

METHOD FOR TREATING LOW QUALITY LIPID FEEDSTOCKS

FIELD OF THE INVENTION

The present invention relates to treating low quality lipid feedstocks, in particular those containing phosphorus and metal impurities in high levels. Specifically the present invention
5 relates to treating low quality lipid feedstocks to allow production of renewable hydrocarbon products therefrom through impurity removal and subsequent hydroprocessing, such as catalytic hydroprocessing.

BACKGROUND OF THE INVENTION

It is a well-known fact that low quality lipid materials, such as oils and fats, can contain
10 impurities that need to be removed before catalytic processing as they are detrimental to the quality of the final product, and may cause e.g. deactivation of the used catalyst. Heat treatment in the presence or in the absence of water is an efficient method to convert oil soluble impurities, especially phosphorus and metal impurities into more easily removable form. However, current heat treatment methods may not be fully suitable for the most
15 difficult feedstocks as hot surfaces in the heat treatment equipment are subjected to fouling and/or corrosion by the impurities coming from the lipid feedstock.

BRIEF DESCRIPTION OF THE INVENTION

An objective of the present invention is thus to provide a method so as to overcome the above problems. The objectives of the invention are achieved by a method which is
20 characterized by what is stated in the independent claims. The preferred embodiments of the invention are disclosed in the dependent claims.

The invention is based on the surprising realization that lipid feedstocks may be successfully treated by a method removing solid impurities from the lipid feedstock prior to heat treatment to avoid fouling of the heat treatment equipment and to allow direct catalytic processing
25 thereafter. This allows efficient removal of the impurities without detrimental fouling of the heat treatment equipment and simplified purification of the lipid feedstock. Further the method may further improve removal of nitrogen containing impurities and/or removal of chlorine containing impurities. The present method further allows efficient production of renewable hydrocarbons from said lipid feedstocks.

BRIEF DESCRIPTION OF THE DRAWINGS

In the following the invention will be described in greater detail by means of preferred embodiments with reference to attached drawings, in which

Figure 1 illustrates the 1st exemplary process flow of the present method;

5 Figure 2 illustrates the 2nd exemplary process flow of the present method;

Figure 3 illustrates the 3rd exemplary process flow of the present method;

Figure 4 illustrates the 4th exemplary process flow of the present method;

Figure 5 illustrates the 5th exemplary process flow of the present method.

DETAILED DESCRIPTION OF THE INVENTION

- 10 The present invention provides a method for treating lipid feedstock, comprising
- i) providing the lipid feedstock (a);
 - ii) optionally removing free water from the lipid feedstock (a);
 - iii) removing solid impurities from the lipid feedstock (a) to obtain a conditioned lipid feedstock (b);
 - 15 iv) heating the conditioned lipid feedstock (b) to a desired heat treatment temperature;
 - v) heat-treating the conditioned lipid feedstock (b), preferably in the presence of water or an aqueous solution, at a heat treatment temperature of at least 150 °C, such as from 150 to 400 °C, to obtain a heat-treated lipid feedstock (c), whereby the desired heat treatment temperature of step iv) is the heat treatment temperature of step v);
 - 20 vi) optionally further treating the heat-treated lipid feedstock (c) with an acid and/or adsorbent material, preferably under bleaching conditions, to obtain a further treated lipid feedstock (d);
 - vii) recovering the heat-treated lipid feedstock (c) and/or the further treated lipid feedstock (d) by phase separation, to obtain a purified lipid feedstock (e); and
 - 25 vii) optionally subjecting the purified lipid feedstock (e) to hydroprocessing, such as catalytic hydroprocessing, in particular hydrodeoxygenation (HDO), hydroisomerization (HI), and/or hydrocracking (HC), to obtain at least one renewable hydrocarbon product.

In the present description, weight percentages (wt%) are calculated based on the total weight of the material in question (typically a blend or a mixture). Any amounts defined as ppm (parts per million), are based on weight (i.e. mg/kg).

5 The term "renewable" in the context of renewable feed, renewable feedstock or renewable fuel or fuel component refers to one or more organic compounds derived from any renewable source (contrary to source of fossil origin). Thus renewable compounds or compositions are obtainable, obtained, derivable, derived, or originating from plants, animals and/or microbes, including compounds or compositions obtainable, obtained, derivable, derived, or originating from fungi and/or algae, in full or in part, whether these
10 compounds or compositions are in their virgin, recycled or reclaimed form. As used herein, renewable compounds or compositions may comprise gene manipulated compounds or compositions. Renewable feedstocks, components, compounds, or compositions may also be referred to as biological feedstocks, components, compounds, or compositions, or as biogenic feedstocks, components, compounds, or compositions. As used herein, the term
15 "fossil" refers to compounds or compositions that are obtainable, obtained, derivable, derived, or originating from naturally occurring non-renewable compositions, such as crude oil, petroleum oil/gas, shale oil/gas, natural gas, or coal deposits, and the like, and combinations thereof, including any hydrocarbon rich deposits that can be utilized from ground and/or underground sources. Thus, the renewable hydrocarbon is based on
20 renewable sources and consequently does not originate from or is not derived from any fossil based material.

The ¹⁴C-isotope content can be used as evidence of the renewable or biological origin of a feedstock or product. Carbon atoms of renewable material comprise a higher number of unstable radiocarbon (¹⁴C) atoms compared to carbon atoms of fossil origin. Therefore, it
25 is possible to distinguish between carbon compounds derived from biological sources, and carbon compounds derived from fossil sources by analyzing the ratio of ¹²C and ¹⁴C isotopes. Thus, a particular ratio of said isotopes can be used to identify and quantify renewable carbon compounds and differentiate those from non-renewable i.e. fossil carbon compounds. The isotope ratio does not change in the course of chemical reactions.
30 Example of a suitable method for analyzing the content of carbon from biological sources is ASTM D6866 (2020). An example of how to apply ASTM D6866 to determine the renewable content in fuels is provided in the article of Dijs et al., Radiocarbon, 48(3), 2006, pp 315-323. For the purpose of the present invention, a renewable material, such as a feedstock or product, is considered to be of renewable origin if it contains 90 % or more modern carbon
35 (pMC), such as about 100 % modern carbon, as measured using ASTM D6866.

As used herein, “hydrocarbons” refer to compounds consisting of carbon and hydrogen. Examples of hydrocarbons include paraffins, including n-paraffins and i-paraffins, naphthenes, aromatics, and olefins (alkenes). “Oxygenated hydrocarbons” refer herein to hydrocarbons comprising covalently bound oxygen. Examples of oxygenated hydrocarbons include tri-, di-, and monoglycerides, fatty acids and alkyl-esters of fatty acids (e.g. methyl- or ethyl-ester of fatty acids).

As used herein, “paraffins” refer to non-cyclic alkanes, i.e., non-cyclic, open chain saturated hydrocarbons that are linear (normal paraffins, n-paraffins) or branched (isoparaffins, i-paraffins). In other words, paraffins refer herein to n-paraffins and/or i-paraffins.

In the context of the present disclosure, “olefins” refer to unsaturated, linear, branched, or cyclic hydrocarbons, excluding aromatic compounds. In other words, olefins refer to hydrocarbons having at least one unsaturated bond, excluding unsaturated bonds in aromatic rings.

“Naphthenes” refer herein to cycloalkanes or cycloalkenes containing at least one cyclic structure, with or without side chains, including also compounds having one or more olefinic bonds in the cyclic structure and/or in a side chain, but excluding compounds with any aromatic ring structure(s).

“Aromatics” refers herein to hydrocarbons containing at least one aromatic ring structure, i.e. cyclic structure having delocalized, pi bonds satisfying the Hückel ($4n + 2$) rule.

Term “fuel” refers to both fuels usable as such and/or as fuel components, which fulfill the requirements of standards for the respective use. For example, within the EU, the standard for gasoline is EN 228 (2017), for paraffinic diesel EN 15940 (2019), and for aviation turbine fuel containing synthesized hydrocarbons D7566 (2020).

Lipid feedstock

The term “lipid feedstock” refers to lipid material which is intended to be converted by catalytic hydroprocessing into renewable hydrocarbons or other valuable renewable products, including fuels, but which comprises impurity concentration that is too high for the lipid feedstock to be fed to the hydroprocessing processes as such. Lipid feedstock contemplated herein typically comprises at least 5 mg/kg, such as from 5 to 5000 mg/kg, phosphorus impurities, and at least 10 mg/kg, such as from 10 to 10000 mg/kg, metal impurities, measured as elemental phosphorus and elemental metal(s). Preferably the lipid feedstock contemplated herein comprises at least 15 mg/kg, such as 15 to 2000 mg/kg, phosphorus impurities, and at least 20 mg/kg, such as 20 to 3000 mg/kg, metal impurities,

measured as elemental phosphorus and elemental metal(s). The total net elemental charge of the lipid feedstock contemplated herein based on phosphorus and the metal(s) contained in the lipid feedstock may be positive or negative. In an embodiment the lipid feedstock is a lipid feedstock having total net elementary charge Q1 below 0 mmol/kg, such as from -60 to -0.5 mmol/kg, in particular below -0.5 mmol/kg, such as from -30 to -1 mmol/kg. In particular, in such embodiment the conditioned feedstock (c) subjected to heat treatment has a total net elementary charge Q1 below 0 mmol/kg, such as from -60 to -0.5 mmol/kg, in particular below -0.5 mmol/kg, such as from -30 to -1 mmol/kg.

