Claims:

~~1. A process for the transesterification/esterification of a fatty acid source~~ with an alcohol, to form fatty acid alkyl esters, comprising reacting a fatty acid source and an alcohol or an alcohol donor in the presence of an immobilized lipase preparation, wherein the immobilized lipase preparation comprises at least one lipase immobilized on a hydrophobic porous support and the reaction medium contains an aqueous alkaline buffer solution.

2. The process of claim 1, wherein said aqueous alkaline buffer solution is a mild aqueous alkaline buffer solution.

3. The process of claim 1 or claim 2, wherein said aqueous alkaline buffer solution is contained at a quantity of up to 5% wt. of the fatty acid source.

4. The process of any one of claims 1 to 3, wherein the aqueous buffer solution has a pH from 7 to about 11.

5. The process of claim 4, wherein the pH is any one of 7-8.5, 7-9, 7-9.5, 7-10 and 7-11.

6. The process of claim 1, wherein the pKa of the supplemented mild alkaline reagent comprising of the buffer solution is higher or equal than the pKa of free acids present in the fatty acid source.

7. A process for the transesterification/esterification of a fatty acid source with an alcohol, to form fatty acid alkyl esters, comprising reacting a fatty acid source and an alcohol in the presence of an immobilized lipase preparation, wherein the immobilized lipase preparation comprises at least one lipase immobilized on a hydrophobic porous support and the reaction ~~medium contains water.~~

~~8. The process of claim 7, wherein the water is in the form of a water~~ solution of dissolved salts with a pH of from 3 to 11.

9. The process of claim 7 or claim 8, wherein the reaction medium contains the water or water solution of dissolved salts at up to 30% wt., particularly up to 25% wt., more particularly up to 20% wt., more particularly up to 15% wt., more particularly up to 10% wt., more particularly up to 5%wt. of the fatty acid source.

10. The process of any one of the preceding claims, wherein said alcohol is a short-chain alcohol.

11. The process of any one of claims 1 to 9, wherein said alcohol donor is a mono-alkyl ester, such as methyl acetate or a di-alkyl carbonate, such as di-methyl carbonate, serving also as a source for mild alkaline reagent in the reaction medium.

12. The process of any one of the preceding claims, wherein said at least one lipase is a lipase derived from any one *Rhizomucor miehei, Pseudomonas sp., Rhizopus niveus, Mucor javanicus, Rhizopus oryzae, Aspergillus niger, Penicillium camembertii, Alcaligenes sp., Acromobacter sp., Burkholderia sp., Thermomyces lanuginosus, Chromobacterium viscosum, Candida antarctica B, Candida rugosa, Candida antarctica* A, papaya seeds and pancreatin.

13. The process of any one of the preceding claims, wherein said immobilized lipase is capable of catalyzing the esterification of free fatty acids to yield fatty acid alkyl esters and water as by-product, and the transesterification of triglycerides and partial glycerides to yield fatty acid ~~alkyl esters and glycerol as by-product.~~

~~14. The process of any one of claims 1 to 6 and 10 to 13, wherein the~~ amount of said alkaline solution in the reaction medium is up to 30% wt., particularly up to 25% wt., more particularly up to 20% wt., more particularly up to 15% wt., more particularly up to 10% wt., more particularly up to 5%wt. of the fatty acid source.

15. The process of any one of the preceding claims, wherein said lipase preparation comprises at least two lipases which may be each separately immobilized on a hydrophobic support or co-immobilized on the same hydrophobic support.

16. The process of claim 15, wherein said lipases possess identical or different regio-specificity.

17. The process of claim 15 or claim 16, wherein said lipases are capable of simultaneously or consecutively catalyzing the esterification of free fatty acids to yield fatty acid alkyl esters and water as by-product, and the transesterification of triglycerides and partial glycerides to yield fatty acid alkyl esters and glycerol as by-product.

18. The process of any one of the preceding claims, wherein said support is any one of hydrophobic aliphatic polymer-based support and hydrophobic aromatic polymer-based support.

19. The process of claim 18, wherein said hydrophobic polymer support is comprised of linear or branched organic chains.

20. The process of claim 19, wherein said support comprises ~~macroreticular organic polymer or co-polymer chains~~.

~~21. The process of any one of claims 1 to 17, wherein said support is porous~~ or non-porous inorganic support, which may be hydrophobic or is coated with hydrophobic organic material.

