Embodiments

1. Method for producing a renewable base oil from a feedstock of biological origin, the method comprising:
   a) providing a feedstock, the feedstock comprising 2-95 wt% of a mixture of free fatty acids; 5-98 wt% fatty acid glycerols selected from mono-glycerides, di-glycerides and tri-glycerides of fatty acids; 0-50 wt% of one or more compounds selected from the list consisting of: fatty acid esters of the non-glycerol type, fatty amides and fatty alcohols; wherein the major part of the feedstock being the mixture of free fatty acids and fatty acid glycerols;
   b) subjecting all or part of the feedstock to ketonisation reaction conditions in the presence of a ketonisation catalyst selected as a metal oxide catalyst essentially comprising titanium as the metal, and where two free fatty acids react to yield a ketone stream, the ketone stream comprising as the major part saturated ketones; and
   c) subjecting the ketone stream to both hydrodeoxygenation reaction conditions and to hydroisomerisation reaction conditions, simultaneously or in sequence, to yield a deoxygenated and isomerised base oil product stream comprising the renewable base oil.

2. Method according to embodiment 1, wherein the method further comprises producing a diesel fuel from the feedstock of biological origin, the method comprising after step a) that the feedstock is separated into at least the following two feeds:
   - a1) a free fatty acid enriched feed which feed is having a higher concentration of free fatty acids than the feedstock and wherein the free fatty acids comprise C_{10}-C_{24} fatty acids, preferably C_{14}-C_{22}, such as C_{14}, C_{16}, C_{18}, C_{20} and C_{22} fatty acids; and
   - a2) one or more free fatty acid depleted feed(s) which feed(s) is having a higher concentration of compounds selected from mono-

glycerides, di-glycerides, and tri-glycerides of fatty acids, and a higher boiling point than the free fatty acid enriched feed;

b) subjecting the free fatty acid enriched feed to ketonisation reaction conditions in the presence of a ketonisation catalyst selected as metal oxide catalyst essentially comprising titanium as metal, and where two free fatty acids react to yield a ketone stream, the ketone stream comprising as the major part saturated ketones;

c) subjecting the ketone stream to both hydrodeoxygenation reaction conditions and to hydroisomerisation reaction conditions, simultaneously or in sequence, to yield a deoxygenated and isomerised base oil product stream comprising the renewable base oil; and

d) transforming the one or more free fatty acid depleted feed(s) into a diesel product, preferably by subjecting the one or more free fatty acid depleted feed(s) to both hydrodeoxygenation reaction conditions and to hydroisomerisation reaction conditions, simultaneously or in sequence, to yield a deoxygenated and isomerised diesel product stream comprising the diesel fuel.

3. The method according to any of embodiments 1 - 2, wherein the ketonisation catalyst is TiO_2, optionally on a support.

4. The method according to any one of the embodiments 1 – 3, wherein the ketonisation catalyst is a catalyst, where the content of the elements manganese, magnesium, calcium and potassium, are 0.05 wt% or less compared to the total catalyst weight as measured using x-ray diffraction.

5. The method according to any one of the embodiments 1 - 4, wherein the ketonisation catalyst is a catalyst, where the content of the element potassium, is 0.05 wt% or less compared to the total catalyst weight as measured using x-ray diffraction.

6. The method according to any one of the embodiments 3 - 5, wherein the TiO_2 is in anatase form having an average pore diameter of 80-160 Å, and/or a BET area of 20-140 m^2/g, and/or porosity of 0.1-0.3 cm^3/g.

7. The method according to any one of the embodiments 1 – 6, wherein the ketonisation reaction conditions comprise that the ketonisation is conducted at a temperature in the range of 300 to 400 ^oC.

8. The method according to any one of the embodiments 1 – 7, wherein the ketonisation reaction conditions comprise that the ketonisation is conducted at a pressure in the range of 5 to 30 barg.

9. The method according to any one of the embodiments 1 – 8, wherein the ketonisation reaction conditions comprise that the ketonisation is conducted at a WHSV (Weight Hourly Space Velocity) in the range of 0.25 to h^{-1}.

