Claims

1. A continuous flow biodiesel production and purification system comprising a tandem arrangement comprising at least one continuous flow modular biodiesel reactor unit and at least one continuous flow separation and purification unit, wherein the modular biodiesel reactor unit comprises a plurality of contact plates, providing adjacent reactant channel and thermal channel for reactant mixture and thermal media for temperature control, respectively.

2. The system according to claim 1, wherein the continuous flow separation and purification unit is arranged in one column that comprises at least one separation section, at least one wet washing section and at least one dry washing/purification section.

3. The system according to claim 1, wherein the biodiesel reactor unit comprises a plurality of contact plates wherein surfaces of said contact plates provide catalytic activity for esterification and/or transesterification of free fatty acids and or transesterification of glycerides in said reactant channel provided by the contact plates for the reactant mixture.

4. The system according to claim 1, wherein the biodiesel reactor comprises a plurality of contact plates coated with at least one esterification and/or transesterification catalyst for catalyzing esterification of free fatty acids and or transesterification of glycerides.

5. The system according to claim 4, wherein the contact plates are arranged such that alternating coated sides face each other forming said reactant channel and two non-coated sides face each other forming said thermal channel, such that reactants flow between the coated sides of the contact plates along said reactant channel while thermal media for temperature control of the reactants flows through said thermal channel between the non-coated sides of the contact plates.

6. The system according to any of claims 1 to 5, further comprising one or more spacers and/or static mixers for adjusting spacing between contact plates and enhancing turbulent mixing, respectively.

7. The system according to claim 6, wherein a static mixer is placed between catalytic sides of two contact plates that face each other and provide a reactant channel.

8. The system according to any of claims 1 to 7, wherein said reactant channel is configured such that reactants can flow through two adjacent contact plates that are provided with at least one static mixer between them, and wherein said thermal channel is provided between two contact plates of which provide the boundary to the adjacent reactant channel as to allow for thermal transfer between a thermal channel and an adjacent reactant channel.

9. The system according to any of claims 6 - 8, wherein the distance between adjacently arranged contact plates and static mixers is adjusted by means of an intermediate spacer.

10. The system according to claim 9, where the internal surface of said spacer provides a catalytic surface for esterification and/or transesterification of free fatty acids and or transesterification of glycerides.

11. The system according to claim 8, where the surface of said static mixers provides a catalytic surface for esterification and/or transesterification of free fatty acids and or transesterification of glycerides

12. The system according to any of claims 1 – 11, where surfaces of said contact plates is mechanically roughened or roughened by other means on at least on one side.

13. The system according to any of claims 7 – 12, where internal surface of said one or more spacer is mechanically roughened or roughened by other means.

14. The system according to any of claims 7 – 13, where surfaces of said one or more static mixer is mechanically roughened or roughened by other means.

15. The system according to any of the preceding claims, wherein said contact plates providing a catalytic surface for esterification of free fatty acids are arranged to provide a first section of the system and said contact plates providing a catalytic surface for transesterification of glycerides. are arranged to provide a second section of the system.

16. The system according to any of the preceding claims, wherein said contact plates are corrugated.

17. The system according to claim 1 or 2, wherein said continuous-flow biodiesel unit comprises at least two reactors, wherein each reactor comprises non-coated contact plates, spacers and static mixers, whereby esterification with a homogeneous acid catalyst is effectuated in the first reactor and transesterification with a homogeneous basic catalyst is effectuated in the second reactor.

18. The system according to any of the preceding claims, wherein the biodiesel reactor comprises a pre-mixing inlet system for allowing mixing of reactants prior to and/or during their delivery into the reactor.

19. The system according to any one of the preceding claims, wherein said biodiesel reactor unit accommodates as input either or both of triglycerides and free fatty acids, wherein said unit comprises at least one catalyst that catalyses transesterification of glycerides and at least one catalyst that catalyses esterification of free fatty acids.

20. The system according to any of the preceding claims, further comprising a reactant high pressure pump, for providing a feed of reactants into the continuous flow biodiesel reactor and a reactant backpressure regulator to control the reactant pressure in the reactant channel and the system further comprising a thermal media high pressure pump, for providing thermal media into the thermal channel and a thermal media backpressure regulator to control the pressure in the thermal channel.

21. The system according to claim 20, further comprising a control unit that is adapted to receive signal from said back pressure regulators and upon analysis of thus received data, adjust and synchronize the pressure in the reactant and thermal channels of the reactor by providing a control signal to the respective high-pressure pumps to minimize differential pressure between the reactant channel and the thermal media channel.

22. The system according to any of the preceding claims, wherein the continuous-flow biodiesel reactor unit is enclosed within a differential pressure equalizing chamber enabling high-pressure operation of the reactor.