The term "net elementary charge of a feedstock" means the net elementary charge of phosphorus and the metal(s) contained in the feedstock, while the term "net elementary charge of the feedstock" is used for brevity. Also, when a numerical value of the net elementary charge of a feedstock is given, the unit is mmol elementary charge/kg of feedstock in question, while also mmol/kg may be used for brevity.

The total net elementary charge of the lipid feedstock is determined by the net elementary charge Q1 based on phosphorus and the at least one metal obtained by equation (I)

$$Q1 = (CPQP) + i(CMiQMi) \quad (I)$$

wherein

CP is the concentration of dissolved phosphorus in the feedstock in mmol/kg of feedstock,

QP is the elementary charge of dissolved phosphorus in the feedstock,

CMi is the concentration of dissolved metal i in the feedstock in mmol/kg of feedstock,

QMi is the elementary charge of the dissolved metal i in the feedstock, and

i is the number of dissolved metals taken into account, and i is 1-n.

The total net elementary charge Qt is then the sum of the net elementary charges of each component of the lipid feedstock, i.e.

$$Qt = Q1 + Q2 + Q3 + \dots + QC$$

The elementary charge of phosphorus is -3 e in this equation, as assumed herein to be in the form of a phosphate. The elementary charge of sodium is +1 e, that of potassium +1 e, that of magnesium +2 e, that of calcium +2 e, and that of iron +3 e, depending on the compounds present. In case there are other dissolved metals present in the feed in significant amounts, in an amount higher than 0.1 ppm by weight, those metals are also considered in the calculation of the net elementary charge, with their elementary charge.

The same limit of significant amount (0.1 ppm) may also be used for sodium, potassium, magnesium, calcium and iron. The metals include Na, K, Mg, Ca, Fe, Al, Cr, Pb, Mn, Zn, W, Ni and Cu, or any combinations thereof. The elementary charge of a metal is the valence the metal typically has when forming a metal salt, such as metal phosphate. A person skilled
5 in the art may also use another method for this determination. Only the concentration of dissolved phosphorus and metal(s) (not solid impurities) are used in the net elementary charge calculation. In accordance with the present method, solid impurities are removed from the feedstock to be treated by heat treatment in step iii) and are thus not considered for determining the net elementary charge Q_1 and/or total net elementary charge Q_t .

10 Phosphorus impurities may be present in the lipid feedstock in various chemical forms in varying phosphorus containing compounds, such as in the form of phospholipids, oil or water soluble or insoluble phosphorus compounds, or inorganic phosphates, diphosphates, and phosphites. Typical phosphorus containing compounds may further comprise glycerophospholipids, sphingolipids, phosphatidic acid complexes, phosphatidylethanol-
15 amines, nucleoside phosphates, apatite or bone meal (calcium phosphate), and the like.

Metal impurities may similarly be present in the lipid feedstock in various chemical forms in varying metal containing compounds, inorganic or organic, in water soluble, oil soluble, or insoluble forms.

The lipid feedstock may contain both dissolved and undissolved impurities, including
20 dissolved and undissolved phosphorus and/or metal impurities. The term "dissolved impurities" as used herein refers to impurities which remain in the liquid phase after filtration with 0.45 μm filter, i.e. impurities in solid form i.e. "solid impurities" that are removed by such filtration are not considered dissolved impurities in this context. Thus the amounts of impurities soluble in the feedstock, i.e. the oil insoluble impurities, are not considered to be
25 part of the dissolved impurities, but are taken into account as solid impurities and are treated accordingly, i.e. removed together with the other solid impurities (in step iii). Thus, for the determination of the dissolved phosphorus and metal impurities, a sample of the feedstock is filtered to remove any solid particles, and the amounts of various metals and phosphorus as elemental metals and elemental phosphorus are measured thereafter.

30 The present method may be used to purify any lipid feedstock, such as plant oils, plant fats, animal fats, animal oils, fish fats, fish oils, waste fats, waste oils, residue fats, residue oils, a fatty acid distillate, acidulated soapstock, mold oils, rapeseed oil, canola oil, colza oil, babassu oil, carinata oil, pongamia oil, coconut butter, muscat butter oil, sesame oil, maize oil, poppy seed oil, cottonseed oil, soy oil, laurel seed oil, jatropha oil, palm kernel oil,

camelina oil, tall oil, fraction of tall oil, crude tall oil, tall oil pitch, sunflower oil, corn oil, technical/distillers corn oil, soybean oil, hemp seed oil, olive oil, linseed oil, cottonseed oil, mustard oil, mustard seed oil, peanut oil, castor oil, coconut oil, palm oil, crude palm oil, palm seed oil, palm fatty acid distillate, a sludge originating from plant oil production, palm oil mill effluent, arachis oil, castor oil, coconut oil, archaeal oil, bacterial oil, fungal oil, protozoal oil, algal oil, seaweed oil, oils from halophiles, poultry fat, dry rendered poultry fat, brown grease, used cooking oil, suet, lard, tallow, blubber, recycled alimentary fats, acid oil, train oil, spent bleaching earth oil, lignocellulosic based feeds, materials produced by genetic engineering, and biological materials produced by microbes, or any combinations or mixtures thereof. The present method is particularly suitable for lipid materials containing high amounts of phosphorus, metals, and solid impurities and/or oil insoluble impurities.

The lipid feedstock may be in unprocessed form (e.g. animal fat) or in processed form (e.g. used cooking oil).

Typical lipid feedstocks comprise waste and recycle oils, typically combinations thereof. Such lipid materials typically initially contain high amounts of phosphorus, typically as phosphorus containing compounds, metals, typically as metal containing compounds, and solid impurities.

Solid impurities and oil insoluble impurities contribute to a significant part of the total impurities of typical lipid feedstocks used for renewable hydrocarbon production. Especially lipid feedstock comprising or consisting of waste and residue streams may contain significant levels of solid impurities. The solid impurities include e.g. salts, protein residues, bone meal, fibers, carbohydrates, and/or sand. The present method is particularly suitable for lipid feedstocks comprising at least 0.05 wt%, such as from 0.05 to 10 wt%, preferably at least 0.1 wt%, such as 0.1 to 3 wt%, more preferably 0.5 to 1 wt%, solid impurities of the total weight of the lipid feedstock.

Examples of lipid materials benefitting from the present purification method include soapstock acid oil (SAO), low quality animal fat (LQAF) grades such as choice white grease (CWG) and poultry fat (APF), brown grease (BG), used cooking oil (UCO), and palm oil mill effluent (POME), crude tall oil (CTO), and tall oil pitch (TOP), as well as mixtures thereof.

Soapstock acid oil (SAO) is a by-product from the vegetable oil refining industry obtained by acidification of soapstock. Typically SAO comprises high amounts of phosphorus and metal impurities, such as at least 30 mg/kg, e.g. 50 to 700 mg/kg, phosphorus, at least 10 mg/kg, e.g. 10 to 3000 mg/kg, metals, and at least 0.1 wt%, e.g. 0.1 to 3 wt%, solid

impurities. Typically the net elementary charge of SAO is -13 mmol/kg, such as from -60 to -10 mmol/kg.

Low quality animal fat (LQAF) is typically inedible lipids derived from animals. Typically LQAF comprises high amounts of phosphorus and metal impurities, such as at least 50 mg/kg, e.g. 100 to 700 mg/kg, phosphorus, at least 50 mg/kg, e.g. 50 to 1200 mg/kg, metals, and at least 0.01 wt%, e.g. 0.01 to 2.0 wt%, solid impurities. Typically the net elementary charge of LQAF is -30 mmol/kg, such as from -50 to -5 mmol/kg.

An example of LQAF, choice white grease (CWG) is an inedible low quality animal fat obtained from the rendering process of swine in the North American feedstock market. Typically CWG comprises high amounts of phosphorus and metal impurities, such as at least 300 mg/kg, e.g. 300 to 700 mg/kg, phosphorus, at least 600 mg/kg, e.g. 600 to 1200 mg/kg, metals, and at least 0.4 wt%, e.g. 0.4 to 2.0 wt%, solid impurities. Typically the net elementary charge of CWG is -10 mmol/kg, such as from -30 to -5 mmol/kg.

A further example of LQAF, poultry fat (AFP) is fat obtained from poultry rendering and processing. Typically AFP comprises high amounts of phosphorus and metal impurities, such as at least 50 mg/kg, e.g. 100 to 700 mg/kg, phosphorus, at least 10 mg/kg, e.g. 50 to 500 mg/kg, metals, and at least 0.01 wt%, e.g. 0.1 to 1.0 wt%, solid impurities. Typically the net elementary charge of AFP is -30 mmol/kg, such as from -50 to -15 mmol/kg.

