

Claims

1. A method for producing ketones, suitable for manufacture of base oil or diesel fuel components, from a feedstock of biological origin comprising fatty acids and/or fatty acid derivatives, wherein the feedstock is at least partly in liquid phase, by subjecting the feedstock to a catalytic ketonisation reaction, wherein the ketonisation reaction is carried out in a system comprising one or more ketonisation reactor(s) each comprising at least one ketonisation catalyst bed, further comprising that

- the feedstock is introduced into a ketonisation reactor together with a carrier gas stream comprising CO₂;
- gas comprising CO₂ is separated from the effluent exiting a ketonisation reactor whereby the effluent comprising ketones is used either as a feedstock for a further ketonisation reactor or for recovery of ketones from the effluent; and
- the separated gas comprising CO₂ is recycled and used in the carrier gas stream in a ketonisation reactor.

2. Method according to claim 1, wherein the feedstock is at least 60 wt-% in liquid phase, preferably at least 65 wt-%, more preferably at least 70 wt-%, at least 75 wt-%, at least 80 wt-%, or at least 90 wt-% in liquid phase, and most preferred 100 wt-% in liquid phase.

3. Method according to any one of the claims 1 to 2, wherein the feedstock of biological origin comprises saturated free fatty acids and/or saturated fatty acid esters, such as esters, amides, aldehydes, alcohols, anhydrides, metal salts, or mixture thereof, preferably fatty acid glycerols.

4. Method according to any one of the claims 1 to 3, wherein the feedstock of biological origin comprises saturated free fatty acids and/or saturated fatty acid esters having an average carbon chain length of from C₄ to C₂₄, preferably having an average carbon chain length of from C₆ to C₂₄.

5. Method according to any one of the claims 1 to 4, wherein the catalyst bed comprises a ketonisation catalyst which is a metal oxide catalyst, preferably selected from the list consisting of one or more of: Ti, Mn, Mg, Ca, and Zr containing metal oxide catalyst, most preferably the ketonisation catalyst is a Ti containing metal oxide catalyst.

6. Method according to any of the claims 1 to 5, wherein the temperature in the feedstock is at least 330 °C, preferably at least 340 °C, more preferably at least 350 °C, even more preferably at least 355 °C, and most preferred 360-365°C.

7. Method according to any of the claims 1 to 6, wherein the temperature is 365°C or less.

8. Method according to any one of the claims 1 to 7, wherein the pressure in a ketonisation reactor is at least 1000 kPa, preferably at least 1200 kPa, more preferably at least 1300 kPa, even more preferably at least 1500 kPa, most preferably at least 2000 kPa, or most preferred at least 2500 kPa.

9. Method according to any one of the claims 1 to 8, wherein the liquid feed flow rate, WHSV, is from 0.1 to 10 h⁻¹, preferably from 0.2 to 5 h⁻¹, more preferably from 0.3 to 3 h⁻¹, most preferably from 0.5 to 1 h⁻¹.

10. A method according to any one of the claims 1 to 9, wherein the ketonisation reaction is carried out in a system comprising two or more ketonisation reactors in series each comprising a ketonisation catalyst bed; further comprising that

- the feedstock is introduced into the first ketonisation reactor together with a first carrier gas stream comprising CO₂; and
- the gas comprising CO₂ is separated from the effluent exiting the first ketonisation reactor whereby the effluent is introduced into the second ketonisation reactor together with a second carrier gas stream comprising CO₂; and
- if the system comprises more than two ketonisation reactors, the gas comprising CO₂ is separated from the effluent exiting each ketonisation reactor leaving a degassed effluent which is subsequently introduced into the next ketonisation reactor together with a further carrier gas stream comprising CO₂;
- gas comprising CO₂ is separated from the effluent exiting the final ketonisation reactor whereby the effluent comprising ketones is used for recovery; and
- the separated gas streams comprising CO₂ are recycled and used as the carrier gas stream in one or more of the ketonisation reactor(s).

11. Method according to claim 10, wherein the pressure in each ketonisation reactor in series following the first ketonisation reactor is lower than the pressure in the preceding ketonisation reactor.

12. Method according to any of the claims 10 and 11, wherein the catalyst loading in the catalyst bed in each ketonisation reactor in series following the first ketonisation reactor is higher than the catalyst loading in the first ketonisation reactor, preferably at least 10 % higher in the second reactor, and/or preferably at least 50 % higher in the third reactor.

13. Method according to any of the claims 1 to 12, wherein the system comprises at least two ketonisation reactors.

14. Method according to claim 13, wherein the effluent exiting a ketonisation reactor and separated from gas comprising CO₂ is heated before introduction into a subsequent ketonisation reactor.

15. Method according to any of the claims 1 to 14, wherein the separated gas streams comprising CO₂ are purified before recycling, and recovered in a separation process comprising steps of separating CO₂ and H₂O vapour from unreacted fatty acids and volatile organic compounds and/or separating substantially pure CO₂, such as at least 98 % pure, preferably 99 % pure CO₂, more preferably 99.5 %, most preferably 99.9 % pure CO₂, from the waste water, and wherein the unreacted fatty acids and/or fatty acid derivatives are optionally recycled to a ketonisation reactor.