10. The method according to any one of the embodiments 1 – 9, wherein the ketonisation reaction conditions comprise that the ketonisation is conducted in the presence of a gas, such as CO_2, H_2, N_2, CH_4, H_2O, in the range of 0.1 to 1.5 gas/fed ratio (w/w).

11. The method according to any one of the embodiments 1 – 10, wherein the ketonisation reaction conditions comprise ketonisation at least partly in liquid form.

12. The method according to any one of the embodiments 1 – 11 wherein the deoxygenated and isomerised base oil product stream comprising the renewable base oil is distilled to obtain distilled renewable base oil.

13. The method according to any one of the embodiments 2 – 12, wherein the deoxygenated and isomerised diesel product stream comprising the diesel fuel is distilled to obtain distilled diesel fuel.

14. The method according to any one of the embodiments 2 – 13, additionally for producing a naphtha fuel, where the naphtha fuel is obtained from distillation of the deoxygenated and isomerised base oil product stream comprising the renewable base oil and and/or the deoxygenated and isomerised diesel product stream comprising the diesel fuel.

15. The method according to any one of the embodiments 1 – 14, wherein, prior to step a), an initial feedstock comprising fatty acid esters is pre-treated in at least a hydrolysis step thereby producing the feedstock, wherein the ratio of free fatty acids to fatty acid esters has been increased compared to the initial feedstock.

16. The method according to any one of embodiments 1 – 15, wherein no pretreatment by hydrogenation or by hydrolysis is made in or in-between any of the steps a), a1), a2), and b).

17. The method according to any one of embodiments 1 – 16, where the hydrodeoxygenation and hydroisomerisation of the ketone stream take place in sequence, and where in-between the hydrodeoxygenation and hydroisomerisation there is a stripping step, where gasses are separated from liquids in a high temperature and high pressure separation step, preferably at a temperature in the range from 300 to 330 °C, and/or at a pressure in the range from 40 to 50 barg.

18. The method according to any one of embodiments 12 – 17, wherein prior to the distillation step of the deoxygenated and isomerised base oil product stream comprising the renewable base oil there is a stripping step, where gasses are separated from liquids, preferably at a temperature in the range from 320 to 350 °C, and/or at a pressure in the range from 3 to 6 barg.

19. The method according to any one of embodiments 1 – 18 wherein the feedstock or the free fatty acid enriched feed mainly comprises saturated fatty acids.

20. The method according to any one of embodiments 1 – 19, wherein the feedstock or the free fatty acid enriched feed mainly comprises C_{16} fatty acids.

21. The method according to any one of embodiments 1 – 20, wherein the feedstock is palm oil fatty acid distillate (PFAD).

22. The method according to any one of embodiments 1 – 21, wherein the ketonisation catalyst is $TiO_{2,}$ and wherein the content of metal impurities in the feedstock or the free fatty acid enriched feed immediately before it is subjected to the ketonisation reaction conditions and in the ketone stream obtained immediately after it has been subjected to the ketonisation reaction conditions comprise at most 20 ppm manganese, at most 20 ppm magnesium, at most 20 ppm calcium, at most 20 ppm potassium, measured using inductively coupled plasma (ICP) metal analysis.

23. The method according to any one of embodiments 1 – 22, where the ketone stream obtained immediately after it has been subjected to the ketonisation reaction conditions comprises at most 5 ppm manganese, at most 5 ppm magnesium, at most 5 ppm calcium, at most 5 ppm potassium, measured using inductively coupled plasma (ICP) metal analysis.

24. The method according to any one of embodiments 1 – 23, where the ketone stream obtained immediately after it has been subjected to the ketonisation reaction conditions comprises at most 3 ppm manganese, at most 3 ppm magnesium, at most 3 ppm calcium, at most 3 ppm potassium, measured using inductively coupled plasma (ICP) metal analysis.

25. The method according to any one of embodiments 1 – 24, wherein the hydrodeoxygenation reaction conditions comprise a temperature in the range from 250 to 400 °C, a pressure in the range from 20 to 80 barg, a WHSV in the range from 0.5 – 3 h^{-1}, and/or a H_2 flow of 350-900 nl H_2/l feed, in the presence of a hydrodeoxygenation catalyst, such as NiMo on an alumina support.