22. The process of claim 21, wherein said organic material is a linear, branched, or functionalized hydrophobic organic chain.

23. The process of any one of claims 1 to 6 and 10 to 22, wherein said aqueous alkaline buffer solution is a solution of an inorganic alkaline salt or an organic base.

24. The process of claim 23, wherein said alkaline buffer solution is a solution of any one of an alkaline metal hydroxide, carbonate, bicarbonate, phosphate, sulfate, acetate, fatty acid carboxylates and citrate, a primary, secondary and tertiary amine, and any mixture thereof.

25. The process of claim 24, wherein said alkaline buffer solution is a solution of a weak base selected from sodium or potassium bicarbonates and carbonates.

26. The process of any one of claims 1 to 6 and 10 to 25, wherein said alkaline buffer solution is added to said fatty acid source in a premixing stage or directly to the reaction medium.

27. The process of any one of claims 1 to 6 and 10 to 26, wherein the content of said alkaline buffer solution in the transesterification/ esterification reaction medium is 30% wt., particularly up to 25% wt., more particularly up to 20% wt., more particularly up to 15% wt., more ~~particularly up to 10% wt., more particularly up to 5%wt. of the oil feedstock~~.

~~28. The process of claim 27, wherein the content of said alkaline buffer~~ solution is 1-20% wt., particularly 1-15%wt., more particularly 1-10%wt., more particularly 1-5%wt., more particularly 1-2%wt. of the oil feedstock.

29. The process of any one of claims 1 to 6 and 10 to 28, wherein the fatty acid source is first mixed with said alkaline buffer solution, the mixture is then treated with said immobilized lipase preparation, followed by adding said alcohol and allowing the reaction to proceed under suitable conditions until said fatty acid source is converted to fatty acid esters.

30. The process of any one of the preceding claims wherein said fatty acid source is any one of plant oil, animal fat, algal oil, fish oil, waste oil and any mixtures thereof.

31. The process of any one of the preceding claims wherein said fatty acid source comprises free fatty acids, mono-, di- or tri-glycerides, their mixtures at any ratio, in the absence or presence of other minor fatty acid derivatives such as phospholipids and sterol esters, more specifically said fatty acid source is unrefined, refined, bleached, deodorized or any of their combinations.

32. The process of any one of claims 1 to 10 and 12 to 31, wherein said alcohol is a short-chain alkyl alcohol, specifically C_1-C_6 alkyl alcohol, more specifically C_1-C_4 alkyl alcohol, particularly methanol or ethanol.

33. The process of any one of claims 1 to 10 and 12 to 31, wherein said alcohol is methanol and said resulting fatty acid esters are fatty acid methyl ~~esters (FAME – Biodiesel)~~.

~~34. The process of any one of claims 1 to 10 and 12 to 31, wherein said~~ alcohol is a medium-chain fatty alcohol (C_6-C_{10}) or long-chain fatty alcohols (C_{12}-C_{22}).

35. The process of any one of the preceding claims, wherein the reaction is carried out at a temperature between 10°C and 100°C, specifically between 25-30°C.

36. The process of any one of the preceding claims wherein said fatty acid source is pre-mixed with said alcohol or alcohol donor and with said water or buffer solution in a pre-reaction preparation vessel to form an emulsion which is then fed together with said immobilized lipase preparation into a transesterification/esterification reaction vessel.

37. The process of any one of the preceding claims, wherein said immobilized lipase is used in continuous stirred-tank reactors or in packed-bed column reactors operating in batch or continuous modes.

38. A system for the transesterification/esterification of a fatty acid with an alcohol, to form fatty acid alkyl esters, comprising:
a reaction vessel configured for reacting a reaction medium including a fatty acid and at least one of an alcohol and an alcohol donor in the presence of an immobilized lipase preparation, wherein the immobilized lipase preparation comprises at least one lipase immobilized on a hydrophobic porous support and the reaction medium contains at least one of an aqueous alkaline buffer solution and water.

39. The system according to claim 38, wherein said reaction vessel comprises the immobilized lipase preparation, at least during operation of ~~said system for the production of said fatty acid alkyl esters~~.

~~40. The system according to claim 38 or claim 39, wherein said reaction~~ vessel comprises the fatty acid and the at least one of an alcohol and an alcohol donor, at least during operation of said system for the production of said fatty acid alkyl esters.

