

A METHOD OF PRETREATING A RENEWABLE FEEDSTOCK

TECHNICAL FIELD

- 5 The present disclosure generally relates to a method of pretreating a renewable feedstock. The disclosure relates particularly, though not exclusively, to a method of pretreating a renewable feedstock by subjecting the renewable feedstock to at least one pretreatment process for reduction of at least one impurity in the renewable feedstock.

10 BACKGROUND

This section illustrates useful background information without admission of any technique described herein representative of the state of the art.

- Renewable feedstocks are utilized widely, for example in the production of renewable fuel components, and in other chemical industries. Cooking oils as well as side streams and wastes from the food and agricultural industry can be used as source of such feedstocks. The quality and content of such feedstocks however varies greatly, even from the same source, from one batch to another, and the sources are typically such that one particular feedstock is not industrially usable on its own. Indeed, these kinds of renewable feedstocks contain various impurities, which cause problems in their processing. Typically, such renewable feedstocks contain different types of impurities than feedstocks of fossil origin. Therefore, renewable feedstocks often require an efficient pretreatment for removal of impurities. Particularly challenging impurities are e.g. phosphorus containing compounds, which are present in renewable feedstocks which are intended for catalytic hydrotreatment. Different impurities can be reduced in the renewable feedstocks through various pretreatment processes, typically such as bleaching, heat treatment, degumming, water washing, and acid- or enzymatic treatments.

- At present, the evaluation of the composition of renewable feedstocks, including the impurities, is laborious and time-consuming. Consequently, determining the precise required feedstock pretreatment process is often a complex task which is prone to errors. As a result, selection, and optimization of pretreatment parameters, especially when dealing with changing feedstock compositions, can be inaccurate. Moreover, the time delay in obtaining knowledge of the impurity profile of the feedstock causes burden on the post

processing, as a considerable quantity of impurities may be carried over to the subsequent processing step before being able to adjust the pretreatment suitably.

There exists thus a need for providing an accurate and timely analysis of the impurities present in various renewable feedstocks, for purifying said feedstocks by pretreatment processes. There exists also a need for efficient pretreatment of renewable hydrocarbons from renewable feedstocks, for removal of impurities. There is currently a need to provide a method that includes purifying a renewable feedstock from impurities that cause problems in subsequent processing steps, such as in catalytic hydrotreatment, and thus to provide a method for purifying renewable feedstocks to a predefined degree of purity sufficient for further treatment of the feed.

Analogously, there exists also a need for providing an accurate and timely analysis of the impurities present in hydrocarbon intermediate products in a refining unit before downstream processing, such as isomerization. There is currently a need to provide a method that includes purifying the renewable feedstock and intermediate products from impurities that cause problems in subsequent processing steps, such as in hydroisomerization, and thus to provide a method for purifying to a predefined degree of purity sufficient for further treatment. Based on above, there is a need for an improved method for producing renewable fuels. There is also a need for an improved method for removing impurities in hydroprocessing.

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SUMMARY

The present application concerns the inventions defined in the appended independent claims, and their embodiments disclosed below. The appended claims define the present invention. Any examples and technical descriptions of apparatuses, products and/or methods in the description and/or drawings not covered by the claims are presented not as embodiments of the invention but as background art or examples useful for understanding the invention.

According to a first example aspect there is provided a method for pretreating a renewable feedstock, the method comprising:

- providing the renewable feedstock;
- subjecting the renewable feedstock to at least one pretreatment process for reduction of at least one impurity in the renewable feedstock, and to an *in situ* measurement with an online analyzer thereby obtaining real time information on a quantity of said at least one impurity; and

- obtaining a pretreated renewable feedstock having a reduced quantity of said at least one impurity.

