Embodiments

1. Method for producing a renewable base oil and a diesel fuel 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) separating the feedstock into at least:
      - a free fatty acid feed having a higher concentration of free fatty acids than the feedstock, the free fatty acids comprising 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
      - one or more free fatty acid depleted feed(s) having higher concentration of the compounds selected from mono-glycerides, di-glycerides and tri-glycerides of fatty acids, and having a higher boiling point than the free fatty acid feed;
   c) subjecting the free fatty acid feed to ketonisation reaction conditions where two fatty acids react to yield a ketone stream, the ketone stream comprising as the major part saturated ketones;
   d) 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 stream comprising the renewable base oil;
   e) optionally distilling the product of step d) to obtain a distilled renewable base oil;
   f) where the one or more free fatty acid depleted feed(s) is transformed 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 stream comprising the diesel fuel;

g) optionally distilling the stream obtained from step f) to obtain a distilled diesel fuel.

2. The method according to embodiment 1, additionally for producing a naphtha fuel, where the naphtha fuel is obtained from distillation of both the deoxygenated and isomerised base oil stream of step d) and from the distillation of the deoxygenated and isomerised diesel stream of step f).

3. The method according to embodiments 1 or 2, 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, where the ratio of free fatty acids to fatty acid esters has been increased compared to the initial feedstock.

4. The method according to any one of embodiments 1 – 3, wherein no pre-treatment by hydrogenation or by hydrolysis is made in or in-between steps a) – c).

5. The method according to any one of embodiments 1 – 4, where the hydrodeoxygenation and hydroisomerisation of step d) 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 between 300-330 °C and pressure between 40-50 barg.

6. The method according to any one of embodiments 1 – 5, wherein between steps d) and e) there is a stripping step, where gasses are separated from liquids, preferably at a temperature between 320-350 °C and pressure between 3-6 barg.

7. The method according to any one of embodiments 1 – 6, wherein the free fatty acid feed mainly comprise saturated fatty acids.

8. The method according to any one of embodiments 1 – 7, wherein the free fatty acid feed mainly comprises C_{16} fatty acids.

9. The method according to any one of embodiments 1 – 8, wherein the feedstock is palm oil fatty acid distillate (PFAD).

10. The method according to any one of embodiments 1 – 9, wherein the ketonisation reaction conditions comprise a temperature in the range from 300 to 400 °C, a pressure in the range from 5 to 30 barg and a WHSV in the range from 0.25 – 3 h^{-1}, in the presence of a ketonisation catalyst, the ketonisation catalyst comprising a metal oxide catalyst, optionally in the presence of a gas in the range from 0.1-1.5 gas/feed ratio (w/w), the gas being selected from one or more of: CO_2, H_2, N_2, CH_4, H_2O.

11. The method according to any one of embodiments 1 – 10, wherein the ketonisation reaction conditions ensure liquid phase ketonisation.

12. The method according to any one of embodiments 1 – 11, wherein the ketonisation catalyst is a metal oxide catalyst selected from the list consisting of one or more of: Ti, Mn, Mg, Ca, and Zr containing metal oxide catalyst, preferably the ketonisation catalyst is a Ti containing metal oxide catalyst.

13. The method according to any one of embodiments 1 – 12, wherein the ketonisation catalyst is TiO_2, such as TiO_2 in anatase form having an average pore diameter of 80-160 Å, and/or a BET area of 40-140 m^2/g, and/or porosity of 0.1-0.3 cm^3/g.

14. The method according to any one of embodiments 1 – 13, wherein the ketonisation catalyst is TiO_2, optionally on a support.

15. The method according to any one of embodiments 1 – 14, wherein the ketonisation catalyst is TiO_2, optionally on a support, 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.

16. The method according to any one of embodiments 1 – 15, wherein the ketonisation catalyst is TiO_2, optionally on a support, 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.

17. The method according to any one of embodiments 1 – 16, 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 and a WHSV in the range from 0.5 – 3 h^{-1}, and 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.

18. The method according to any one of embodiments 1 – 17, 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 and a WHSV in the range from 0.5 – 3 h^{-1}, and 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 a molecular sieve, optionally on an alumina and/or silica support.

19. The method according to any one of embodiments 1 – 18, wherein the hydrodeoxygenation and isomerisation catalyst are the same, such as NiW.

20. The method according to any one of embodiments 1 – 19, wherein more than 50 wt% of the feedstock is said mixture of free fatty acids and fatty acid glycerols.

21. The method according to embodiment 20, wherein more than 70 wt% of the feedstock, preferably more than 90 wt% of the feedstock is said mixture of free fatty acids and fatty acid glycerols.

22. The method according to any one of embodiments 1 – 21, wherein the feedstock comprise at least 10 wt% free fatty acids.

23. The method according to any one of embodiments 1 – 22, wherein the feedstock comprise below 90 wt% free fatty acids.

24. The method according to any one of embodiments 1 – 23, wherein the feedstock comprise at least 10 wt% and below 90 wt% free fatty acids.

25. The method according to any one of embodiments 1 – 24, wherein the feedstock comprise at least 10 wt% fatty acid esters.

26. The method according to any one of embodiments 1 – 25, wherein the feedstock comprise below 90 wt% fatty acid esters.

27. The method according to any one of embodiments 1 – 26, wherein the feedstock comprise at least 10 wt% and below 90 wt% fatty acid esters.