Used cooking oil (UCO) is oils and fats that have been used for cooking or frying. Typically UCO comprises high amounts of phosphorus and metal impurities, such as at least 2 mg/kg, e.g. 5 to 300 mg/kg, phosphorus, at least 10 mg/kg, e.g. 20 to 2000 mg/kg, metals, and at least 0.01 wt%, e.g. 0.01 to 1.0 wt%, solid impurities. Typically the net elementary charge of UCO is at least 0 mmol/kg, such as from 0 to 10 mmol/kg.

Brown Grease (BG) is intended to mean any emulsion of fat, oil, grease, solids, and water separated from wastewater in a grease interceptor (grease trap) and collected for use as a fuel feedstock. Typically BG comprises high amounts of phosphorus and metal impurities, such as at least 5 mg/kg, e.g. 15 to 300 mg/kg, phosphorus, at least 20 mg/kg, e.g. 200 to 3000 mg/kg, metals, and at least 0.1 wt%, e.g. 0.1 to 3 wt%, solid impurities. Typically the net elementary charge of BG is 10 mmol/kg, such as from -10 to 100 mmol/kg.

Palm oil mill effluent (POME) is oil waste separated from wastewaters generated in palm oil milling. Typically POME comprises high amounts of phosphorus and metal impurities, such as at least 5 mg/kg, e.g. 5 to 150 mg/kg, phosphorus, at least 10 mg/kg, e.g. 10 to 4000

mg/kg, metals, and at least 0.01 wt%, e.g. 0.1 to 2.0 wt%, solid impurities. Typically the net elementary charge of POME is 10 mmol/kg, such as from 0 to 70 mmol/kg.

Crude tall oil (CTO) is an oil composition comprising fatty acids, rosin acids and other neutral materials obtained from the wood pulping industry. Typically CTO comprises high amounts
5 of phosphorous and metal impurities, such as at least 5 mg/kg, e.g. 10 to 120 mg/kg, phosphorus, at least 50 mg/kg, e.g. 100 to 6000 mg/kg, metals, and at least 0.01 wt%, e.g. 0.1 to 1 wt% solid impurities. Typically the net elementary charge of CTO is at least 0 mmol/kg, such as 10 to 200 mmol/kg.

Tall oil pitch is a nonvolatile residue in the fractional distillation process of crude tall oil.
10 Typically CTO comprises high amounts of phosphorous and metal impurities, such as at least 10 mg/kg, e.g. 10 to 150 mg/kg, phosphorus, at least 100 mg/kg, e.g. 100 to 2000 mg/kg, metals, and at least 0.01 wt%, e.g. 0.1 to 1 wt% solid impurities. Typically the net elementary charge of CTO is at least 0 mmol/kg, such as 10 to 90 mmol/kg.

The amount of phosphorus and metal impurities may be determined e.g. according to ASTM
15 D5185-18 standard test method or as described herein in the experimental part, preferably as described herein.

Drying of the Lipid Feedstock, Step ii)

In step ii), prior to removing the solid impurities in step iii), the lipid feedstock may optionally be subjected to removing free water, in particular evaporation, under conditions capable of
20 removing water vapor from the lipid feedstock. However, the evaporation conditions are controlled such that low-boiling components, such as low-boiling fatty acids of the lipid feedstock are not lost. According to an embodiment comprising evaporation, the evaporation may be performed at temperature from 50 to 130 °C, and pressure from 1 to 100 kPa(a). As an example, a combination of temperature of 105 °C and pressure of 8
25 kPa(a) could be applied to evaporation.

Advantageously, in particular when the removal of solid impurities in step iii) is accomplished by filter aid filtration with filter aid material comprising or consisting of mineral based material, at least part of or all free water is removed from the lipid feedstock before the removal of solid impurities in step iii) to avoid leaching of metals from the mineral based
30 filter aid material, i.e. the lipid feedstock is at least partly dried. Drying is preferably accomplished so that the lipid feedstock entering step iii) does not contain any free water. The presence of free water in lipid feedstock may be determined by visual inspection of the sample for the presence of a second liquid phase as dispersion or as a discrete phase

settled based on density difference to the oil. The presence of free water may also be estimated based on the difference of total water content of the oil and estimated water dissolution capability of the oil bulk components. Water solubility may vary between different feedstocks and is dependent on the temperature of the feedstocks and thus absolute total water content for free water may vary. A skilled person will be able to determine the presence of free water in the lipid feedstock. Typically when the lipid feedstock does not contain any free water, it comprises up to or less than 2 wt%, such as from 0.05 wt% to 2 wt%, preferably less than 1.5 wt%, such as from 0.2 wt% to 1.5 wt%, more preferably less than 1 wt%, such as from 0.2 wt% to 1 wt%, more preferably less than 0.5 wt% water, of the total weight of the lipid feedstock. The total water content of the lipid feedstock may be determined according to ASTM D6304-20, procedure C. The method is based on a coulometric Karl Fischer titration.

Removal of the Solid Impurities, Step iii)

In step iii) the lipid feedstock is subjected to removing solid impurities from the lipid feedstock (a) to obtain a conditioned lipid feedstock (b). Solid impurities removed in step iii) include e.g. salts, protein residues, bone meal, fibers, carbohydrates, and/or sand.

While the removal of solid impurities may be accomplished by any phase separation method suitable for removing solid impurities from lipid materials, including, but not limited to, settling, centrifuging, filtering, and any combination of those, preferably centrifuging and/or filtering, in the context of the present invention it is particularly preferred to accomplish the removal of solid impurities by filtering the lipid feedstock with a filter aid, i.e. filter aid filtration (FAF). Filter aid filtration may be accomplished e.g. mixing the lipid feedstock (a) with a filter aid material, in amount such as 0.1 to 1 wt% filter aid to the total amount of the lipid feedstock, and then filtering the feed as a pressure cake filtration over the filter aid precoat. The filter aid filtration may be accomplished under suitable conditions, e.g. at a temperature from 50 to 130 °C, preferably from 80 to 120 °C, and at a pressure from 1 to 2000 kPa(a), preferably from 150 kPa(a) to 1500 kPa(a), more preferably from 200 kPa(a) to 1000 kPa(a), even more preferably from 200 kPa(a) to 650 kPa(a), most preferably from 250 kPa(a) to 500 kPa(a).

Filter aid filtration was found to be an efficient means to lower the level of solid impurities by at least 90%, such as from 90 to 99%, advantageously by at least 95%, such as from 95 to 99%. It may be beneficial to remove easily removable denser and larger solid impurities prior to the filter aid filtration by settling or decanting. Filter aid filtration further has the added

benefit of improved filterability over static filter elements or filter screens. Examples of suitable filter aid materials include, but are not limited to, any material comprising or consisting of mineral, silicon, and/or cellulose based material, e.g. diatomaceous earth, diatomite, perlite, bentonite, palygorskite, kaolin, kaolinite, silica in various crystalline or amorphous configurations, sepiolite, magnesium silicate, silicon, aluminum oxide based materials, zinc oxide based materials, neutral bleaching earth, activated carbon, activated charcoal, cellulose fibers, or any combinations thereof. In an embodiment the filter aid material is diatomaceous earth. The filter aid material may be activated by means known in the art.

Advantageously the lipid feedstock is dried to remove free water, in step ii), before the filter aid filtration in step iii) if a filter aid material comprising or consisting of mineral based material is used, in order to avoid leaching of metals from the filter aid material to the lipid feedstock.

After the removal of solid impurities the conditioned lipid feedstock (b) advantageously comprises less than 0.5 wt%, such as 0 to 0.2 wt%, solid impurities of the total weight of the conditioned lipid feedstock (b). Most advantageously lowering the amount of solid impurities and/or oil insoluble impurities in the conditioned lipid feedstock (b) below 0.1 wt%, renders the conditioned lipid feedstock (b) suitable for successful downstream treatment without detrimental fouling of the used heating equipment.

The amount of insoluble impurities may be determined according to ISO 663:2017.

Heating the Lipid Feedstock, Step iv)

After accomplishing step iii) the conditioned lipid feedstock (b) is heated to a desired heat treatment temperature. Heating of the conditioned lipid feedstock (b) is generally done by heat exchangers, either directly to the desired heat treatment temperature or by using several heating steps or by heating partly using a circulation feed of an already heated lipid feedstock. The heat-treated lipid feedstock (c) obtained from step v) may be utilized in the heat exchangers to heat the conditioned lipid feedstock (b) and thus to cool down the heat-treated lipid feedstock (c).

In the heating step the conditioned lipid feedstock (b) is heated by heat exchangers and is thus in contact with hot surfaces, typically having a temperature of at least 200 to 450 °C, such as from 200 to 350 °C, depending on the desired heat treatment temperature of the lipid feedstock. By the present method, the fouling rate is seen to significantly reduce, in

comparison to a crude lipid feedstock (a), when a conditioned lipid feedstock (b) is heat-treated, thus resulting in less frequent cleaning frequency of the heating equipment.