In view of the above, an object of the invention is to provide a method enabling a fast and continuous impurity measurement *in situ* from a renewable feedstock. Another aim is to provide a method providing a continuous analysis of at least one impurity in the renewable feedstock. An aim is to provide a method of selecting at least one pretreatment process of a renewable feedstock for reduction of at least one impurity in the renewable feedstock. An aim is also to provide a method enabling a fast and continuous impurity measurement in real time from the pretreated renewable feedstock, for verifying the efficacy of the selected at least one pretreatment process.

Another aim is to increase the speed of quantifying the impurities within the renewable feedstock, by making the measurements *in situ* in said at least one pretreatment process in real time with an online analyzer. Thus, an object of the invention is to provide a method enabling a fast and continuous online impurity measurement *in situ* from a renewable feedstock and provide the measurement in real time, thus allowing continuous real time adjustment of the pretreatment process.

Yet another aim is to enable a quick adjustment of the pretreatment process(es), or pretreatment process sequence, based on the *in situ* measurement of the impurities within the renewable feedstock. Thus, an aim is to provide a method wherein said at least one pretreatment process can be adjusted in real time. Said adjusting is beneficial, as by adjusting the pretreatment process(es) or pretreatment process sequence allows efficient removal of said at least one impurity from the renewable feedstock, thus diminishing or even preventing catalyst poisoning and deactivation in downstream reactions. Consequently, an aim is also to provide an agile method of re-selecting the at least one pretreatment process, based on an *in situ* measurement of the pretreated renewable feedstock with an online analyzer.

Another aim is to optimize said at least one pretreatment process of a renewable feedstock, wherein the optimization is tailored for the needs of the specific renewable feedstock used in the at least one pretreatment process.

Another aim is to improve the accuracy of the measurement of impurities, measured from the renewable feedstock before and/or after and/or during the at least one pretreatment process. Therefore, an aim is also to improve the overall pretreatment process(es), thereby obtaining a pretreated renewable feedstock with lower level of impurities when compared to feedstocks obtained with prior art methods.

A further aim of the invention is to provide a method for producing a pretreated renewable feedstock for post-processing, such as hydrotreatment.

- An object of the invention is also to provide an improved method for producing renewable fuels from the renewable feedstock. Another aim is to provide a method providing more efficient hydroprocessing, thus improving production of renewable fuels from a renewable feedstock. A further object is to use an online analysis to continuously monitor level of impurities in a stripped liquid stream in order to optimize the hydroprocessing step and to maximize the yield of desirable products from the hydroisomerization step, hydrocracking step and/or in a dewaxing step, such as the yield of sustainable aviation fuel component.
- 10 An aim is to provide a method for improving reduction of impurities in hydroprocessing by adjusting the hydroprocessing reaction conditions based on *in situ* online analysis of the hydroprocessed stream.

- Different non-binding example aspects and embodiments have been illustrated in the foregoing. The embodiments in the foregoing are used merely to explain selected aspects or steps that may be utilized in different implementations. Some embodiments may be presented only with reference to certain example aspects. It should be appreciated that corresponding embodiments may apply to other example aspects as well.

BRIEF DESCRIPTION OF THE FIGURES

- Some example embodiments will be described with reference to the accompanying figures, in which:

- Fig. 1 schematically shows a method for pretreating a renewable feedstock according to an exemplary embodiment; and
- Fig. 2 schematically shows a method for pretreating a renewable feedstock according to another exemplary embodiment.
- 25 Fig. 3 schematically shows a method for producing renewable fuels and components thereto according to an exemplary non-limiting embodiment of the present disclosure.

DETAILED DESCRIPTION

DEFINITIONS

- 30 In the following description, like reference signs denote like elements or steps.

As used herein, the term "comprising" includes the broader meanings of "including", "containing", and "comprehending", as well as the narrower expressions "consisting of" and "consisting only of".

As used herein, with the term "feed" or "feedstock" is meant any feedstock which is directed
5 into a particular reaction or process, such as a pretreatment process.

