CLAIMS

1. A microbial cell for producing at least one ω-functionalized carboxylic acid ester from at least one alkane, wherein the cell is genetically modified to increase the expression relative to the wild type cell of

   (i) Enzyme E_1 capable of converting the alkane to the corresponding 1-alkanol;

   (ii) Enzyme E_2 capable of converting the 1-alkanol of (i) to the corresponding 1-alkanal;

   (iii) Enzyme E_3 capable of converting the 1-alkanal of (ii) to the corresponding alkanoic acid;

   (iv) Enzyme E_4 capable of converting the alkanoic acid of (iii) to the corresponding alkanoic acid ester; and

   (v) Enzyme E_5 capable of converting the alkanoic acid ester of (iv) to the corresponding ω-hydroxy-alkanoic acid ester,

   wherein the cell does not comprise a previous genetic modification that increases the formation of carboxylic acid or carboxylate ester from at least one simple carbon source and the excluded previous genetic modification is an increase in the expression relative to the wild type cell of any of the following enzymes E_{20}- E_{24} selected from the group consisting of:

   - E_{20} Acyl-ACP thioesterase, of EC 3.1.2.14 or EC 3.1.2.22,
   - E_{21} Acyl-CoA thioesterase, of EC 3.1.2.2, EC 3.1.2.18, EC 3.1.2.19, EC 3.1.2.20 or EC 3.1.2.22,
   - E_{22} Acyl-CoA:ACP transacylase,
   - E_{23} Polyketide synthase, and
   - E_{24} Hexanoic acid synthase, and

   wherein the Enzyme E_1 is selected from the group consisting of P450 alkane hydroxylases (E_a) of EC 1.14.15.3- and AlkB alkane hydroxylases (E_b) of EC 1.14.15.3;

   - the Enzyme E_2 is selected from the group consisting of P450 alkane hydroxylases (E_a) of EC 1.14.15.3-, AlkB alkane hydroxylases (E_b) of EC 1.14.15.3, alcohol oxidases (E_c) of EC 1.1.3.20 and alcohol dehydrogenases (E_d) of EC 1.1.1.1 or EC 1.1.1.2;
   - the Enzyme E_3 is selected from the group consisting of P450 alkane hydroxylases (E_a) of EC 1.14.15.3-, AlkB alkane hydroxylases (E_b) of EC 1.14.15.3, aldehyde dehydrogenases (E_e), bifunctional alcohol oxidases (E_c) of EC 1.1.3.20, bifunctional AlkJ alcohol dehydrogenases (E_{di}) and bifunctional alcohol dehydrogenases (E_{dii}) of EC 1.1.1.1 or EC 1.1.1.2, wherein E_c, E_{di}, and E_{dii} are capable of oxidizing an ω-hydroxy alkanoic acid ester directly to the corresponding ω-carboxy alkanoic acid ester;
   - the Enzyme E_4 is selected from the group consisting of wax-ester synthases (E_f) of EC 2.3.1.75 or alcohol O-acyl transferases (E_g) of EC 2.3.1.84;
   - the Enzyme E_5 is selected from the group consisting of P450 alkane hydroxylases (E_a) of EC 1.14.15.3- and AlkB alkane hydroxylases (E_b) of EC 1.14.15.3,

   and wherein the enzymes E_1, E_2, E_3 and E_5 are each different enzymes.

2. The cell according to claim 1, wherein the cell is further genetically modified to increase the expression relative to the wild type cell of

(vi) Enzyme E_6 capable of converting the corresponding ω-hydroxy-alkanoic acid ester of (v) to the corresponding ω-oxo alkanoic acid ester; or

(vii) Enzyme E_6 capable of converting the corresponding ω-hydroxy-alkanoic acid ester of (v) to the corresponding ω-oxo alkanoic acid ester and Enzyme E_7 capable of converting the ω-oxo alkanoic acid ester to the corresponding ω-amino alkanoic acid ester; or

(viii) Enzyme E_6 capable of converting the corresponding ω-hydroxy-alkanoic acid ester of (v) to the corresponding ω-oxo alkanoic acid ester and Enzyme E_{13} capable of converting the ω-oxo alkanoic acid ester to the corresponding ω-carboxy alkanoic acid ester and Enzyme E_{14} capable of converting the ω-carboxy alkanoic acid ester to the corresponding ω-carboxy alkanoic acid diester,

wherein the Enzyme E_6 is selected from the group consisting of P450 alkane hydroxylases (E_a) of EC 1.14.15.3-, AlkB alkane hydroxylases (E_b) of EC 1.14.15.3, alcohol oxidases (E_c) of EC 1.1.3.20, aldehyde dehydrogenases (E_e) and alcohol dehydrogenases (E_d) of EC 1.1.1.1 or EC 1.1.1.2.

