting of:

an enzymatic conversion of guluronic acid into D-glucarate (Step 7);

an enzymatic conversion of 5-ketogluconate (5-KGA) into L-Iduronic acid (Step 15);

an enzymatic conversion of L-Iduronic acid into Idaric acid Step 7b); and

an enzymatic conversion of 5-ketocluconate into 4,6-dihydroxy 2,5-diketo hexanoate (2,5-DDH) (Step 16);

an enzymatic conversion of 1,5-gluconolactone to gulurono-lactone (Step 19).

2. The method of claim 1 wherein the one or more conversion steps is the enzymatic conversion of guluronic acid into D-glucarate (Step 7).

3. The method of claim 1 wherein the one or more conversion steps is the enzymatic conversion of 5-ketogluconate (5-KGA) into L-Iduronic acid (Step 15).

4. The method of claim 1 wherein the one or more conversion steps is the enzymatic conversion of L-Iduronic acid into Idaric acid Step 7b).

5. The method of claim 1 wherein the one or more conversion steps is the enzymatic conversion of 5-ketogluconate into 4,6-dihydroxy 2,5-diketo hexanoate (2,5-DDH) (Step 16).

6. The method of claim 1 wherein the one or more conversion steps is the enzymatic conversion of 1,5-gluconolactone to gulurono-lactone (Step 19).

7. The method of claim 1 wherein the product of the enzymatic pathway is 5-dehydro-4-deoxy-glucarate (DDG).

8. The method of claim 1 wherein the substrate is glucose and the product is 5-dehydro-4-deoxy-glucarate (DDG), comprising the steps of:

the enzymatic conversion of D-glucose to 1,5-gluconolactone (Step 1);

the enzymatic conversion of 1,5-gluconolactone to gulurono-lactone (Step 19);

the enzymatic conversion of gulurono-lactone to guluronic acid (Step 1B);

the enzymatic conversion of guluronic acid to D-glucarate (Step 7);

the enzymatic conversion of D-glucarate to 5-dehydro-4-deoxy-glucarate (DDG) (Step 8).

9. The method of claim 1 wherein the substrate is glucose and the product is DDG, comprising the steps of:

the conversion of D-glucose to 1,5-gluconolactone (Step 1);

the conversion of 1,5-gluconolactone to gluconic acid (Step 1a);

the conversion of gluconic acid to 5-ketogluconate (5-KGA) (Step 14);

the conversion of 5-ketogluconate (5-KGA) to L-Iduronic acid (Step 15);

the conversion of L-Iduronic acid to Idaric acid (Step 7b); and

the conversion of Idaric acid to DDG (Step 8a).

10. The method of claim 1 wherein the substrate is glucose and the product is DDG, comprising the steps of:

the conversion of D-glucose to 1,5-gluconolactone (Step 1);

the conversion of 1,5-gluconolactone to gluconic acid (Step 1a);

the conversion of gluconic acid to 5-ketogluconate (5-KGA) (Step 14);

the conversion of 5- ketogluconate (5-KGA) to 4,6-dihydroxy 2,5-diketo hexanoate (2,5-DDH) (Step 16);

the conversion of 4,6-dihydroxy 2,5-diketo hexanoate (2,5-DDH) to 4-deoxy-5-threo-hexosulose uronate (DTHU) (Step 4); and

the conversion of 4-deoxy-5-threo-hexosulose uronate (DTHU) to DDG (Step 5).

11. The method of claim 1 wherein the substrate is glucose and the product is DDG, comprising the steps of:

the conversion of D-glucose to 1,5-gluconolactone (Step 1);

the conversion of 1,5-gluconolactone to gluconic acid (Step 1a);

the conversion of gluconic acid to 5-ketogluconate (5-KGA) (Step 14);

the conversion of 5-ketogluconate (5-KGA) to L-Iduronic acid (Step 15);

the conversion of L-Iduronic acid to 4-deoxy-5-threo-hexosulose uronate (DTHU) (Step 7c); and

the conversion of 4-deoxy-5-threo-hexosulose uronate (DTHU) to DDG (Step 5).

12. The method of claim 8 further comprising the step of converting the DDG to 2,5-furan-dicarboxylic acid (FDCA).

13. The method of claim 9 further comprising the step of converting the DDG to 2,5-furan-dicarboxylic acid (FDCA).

14. The method of claim 10 further comprising the step of converting the DDG to 2,5-furan-dicarboxylic acid (FDCA).

15. The method of claim 11 further comprising the step of converting the DDG to 2,5-furan-dicarboxylic acid (FDCA).

16. The method of claim 12 wherein converting the DDG to FDCA comprises contacting DDG with acid to convert the DDG to FDCA.

17. The method of claim 13 wherein converting the DDG to FDCA comprises contacting DDG with acid to convert the DDG to FDCA.