23. The system according to claim 22, wherein said control unit is further adapted to receive signal from pressure sensor(s) in said pressure equalizing chamber and upon analysis of thus received data, adjust and synchronize pressure in

the pressure equalizing chamber with the pressure in the reaction and thermal channels of the reactor to minimize differential pressure between these channels.

24. The system according to claim 2, wherein the continuous flow separation, wet washing and purification unit further comprises at least one feed pipe, through which untreated biodiesel is delivered into the unit, wherein the at least one feed pipe extends into said one column, at an angle that is about 90° to a longitudinal axis along the column, wherein the at least one feed pipe preferably extends into the column by a distance that is in the range of about 1/5 to about 2/5, preferably about 1/3, of the diameter of the column.

25. The system according to claim 24, wherein the wet washing section comprises a grid of pipes comprising a plurality of nozzles for delivering a spray of water, preferably so that the grid of pipes is provided as a grid assembly in a plane that is substantially perpendicular to a longitudinal axis of the column.

26. The system according to claim 25 where said grid of pipes is provided above and downstream from the separation section, preferably at a height in the range of 1/3 to 2/3 of the column height, measured from its bottom (biodiesel entry point), so that, during use, the grid of pipes is immersed in rising biodiesel above the separation section.

27. The system according to any of claims 2 to 26, wherein the wet washing section and the separation section are separated by at least one grating, preferably a stainless steel grating.

28. The system according to any of claims 2 to 27, wherein the dry washing/ purification section comprises at least one resin material for removing impurities, residual water and/or small particles from the biodiesel.

29. The system according to any of claims 2 to 28, further comprising at least one heating unit, for controlling the temperature of reagent feed into the continuous flow separation and purification unit.

30. The system according to any of claims 2 to 29, further comprising at least one temperature sensor and at least one conductivity meter, and at least one control unit that is adapted to receive signal from the temperature sensor and conductivity meter and upon analysis of thus received data, adjust the

temperature of feed into the unit and/or water spray into the unit, and or one or more pump in the unit, so as to synchronize feed and draining pumps in the unit.

31. The system according to any one of the previous claims, further comprising at least one evaporation unit arranged between the continuous flow biodiesel reactor unit and the continuous flow separation and purification unit, wherein the evaporation unit preferably comprises a flash evaporation unit.

32. A method for the continuous production of biodiesel, the method comprising:

    a. providing a continuous stream of reactants comprising free fatty acids and/or fatty acid glycerides comprising fat and/or oil into a biodiesel reactor, where the reactants are reacted with at least one alcohol and thus converted into fatty acid esters and/or transesterified fatty acid glycerides;

    b. removing excess alcohol and/or water by evaporation to provide crude biodiesel; and

    c. converting the resulting crude biodiesel to purified biodiesel by a continuous process that includes at least one separation step, at least one wet washing step and at least one purification step.

33. A method for the continuous production of biodiesel according to claim 32, whereby in step a) transesterification of triglycerides is catalyzed by introduction of sodium hydroxide, sodium methoxide or potassium hydroxide or potassium methoxide or other base to the reactant mixture.

34. A method for the continuous production of biodiesel according to claim 32, whereby in step a) esterification of free fatty acids is catalyzed by introduction of sulfuric acid or other acid to the reactant mixture.

35. A method for the continuous production of biodiesel according to claim 32, whereby in step a) transesterification of triglycerides and/or esterification of free fatty acids is promoted by catalytic activity of the surface of said contact plates confining said reaction channel, said catalytic activity provided by coating of said surfaces with suitable solid state catalysts and/or thermal treatment and chemical conversion of said surfaces to achieve suitable catalytic activity.

36. A method for the continuous production of biodiesel according to any of claims 32 to 35, whereby in step a) esterification of free fatty acids is conducted in a first step and transesterification of triglycerides in a second step whereby both steps are arranged in sequence in a continuous flow.

37. A method according to any of claims 32-36 where the reaction is carried out at elevated pressure with the reactant mixture provided into said reaction channel by a high-pressure pump and the pressure of the reactants is controlled by means backpressure regulation.

38. A method according to claim 37 where the reaction is carried out at elevated temperature with thermal media provided into the thermal channel by a high pressure pump and the pressure of the thermal media is adjusted to match that of the reactants by means backpressure regulation of the thermal media and synchronization with the backpressure regulation of the reactants.

39. The method according to claim 32, wherein the evaporation in step b) is performed by means of a flash evaporation drum.

40. The method according to claim 32, wherein the washing and purification step c) comprises treatment with water, followed by treatment by at least one chromatographic resin, preferably an ion exchange resin.

41. A method for the continuous production of biodiesel according to claim 32, wherein following step a and b, the method comprises: converting the resulting crude biodiesel to purified biodiesel by a continuous process that includes at least one separation step, at least one wet washing step and at least one purification step achieved in one separation, wet wash and purification column.

42. The method of any of claims 32 to 41, wherein the method is performed by using a system as set forth in any one of the claims 1 to 31.