28. The method according to any one of embodiments 1 – 27, wherein the feedstock comprise at least 10 wt% and below 90 wt% free fatty acids and at least 10 wt% and below 90 wt% fatty acid esters, and wherein more than 70 wt% of the feedstock, preferably more than 90 wt% of the feedstock is said mixture of free fatty acids and fatty acid glycerols.

29. The method according to any one of embodiments 25 – 28, wherein said fatty acid esters are fatty acid glycerols.

Claims

1. Method for producing a renewable base oil and a diesel fuel 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 at least 50 wt% of the feedstock being the mixture of free fatty acids and fatty acid glycerols;
   b) separating the feedstock into at least:
      - a free fatty acid feed having a higher concentration of free fatty acids than the feedstock, the free fatty acids comprising 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
      - one or more free fatty acid depleted feed(s) having higher concentration of the compounds selected from mono-glycerides, di-glycerides and tri-glycerides of fatty acids, and having a higher boiling point than the free fatty acid feed;
   c) subjecting the free fatty acid feed to ketonisation reaction conditions where two fatty acids react to yield a ketone stream, the ketone stream comprising as the major part saturated ketones; wherein the ketonisation reaction conditions comprise a temperature in the range from 300 to 400 °C, a pressure in the range from 5 to 30 barg, a WHSV in the range from 0.25 – 3 h-1, and the presence of a ketonisation catalyst, and preferably the presence of a gas in the range from 0.1-1.5 gas/feed ratio (w/w), the gas being selected from one or more of: CO_2, H_2, N_2, CH_4, H_2O;
   d) 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 stream comprising the renewable base oil;
   e) optionally distilling the product of step d) to obtain a distilled renewable base oil;

f) where the one or more free fatty acid depleted feed(s) is transformed 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 stream comprising the diesel fuel;

g) optionally distilling the stream obtained from step f) to obtain a distilled diesel fuel.

2. The method according to claim 1, additionally for producing a naphtha fuel, where the naphtha fuel is obtained from distillation of both the deoxygenated and isomerised base oil stream of step d) and from the distillation of the deoxygenated and isomerised diesel stream of step f).

3. The method according to claims 1 or 2, 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, where the ratio of free fatty acids to fatty acid esters has been increased compared to the initial feedstock.

4. The method according to any one of claims 1 – 3, wherein no pre-treatment by hydrogenation or by hydrolysis is made in or in-between steps a) – c).

5. The method according to any one of claims 1 – 4, where the hydrodeoxygenation and hydroisomerisation of step d) 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 between 300-330°C and pressure between 40-50 barg.

6. The method according to any one of claims 1 – 5, wherein between steps d) and e) there is a stripping step, where gasses are separated from liquids, preferably at a temperature between 320-350 °C and pressure between 3-6 barg.

7. The method according to any one of claims 1 – 6, wherein the free fatty acid feed comprises more than 90 wt% saturated fatty acids; preferably C_{16} fatty acids.

8. The method according to any one of claims 1 – 7, wherein the feedstock is palm oil fatty acid distillate (PFAD).

9. The method according to any one of claims 1 – 8, wherein the ketonisation reaction conditions ensure liquid phase ketonisation.

10. The method according to any one of claims 1 – 9, wherein the ketonisation catalyst is a metal oxide catalyst selected from the list consisting of one or more of: Ti, Mn, Mg, Ca, and Zr containing metal oxide catalyst, preferably the ketonisation catalyst is a Ti containing metal oxide catalyst.

11. The method according to any one of claims 1 – 10, wherein the ketonisation catalyst is TiO_2, optionally on a support, such as TiO_2 in anatase form having an average pore diameter of 80-160 Å, and/or a BET area of 40-140 m^2/g, and/ or porosity of 0.1-0.3 cm^3/g.

12. The method according to any one of claims 1 – 11, wherein the ketonisation catalyst is TiO_2, optionally on a support, 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; preferably

wherein the ketonisation catalyst is TiO_2, optionally on a support, 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.

13. The method according to any one of claims 1 – 12, 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 and a WHSV in the range from 0.5 – 3 h^{-1}, and 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; and/or

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 and a WHSV in the range from 0.5 – 3 h^{-1}, and 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 a molecular sieve, optionally on an alumina and/or silica support.

14. The method according to any one of claims 1 – 13, wherein the hydrodeoxygenation and isomerisation catalyst are the same, such as NiW.

15. The method according to any one of claims 1 – 14, wherein more than 50 wt% of the feedstock is said mixture of free fatty acids and fatty acid glycerols.

16. The method according to claim 15, wherein more than 70 wt% of the feedstock, preferably more than 90 wt% of the feedstock is said mixture of free fatty acids and fatty acid glycerols.

17. The method according to any one of claims 1 – 16, wherein the feedstock comprises below 90 wt% free fatty acids; preferably

wherein the feedstock comprises at least 10 wt% and below 90 wt% free fatty acids.

18. The method according to any one of claims 1 – 17, wherein the feedstock comprises at least 10 wt% and below 90 wt% fatty acid esters; preferably wherein said fatty acid esters are fatty acid glycerols.

19. The method according to any one of claims 1 – 18, wherein the feedstock comprises at least 10 wt% and below 90 wt% free fatty acids and at least 10 wt% and below 90 wt% fatty acid esters, and wherein more than 70 wt% of the feedstock, preferably more than 90 wt% of the feedstock is said mixture of free fatty acids and fatty acid glycerols.