18. The method of claim 14 wherein converting the DDG to FDCA comprises contacting DDG with acid to convert the DDG to FDCA.

19. The method of claim 15 wherein converting the DDG to FDCA comprises contacting DDG with acid to convert the DDG to FDCA.

20. A method for synthesizing a derivative of FDCA comprising:
contacting DDG with an alcohol, an inorganic acid at a temperature in excess of 60 C to form FDCA.

21. The method of claim 20 wherein the alcohol is butanol or ethanol.

22. The method of claim 20 having a yield of at least 25% molar.

23. A method of synthesizing a derivative of DDG comprising:
contacting DDG with an alcohol, an inorganic acid, and optionally a co-solvent to produce a derivative of DDG.

24. The method of claim 23 wherein:
a) the alcohol is ethanol or butanol;
b) the inorganic acid is sulfuric acid; and
c) the co-solvent is selected from the group consisting of: THF, acetone, acetonitrile, an ether, ethyl acetate, butyl acetate, an dioxane, chloroform, methylene chloride, 1,2-dichloroethane, a hexane, a heptane, toluene, carbon tetrachloride, petroleum ether, and a xylene.

25. A method for synthesizing derivative of FDCA comprising:
contacting a derivative of DDG with an inorganic acid to produce a derivative of FDCA.

26. The method of claim 25 having a yield of greater than 25% molar.

27. The method of claim 26 wherein the derivative is DDG is selected from the group consisting: methyl-DDG, ethyl-DDG, butyl-DDG, di-methyl DDG, di-ethyl-DDG, and di-butyl DDG.

28. The method of claim 25 further comprising that the derivative of FDCA is de-esterified to yield FDCA.

29. The method of claim 25 further comprising a step of polymerizing the derivative of FDCA.

30. A method for synthesizing FDCA comprising:

contacting DDG with an inorganic acid in a gas phase.

31. A method for synthesizing FDCA comprising:

contacting DDG with an inorganic acid at a temperature in excess of 120 C.

32. A method for synthesizing FDCA comprising:

contacting DDG with an inorganic acid under anhydrous reaction conditions.

33. A method for producing a product of an enzymatic or chemical pathway from a starting substrate, the pathway comprising one or more conversion steps selected from the group consisting of:

the conversion of DTHU to DDG (Step-5);

the conversion of gluconic acid to guluronic acid (Step-6);

the conversion of DEHU to DDH (Step 7A).

the conversion of guluronic acid to DEHU (Step 17A);

34. The method of claim 33 wherein the substrate is glucose and the product is DDG, comprising the steps of:

the conversion of D-glucose to 1,5-gluconolactone (Step 1);

the conversion of 1,5-gluconolactone to gluconic acid (Step 1a);

the conversion of gluconic acid to 3-dehydro-gluconic (DHG) (Step-2)

the conversion of 3-dehydro-gluconic (DHG) to 4,6-Dihydroxy 2,5-diketo hexanoate (2,5-DDH) (Step-3)

the conversion of 2,5 DDH to 4-deoxy-5-threo-hexosulose uronate (DTHU) (Step 4)

the conversion of DTHU to DDG (Step-5).

35. The method of claim 33 wherein the substrate is glucose and the product is DDG, comprising the steps of:

the conversion of D-glucose to 1,5-gluconolactone (Step 1);

the conversion of 1,5-gluconolactone to gluconic acid (Step 1a);

the conversion of gluconic acid to guluronic acid (Step-6)

the conversion of guluronic to glucarate (Step-7)

the conversion of glucarate to DDG (Step-8)

36. The method of claim 33 wherein the substrate is glucose and the product is DDG, comprising the steps of:

the conversion of D-glucose to 1,5-gluconolactone (Step 1);

the conversion of 1,5-gluconolactone to gluconic acid (Step 1a);

the conversion of gluconic acid to 5-ketogluconate (5-KGA) (Step 14);

the conversion of 5- ketogluconate (5-KGA) to 4,6-dihydroxy 2,5-diketo hexanoate (2,5-DDH) (Step 16);

the conversion of 4,6-dihydroxy 2,5-diketo hexanoate (2,5-DDH) to 4-deoxy-5-threo-hexosulose uronate (DTHU) (Step 4); and

the conversion of 4-deoxy-5-threo-hexosulose uronate (DTHU) to DDG (Step 5).

37. The method of claim 33 wherein the substrate is glucose and the product is DDG, comprising the steps of:

the conversion of D-glucose to 1,5-gluconolactone (Step 1);

the conversion of 1,5-gluconolactone to gluconic acid (Step 1a);

the conversion of gluconic acid to 5-ketogluconate (5-KGA) (Step 14);

the conversion of 5-ketogluconate (5-KGA) to L-Iduronic acid (Step 15);

the conversion of L-Iduronic acid to 4-deoxy-5-threo-hexosulose uronate (DTHU) (Step 7B);

the conversion of 4-deoxy-5-threo-hexosulose uronate (DTHU) to DDG (Step 5).