41. The system according to any one of claims 38 to 40, wherein said reaction medium comprises a mixture, said system further comprising a pre-reaction vessel in selective fluid communication with said reaction vessel, said pre-reaction vessel being configured for premixing at least the fatty acid and the at least one of an alcohol and an alcohol donor to form said mixture, and for selectively delivering said mixture to said reaction vessel at least during operation of said system for the production of said fatty acid alkyl esters.

42. The system according to claim 41, further comprising a fatty acid source in selective fluid communication with said pre-reaction vessel and configured for selectively delivering the fatty acid to said pre-reaction vessel at least during said operation of said system, and an alcohol source in selective fluid communication with said pre-reaction vessel and configured for selectively delivering the at least one of an alcohol and an alcohol donor to said pre-reaction vessel at least during said operation of said system.

43. The system according to claim 42, further comprising a buffer source in selective fluid communication with said pre-reaction vessel and configured for selectively delivering the at least one of an aqueous alkaline buffer solution and water to said pre-reaction vessel to be included in said mixture at least ~~during said operation of said system.~~

~~44. The system according to claim 42 or claim 45, configured for selectively~~ delivering one or more of the fatty acid and the at least one of an alcohol and an alcohol donor to said pre-reaction vessel in a continuous manner at least during said operation of said system.

45. The system according to claim 43 or claim 44, configured for selectively delivering the at least one of an aqueous alkaline buffer solution and water to said pre-reaction vessel in a continuous manner at least during said operation of said system.

46. The system according to any one of claims 42 to 45, configured for selectively delivering one or more of the fatty acid and the at least one of an alcohol and an alcohol donor to said pre-reaction vessel in discrete batches at least during said operation of said system.

47. The system according to any one of claims 43 to 46, configured for selectively delivering the at least one of an aqueous alkaline buffer solution and water to said pre-reaction vessel in discrete batches at least during said operation of said system.

48. The system according to any one of claims 41 to 47, wherein said pre-reaction vessel is configured for selectively delivering said mixture to said reaction vessel in a continuous manner at least during said operation of said system.

49. The system according to any one of claims 41 to 48, wherein said pre-reaction vessel is configured for selectively delivering said mixture to said reaction vessel in discrete batches at least during said operation of said ~~system.~~

~~50. The system according to any one of claims 38 to 49, the system being~~ configured for selectively and directly delivering to said reaction vessel at least one of the fatty acid; the at least one of an alcohol and an alcohol donor; and the at least one of an aqueous alkaline buffer solution and water.

51. The system according to any one of claims 38 to 50, wherein said reaction vessel comprises a thermal regulation system configured for maintain the reaction medium in said reaction vessel within a selected temperature range.

52. The system according to any one of claims 38 to 51, further comprising a retaining arrangement configured for retaining the immobilized lipase preparation within said reaction vessel at least during operation of said system.

53. The system according to any one of claims 38 to 52, further comprising a product separation vessel in selective fluid communication with said reaction vessel, said system being configured for selectively delivering a reaction mixture including reaction products from said reaction vessel to said product separation vessel, and wherein said product separation vessel is configured for selectively separating a yield of the fatty acid alkyl esters from the reaction mixture delivered thereto.

54. The system according to claim 53, wherein said product separation vessel comprises one of a centrifuge and gravity separation system.

55. The system according to any one of claims 53 and 54, wherein said reaction vessel is configured for selectively delivering said reaction mixture to said product separation vessel in a continuous manner at least during said ~~operation of said system.~~

~~56. The system according to any one of claims 53 to 55, wherein said reaction~~ vessel is configured for selectively delivering said reaction mixture to said product separation vessel in discrete batches at least during said operation of said system.

57. The system according to any one of claims 53 to 56, configured for selectively delivering said yield of fatty acid alkyl esters from said product separation vessel.

58. The system according to claim 57, configured for selectively delivering said yield of fatty acid alkyl esters from said product separation vessel in a continuous manner.

59. The system according to claim 57, configured for selectively delivering said yield of fatty acid alkyl esters from said product separation vessel in discrete batches.

60. The system according to any one of claims 53 to 59, wherein said system is configured for increasing said yield of the fatty acid alkyl esters from the reaction mixture delivered to said product separation vessel.