As used herein the term "renewable feedstock" can refer to renewable feedstock 100, as exemplified in the figures 1 and 2, which has not yet been subjected to at least one pretreatment process, or it can refer to pretreated renewable feedstock 200, as also exemplified in the figures 1 and 2, which has already been subjected to at least one
10 pretreatment process. In the preferred embodiment the renewable feedstock is a liquid feedstock, which comprises one or more of solid and/or volatile impurities.

As used herein, with the term "pretreatment process" is meant a unit operation, i.e., a process comprising one or more individual pretreatment actions or reactions for removal of at least one impurity. If the pretreatment process comprises more than one pretreatment
15 actions/reactions, the separate pretreatment actions/reactions may be the same or different ones. Thus, the pretreatment process can be a pretreatment process sequence. In general pretreatment refers to processing of feedstock for removal of harmful material before directing the feedstock to post-processing, such as catalytic hydrotreatment.

As used herein, the term "adjusted pretreatment process" refers to a pretreatment process
20 which has been adjusted in at least one aspect, based on the obtained *in situ* measurement of the pretreated renewable feedstock 200.

As used herein, the term "same pretreatment process" refers to a pretreatment process which is the same pretreatment process, i.e. the parameters of which have not been adjusted, in respect of a previous pretreatment process, which has been performed to the
25 renewable feedstock 100 before obtaining the *in situ* measurement of the pretreated renewable feedstock 200.

As used herein, the term "subsequent pretreatment process" refers to a pretreatment process which is a pretreatment process following or consecutive to a previously performed pretreatment process for the same renewable feedstock 100 or the same pretreated
30 renewable feedstock 200.

As used herein, the term "renewable" refers to compounds of compositions that are obtainable, derivable, or originating from plants and/or animals, including compounds or compositions obtainable, derivable, or originating from fungi and/or algae, in full or in part. As used herein, renewable compounds or compositions may comprise gene manipulated

compounds or compositions. Renewable feeds, components, compounds, or compositions may also be referred to as biological compounds or compositions, or as biogenic compounds or compositions.

Renewable carbon containing compounds can be differentiated chemically from those of fossil origin, including hydrocarbons, by suitable method for analyzing the content of carbon from renewable sources, such as DIN 51637 (2014), ASTM D6866 (2020) and EN 16640 (2017). Said methods are based on the fact that carbon atoms of renewable or biological origin comprise a higher number of unstable radiocarbon (^{14}C) atoms compared to carbon atoms of fossil origin. Therefore, it is possible to distinguish between carbon compounds derived from renewable or biological sources or raw material and carbon compounds derived from fossil sources or raw material by analyzing the ratio of ^{12}C and ^{14}C isotopes. Thus, a particular ratio of said isotopes can be used as a "tag" to identify a renewable carbon containing compound and differentiate it from non-renewable carbon containing compounds. The isotope ratio does not change during chemical reactions. Therefore, the isotope ratio can be used for identifying renewable carbon containing compounds, components, and compositions and distinguishing them from non-renewable, fossil materials in reactor feeds, reactor effluents, separated product fractions and various blends thereof. Numerically, the biogenic carbon content can be expressed as the amount of biogenic carbon in the material as a weight percent of the total carbon (TC) in the material (in accordance with ASTM D6866 (2020) or EN 16640 (2017)). In the present context, the term renewable preferably refers to a material having a biogenic carbon content of more than 95 wt-%, even more preferably about 100 wt-%, based on the total weight of carbon in the material (EN 16640 (2017)).

As used herein, the term "subsequent renewable feedstock 100" refers to the renewable feedstock 100, which has not yet entered the pretreatment process at the time of obtaining information on a quantity of said at least one impurity in the already pretreated renewable feedstock 200. In other words, the term "subsequent renewable feedstock 100" refers to a portion or remaining part of the renewable feedstock 100, which has not yet entered the pretreatment process at the time of obtaining information on a quantity of said at least one impurity in the already pretreated renewable feedstock 200. In a continuous process, feedstock is continuously directed into the processing whereby part of the feedstock has already passed some of the pretreatment process(es) while the rest of the feedstock is still about to enter the pretreatment stage.