38. The method of claim 33 wherein the substrate is glucose and the product is DDH, comprising the steps of:

the conversion of D-glucose to 1,5-gluconolactone (Step 1);

the conversion of 1,5-gluconolactone to guluronic acid lactone (Step19);

the conversion of guluronic acid lactone to guluronic acid (Step 1B);

the conversion of guluronic acid to DEHU (Step 17A);

the conversion of DEHU to DDH (Step 7A).

39. The method of claim 33 wherein the substrate is glucose and the product is DDH, comprising the steps of:

the conversion of D-glucose to 1,5-gluconolactone (Step 1);

the conversion of 1,5-gluconolactone to gluconic acid (Step 1a);

the conversion of gluconic acid to guluronic acid (Step 6);

the conversion of guluronic acid to DEHU (Step 17A);

the conversion of DEHU to DDH (Step 7A).

40. The method of claim 33 wherein the one or more conversion steps is the conversion of DTHU to DDG (Step-5).

41. The method of claim 33 wherein the one or more conversion steps is the conversion of gluconic acid to guluronic acid (Step-6).

42. The method of claim 33 wherein the one or more conversion steps is the conversion of DEHU to DDH (Step 7A).

43. The method of claim 33 wherein the one or more conversion steps is the conversion of guluronic acid to DEHU (Step 17A).

CLAIMS

1. A method for synthesizing a derivative of FDCA comprising:
contacting DDG with an alcohol and an inorganic acid at a temperature in excess of 60 °C to form a derivative of FDCA.

2. The method of claim 1 wherein the alcohol is butanol or ethanol and the derivative of FDCA is a butyl or ethyl derivative of FDCA, respectively.

3. The method of claim 1 having a yield of at least 25% molar.

4. A method of synthesizing a derivative of DDG comprising:
contacting DDG with an alcohol, an inorganic acid, and optionally a co-solvent to produce a derivative of DDG.

5. The method of claim 4 wherein:
a) the alcohol is ethanol or butanol;
b) the inorganic acid is sulfuric acid; and
c) the co-solvent is selected from the group consisting of: THF, acetone, acetonitrile, an ether, ethyl acetate, butyl acetate, an dioxane, chloroform, methylene chloride, 1,2-dichloroethane, a hexane, a heptane, toluene, carbon tetrachloride, petroleum ether, and a xylene.

6. A method for synthesizing a derivative of FDCA comprising:
contacting a derivative of DDG with an inorganic acid to produce a derivative of FDCA.

7. The method of claim 6 having a yield of greater than 25% molar.

8. The method of claim 6 wherein the derivative of DDG is selected from the group consisting: methyl-DDG, ethyl-DDG, butyl-DDG, di-methyl DDG, diethyl-DDG, and di-butyl DDG; and
the derivative of FDCA is a methyl, ethyl, butyl, dimethyl, diethyl, or dibutyl derivative of FDCA, respectively.

9. The method of claim 8 further comprising that the derivative of FDCA is de-esterified to yield FDCA.

10. The method of claim 6 further comprising a step of polymerizing the derivative of FDCA.

11. A method for synthesizing FDCA comprising:
contacting DDG with an inorganic acid at a temperature greater than 70 °C to synthesize FDCA.

12. A method for synthesizing FDCA comprising:
contacting DDG with an inorganic acid in a gas phase at a temperature in excess of 120 °C to synthesize FDCA.

13. A method for synthesizing FDCA comprising:
contacting DDG with an inorganic acid under anhydrous reaction conditions to synthesize FDCA.

14. The method of claim 1 wherein:
the alcohol is selected from: butanol, ethanol, methanol, and propanol;
the acid is sulfuric acid;
the contacting occurs at a temperature of greater than 70 °C; and
thereby synthesizing a butyl, ethyl, methyl, or propyl derivative of FDCA, respectively.

15. The method of claim 14 wherein the contacting occurs in a gas phase at a temperature of greater than 150 °C.

16. The method of claim 5 further comprising a step of removing water from a solvent comprising the DDG prior to performing the method.

17. The method of claim 16 wherein greater than 90% of the water is removed from the solvent comprising the DDG prior to performing the method.

18. The method of claim 8 wherein the contacting occurs in the gas phase at a temperature of at least 90 °C.

19. The method of claim 11 wherein the inorganic acid is sulfuric acid.

20. The method of claim 12 wherein the inorganic acid is sulfuric acid.

21. The method of claim 13 wherein the contacting occurs at a temperature of greater than 80 °C.

22. The method of claim 13 wherein the DDG is comprised in a solvent that contains less than 10% water (w/w).

23. The method of claim 22 wherein the DDG is comprised in a solvent that contains less than 5% water (w/w).

24. The method of claim 8 further comprising a step of polymerizing the derivative of FDCA.