61. The system according to claim 60, wherein said system is configured for selectively rerouting said yield of the fatty acid alkyl esters to said reaction vessel to further increase said yield of the fatty acid alkyl esters from the reaction mixture subsequently delivered to said product separation vessel.

62. The system according to claim 60, wherein said system is configured ~~for selectively rerouting said yield of the fatty acid alkyl esters to an auxiliary~~

~~reactor module, wherein said auxiliary reactor module comprises an auxiliary~~ reactor vessel and an auxiliary product separation vessel, wherein said further increased yield of the fatty acid alkyl esters is selectively subsequently delivered via said auxiliary product separation vessel.

63. The ~~process~~ of any one of claims 1 to 37, conducted in the system of any ~~one of claims 38 to 62~~.

The claims defining the invention are as follows:

1. A process for the transesterification/esterification of a fatty acid source with an alcohol, to form fatty acid alkyl esters and water and glycerol as by-products, respectively, comprising reacting a fatty acid source and an alcohol or an alcohol donor in the presence of an immobilized lipase preparation, wherein the immobilized lipase preparation comprises at least one lipase immobilized on a hydrophobic porous support and the reaction medium contains an aqueous alkaline buffer solution, wherein the aqueous buffer solution has a pH from 7 to about 11, and wherein the said aqueous alkaline buffer solution is contained in the reaction mixture at a quantity of more than 5% wt. and up to 99% wt. of the fatty acid source, and wherein said transesterification/esterification are carried out simultaneously or sequentially.

2. A process for the transesterification/esterification of a fatty acid source with an alcohol, to form fatty acid alkyl esters and water and glycerol as by-products, respectively, comprising reacting a fatty acid source and an alcohol in the presence of an immobilized lipase preparation, wherein the immobilized lipase preparation comprises at least one lipase immobilized on a hydrophobic porous support and the reaction medium contains water at a quantity of more than 5% wt. and up to 99% wt. of the fatty acid source, and wherein said transesterification/esterification are carried out simultaneously or sequentially.

3. The process of claim 2, wherein the water is in the form of a water solution of dissolved salts with a pH of from 3 to 11.

4. The process of any one of the preceding claims, wherein the aqueous alkaline buffer contained in the reaction mixture is at a quantity of more than 6% wt. of the fatty acid source.

5. The process of any one of the preceding claims, wherein the aqueous alkaline buffer in contained in the reaction mixture at a quantity of more than 8% wt. of the fatty acid source.

6. The process of any one of the preceding claims, wherein the aqueous alkaline buffer in contained in the reaction mixture at a quantity of more than 10% wt. of the fatty acid source.

7. The process of any one of the preceding claims, wherein the aqueous alkaline buffer in contained in the reaction mixture at a quantity of more than 12% wt. of the fatty acid source.

8. The process of any one of the preceding claims, wherein the aqueous alkaline buffer in contained in the reaction mixture at a quantity of more than 15% wt. of the fatty acid source.

9. The process of any one of the preceding claims, wherein the aqueous alkaline buffer in contained in the reaction mixture at a quantity of more than 20% wt. of the fatty acid source.

10. The process of any one of the preceding claims, wherein the aqueous alkaline buffer in contained in the reaction mixture at a quantity of more than 25% wt. of the fatty acid source.

11. The process of any one of the preceding claims, wherein the aqueous alkaline buffer in contained in the reaction mixture at a quantity of more than 30% wt. of the fatty acid source.

12. The process of any one of the preceding claims, wherein the aqueous alkaline buffer in contained in the reaction mixture at a quantity of more than 40% wt. of the fatty acid source.

13. The process of any one of the preceding claims, wherein the aqueous alkaline buffer in contained in the reaction mixture at a quantity of more than 50% wt. of the fatty acid source.

14. The process of any one of the preceding claims, wherein the aqueous alkaline buffer in contained in the reaction mixture at a quantity of more than 60% wt. of the fatty acid source.

15. The process of any one of the preceding claims, wherein the aqueous alkaline buffer in contained in the reaction mixture at a quantity of more than 70% wt. of the fatty acid source.

16. The process of any one of the preceding claims, wherein the aqueous alkaline buffer in contained in the reaction mixture at a quantity of more than 80% wt. of the fatty acid source.

17. The process of any one of the preceding claims, wherein the aqueous alkaline buffer in contained in the reaction mixture at a quantity of more than 90% wt. of the fatty acid source.