All standards referred to herein are the latest revisions available at the filing date, unless otherwise mentioned.

With the expression "*in situ*" or "measuring *in situ*" is meant here conducting the measurement or analysis directly at the location, such as in the actual processing unit at a plant conditions, where the measured sample, such as feedstock is present, or is being processed, without the need for feedstock sample to be separately collected or removed
5 from the processing unit, and/or transported elsewhere (e.g. to a laboratory) for analysis, and without the need to process or alter the sample in any way prior to the measurement (e.g. by combustion, dissolving etc.). For example, in-line measurement is an example of a measurement taking place *in situ*. In other words, the sample, such as a feedstock, measured "*in situ*" can continue to be processed within a processing system after being
10 measured. The measurement taking place *in situ*, means also that the state of the matter or consistency of the measured feedstock does not need to be altered for the measurement to take place, i.e. it is not necessary to gasify the feedstock.

Total Acid Number (TAN) traditionally relates to a measurement of acidity that is determined by the amount of potassium hydroxide needed in milligrams to neutralize the acids in one
15 gram of oil. It is a frequently used important quality measurement of e.g. crude oil indicating the potential for corrosion problems. Similarly, it is used as a measure of the quantity of acidic compounds present in a sample, such as a feedstock. Many different types of acidic compounds can contribute to the increase the TAN value of an oil sample, with oxidation products being the largest contributor in used oil. Organic and inorganic acids, phenols,
20 esters, detergents, and inhibitors are common auxiliary components and can also contribute to the increase of TAN value of an oil sample. TAN value only measures the amount of acid in a sample, not the specific quantities of different acidic compounds in the sample. With the expression "TAN increasing acid" is thus meant here any acidic component, which increases the total acid number of a sample in question.

25 With the expression "online measurement" is meant here that the measurement is continuous, constantly measuring, or constantly taking the measurement, wherein "online" refers to conducting the analysis directly at the location, such as in the actual processing unit at plant conditions, without the need for collecting a sample from the processing unit for analysis e.g. in a laboratory.

30 With the expression "real time measurement" is meant here that the measurement takes place in the actual time during which a measurement is taken from a feedstock without any significant delays in measuring the sample and providing the measurement results. In this respect providing the real time measurement of feedstock without any significant delays means a delay of 20 min or less, such as a delay from 10 sec to 20 min, or such as a delay
35 from 10 sec to 10 min. A "real-time measurement" in the context of measuring impurities in

a feedstock refers to the continuous and immediate monitoring and assessment of impurity levels as they occur in that particular feedstock stream.

With the expression “impurity” is meant here any species, elements or compounds that undermines the processing of renewable feedstock into a hydrocarbon product, i.e. is detrimental for catalytic reactions involved, or forms undesired by-products or decreases conversion, selectivity, or yield, and thus needs to be removed from the feedstock before further processing. The term impurity refers to an impurity present as minority species in the feedstock, which minority species can be removed, or the amount at least considerably decreased, in a pretreatment with a selected suitable pretreatment process.

- 10 With the expression “mid-FTIR spectrophotometer” is meant here an equipment configured to perform a vibrational spectroscopy technique that is able to identify chemicals based on the interaction of molecules with electromagnetic radiation in the mid-infrared wavelength region using a Fourier transformation infrared (FTIR) spectrometer. In the present disclosure the spectral range of the mid-FTIR spectrometer is from about 500 to 4000 cm^{-1}
- 15 (see e.g. https://en.wikipedia.org/wiki/Fourier-transform_infrared_spectroscopy), corresponding to the region of the electromagnetic spectrum where vibrations are associated with the main functional groups and typical bonds of organic molecules. The preferred mid-FTIR spectral region is from 800 to 1800 cm^{-1} . The exact usable spectral range depends on the choice of e.g. a suitable radiation source and detector combination.
- 20 With the unit “wt-ppm” is meant a concentration measurement, indicating the weight parts per million of the substance in question in a mixture or solution, from the total weight of the mixture or solution. The “wt” stands for weight, which represents the mass of the substance of interest, and “ppm” stands for parts per million, which indicates the number of parts of the substance per million parts of the total mixture or solution by weight. For example 5 wt-
- 25 ppm of sulfur indicates 5 parts of elemental sulfur for every one million parts of the entire sample of the mixture or solution of what the sulfur is part of, by weight.