Heat Treatment, Step v)

After accomplishing steps ii) to iv) as described above, the thus obtained conditioned lipid feedstock (b) is subjected in step v) to a heat treatment. The term "heat treatment" as used
5 feedstock (b) is subjected in step v) to a heat treatment. The term "heat treatment" as used herein refers to maintaining the lipid feedstock within a desired heat treatment temperature for a sufficient time period. Further conditions of the heat treatment step v) may vary as described hereby.

The conditioned lipid feedstock (b) may be heat-treated as such or in the presence of water.
10 Advantageously at least a small amount of water is present in the heat treatment step v). Water in step v) can be water dissolved in the conditioned lipid feedstock (b) or water added to the conditioned lipid feedstock (b), either as such or as an aqueous solution, resulting in an oil-water mixture. The aqueous solution may further comprise acid such as citric acid, phosphoric acid or sulphuric acid, or alkali, such as NaOH, in order to enhance the removal
15 of metals, phosphorus, and/or chlorine. Need for acid or alkali addition depends on feedstock impurities and the possibility to post-treat the heat-treated product.

Generally the amount of water dissolved in the conditioned lipid feedstock is adequate and no water addition for the heat treatment step v) is done. Keeping the water content low contributes to avoidance of emulsions and allows lower processing pressure, in particular
20 when the water content is less than 1 wt%, or preferably less than 0.5 wt% water of the total weight of the conditioned lipid feedstock (b).

In an embodiment the conditioned lipid feedstock (b) advantageously contains less than 10 wt%, preferably less than 5 wt%, such as 0.05 wt% to 2 wt%, preferably less than 1.5 wt%, such as from 0.2 wt% to 1.5 wt%, more preferably less than 0.5 wt% water of the total weight
25 of the conditioned lipid feedstock (b).

In an alternative embodiment water is added to the lipid feedstock. The amount of water may be e.g. in a ratio (w/w) of feedstock to water of about 1:1, such as e.g. about 2:1, such as e.g. about 3:1, such as e.g. about 4:1, such as e.g. about 5:1, such as e.g. about 6:1, such as e.g. about 7:1, such as e.g. about 8:1, such as e.g. about 9:1, such as e.g. about
30 10:1 etc. However, the amount of water may also be about 5 wt% (in relation to weight of feedstock), such as e.g. about 10 wt%, such as e.g. about 20 wt%, such as e.g. about 30 wt%, such as e.g. about 40 wt%. In one aspect, the amount of added water may be in any

range of from 1 wt% to 10 wt%, such as from 5 wt% to 8 wt% in relation to the conditioned lipid feedstock (b), the water being provided as such or as part of an aqueous solution.

Water can be added to the lipid feedstock as such or as an aqueous solution, as discussed earlier, either directly to the heat treatment step v) or before or during the heating step iv).

- 5 When water is added directly to the heat treatment step v) it is advantageously heated before the addition to a desired heat treatment temperature, i.e. the heat treatment temperature of step v). Without bounding to a theory, higher amounts of water may be advantageous as it results in hydrolysis of the organic chlorine compounds as well as phospholipids present in the lipid feedstock resulting in lower chlorine and phosphorus
- 10 impurities in the heat-treated lipid feedstock. Additionally or alternatively, water may dissolve at least part of the impurities precipitated in the heat treatment. This is based on the water solubility and polarity of the precipitated salts and/or oil soluble impurities, which are transferred from oil or solid phase to water.

- The heat treatment in step v) is accomplished at a temperature of at least 150°C, such as
- 15 from 150°C to 400 °C, preferably at least 180 °C such as from 180 to 350 °C, preferably of at least 200 °C, such as from 200 to 350 °C, preferably of at least 220 °C, such as from 220 to 350 °C, more preferably of at least 270°C, such as from 270 to 350 °C, most preferably of at least 330 °C, such as from 330 to 350 °C. Depending on the desired other conditions a temperature of preferably at least 180 °C, such as from 180 to 325 °C, preferably of at
- 20 least 200 °C, such as from 200 to 350 °C, preferably of at least 220 °C, such as from 220 to 325 °C, more preferably of at least 270°C, such as from 270 to 300 °C, most preferably of at least 280 °C, such as from 280 to 290 °C, may also be considered. The heat treatment promotes the separation of impurities, such as phosphorus, as solid precipitates i.e. solid rejects. Temperatures above 150 °C allow formation of solid rejects from the lipid material,
- 25 which may, in the presence of free water, become at least partly dissolved in the water phase. In temperatures above 325 °C thermal cracking of the components may start to be observed, however in presence of water temperatures up to 400 °C may be desirable.

- The heat treatment in step v) may be carried out at a pressure from 100 to 6500 kPa(a), such as from 100 to 5100 kPa(a), preferably from 150 to 2100 kPa(a), more preferably from
- 30 200 to 600 kPa(a), most preferably from 300 to 500 kPa(a). A person skilled in the art will be competent to adjust the pressure to fit the intended purpose, appreciating that elevating the pressure minimizes losses of lipid material in the heat treatment step.

The residence time in the heat treatment step v) may be from less than a minute up to a few hours depending on the temperature. A person skilled in the art will be competent to

adjust the time to fit the intended purpose, appreciating that at higher temperatures a shorter residence time is sufficient. In an embodiment the residence time is from 1 to 300 minutes, such as 1 to 120 minutes, preferably 1 to 30 minutes. In an embodiment where at least 5 wt%, such as 5 to 50 wt% water in relation to the conditioned lipid feedstock (b), provided
5 as such or as an aqueous solution, is present in the heat treatment, the residence time is advantageously from 1 to 100 minutes, preferably from 1 to 5 minutes, to prevent excessive hydrolysis of the heat-treated lipid feedstock.

In one embodiment, the heat treatment is accomplished at a high temperature, such as from 300 °C to 400 °C, preferably from 350 °C to 400 °C, in presence of water or an aqueous
10 solution, such as 30 wt% to 50 wt% of water, wherein the residence time may be short, such as from 1 min to 100 min, and, preferably, a pressure from 4000 to 6500 kPa(a).

Heat treatment in step v) may be performed in any suitable reactor wherein the indicated conditions may be achieved. Examples of suitable reactors include mixed reactors and/or tube reactors. Further, the heat treatment in step v) may be performed in one or more
15 batches and/or in continuous mode.

Generally, it is advantageous to boost the contact and transfer between free water, such as the added water or the aqueous solution, and the lipid feedstock during the heat treatment. Accordingly, in preferred embodiments, mixing is provided.

After the heat treatment in step v) a heat-treated lipid feedstock (c) is obtained. The heat-treated lipid feedstock (c) may then be directly subjected to recovery by phase separation in step vii) and/or it may be further purified by treatment with an acid and/or adsorbent material in step vi). The present method advantageously avoids the need of further purification of the heat-treated lipid feedstock and the heat-treated lipid feedstock may be directly subjected to recovery by phase separation in step vii) and subsequent
20 hydrotreatment.
25

Further treatment, Step vi)

In step vi) the heat-treated lipid feedstock (c) is optionally subjected to further purification by treating the heat-treated lipid feedstock (c) with an acid and/or adsorbent material, in particular under bleaching conditions, to obtain a further treated lipid feedstock (d). The
30 further purification of the heat-treated lipid feedstock (c) is particularly advantageous for lipid feedstock (a) having higher amounts of phosphorous and/or metal impurities.

Advantageously with the present method further treatment vi) with an acid and/or adsorbent material is not required and the heat-treated lipid feedstock (c) can be directly subjected to

recovery in step vii) to be then used as such and/or subjected to further valorization, such as catalytic hydroprocessing, to obtain one or more renewable hydrocarbon products such as e.g. drop-in renewable fuel(s), renewable fuel component(s) and/or other valuable renewable hydrocarbon products.

- 5 The further treatment with acid and/or adsorbent material aims at minimizing the content of impurities, such as pigments (e.g. carotenoids and chlorophylls), metals and/or phosphorus, in the treated material. It involves contacting, in particular mixing, the material to be treated with an acid and/or an adsorbent material. Further treatment in step vi) may be carried out in the presence of an acid, such as citric acid and/or phosphoric acid and/or acidic or acid
- 10 activated adsorbent. Further, further treatment in step vi) is typically carried out in the presence of a small amount of water. Advantageously bleaching earth or other adsorbent such as silica can be added to the heat-treated lipid feedstock (c) in step vi) to adsorb impurities, such as remaining metals and/or phosphorus.

- The further treatment is preferably accomplished under bleaching conditions. A skilled
- 15 person will be competent to select the bleaching conditions. Typically the temperature in the further treatment step vi) can be for example in the range from 80 to 120 °C. Further, typically the pressure is close to atmospheric pressure, such as from 60 kPa(a) to 600 kPa(a), preferably from 80 kPa(a) to 200 kPa(a).

- Prior to further treatment in step vi) and after the heat treatment in step v) the heat-treated
- 20 lipid feedstock (c) may be subjected to phase separation, in particular solids removal, and impurities containing reject may be discarded. Solids formed in the heat treatment and containing solid impurities may be phase-separated based on the lipid material forming a phase of its own, an oily phase, from which any impurities containing aqueous and/or solid rejects may be removed by ordinary separation unit processes. Accordingly, the term
- 25 "phase-separating" or "phase separation" as used herein and hereafter refers both to liquid-liquid and liquid-solid phase separation. Suitable phase separation means include, but are not limited to, filtration, centrifugation, settling, and any combination thereof.