3. The cell according to claim 2, wherein

- when present the Enzyme E_7 is an ω-transaminase (E_h) EC 2.6.1;
- when present the Enzyme E_{13} is selected from the group consisting of P450 alkane hydroxylases (E_a) of EC 1.14.15.3-, AlkB alkane hydroxylases (E_b) of EC 1.14.15.3, aldehyde dehydrogenases (E_e), bifunctional alcohol oxidases (E_c) of EC 1.1.3.20, bifunctional AlkJ alcohol dehydrogenases (E_{di}) and bifunctional alcohol dehydrogenases (E_{dii}) of EC 1.1.1.1 or EC 1.1.1.2, wherein E_c, E_{di}, and E_{dii} are capable of oxidizing an ω-hydroxy alkanoic acid ester via an ω-oxo alkanoic acid ester directly to the corresponding ω-carboxy alkanoic acid ester; and
- when present the Enzyme E_{14} is selected from the group consisting of wax-ester synthases (E_f) of EC 2.3.1.75 or alcohol O-acyl transferases (E_g) of EC 2.3.1.84.

4. The cell according to any one of the preceding claims, wherein the Enzymes E_1, E_2, E_3, E_5 and E_6, is at least one AlkB alkane hydroxylase (E_b) and Enzyme E_4 is a wax-ester synthase (E_f).

5. The cell according to claim 4, wherein

- the AlkB alkane hydroxylase (E_b) comprises at least 60% sequence identity relative to SEQ ID NO:1;
- the wax-ester synthase (E_f) comprises at least 60% sequence identity relative to SEQ ID NO:2; and

- when present the ω-transaminase (E_h) comprises at least 60% sequence identity relative to SEQ ID NO:3.

6. The cell according to any one of the preceding claims, wherein the cell is further genetically modified to increase the expression relative to the wild type cell of at least one acyl-CoA synthetase (E_{12}) of EC 6.2.1.3 or EC 2.3.1.86.

7. A method of producing at least one ω-functionalized carboxylic acid ester, wherein the method comprises a step of contacting at least one cell according to any one of claims 1 to 6 with at least one alkane.

8. The method according to claim 7, wherein
   - the ω-functionalized carboxylic acid ester is 12-amino lauric acid methyl ester, 12-hydroxy lauric acid methyl ester, 12-carboxy lauric acid methyl (di) ester and/or lauric acid methyl ester from the alkane dodecane; and/or
   - the ω-functionalized carboxylic acid ester is 11-amino undecanoic acid methyl ester, 11-hydroxy undecanoic acid methyl ester, 11-carboxy undecanoic acid methyl (di) ester and/or undecanoic acid methyl ester from the alkane undecane.

9. A method of producing at least one ω-functionalized carboxylic acid ester from an alkane, wherein the method comprises:
   (a) contacting the following enzymes with the alkane:
      (i) Enzyme E_1 capable of converting the alkane to the corresponding 1-alkanol;
      (ii) Enzyme E_2 capable of converting the 1-alkanol of (i) to the corresponding 1-alkanal;
      (iii) Enzyme E_3 capable of converting the 1-alkanal of (ii) to the corresponding alkanoic acid;
      (iv) Enzyme E_4 capable of converting the alkanoic acid of (iii) to the corresponding alkanoic acid ester; and
      (vi) Enzyme E_5 capable of converting the alkanoic acid ester of (iv) to the corresponding ω-hydroxy-alkanoic acid ester,

   and wherein
   - the Enzyme E_1 is selected from the group consisting of P450 alkane hydroxylases (E_a) and AlkB alkane hydroxylases (E_b) of EC 1.14.15.3;
   - the Enzyme E_2 is selected from the group consisting of P450 alkane hydroxylases (E_a), AlkB alkane hydroxylases (E_b) of EC 1.14.15.3, alcohol oxidases (E_c) and alcohol dehydrogenases (E_d);
   - the Enzyme E_3 is selected from the group consisting of P450 alkane hydroxylases (E_a) of EC 1.14.15.3-, AlkB alkane hydroxylases (E_b) of EC 1.14.15.3, aldehyde dehydrogenases (E_e), bifunctional alcohol oxidases (E_c) of EC 1.1.3.20, bifunctional AlkJ alcohol dehydrogenases (E_{di}) and bifunctional alcohol dehydrogenases (E_{dii}) of

EC 1.1.1.1 or EC 1.1.1.2, wherein E_c, E_{di}, and E_{dii} are capable of oxidizing an 1-alkanol via an 1-alkanal directly to the corresponding alkanoic acid;

- the Enzyme E_4 is selected from the group consisting of wax-ester synthases (E_f) and alcohol O-acyl transferases (E_g);
- the Enzyme E_5 is selected from the group consisting of P450 alkane hydroxylases (E_a) and AlkB alkane hydroxylases (E_b) of EC 1.14.15.3,

and wherein the enzymes E_1, E_2, E_3 and E_5 are each different enzymes.