With the term “absolute pressure”, contrary to gauge pressure, is meant the pressure of having no matter inside a space, or a perfect vacuum. Measurements taken in absolute pressure use this absolute zero as their reference point. The best example of an absolute

30 referenced pressure is the measurement of barometric pressure.

In the context of the present disclosure, weight-% is abbreviated as wt-%, referring to the indicated weight of a liquid stream or effluent in question obtained through gas-liquid separation, relative to the (total) weight of the feed, stream, effluent, product, component, or sample in question. Any known method can be used for the analysis. One example of a

usable method includes the PIONA method (method to determine n-paraffins, iso-paraffins, olefins, naphthenes and aromatics), which is a GCxGC analysis method, as published e.g., by Pyl et al. in Journal of Chromatography A, 1218 (2011) 3217–3223, for the GCxGC description. The weight-% of fatty acids, fatty acid methyl esters and trans fatty acid isomers
5 in a liquid animal and/or vegetable fats and oils can be analyzed, for example, according to ISO 12966-1:2014.

As used herein, the term "catalyst deactivation" refers to decreased activity of the catalyst, reflected by the amount of unconverted feed in the reactor effluent, and/or decreased selectivity of the catalyst, reflected by decreased amount of desired reaction products in the
10 reactor effluent, at a given time point, compared to the activity and/or selectivity of the catalyst in the beginning of the process of the present disclosure. As used herein, the term catalyst deactivation is not limited to any specific deactivation type or mechanism.

As used herein, the term "noble metal" refers to metallic chemical elements that can resist corrosion and typically are found in its elemental form, such as Au, Pt, Ru, Rh, Pd, Os, and
15 Ir.

As used herein, the term "hydrotreatment" means a catalytic process for treating organic material by means of molecular hydrogen. In the context of the present disclosure, hydrotreatment comprises at least removal of oxygen from organic oxygen compounds, wherein the oxygen can be removed as water i.e. hydrodeoxygenation, (HDO), as carbon
20 monoxide (i.e. decarbonylation) and/or as carbon dioxide (i.e. decarboxylation). In the context of the present disclosure hydrotreatment may also refer to removal of sulfur from organic sulfur compounds as dihydrogen sulfide (H_2S) i.e. hydrodesulphurization (HDS); removal of nitrogen from organic nitrogen compounds as ammonia (NH_3) i.e. hydrodenitrogenation (HDN); and/or to removal of halogens, for example chlorine from
25 organic chloride compounds as hydrochloric acid (HCl) i.e. hydrodechlorination (HDCl). The term "hydrotreatment" or "catalytic hydrotreatment" can thus refer to a catalytic process for treating organic material by means of hydroprocessing. With the expression "hydroprocessing" is meant herein a catalytic process of organic material by all means of molecular hydrogen. Preferably, hydroprocessing removes oxygen from organic oxygen
30 compounds as water i.e. by hydrodeoxygenation (HDO). Additionally, or alternatively hydroprocessing may remove sulphur from organic sulphur compounds as hydrogen sulphide (H_2S), i.e. by hydrodesulphurization, (HDS), it may further remove nitrogen from organic nitrogen compounds as ammonia (NH_3), i.e. by hydrodenitrogenification (HDN), and/or it may remove halogens, for example chlorine, from organic chloride compounds as

hydrochloric acid (HCl), i.e. by hydrodehalogenation such as chlorination (HDCI). It may further remove aromatic compounds by hydrodearomatization (HDA).