26. The method according to any one of embodiments 1 – 25, wherein the isomerisation reaction conditions comprise a temperature in the range from 250 to 400 °C, a pressure in the range from 10 to 60 barg, a WHSV in the range from 0.5-3 h^{-1}, and/or a H_2 flow of 100-800 nl H_2/l feed, in the presence of an isomerisation catalyst, such as a catalyst comprising a Group VIII metal and and a molecular sieve, optionally on an alumina and/or silica support.

27. The method according to any one of embodiments 1 – 26, wherein the hydrodeoxygenation and isomerisation catalyst are the same, such as NiW.

28. The method according to any one of embodiments 1 – 27, wherein at least 50 wt% of the feedstock is the mixture of free fatty acids and fatty acid glycerols.

29. The method according to any one of the embodiments 1 – 28, wherein the renewable base oil is a hydrocarbon composition having a viscosity index of at least 80, preferably the renewable base oil fulfils the requirements for sulfur, saturates and viscosity index of API (the American Petroleum Institute) group I, II or III.

30. The method according to any one of the embodiments 1 - 29, wherein at least 70 wt% of the feedstock, preferably at least 90 wt% of the feedstock, is the mixture of free fatty acids and fatty acid glycerols.

31. The method according to any one of the embodiments 1 – 30, wherein the feedstock comprises at least 10 wt% free fatty acids.

32. The method according to any one of embodiments 1 – 31, wherein the feedstock comprises 90 wt% free fatty acids or less.

33. The method according to any one of embodiments 1 – 32, wherein the feedstock comprises from 10 to 90 wt% free fatty acids.

34. The method according to any one of embodiments 1 – 33, wherein the feedstock comprises at least 10 wt% fatty acid glycerols.

35. The method according to any one of embodiments 1 – 34, wherein the feedstock comprises 90 wt% fatty acid glycerols or less.

36. The method according to any one of embodiments 1 – 35, wherein the feedstock comprises from 10 to 90 wt% fatty acid glycerols.

37. The method according to any one of the embodiments 1 – 36, wherein the feedstock comprises at least 10 % of one or more compounds selected from the list consisting of: fatty acid esters of the non-glycerol type, fatty amides and fatty alcohols.

38. The method according to any one of the embodiments 1 - 37, wherein the feedstock comprises from 15 to 45 % of one or more compounds selected from the list consisting of: fatty acid esters of the non-glycerol type, fatty amides, and fatty alcohols, preferably from 20 to 40 % or from 25 to 35 %, e.g. 30 %.

39. The method according to any one of the embodiments 1 – 38, wherein the feedstock comprises from 10 to 50 % fatty acid esters of the non-glycerol type, preferably from 15 to 45 %, more preferably from 20 to 40 % or from 25 to 35 %, e.g. 30 %.

40. Use of a ketonisation catalyst selected as a ketonisation catalyst selected as metal oxide catalyst essentially comprising titanium as metal, in particular $TiO_{2,}$ for improving the catalyst life time of a hydrodeoxygenation catalyst in a plant for producing renewable diesel and/or base oil, the plant comprising a fatty acid ketonisation stage comprising a ketonisation catalyst; the plant further comprising a hydrodeoxygenation stage comprising a hydrodeoxygenation catalyst; the hydrodeoxygenation stage being downstream of the ketonisation stage.

41. Use according to embodiment 40, wherein the ketonisation catalyst consists essentially of TiO_2, optionally on a support, and where the content of the elements manganese, magnesium, calcium and potassium, are 0.05 wt% or less compared to the total catalyst weight as measured using x-ray diffraction.

42. Use according to any one of the embodiments 40 - 41, wherein the ketonisation catalyst consists essentially of TiO_2, optionally on a support, and where the content of the element potassium, is 0.05 wt% or less compared to the total catalyst weight as measured using x-ray diffraction.

43. Use according to any one of the embodiments 40 - 42, wherein the fatty acid ketonisation stage comprises fatty acids selected from C_{12}-C_{22} fatty acids.

44. Use according any one of embodiments 40 – 43, wherein the hydrodeoxygenation stage comprises ketones selected from C_{23}-C_{43} ketones.

