

CLAIMS

What is claimed is:

1. A chemoenzymatic process for the preparation of 2,5-furan dicarboxylic acid, the process comprising:

contacting D-glucose with (i) at least two enzymes selected from the group consisting essentially of galactose oxidase, pyranose 2-oxidase, glucarate dehydratase, catalase, and a combination thereof to produce an intermediate; and (ii) contacting the intermediate with a metal catalyst and acid catalyst to form 2,5-furan dicarboxylic acid.

2. The chemoenzymatic process of claim 1, wherein D-glucose is contacted with galactose oxidase and catalase to form D-glucodialdose; and wherein the process further comprises:

contacting D-glucodialdose with pyranose-2-oxidase and catalase under conditions suitable for the formation of 2-keto-glucodialdose;

contacting 2-keto-glucodialdose with a heterogeneous metal catalyst to form 2-keto-glucaric acid; and

dehydrating 2-ketoglucaric acid in the the presence of an acid catalyst to form 2,5-furan dicarboxylic acid.

3. The chemoenzymatic process of claim 1, wherein D-glucose is contacted with galactose oxidase and catalase to form D-glucodialdose; and wherein the process further comprises:

contacting D-glucodialdose with pyranose-2-oxidase and catalase under conditions suitable for the formation of 2-keto-glucodialdose;

dehydrating 2-keto-glucodialdose with an acid catalyst to form 2,5-furandicaboxaldehyde; and

oxidizing 2,5-furandicaboxaldehyde in the the presence of a heterogeneous metal catalyst to form 2,5-furan dicarboxylic acid.

4. The chemoenzymatic process of claim 1, wherein D-glucose is contacted with galactose oxidase and catalase to form D-glucodialdose; and wherein the process further comprises:

contacting D-glucodialdose with a metal catalyst to form D-glucaric acid;
dehydrating D-glucaric acid with glucarate dehydratase to form 5-keto-4-deoxy glucodialdose; and
cyclizing 5-keto-4-deoxy glucodialdose in the presence of an acid catalyst to form 2,5-furan dicarboxylic acid.

5. The chemoenzymatic process of claim 1, wherein D-glucose is contacted with pyranose-2-oxidase and catalase to form 2-keto-glucose; and wherein the process further comprises:

dehydrating 2-keto-glucose with an acid catalyst under condtions suitable for the formation of 2,5-furandicaboxaldehyde;
dehydrating 5-keto-4-deoxyglucodialdose with an acid catalyst to form 2,5-furandicaboxaldehyde; and
oxidizing 2,5-furandicaboxaldehyde in the the presence of a heterogeneous metal catalyst to form 2,5-furan dicarboxylic acid.

6. The chemoenzymatic process of claim 1. wherein the galactose oxidase has any of SEQ ID NO.:1 to SEQ ID NO.:6.

7. The chemoenzymatic process of claim 2, wherein the galactose oxidase has any of SEQ ID NO.:1 to SEQ ID NO.:6.

8. The chemoenzymatic process of claim 3, wherein the galactose oxidase has any of SEQ ID NO.:1 to SEQ ID NO.:6.

9. The chemoenzymatic process of claim 4, wherein the galactose oxidase has any of SEQ ID NO.:1 to SEQ ID NO.:6.

10. The chemoenzymatic process of claim 5, wherein the galactose oxidase has any of SEQ ID NO.:1 to SEQ ID NO.:6.

11. The chemoenzymatic process of claim 1, wherein the galactose oxidase has SEQ ID NO.:1.
12. The chemoenzymatic process of claim 1, wherein the pyruvate-2-oxidase has any of SEQ ID NO.:7 to SEQ ID NO.:11.
13. The chemoenzymatic process of claim 1, carried out at a temperature of less than about 100 °C.
14. The chemoenzymatic process of claim 1, wherein the 2,5-furan dicarboxylic acid has a purity of greater than about 80%.
15. The chemoenzymatic process of claim 2, wherein the 2,5-furan dicarboxylic acid has a purity of greater than about 80%.
16. The chemoenzymatic process of claim 3, wherein the 2,5-furan dicarboxylic acid has a purity of greater than about 80%.
17. The chemoenzymatic process of claim 4, wherein the 2,5-furan dicarboxylic acid has a purity of greater than about 80%.
18. The chemoenzymatic process of claim 5, wherein the 2,5-furan dicarboxylic acid has a purity of greater than about 80%.
19. The chemoenzymatic process of claim 1, wherein the heterogeneous metal catalyst comprises a support comprising carbon, silica, alumina, titania (TiO₂), zirconia (ZrO₂), zeolite, or any combination thereof.
20. The chemoenzymatic process of claim 1, wherein the acid catalyst, the metal catalyst or both are heterogeneous.
21. The chemoenzymatic process of claim 1, wherein the acid catalyst, the metal catalyst or both are homogeneous.

22. The chemoenzymatic process of claim 1 further comprising subjecting the 2,5-furan dicarboxylic to water crystallization, solvent crystallization, and Nutsche filtration.

23. A chemoenzymatic process for the preparation of 2,5-furan dicarboxylic acid, the process comprising:

enzymatic oxidation of 5-hydroxymethylfurfural using an enzymatic oxidizing composition comprising one or more enzymes selected from the group consisting of Aryl-alcohol oxidase (AAO) chloroperoxidase (CPO), 5-hydroxymethylfurfural oxidase (HMFO), glyoxal oxidase (GLOX), periplasmic aldehyde oxidase (PaoABC), unspecific peroxygenase (UPO), horseradish peroxidase (HRP), galactose oxidase (GAO) with and without the activating enzyme horseradish peroxidase (HRP), lactoperoxidase (LPO), myeloperoxidase (MPO), eosinophil peroxidase (EPO), thyroid peroxidase (TPO), ovoperoxidase, salivary peroxidase, vanadium haloperoxidase, non-mammalian vertebrate peroxidase (POX), peroxidasin (Pxd), bacterial peroxidin (Pxc), invertebrate peroxinectin (Pxt) and short peroxidockerin (PxDo), short peroxidockerin (Pxt), alpha-dioxygenase (aDox), dual oxidase (DuOx), prostaglandin H synthase or cyclooxygenase (PGHS/CyOx), linoleate diol synthase (LDS), functional variants thereof, and any combination thereof to form an intermediate; and

oxidizing the intermediate using a metal catalyst to form 2,5-furan dicarboxylic acid.

24. The chemoenzymatic process of claim 23, wherein the enzymatic oxidation is carried out at a temperature of less than about 100 °C.

25. The chemoenzymatic process of claim 23, wherein the 2,5-furan dicarboxylic acid has a purity of greater than about 80%.