By the term "deoxygenation" is meant removal of oxygen from organic molecules, such as fatty acid derivatives, alcohols, ketones, aldehydes or ethers by any means previously described. Deoxygenation can take place in reactions, such as hydrodeoxygenation, decarboxylation and decarbonylation.

As used herein, the term "hydrodeoxygenation (HDO)" means removal of covalently bound oxygen as water from the carboxylic acids of the feedstock using hydrogen. With HDO is meant herein hydrodeoxygenation of feedstock of biological origin, such as feedstock comprising triglycerides or other fatty acid derivatives of fatty acids, and the removal of carboxyl oxygen as water by means of molecular hydrogen under the influence of a catalyst. The hydrodeoxygenation may be accompanied by hydrodesulphurization, hydrodenitrogenification, hydrodearomatization and/or hydrodehalogenation reactions.

Removing oxygen from the feedstock of biological origin may also be done by decarboxylation where oxygen is removed in the form of CO₂, and by decarbonylation where oxygen is removed in the form of CO.

By the term "isomerization" is meant reaction(s) that causes branching of hydrocarbon chains of hydroprocessed feedstock. Branching of hydrocarbon chains improves e.g. cold flow properties of the hydrocarbons. Better cold flow properties refer to e.g. a lower temperature value of a pour point. The formed isoparaffins (also referred to as i-paraffins) may have one or more side chains, or branches, typically methyl or ethyl groups.

In an embodiment the present method is run as a continuous process, during which at least some of the steps or part-processes identified in any aspect, embodiment, or claim occur simultaneously when the method is running.

25 DESCRIPTION OF THE METHOD

In an embodiment, a method is provided for pretreating a renewable feedstock 100. In an embodiment, at least one pretreatment process of the renewable feedstock 100 is configured to reduce the quantity of one or more impurities present in the renewable feedstock 100. In an embodiment, the method reduces the quantity of said at least one impurity to a lower level than in a corresponding renewable feedstock 100 which has not been exposed to said at least one pretreatment process. The numbering is referring to figures 1 and 2.

In an embodiment, the method for pretreating a renewable feedstock 100 comprises providing the renewable feedstock 100.

In an embodiment, in the method of the present disclosure is provided a renewable feedstock 100 which is derived at least partly, or even totally, from renewable sources. In the method, a renewable feedstock or bio-oil is used, which originates from renewable sources, such as fats and oils from plants and/or fats and oils from animals and/or fats and oils from micro-organisms, and/or fats and oils from fish and compounds derived from them.

The structural units of a typical plant or vegetable or animal oil or fat useful as the renewable feedstock are units comprising free fatty acids (FFAs) and/or free carboxylic acids, and/or esters of carboxylic acids such as triglycerides, which are carboxylic acid esters of glycerol, such as triester of glycerol with three fatty acid moieties, diglycerides and monoglycerides. In an embodiment, the renewable feedstock comprises free carboxylic acids, esters of carboxylic acids, triglycerides, free fatty acids, derivatives of said fatty acids, such as esters of fatty acids triglycerides of fatty acids or metal salts of said fatty acids, or combinations of thereof.

In an embodiment, the renewable feedstock comprises natural fats or derivatives thereof. In an embodiment, the renewable feedstock is selected from a feedstock consisting of plant fats, plant oils, plant waxes, animal fats, animal oils, animal waxes, fish fats, fish oils, fish waxes, micro-organism fats, oils, and/or waxes, animal and/or fish and/or plant and/or micro-organism waste and residue materials such as used cooking oils, or any combinations thereof. In an embodiment, the renewable feedstock is liquid renewable feedstock.