Claims

1. Method for producing a renewable base oil from a feedstock of biological origin, the method comprising:
   a) providing a feedstock, the feedstock comprising 2-95 wt% of a mixture of free fatty acids; 5-98 wt% fatty acid glycerols selected from mono-glycerides, di-glycerides and tri-glycerides of fatty acids; 0-50 wt%, preferably at least 10 wt%, of one or more compounds selected from the list consisting of: fatty acid esters of the non-glycerol type, fatty amides and fatty alcohols; wherein at least 50 wt% of the feedstock being the mixture of free fatty acids and fatty acid glycerols;
   b) subjecting all or part of the feedstock to ketonisation reaction conditions in the presence of a ketonisation catalyst selected as a metal oxide catalyst essentially comprising titanium as the metal, wherein the content of the element potassium is 0.05 wt% or less compared to the total catalyst weight as measured using x-ray diffraction; and where two free fatty acids react to yield a ketone stream, the ketone stream comprising as the major part saturated ketones; and
   c) subjecting the ketone stream to both hydrodeoxygenation reaction conditions and to hydroisomerisation reaction conditions, simultaneously or in sequence, to yield a deoxygenated and isomerised base oil product stream comprising the renewable base oil.

2. Method according to claim 1, wherein the method further comprises producing a diesel fuel from the feedstock of biological origin, the method comprising after step a) that the feedstock is separated into at least the following two feeds:
   - a1) a free fatty acid enriched feed which feed is having a higher concentration of free fatty acids than the feedstock and wherein the free fatty acids comprise C_{10}-C_{24} fatty acids, preferably C_{14}-C_{22}, such as C_{14}, C_{16}, C_{18}, C_{20} and C_{22} fatty acids; and
   - a2) one or more free fatty acid depleted feed(s) which feed(s) is having a higher concentration of compounds selected from mono-glycerides, di-

glycerides, and tri-glycerides of fatty acids, and a higher boiling point than the free fatty acid enriched feed;

b) subjecting the free fatty acid enriched feed to ketonisation reaction conditions in the presence of a ketonisation catalyst selected as metal oxide catalyst essentially comprising titanium as metal, and where two free fatty acids react to yield a ketone stream, the ketone stream comprising as the major part saturated ketones;

c) subjecting the ketone stream to both hydrodeoxygenation reaction conditions and to hydroisomerisation reaction conditions, simultaneously or in sequence, to yield a deoxygenated and isomerised base oil product stream comprising the renewable base oil; and

d) transforming the one or more free fatty acid depleted feed(s) into a diesel product, preferably by subjecting the one or more free fatty acid depleted feed(s) to both hydrodeoxygenation reaction conditions and to hydroisomerisation reaction conditions, simultaneously or in sequence, to yield a deoxygenated and isomerised diesel product stream comprising the diesel fuel.

3. The method according to any of claims 1 - 2, wherein the ketonisation catalyst is TiO_2, optionally on a support.

4. The method according to any one of the claims 1 – 3, wherein the ketonisation catalyst is a catalyst, wherein the content of the elements manganese, magnesium, calcium and potassium, are 0.05 wt% or less compared to the total catalyst weight as measured using x-ray diffraction.

5. The method according to any one of the claims 3 - 4, wherein the TiO_2 is in anatase form having an average pore diameter of 80-160 Å, and/or a BET area of 20-140 m^2/g, and/or porosity of 0.1-0.3 cm^3/g.

6. The method according to any one of the claims 1 – 5, wherein the ketonisation reaction conditions comprise that the ketonisation is conducted at a temperature in the range of 300 to 400 ^oC; and/or

wherein the ketonisation reaction conditions comprise that the ketonisation is conducted at a pressure in the range of 5 to 30 barg; and/orwherein the ketonisation reaction conditions comprise that the ketonisation is conducted at a WHSV (Weight Hourly Space Velocity) in the range of 0.25 to h^{-1}; and/or

wherein the ketonisation reaction conditions comprise that the ketonisation is conducted in the presence of a gas, such as CO_2, H_2, N_2, CH_4, H_2O, in the range of 0.1 to 1.5 gas/fed ratio (w/w).