10. The method according to claim 9, wherein the method comprises

(b) contacting the following enzymes with the ω-hydroxy-alkanoic acid ester:

(vi) Enzyme E_6 capable of converting the corresponding ω-hydroxy-alkanoic acid ester of (v) to the corresponding ω-oxo alkanoic acid ester; or

(vii) Enzyme E_6 capable of converting the corresponding ω-hydroxy-alkanoic acid ester of (v) to the corresponding ω-oxo alkanoic acid ester and Enzyme E_7 capable of converting the ω-oxo alkanoic acid ester to the corresponding ω-amino alkanoic acid ester; or

(viii) Enzyme E_6 capable of converting the corresponding ω-hydroxy-alkanoic acid ester of (v) to the corresponding ω-oxo alkanoic acid ester and Enzyme E_{13} capable of converting the ω-oxo alkanoic acid ester to the corresponding ω-carboxy alkanoic acid ester and Enzyme E_{14} capable of converting the ω-carboxy alkanoic acid ester of (vi) to the corresponding ω-carboxy alkanoic acid diester,

wherein the Enzyme E_6 is selected from the group consisting of P450 alkane hydroxylases (E_a), AlkB alkane hydroxylases (E_b) of EC 1.14.15.3, alcohol oxidases (E_c) and alcohol dehydrogenases (E_d).

11. The method according to claim 10, wherein

- when present the Enzyme E_7 is an ω-transaminase (E_h);
- when present the Enzyme E_{13} is selected from the group consisting of P450 alkane hydroxylases (E_a) of EC 1.14.15.3-, AlkB alkane hydroxylases (E_b) of EC 1.14.15.3, aldehyde dehydrogenases (E_e), bifunctional alcohol oxidases (E_c) of EC 1.1.3.20, bifunctional AlkJ alcohol dehydrogenases (E_{di}) and bifunctional alcohol dehydrogenases (E_{dii}) of EC 1.1.1.1 or EC 1.1.1.2, wherein E_c, E_{di}, and E_{dii} are capable of oxidizing an ω-hydroxy alkanoic acid ester via an ω-oxo alkanoic acid ester directly to the corresponding ω-carboxy alkanoic acid ester; and
- when present the Enzyme E_{14} is selected from the group consisting of wax-ester synthases (E_f) and alcohol O-acyl transferases (E_g).

12. The method according to any one of claims 9 to 11, wherein the Enzymes E_1, E_2, E_3, and E_5 are at least one AlkB alkane hydroxylase (E_b) and when present E_6 is at least one AlkB alkane hydroxylase (E_b) and Enzyme E_4 is a wax-ester synthase (E_f).

13. The method according to any one of claims 9 to 12, wherein the enzymes are brought into contact with the alkane in the form of a cell genetically modified to increase the expression relative to a wild type cell of enzymes E_1 to E_5 and E_6 and E_7.

14. The method according to claim 13, wherein the cell is selected from the group consisting of *E. coli, Pseudomonas sp., Pseudomonas fluorescens, Pseudomonas putida, Pseudomonas stutzeri, Acinetobacter sp., Burkholderia sp., Burkholderia thailandensis, Cyanobakterien, Klebsiella sp., Klebsiella oxytoca, Salmonella sp., Rhizobium sp. and Rhizobium meliloti, Bacillus sp., Bacillus subtilis, Clostridium sp., Corynebacterium sp., Corynebacterium glutamicum, Brevibacterium sp., Chlorella sp.* and *Nostoc sp.*

15. The method according to any one of claims 9 to 14, wherein

- the ω-functionalized carboxylic acid ester is 12-amino lauric acid methyl ester, 12-hydroxy lauric acid methyl ester, 12-carboxy lauric acid methyl (di) ester and/or lauric acid methyl ester from the alkane dodecane; and/or
- the ω-functionalized carboxylic acid ester is 11-amino undecanoic acid methyl ester, 11-hydroxy undecanoic acid methyl ester, 11-carboxy undecanoic acid methyl (di) ester and/or undecanoic acid methyl ester from the alkane undecane.