- Prior to further treatment in step vi) the heat-treated lipid feedstock (c) may additionally or alternatively be subjected to drying, in particular evaporation, under conditions capable of
- 30 removing water vapor from said heat-treated lipid feedstock (c). However, the evaporation conditions are controlled such that low-boiling components, such as low-boiling fatty acids of the lipid material are not lost. According to an embodiment containing evaporation, the evaporation may be performed at temperature from 50 to 130 °C, and pressure from 1 to

100 kPa(a). As an example, a combination of temperature of 105 °C and pressure of 8 kPa(a) could be applied to evaporation.

Preferably the heat-treated lipid feedstock is directly subjected to step vii) and no intermediate recovery is accomplished.

5 Recovery, Step vii)

After heat treatment of step v) and/or after optional further treatment of step vi), the heat-treated lipid feedstock (c) and/or the further treated lipid feedstock (d), respectively, is subjected to phase separation, preferably filtration, to provide a purified lipid feedstock (e).

10 The phase separation, preferably filtration, advantageously removes a separate phase comprising impurities separated from the lipid feedstock by the heat treatment. The separate phase may be a gel, a precipitate or a liquid phase that is immiscible with the purified lipid feedstock, allowing it to be separated from the feedstock.

15 Solid impurities, such as those formed in the heat treatment step v), may be phase-separated based on the lipid material of the heat-treated lipid feedstock forming a phase of its own, an oily phase, from which any impurities containing aqueous and/or solid rejects may be removed by ordinary separation unit processes. Further, when free water is present in the heat treatment of step v) at least some of the water soluble solid rejects may become dissolved in the water phase. Accordingly, the term "phase-separating" or "phase separation" as used herein and hereafter refers both to liquid-liquid and liquid-solid phase
20 separation. Suitable phase separation means include, but are not limited to, filtration, any gravitational separation method such as centrifugation, settling, decanting, and any combination thereof.

Where suitable, the phase separation is preferably accomplished by filtration. Filtration may be performed by any means found suitable for this purpose by a skilled person.

25 When free water is present, the phase separation is preferably at least partly or fully accomplished by a gravitational separation method, such as centrifugation.

Prior or after the phase separation the heat-treated lipid feedstock (c) and/or further treated lipid feedstock (d), respectively, may be subjected to drying, in particular evaporation, under conditions capable of removing water vapor from said lipid feedstock. However, the
30 evaporation conditions are controlled such that low-boiling components, such as low-boiling fatty acids of the lipid material are not lost. Typically the evaporation may be performed at temperature from 50 to 130 °C, and pressure from 1 to 100 kPa(a). As an example, a

combination of temperature of 105 °C and pressure of 8 kPa(a) may be applied to evaporation.

The thus rendered purified lipid feedstock (e) typically comprises residual phosphorus and metals both below 30 mg/kg, preferably below 2.0 mg/kg, more typically close to 1.0 mg/kg.

- 5 Impurity reduction for phosphorus is typically over 90% and for metals over 95% as compared to the lipid feedstock (a). Advantageously the thus rendered purified lipid feedstock (e) comprises nitrogen below 400 mg/kg, preferably below 300 mg/kg, most preferably below 200 mg/kg. Impurity reduction for nitrogen may be e.f from 10 to 60%, such as about 30% as compared to the lipid feedstock (a). The actual purification result is
10 dependent on the quality of the initial feedstock.

Figure 1 illustrates a first exemplary process flow of the present method.

- Referring to Figure 1, a feed of lipid feedstock 1 is subjected to a step of removal of solid impurities 20, preferably by filter aid filtration, to remove of solid impurities 29, as discussed herein for step iii) to obtain a filtered lipid feedstock 11. The filtered lipid feedstock 11 is then
15 subjected to a step of heating 30 the filtered lipid feedstock 11 to a desired heat treatment temperature from 150 to 400 °C as discussed herein for step iv). The thus heated lipid feedstock 15 is then heat-treated 40, optionally in the presence of water or an aqueous solution, at a heat treatment temperature from 150 to 400 °C as discussed herein for step v) to obtain a heat-treated lipid feedstock 41. The heat-treated lipid feedstock 41 is then
20 directly subjected to a step of phase separation 50, preferably filtering and/or decanting, to obtain a purified lipid feedstock 51 as discussed herein for step vii). The purified lipid feedstock 51 may be used as such and/or subjected to further valorization, such as catalytic hydroprocessing, (not shown) to obtain renewable hydrocarbons such as e.g. drop-in renewable fuel(s), renewable fuel component(s) and/or other valuable renewable
25 hydrocarbon products as discussed herein for step viii).

Figure 2 illustrates a second exemplary process flow of the present method.

- Referring to Figure 2, a feed of lipid feedstock 1 is subjected to a step of removal of solid impurities 20, preferably by filter aid filtration, to remove of solid impurities 29, as discussed herein for step iii) to obtain a filtered lipid feedstock 11. The filtered lipid feedstock 11 is then
30 subjected to a step of heating 30 the filtered lipid feedstock 11 to a desired heat treatment temperature from 150 to 400 °C as discussed herein for step iv). The thus heated lipid feedstock 15 is then heat-treated 40, optionally in the presence of water or an aqueous solution, at a heat treatment temperature from 150 to 400 °C as discussed herein for step v) to obtain a heat-treated lipid feedstock 41. The heat-treated lipid feedstock 41 is then be

subjected to step of further treating 70 with an acid and/or absorbent material 71, such as under bleaching conditions, to further purify the heat-treated lipid feedstock 41 as discussed herein for step vi) to obtain a further treated lipid feedstock 43. Optionally, prior to further treatment 70, the heat-treated lipid feedstock 41 may be subjected to a step of phase separation 60 to remove non-oil phase 69 comprised in the heat-treated lipid feedstock 41 to obtain a phase-separated heat-treated lipid feedstock 42 which is then subjected to further treatment 70 to obtain the further treated lipid feedstock 43. The further treated lipid feedstock 43 is subjected to a step of phase separation, preferably filtering, 50 to obtain a purified lipid feedstock 51 as discussed herein for step vii). The purified lipid feedstock 51 may be used as such and/or subjected to further valorization, such as catalytic hydroprocessing, (not shown) to obtain renewable hydrocarbons such as e.g. drop-in renewable fuel(s), renewable fuel component(s) and/or other valuable renewable hydrocarbon products as discussed herein for step viii).

Figure 3 illustrates a third exemplary process flow of the present method.

Referring to Figure 3, a feed of lipid feedstock 1 is subjected to a step of removal of solid impurities 20, preferably by filter aid filtration, to remove of solid impurities 29, as discussed herein for step iii) to obtain a filtered lipid feedstock 11. The filtered lipid feedstock 11 is then subjected to a step of heating 30 the filtered lipid feedstock 11 to a desired heat treatment temperature from 300 °C to 400 °C, or from 350 °C to 400 °C, as discussed herein for step iv). The thus heated lipid feedstock 15 is then heat-treated 40, in the presence of at least 1 wt% water or an aqueous solution 2, at a heat treatment temperature from 330 to 400 °C as discussed herein for step v) to obtain a heat-treated lipid feedstock 44. The heat-treated lipid feedstock 44 is subjected to a step of phase separation 50, preferably filtering and/or decanting, to remove impurities containing phase 68 and to obtain a purified lipid feedstock 51 as discussed herein for step vii). The purified lipid feedstock 51 may be used as such and/or subjected to further valorization, such as catalytic hydroprocessing, (not shown) to obtain renewable hydrocarbons such as e.g. drop-in renewable fuel(s), renewable fuel component(s) and/or other valuable renewable hydrocarbon products as discussed herein for step viii).

Figure 4 illustrates a fourth exemplary process flow of the present method.

Referring to Figure 4, a feed of lipid feedstock 1 is subjected to a step of removal of solid impurities 20, preferably by filter aid filtration, to remove of solid impurities 29, as discussed herein for step iii) to obtain a filtered lipid feedstock 11. The filtered lipid feedstock 11 is then subjected to a step of heating 30 the filtered lipid feedstock 11 to a desired heat treatment

temperature from 300 °C to 400 °C, or from 350 °C to 400 °C, as discussed herein for step iv). The thus heated lipid feedstock 15 is then heat-treated 40, in the presence of at least 1 wt% water or an aqueous solution 2, at a heat treatment temperature from 330 to 400 °C as discussed herein for step v) to obtain a heat-treated lipid feedstock 44. The heat-treated
5 lipid feedstock 44 is then subjected to step of further treating 70 with an acid and/or absorbent material 71, such as under bleaching conditions, to further purify the heat-treated lipid feedstock 44 as discussed herein for step vi) to obtain a further treated lipid feedstock 46. Optionally, prior to further treatment 70, the heat-treated lipid feedstock 44 may be subjected to a step of phase separation 60 to remove non-oil phase 67 comprised in the
10 heat-treated lipid feedstock 44 to obtain a phase-separated heat-treated lipid feedstock 45 which is then subjected to further treatment 70 to obtain the further treated lipid feedstock 46. The further treated lipid feedstock 46 is subjected to a step of phase separation 50, preferably filtering, to obtain a purified lipid feedstock 51 as discussed herein for step vii). The purified lipid feedstock 51 may be used as such and/or subjected to further valorization,
15 such as catalytic hydroprocessing, (not shown) to obtain renewable hydrocarbons such as e.g. drop-in renewable fuel(s), renewable fuel component(s) and/or other valuable renewable hydrocarbon products as discussed herein for step viii).