16. Method according to claim 15, wherein the separated gas comprising CO₂ is subject to purification, such as by cooling, and optionally further purification, and/or wherein the recovered purified gas is dried before recycling to a ketonisation reactor.

17. Method according to any of the claims 15 to 16, wherein substantially pure CO₂ is recovered and subjected to compression, optionally under heating, before recycled to a ketonisation reactor.

18. Method according to any of the claims 16 to 17, wherein the heat generated by the cooling is used for compression under heating of the substantially pure CO₂.

19. Method according to any of the claims 1 to 18, which method further comprises a hydrodeoxygenation step, an optional isomerisation step and optional hydrofinishing steps.

20. System for producing ketones by the method according to any of the claims 1 to 19, suitable for manufacture of base oil components, from a feedstock of biological origin comprising fatty acids and/or fatty acid derivatives by subjecting the feedstock to a catalytic ketonisation reaction, wherein

- the system comprises one or more ketonisation reactors (A', B') each comprising a ketonisation catalyst bed (G'), means for heating, preferably an oil heater, inlet means for the feedstock (1') and outlet means for the effluent (2', 4') exiting a ketonisation reactor, wherein
- the one or more ketonisation reactors each further comprises inlet means for carrier gas streams (5', 6'), outlet means for separated gas streams comprising CO₂ (8', 10'); and wherein
- the system further comprises one or more gas-liquid separators (D', E') for separating CO₂ in the separated gas streams (8', 10') from H₂O vapour, unreacted fatty acids and/or fatty acid derivatives, and/or volatile organic compounds, and means (F') for recirculating and optionally compressing the separated CO₂; and optionally
- recycling means for liquid comprising unreacted fatty acids and/or fatty acid derivatives (11') and outlet means for separated CO₂ (12').

21. System according to claim 20, further comprising means for purifying the separated CO₂ to a substantially pure CO₂ gas, preferably at least 98 % pure, more preferably 99 % pure, even more preferably 99.5 % pure, most preferably 99.9 % pure CO₂.

22. System according to any one of the claims 20 to 21 comprising two, three or four ketonisation reactors, preferably in series.

23. System according to any one of the claims 20 to 22 wherein

- the system comprises three ketonisation reactors (A, B, C), preferably in series, each comprising a ketonisation catalyst bed (G), means for heating, inlet means for the feedstock (1) and outlet means for the effluent (2, 3, 4) exiting a ketonisation reactor; wherein
- the three ketonisation reactors each further comprises inlet means for a carrier gas stream (5, 6, 7), outlet means for separated gas streams comprising CO₂ (8, 9, 10); and wherein

- the system further comprises one or more gas-liquid separators (D, E) for separating CO₂ in the separated gas streams (8, 9, 10) from H₂O vapour, unreacted fatty acids and/or fatty acid derivatives, and/or volatile organic compounds, and means (F) for recirculating and optionally compressing the separated CO₂; and optionally
- recycling means for liquid comprising unreacted fatty acids and/or fatty acid derivatives (11) and outlet means for separated CO₂ (12).

24. System according to any one of the claims 20 to 23, wherein the one or more ketonisation reactors is a trickle bed reactor.

25. System according to any one of the claims 20 to 24, further comprising means for purification of gas comprising CO₂, such as means for separating CO₂ and/ H₂O vapour from volatile organic compounds.

26. Use of a gas comprising CO₂ as a carrier gas stream in a ketonisation reaction, wherein the gas comprising CO₂ has been produced in a catalytic ketonisation reaction producing ketones, suitable for manufacture of base oil components, from a feedstock of biological origin comprising fatty acids and/or fatty acid derivatives, wherein the feedstock is at least partly in liquid phase, in one or more ketonisation reactors each comprising a ketonisation catalyst bed, and wherein the gas has been separated from the effluent exiting a ketonisation reactor and recycled.

27. Use according to claim 26 for enhancing the gas flow within a ketonisation reactor comprising a ketonisation catalyst bed wherein a feedstock of biological origin comprising fatty acids and/or fatty acid derivatives is subjected to a ketonisation reaction.

28. Use according to any one of claims 26 and 27, wherein the separated gas comprising CO₂ before recycling has been purified and recovered in a separation process comprising steps of separating CO₂ from H₂O vapour and/or volatile organic compounds and optionally separated as substantially pure CO₂ from the waste water.

29. Use according to claim 28, wherein the separated gas comprising CO₂ has been subject to cooling before purification, and/or wherein the recovered purified gas has been dried before recycling to a ketonisation reactor.

30. Use according to any one of the claims 26 to 30, wherein substantially pure CO₂ has been recovered and subjected to compression, optionally under heating, before recycled to a ketonisation reactor.

31. Use of ketones obtainable by a method of any of the claims 1 to 19 for the manufacture of base oil or base oil components.