18. The process of any one of the preceding claims, wherein said alcohol is a short-chain alcohol.

19. The process of any one of claims 1 to 17, wherein said alcohol donor is a mono-alkyl ester or a di-alkyl carbonate, serving also as a source for mild alkaline reagent in the reaction medium.

20. The process of claim 19, wherein the mono-alkyl ester is methyl acetate.

21. The process of claim 19, wherein the di-alkyl carbonate is di-methyl carbonate.

22. The process of any one of the preceding claims, wherein said at least one lipase is a lipase derived from any one of *Rhizomucor miehei, Pseudomonas sp., Rhizopus niveus, Mucor javanicus, Rhizopus oryzae, Aspergillus niger, Penicillium camembertii, Alcaligenes sp., Acromobacter sp., Burkholderia sp., Thermomyces lanuginosus, Chromobacterium viscosum, Candida antarctica B, Candida rugosa, Candida antarctica* A, papaya seeds and pancreatin.

23. The process of any one of the preceding claims, wherein said immobilized lipase is capable of catalyzing the esterification of free fatty acids to yield fatty acid alkyl esters and water as by-product, and the transesterification of triglycerides and partial glycerides to yield fatty acid alkyl esters and glycerol as by-product.

24. The process of any one of the preceding claims, wherein said lipase preparation comprises at least two lipases which may be each separately immobilized on a hydrophobic support or co-immobilized on the same hydrophobic support.

25. The process of claim 24, wherein said lipases possess identical or different regio-specificity.

26. The process of claim 24 or claim 25, wherein said lipases are capable of simultaneously or consecutively catalyzing the esterification of free fatty acids to yield fatty acid alkyl esters and water as by-product, and the transesterification of triglycerides and partial glycerides to yield fatty acid alkyl esters and glycerol as by-product.

27. The process of any one of the preceding claims, wherein said support is any one of hydrophobic aliphatic polymer-based support and hydrophobic aromatic polymer-based support.

28. The process of claim 27, wherein said hydrophobic polymer support is comprised of linear or branched organic chains.

29. The process of claim 28, wherein said support comprises macroreticular organic polymer or co-polymer chains.

30. The process of any one of claims 1 to 27, wherein said support is porous or non-porous inorganic support, which may be hydrophobic or is coated with hydrophobic organic material.

31. The process of claim 30, wherein said organic material is a linear, branched, or functionalized hydrophobic organic chain.

32. The process of any one of claims 1 and 4 to 31, wherein said aqueous alkaline buffer solution is a solution of an inorganic alkaline salt or an organic base.

33. The process of claim 32, wherein said alkaline buffer solution is a solution of any one of an alkaline metal hydroxide, carbonate, bicarbonate,

phosphate, sulfate, acetate, fatty acid carboxylates and citrate, a primary, secondary and tertiary amine, and any mixture thereof.

34. The process of claim 33, wherein said alkaline buffer solution is a solution of a weak base selected from sodium or potassium bicarbonates and carbonates.

35. The process of any one of the preceding claims wherein said fatty acid source is any one of plant oil, animal fat, algal oil, fish oil, waste oil and any mixtures thereof.

36. The process of any one of the preceding claims wherein said fatty acid source comprises free fatty acids, mono-, di- or tri-glycerides, their mixtures at any ratio, in the absence or presence of other minor fatty acid derivatives.

37. The process of claim 36, wherein the fatty acid derivatives are selected from phospholipids and sterol esters.

38. The process of claim 37, wherein the fatty acid source is unrefined, refined, bleached, deodorized or any of their combinations.

39. The process of any one of claims 1 to 18 and 22 to 36, wherein said alcohol is a short-chain alkyl alcohol.

40. The process of claim 39, wherein said short-chain alcohol is a C_1-C_6 alkyl alcohol.

41. The process of claim 40, wherein said C_1-C_6 alkyl alcohol is a C_1-C_4 alkyl alcohol.

42. The process of claim 41, wherein said C_1-C_4 alkyl alcohol is methanol or ethanol.

43. The process of any one of claims 1 to 18 and 20 to 36, wherein said alcohol is methanol and said resulting fatty acid esters are fatty acid methyl esters (FAME – Biodiesel).

44. The process of any one of claims 1 to 18 and 20 to 36, wherein said alcohol is a medium-chain fatty alcohol (C_6-C_{10}) or long-chain fatty alcohols (C_{12}-C_{22}).