Figure 5 illustrates a fifth exemplary process flow of the present method.

Referring to Figure 5, a feed of lipid feedstock 1 is subjected to drying 10 to remove free
20 water from the lipid feedstock before it is subjected to filter aid filtration 20, to remove of solid impurities 29, as discussed herein for step iii) to obtain a filtered lipid feedstock 11. The filtered lipid feedstock 11 is then subjected to a step of heating 30 the filtered lipid feedstock 11 to a desired heat treatment temperature from 150 to 400 °C as discussed herein for step iv). The thus heated lipid feedstock 15 is then heat-treated 40, optionally in
25 the presence of water or an aqueous solution 2, at a heat treatment temperature from 150 to 400 °C as discussed herein for step v) to obtain a heat-treated lipid feedstock 41. The heat-treated lipid feedstock 41 may then be subjected to step of further treating 70 with an acid and/or absorbent material 71, such as under bleaching conditions, to further purify the heat-treated lipid feedstock 41 as discussed herein for step vi) to obtain a further treated
30 lipid feedstock 43. Optionally, prior to further treatment 70, the heat-treated lipid feedstock 41 may be subjected to a step of phase separation 60 to remove non-oil phase 69 comprised in the heat-treated lipid feedstock 41 to obtain a phase-separated heat-treated lipid feedstock 42 which is then subjected to further treatment 70 to obtain the further treated lipid feedstock 43. The heat-treated lipid feedstock 41 and/or the further treated lipid
35 feedstock 43 is subjected to a step of phase separation, preferably filtering, 50 to obtain a

purified lipid feedstock 51 as discussed herein for step vii). The purified lipid feedstock 51 may be used as such and/or subjected to further valorization, such as catalytic hydroprocessing, (not shown) to obtain renewable hydrocarbons such as e.g. drop-in renewable fuel(s), renewable fuel component(s) and/or other valuable renewable hydrocarbon products as discussed herein for step viii).

Hydroprocessing of the Purified Lipid Feedstock

After the lipid feedstock has been treated as discussed in the foregoing it may be used as such and/or subjected to further valorization, such as catalytic hydroprocessing, to obtain renewable hydrocarbons such as e.g. drop-in renewable fuel(s), renewable fuel component(s) and/or other valuable renewable hydrocarbon products. Such catalytic upgrading processes include, but are not limited to, catalytic cracking, catalytic hydrocracking, thermo-catalytic cracking, catalytic hydrotreatment, fluid catalytic cracking, catalytic ketonization, and catalytic esterification. Such processes require the liquid feedstock to be sufficiently pure and free from impurities that may otherwise hamper the catalytic process or deactivate or poison the catalyst(s) present in the process.

Thus the purified lipid feedstock may be subjected to a post-treatment comprising hydroprocessing.

Consequently, the herein provided purified lipid feedstock obtained from by the method as described herein can be used as feed to at least one catalytic hydroprocessing to obtain renewable hydrocarbons. Further, the purified lipid feedstock obtained from the purification method as described in the foregoing may be used as feed to produce fatty acids, and/or soaps.

The hydroprocessing, preferably catalytic hydroprocessing, may be any upgrading process employing hydrogen and where the lipid material may be used as the process feed, optionally with a co-feed. For example, the hydroprocessing may be an upgrading process to obtain liquid transportation fuel components, solvents, technical fluids, such as electrotechnical fluids, fatty alcohols, cracking feedstocks, such as feedstocks for thermal cracking and/or catalytic cracking, and/or base chemicals for different syntheses. Preferably the hydroprocessing is catalytic hydroprocessing.

According to an embodiment, a co-feed of fossil origin is fed to catalytic hydroprocessing.

The hydroprocessing may comprise altering molecular weight, removal of heteroatoms, altering degree of saturation, rearranging molecular structure, or any combination thereof. The hydroprocessing comprises preferably altering molecular weight of the process feed or

any intermediate stream or intermediate product derivable or derived therefrom, removal of heteroatoms from the process feed or any intermediate stream or intermediate product derivable or derived therefrom, altering degree of saturation of the process feed or any intermediate stream or intermediate product derivable or derived therefrom, rearranging
5 molecular structure of the process feed or any intermediate stream or intermediate product derivable or derived therefrom, or any combination thereof.

In certain preferred embodiments, the hydroprocessing comprises hydrotreatment, isomerization, and/or cracking, preferably hydrodeoxygenation (HDO), hydroisomerization (HI), and/or hydrocracking (HC), of the process feed or an intermediate stream or
10 intermediate product derivable or derived therefrom, optionally followed by fractionation.

In certain preferred embodiments, the catalytic hydroprocessing comprises catalytic hydroprocessing converting the lipid material to one or more drop-in liquid transportation fuel(s), one or more liquid transportation fuel component(s) and/or other valuable hydrocarbon product(s)chemicals. The process comprises subjecting the process feed to
15 hydroprocessing comprising hydrodeoxygenation, hydroisomerization, and optionally hydrocracking, followed by fractionation of the hydroprocessing effluent and recovery of one or more drop-in liquid transport fuel(s), one or more liquid transportation fuel component(s) and/or other valuable hydrocarbon products from the fractionation.

According to an embodiment the catalytic hydrotreating comprises one or more of
20 hydrodeoxygenation, hydroisomerization, hydrocracking, hydrodenitrogenation, hydrodesulfurization, hydrodehalogenation, hydrodearomatization, and hydrogenation of double bonds.

The catalytic hydroprocessing may occur in the presence of a catalyst selected from Pd, Pt, Ni, Co, Mo, Ru, Rh, W, or any combination of these, such as CoMo, NiMo, NiW, CoNiMo, NiMoW or together with SAPO-11, SAPO-41, ZSM-22, ZSM-23, ZSM-12, ZSM-48, ZSM-5, beta zeolites, ferrierite and mixtures thereof, such as Pt/SAPO-11/Al₂O₃, Pt/ZSM-22/
25 Al₂O₃, Pt/ZSM-23/Al₂O₃, Pt/SAPO-11/SiO₂, optionally on a support, wherein the support comprises preferably alumina and/or silica.

EXPERIMENTAL

30 P and metal analysis: The concentration of phosphorus and metals was analyzed from all samples by first digesting the sample with acids in a microwave oven to obtain a clear water/acid matrix (assessed visually), then diluting it to a known amount and analyzing it against the acid based calibration using ICP-MS/MS (tandem Inductively Coupled Plasma

Mass Spectrometry). Metals detected by the method include Li, B, Na, Mg, Al, P, K, Ca, Ti, V, Ch, Mn, Fe, Co, Ni, Cu, Zn, As, Mb, Cd, Sn, and Ba.

Water analysis: Water content of all the samples was determined according to ASTM D6304-20, procedure C. The method is based on a coulometric Karl Fischer titration.

5 Nitrogen (N) analysis: The total nitrogen content of all samples was determined according to ASTM D4629-2012.

Solids analysis: The amount of insoluble impurities i.e. solid impurities of all samples was determined according to ISO 663:2017.

10 Chlorine (Cl) analysis: The total chlorine of all samples was determined according to UOP 779-08.

Organic chlorine (Cl): Organic chlorine of all samples was determined by washing the sample with hot water and then analyzing it for chlorine according to UOP 779-08.

Example 1. Effect of water content in feed to filter aid filtration

15 Crude POME samples as such including relatively high moisture content and after drying were subjected to filter aid filtration with commercially available diatomaceous earth type filter aid. Drying of POME samples was performed in a rotavapor (105 °C, 80 mbar, 60 min). As demonstrated by Table 1, drying prevents leaching of possible metals (Ca) from the filter aid material.

20 Table 1. Calcium (Ca) analysis results of POME feeds and filter aid filtered samples with or without drying.

FEED	POME #1		POME #2		POME #3	
Drying before filtration	No	Yes	No	Yes	No	Yes
Moisture / mg/kg	19126	1776	15100	2270	7345	2859
Ca before filtration / mg/kg	9	9	61	61	120	120
Ca after filtration / mg/kg	263	4	300	39	138	67

Example 2 - Effect of filter aid filtration on feedstock impurity level

Crude POME, AF, UCO, CTO and TOP feedstocks as well as their mixtures were subjected to filter aid filtration with three different commercially available diatomaceous earth type filter aids. Filter aid filtration of the lipid feedstock samples were carried out by mixing in 0.5 to 0.7 wt% filter aid to the feed and then filtering the feed as a pressure (2.5 bar overpressure) cake filtration over the filter aid precoat (1 kg/m²) at 105 °C. The total impurity level of each feedstock or feedstock blend was analyzed before and after filtration with the analysis methods indicated above. The analysis results presented in Table 2 indicate effective removal of solid impurities with the method employed.