7. The method according to any one of the claims 1 – 6, wherein the ketonisation reaction conditions comprise ketonisation at least partly in liquid form.

8. The method according to any one of the claims 1 – 7 wherein the deoxygenated and isomerised base oil product stream comprising the renewable base oil is distilled to obtain distilled renewable base oil.

9. The method according to any one of the claims 2 – 8, wherein the deoxygenated and isomerised diesel product stream comprising the diesel fuel is distilled to obtain distilled diesel fuel.

10. The method according to any one of the claims 2 – 9, additionally for producing a naphtha fuel, where the naphtha fuel is obtained from distillation of the deoxygenated and isomerised base oil product stream comprising the renewable base oil and and/or the deoxygenated and isomerised diesel product stream comprising the diesel fuel.

11. The method according to any one of the claims 1 – 10, wherein, prior to step a), an initial feedstock comprising fatty acid esters is pre-treated in at least a hydrolysis step thereby producing the feedstock, wherein the ratio of free fatty acids to fatty acid esters has been increased compared to the initial feedstock; and/or

wherein no pretreatment by hydrogenation or by hydrolysis is made in or in-between any of the steps a), a1), a2), and b).

12. The method according to any one of claims 1 – 11, where the hydrodeoxygenation and hydroisomerisation of the ketone stream take place in sequence, and where in-between the hydrodeoxygenation and hydroisomerisation there is a stripping step, where gasses are separated from liquids in a separation step at a temperature in the range from 300 to 330 °C, and at a pressure in the range from 40 to 50 barg.

13. The method according to any one of claims 7 – 12, wherein prior to the distillation step of the deoxygenated and isomerised base oil product stream comprising the renewable base oil there is a stripping step, where gasses are separated from liquids, preferably at a temperature in the range from 320 to 350 °C, and/or at a pressure in the range from 3 to 6 barg.

14. The method according to any one of claims 1 – 13, wherein the ketonisation catalyst is TiO_2, and wherein the content of metal impurities in the feedstock or the free fatty acid enriched feed immediately before it is subjected to the ketonisation reaction conditions and in the ketone stream obtained immediately after it has been subjected to the ketonisation reaction conditions comprise at most 20 ppm manganese, at most 20 ppm magnesium, at most 20 ppm calcium, at most 20 ppm potassium, measured using inductively coupled plasma (ICP) metal analysis.

15. The method according to any one of claims 1 – 14, where the ketone stream obtained immediately after it has been subjected to the ketonisation reaction conditions comprises at most 5 ppm manganese, at most 5 ppm magnesium, at most 5 ppm calcium, at most 5 ppm potassium, measured using inductively coupled plasma (ICP) metal analysis.

16. The method according to any one of claims 1 – 15, where the ketone stream obtained immediately after it has been subjected to the ketonisation reaction conditions comprises at most 3 ppm manganese, at most 3 ppm magnesium, at most 3 ppm calcium, at most 3 ppm potassium, measured using inductively coupled plasma (ICP) metal analysis.

17. The method according to any one of claims 1 – 16, wherein the feedstock comprises from 10 to 90 wt% free fatty acids; and/or

    wherein the feedstock comprises from 10 to 90 wt% fatty acid glycerols.

18. Use of a ketonisation catalyst selected as a ketonisation catalyst selected as metal oxide catalyst essentially comprising titanium as metal, wherein the content of the element potassium is 0.05 wt% or less compared to the total catalyst weight as measured using x-ray diffraction; in particular TiO_2, for improving the catalyst life time of a hydrodeoxygenation catalyst in a plant for producing renewable diesel and/or base oil, the plant comprising a fatty acid ketonisation stage comprising a ketonisation catalyst; the plant further comprising a hydrodeoxygenation stage comprising a hydrodeoxygenation catalyst; the hydrodeoxygenation stage being downstream of the ketonisation stage.

19. Use according to claim 18, wherein the ketonisation catalyst consists essentially of TiO_2, optionally on a support, and where the content of the elements manganese, magnesium, calcium and potassium, are 0.05 wt% or less compared to the total catalyst weight as measured using x-ray diffraction.