- 10 Table 2. Analysis results of impurities from crude feedstock and after filter aid filtration (CF = crude feed, FP = filtration product).

Filter aid #	#1		#1		#2		#3		#3	
Feed	POME		POME : AF Blend		UCO		AF		CTO : TOP Blend	
	CF	FP	CF	FP	CF	FP	CF	FP	CF	FP
Metals* (mg/kg)	515	227	248	179	744	19	170	33	468	250
P (mg/kg)	62	18	68	40	19	5	57	9	36	28
N (mg/kg)	259	175	377	316	n.a.	n.a.	n.a.	n.a.	330	320
Cl (mg/kg)	18	10	11	6	450	148	n.a.	n.a.	4	4
Solids (wt%)	0.83	0.03	0.23	0.01	0.54	0.03	0.12	0.01	n.a.	n.a.

*Li, B, Na, Mg, Al, K, Ca, Ti, V, Ch, Mn, Fe, Co, Ni, Cu, Zn, As, Mb, Cd, Sn, and Ba.

Example 3 - Effect of solid removal prior to heat treatment on fouling tendency at lab scale

- 15 The fouling tendency of crude feedstock samples and filtered (either by static paper filtration or with filter aid) was measured with a commercially available laboratory scale fouling tester (Falex 450 Thermal Fouler). The fouling tendency of the feedstock was evaluated based on temperature measurement drop in the outlet line of the fouling tester compared to the initial outlet line temperature at the start of the experiment. The presence of fouling can be
- 20 observed based on a measurable decrease in outlet temperature (heat transfer coefficient from heating rod to oil is reduced), whereas the qualitative fouling tendency between feedstocks can be evaluated based on the magnitude of temperature drop. A higher decrease in temperature suggests a higher fouling tendency. Feedstock flow to the fouling tester was arranged in a once-through flow arrangement (flow 1 ml/min) with no recirculation
- 25 of feed. The heating rod temperature of the tester was maintained at 330 °C, which may be similar to wall temperature of a high temperature heat exchanger used for heating a

feedstock to heat treatment conditions. The results of the fouling tendency for crude and unfiltered feedstocks are presented in Table 3. The results show significant fouling (high temperature drop, delta T) for the crude feedstock, whereas the temperature drop was significantly smaller or non-existent for filtered feedstock.

- 5 Table 3. Analysis results of impurities and temperature decrease during fouling experiments with crude feedstock and filtered feedstock.

	LQAF		35%CTO+25%TOP + 20%SAO+20%BG		CTO		TOP	
	Crude	Filtered	Crude	Filtered	Crude	Filtered	Crude	Filtered
Metals*(mg/kg)	476	86	260	194	375	338	264	95
P (mg / kg)	170	72	51	47	15	12	57	39
N (mg / kg)	320	230	539	470	140	n.a.	410	400
DeltaT** (°C)	-22.6	0.2	-29.2	0.9	-45.3	0.2	-34	-9

* Li, B, Na, Mg, Al, K, Ca, Ti, V, Ch, Mn, Fe, Co, Ni, Cu, Zn, As, Mb, Cd, Sn, and Ba

**Change of fouling tester outlet temperature measurement over experiment compared to initial outlet temperature.

10 Example 4 - Effect of filter aid filtration on heat treatment process high temperature heat exchanger fouling rate in pilot scale

Crude POME/AF (45%/55%) or CTO/TOP (60%/40%) blend was heated to 90 °C, mixed with filter aid (0.6 or 1 wt%, diatomaceous earth). Mixture was stirred for 20 minutes at 90 °C. Removal of filter aid media and solid impurities was done as filter aid filtration using a leaf filter (total 1m² filtration area) with a preformed precoat (diatomaceous earth, 1 kg/m²) at <4 bar pressure difference over the leaf element at 95 °C.

- 20 The effect of filter aid filtration on feedstock fouling rate in high temperature heat exchangers when heating the oil to heat treatment temperature range (220 to 260 °C) with hot oil (325 to 335 °C) was evaluated in a pilot-scale shell and tube heat exchanger (~ 0.1 t/h). The heat exchanger has similar flow conditions to industrial scale shell and tube heat exchangers in terms of linear velocity of the processed oil. Two different feedstock blends were evaluated with this method: a blend of POME and AF as well as a blend of CTO and TOP. The rate of fouling was calculated based on a heat transfer model of the system using measured inlet and outlet temperatures (process side and hot oil) as well as mass flow measurements. The resulting comparison of fouling rate with crude feedstock compared to filter aid filtered

feedstock are presented in Table 4. Fouling rate is dramatically reduced after filter aid filtration for both feedstock blends considered.

Table 4. Analysis results of impurities from crude feedstock and after filter aid filtration and the estimated fouling rate in pilot scale test run.

Feed	POME : AF Blend (Crude)	POME : AF Blend (filter aid filtered)	CTO : TOP Blend (Crude)	CTO : TOP Blend (filter aid filtered)
Hot oil temperature (° C)	325-330	325-330	335	335
Estimated fouling rate (m ² -° C) / (kW- d))	1.9	0.365	2.0	0.7

5

Example 5 - Effect of solid impurities on fouling rate at industrial scale

Process data from a 200 ktpa process plant with a heat treatment step was analyzed to evaluate the effect of feedstock insoluble impurities, soluble impurities and total impurities on the calculated rate of apparent heat transfer coefficient reduction. Calculation was performed based on the apparent heat transfer coefficient calculated from flow rate and temperature measurements over the heat exchanger with animal fat type oil on both sides of the exchanger and in the temperature range of 100-230 °C. The data analyzed included process data over 2 years from which fouling rate was calculated over 1 month time periods and the feedstock impurity analysis was averaged with a mass weighted average over the same time period. A linear regression analysis of the fouling rate and the measured impurity levels was performed. The results of the analysis indicate that the strongest linear correlation of fouling rate is observed for feed insoluble impurities ($R^2 \sim 0.6$), whereas the weakest correlation is observed for oil soluble impurities ($R^2 \sim 0.02$). The deviation of the coefficient of determination for the correlation of fouling rate and feed insoluble impurities from the value of 1.0 is explained by day-to-day variations in feedstock quality as well as differences in the underlying phosphorus compounds, which are not captured by elemental phosphorus analysis. The analysis suggests that reduction of feed solid impurities with a suitable method reduces the rate of fouling.

Example 6 - Effect of filter aid filtration on side reactions in heat treatment

The same low quality animal fat (LQAF) as used in the lab scale fouling experiment (Example 3) was heat-treated (HT) as crude feed (no solids removal) and after solids removal (Table 5). In addition, another LQAF (Choice white grease, CWG) and POME were treated in a similar way (Table 6 and 7). Heat treatment was performed with a 1 liter Parr

25

pressure reactor, where feed was heated to a desired heat treatment temperature and held there for a desired time, initial pressure 300 kPa(a) (nitrogen) with mixing of 500 rpm. The heat-treated product was further filtered (2 µm filter paper) or bleached (treated with citric acid and bleaching earth, and filtered) and the phosphorus, metals and nitrogen content were analyzed.

The results show in all cases an increase in nitrogen in the product that was produced by heat treating the crude unfiltered (no removal of solid impurities) feed. However, if the solid impurities were removed from the feed by filtration or centrifugation or settling prior heat treatment the nitrogen level of the final product after post-treatment by filtration or bleaching was significantly smaller (no increase).

Table 5. Effect of removal of solid impurities on impurity removal of LQAF. Heat treatment (HT) conditions were 260 °C / 5 min.

	Feed	Feed unfiltered, HT (comp.)	Feed filtered, HT
Nitrogen in unfiltered sample, mg/kg	320	-	-
Nitrogen in filtered sample, mg/kg	230	450	207
Nitrogen in bleached sample, mg/kg	-	310	107
P in filtered sample, mg/kg	83	16	18
P in bleached sample, mg/kg	6.8	0.9	1.1

Table 6. Effect of removal of solid impurities to impurity removal on LQAF #2. Heat treatment conditions 280 °C / 30 min. (FAF = filter aid filtered, HT = heat-treated)

	Feed LQ AF #2	HT + filtered (comp.)	HT + bleached (comp.)	FAF (comp.)	FAF + HT + filtered	FAF + HT + bleached	Centrif. (comp.)	Centrif. + HT + filtered	Centrif. + HT + bleached
N (mg/kg)	546	674	564	513	485	329	395	399	366
P (mg/kg)	403	1.3	0.7	258	1.2	1.5	246	5.7	1.1
Main metals (mg/kg)	757	73	2.2	430	230	2.2	423	117	0.8

Table 7. Effect of removal of solid impurities to impurity removal on POME. Heat treatment conditions 280 °C / 30 min. (HT = heat-treated)

	Feed POME #2	HT + Filtered (comp.)	HT + bleached (comp.)	Settled (comp.)	Settled + HT + filtered	Settled + HT + bleached	Centrif.	Centrif. + HT + filtered	Centrif. + HT + bleached
N (mg/kg)	462	493	397		326	269	180	183	135
Cl (mg/kg)	21	6.7	6.0		3.7	4.1	5.5	4.6	3.6
P (mg/kg)	14	9.4	1.5	8.9	5.6	1.2	3.6	2.3	1.1
Metals (mg/kg)	513	378	7.2	400	285	3.5	223	235	3.7

Used cooking oil (UCO) was treated by heat treatment at 250 °C/ 30 min similarly as in examples above (Table 8). A significant increase in organic Cl was observed. With heat treatment with filter aid filtration almost all inorganic Cl is removed and practically no increase in organic Cl occurs during high temperature treatment.

Table 8. Impurities in UCO samples. (FAF = filter aid filtered, HT = heat-treated)

	Crude feed	HT (comp.)	HT + filtered (comp.)	HT + centrifuged (comp.)	Filtered feed	FAF + HT + filtered
Total Cl, mg/kg	56	44	23	30	10	9
Organic Cl, mg/kg	8	22	21	21	8	9
Inorganic Cl, mg/kg	48	22	2	9	2	0

Example 7 - Heat treatment with additional dosing of water

- 10 A low quality animal fat (LQAF) was filtered to remove solid impurities, and then heat-treated (HT) (240 °C/ 30 min) without water addition (feed moisture 1500 mg/kg) and with variable water additions (0.5 wt%, 1 wt%, 2 wt%, 10 wt%, 20 wt% of the weight of the lipid feedstock). After heat treatment the samples were centrifuged and filtered or first evaporated and filtered, before analysis of the impurities. As can be seen from Table 9, the present invention
- 15 allows removal of impurities in variable water concentrations in the heat treatment.

Table 9. Impurities in the feed and heat-treated products after removal of solid impurities.

	Feed	HT with no added water + Centrif. + Filtered	HT with 0.5 wt% water + Centrif. + Filtered	HT with 0.5 wt% water + evap. + Filtered	HT with 1 wt% water + Centrif. + Filtered	HT with 1 wt% water + evap. + Filtered
P (mg/kg)	120	51.9	43	43.7	0.8	<0.6
Total metals (mg/kg)	203.7	97.8	77.8	79.4	8.9	10.8
	HT with 3 wt% water + Centrif. + Filtered	HT with 3 wt% water + evap. + Filtered	HT with 10 wt% water + Centrif. + Filtered	HT with 10 wt% water + evap. + Filtered	HT with 20 wt% water + Centrif. + Filtered	HT with 20 wt% water + evap. + Filtered
P (mg/kg)	0.8	0.8	1.9	1.1	3.4	<0.6
Total metals (mg/kg)	9.1	8.5	66.6	29.7	126.9	101.2

CLAIMS

1. A method for treating lipid feedstock (a), the method comprising
- i) providing the lipid feedstock (a);
 - ii) optionally removing free water from the lipid feedstock (a);
 - 5 iii) removing solid impurities from the lipid feedstock (a) to obtain a conditioned lipid feedstock (b);
 - iv) heating the conditioned lipid feedstock (b) to a desired heat treatment temperature;
 - v) heat-treating the conditioned lipid feedstock (b), preferably in the presence of water, at a heat treatment temperature of at least 150 °C, such as from 150 to 400 °C, to obtain a heat-
 - 10 treated lipid feedstock (c), whereby the heat treatment temperature of step iv) is the desired heat treatment temperature of step v);
 - vi) optionally further treating the heat-treated lipid feedstock (c) with an acid and/or adsorbent material, preferably under bleaching conditions, to obtain a further treated lipid feedstock (d);
 - 15 vii) recovering the heat-treated lipid feedstock (c) and/or the further treated lipid feedstock (d) by phase separation, preferably by filtration, to obtain a purified lipid feedstock (e); and
 - viii) optionally subjecting the purified lipid feedstock (d) to hydroprocessing to obtain at least one renewable hydrocarbon product.
2. The method as claimed in claim 1, wherein the lipid feedstock comprises at least 5 mg/kg, such as from 5 to 5000 mg/kg, preferably at least 15 mg/kg, such as 15 to 2000 mg/kg, phosphorus impurities, and at least 10 mg/kg, such as from 10 to 10000 mg/kg, preferably at least 20 mg/kg, such as 20 to 3000 mg/kg mg/kg, metal impurities, measured as elemental phosphorus and elemental metal(s).
3. The method as claimed in claim 1 or 2, wherein the lipid feedstock is selected from a group consisting of soapstock acid oil (SAO), low quality animal fat grades (LQAF), brown grease (BG), used cooking oil (UCO), palm oil mill effluent (POME), crude tall oil (CTO), tall oil pitch (TOP), and mixtures thereof.
4. The method as claimed in any one of claims 1 to 3, wherein removing solid impurities in step iii) is accomplished by settling, centrifuging, filtering, decanting, and/or filter aid
- 30 filtration.

5. The method as claimed in any of claims 1 to 4, wherein removing solid impurities in step iii) is accomplished by filter aid filtration.
6. The method as claimed in claim 5, wherein the filter aid material comprises or consists of mineral, silicon, and/or cellulose based material, preferably selected from diatomaceous earth, diatomite, perlite, bentonite, palygorskite, kaolin, kaolinite, silica in various crystalline or amorphous configurations, sepiolite, magnesium silicate, silicon, aluminum oxide based materials, zinc oxide based materials, neutral bleaching earth, activated carbon, activated charcoal, cellulose fibers, and any combinations thereof.
7. The method as claimed in claim 5 or 6, wherein step iii) is accomplished at a temperature from 50 to 130 °C, preferably from 80 to 120 °C, and at a pressure from 1 to 2000 kPa(a), preferably from 150 kPa(a) to 1500 kPa(a), more preferably from 200 kPa(a) to 1000 kPa(a), even more preferably from 200 kPa(a) to 650 kPa(a), most preferably from 250 kPa(a) to 500 kPa(a).
8. The method as claimed in any one of claims 1 to 7, wherein the method comprises vii) subjecting the purified lipid feedstock (d) to hydroprocessing to obtain at least one renewable hydrocarbon product.
9. The method as claimed in any one of claims 1 to 8, wherein the lipid feedstock (a) and/or the conditioned feedstock (c) subjected to heat treatment has total net elementary charge Q1 below 0 mmol/kg, such as from -60 to -0.5 mmol/kg, in particular below -0.5 mmol/kg, such as from -30 to -1 mmol/kg.
10. The method as claimed in any one of claims 1 to 9, wherein the lipid feedstock (a) comprises at least 0.05 wt%, such as from 0.05 to 10 wt%, preferably at least 0.1 wt%, such as 0.1 to 3 wt%, more preferably 0.5 to 1 wt%, solid impurities of the total weight of the lipid feedstock.
11. The method as claimed in any one of claims 1 to 10, wherein further treatment vi) with an acid and/or adsorbent material is not performed and the heat-treated lipid feedstock (c) is directly subjected to recovery in step vii) to be then used as such and/or subjected to further valorization, such as catalytic hydroprocessing, to obtain one or more renewable hydrocarbon products such as e.g. drop-in renewable fuel(s), renewable fuel component(s) and/or other valuable renewable hydrocarbon products.
12. The method as claimed in any one of claim 1 to 11, wherein the heat treatment in step v) is accomplished at a temperature of at least 150 °C, such as from 150°C to 400 °C, preferably at least 180 °C such as from 180 to 350 °C, preferably of at least 200 °C, such

as from 200 to 350 °C, preferably of at least 220 °C, such as from 220 to 350 °C, more preferably of at least 270 °C, such as from 270 to 350 °C, most preferably of at least 330 °C, such as from 330 to 350 °C.

13. The method as claimed in claim 12, wherein the temperature is at least 180 °C, such as
5 from 180 to 325 °C, preferably of at least 200 °C, such as from 200 to 350 °C, preferably of at least 220 °C, such as from 220 to 325 °C, more preferably of at least 270 °C, such as from 270 to 300 °C, most preferably of at least 280 °C, such as from 280 to 290 °C.

14. The method as claimed in claim 12 or 13, wherein the heat treatment in step v) is carried out at a pressure from 100 to 6500 kPa(a), such as from 100 to 5100 kPa(a), preferably
10 from 150 to 2100 kPa(a), more preferably from 200 to 600 kPa(a), most preferably from 300 to 500 kPa(a) and/or the residence time in the heat treatment step v) is from 1 to 300 minutes, such as 1 to 120 minutes, preferably 1 to 30 minutes.

15. The method as claimed in claim 12, wherein the heat treatment is accomplished at a high temperature, such as from 300 °C to 400 °C, preferably from 350 °C to 400 °C, in
15 presence of water or an aqueous solution, such as 30 wt% to 50 wt% of water, wherein the residence time is from 1 min to 100 min, and, preferably, at a pressure from 4000 to 6500 kPa(a).