The feedstock may include, but is not limited to, plant oils, vegetable oils, microbial oils like babassu oil, palm seed oil, carinata oil, olive oil, coconut butter, soybean oil, canola oil, coconut oil, muscat butter oil, rapeseed oil, peanut oil, sesame oil, maize oil, sunflower oil, poppy seed oil, cottonseed oil, soy oil, laurel seed oil, crude palm oil, palm oil, palm oil fatty acid distillate, jatropha oil, palm kernel oil, camelina oil, archaeal oil, bacterial oil, fungal oil, protozoal oil, algal-based oils, muscat butter oil, seaweed oil, mustard seed oil, oils from halophiles, lauric-myristic acid group (C12-C14) including milk fats, palmitic acid group (C16) including earth animal fats, stearic acid group (C18) including earth animal fats, linoleic acid group (unsaturated C18) including whale and fish oils, erucic acid group (mono unsaturated carboxylic acid, C22:1) including whale and fish oils, oleo stearic acid group (conjugated unsaturated C18) including whale and fish oils, fats with substituted fatty acids (ricin oleic acid, C18) such as castor oil, or mixtures of any two or more thereof. Further, the

feedstock may include crude tall oil, tall oil, tall oil fatty acid and/or tall oil pitch. In an embodiment, the renewable feedstock is selected from resin free feedstock, comprising plant fats, plant oils, plant waxes, animal fats, animal oils, animal waxes, fish fats, fish oils, fish waxes, animal and/or fish and/or plant waste and residue materials such as used
5 cooking oils, or any combinations thereof. Resin-containing renewable feedstocks can comprise high amounts of complex compounds, which can interfere with downstream processing steps and product recovery, and thus may require complicated pretreatment processes.

In one embodiment, the renewable feedstock is selected from suitable feedstocks,
10 preferably wastes and residues, listed in Annex IX, Part A or Annex IX, Part B of the Renewable Energy Directive (EU) 2018/2001, and mixtures thereof.

In an embodiment, the renewable feedstock 100 comprises waste and residue of one or more of: food plant oil materials, agricultural residues, fungal oil, animal fats, algae oil, and microbial source oil.

15 In an embodiment, the renewable feedstock 100 comprises one or more of: crop plant oil, flowering plant oil, vegetable oil, fungal oil, animal fats, algae-based oils, microbial source oil and waste and residues thereof. Crop plant oils refer to oils from plants which are specifically grown for the oils, and include the most prominent oil crops, such as palm, soybean, rapeseed and sunflower, many other crops such as, canola, mustard, flax,
20 jatropha, coconut, hemp, pennycress, and Brassica carinata. Flowering plant oils refer to oils from plants that are typically grown specifically for their seeds, which are high in oil content and can be pressed to extract the oil, such as safflower and canola.

In an embodiment, the renewable feedstock 100 comprises at least one component selected from: poultry fat, dry rendered poultry fat (AFP), brown grease (BG), used cooking
25 oil (UCO), acid oils (ASK) from edible oils, sludge palm oil, such as palm effluent sludge (PES) or palm oil mill effluent (POME), crude palm oil (CPO), palm oil, palm seed oil, palm fatty acid distillate (PFAD), babassu oil, carinata 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, archaeal oil, bacterial oil, fungal oil, protozoal oil, algal oil,
30 seaweed oil, mustard seed oil, oils from halophiles, soybean oil (SBO), technical corn oil (TCO), rapeseed oil (RSO), colza oil, canola oil, sunflower oil, hemp seed oil, olive oil, linseed oil, mustard oil, peanut oil, castor oil, coconut oil, lard, tallow, train oil, spent bleaching earth oil (SBEO), lignocellulosic based feeds, municipal solid waste-based oils, and algae-based oils, or any mixture thereof. These include feedstocks which typically are

abundant with impurities and/or originate from waste and residues, specifically low quality waste and residues.

5 An exemplary renewable feedstock preferably includes waste and residue materials originating from animal fat/oil, and/or plant fat/oil and/or fish fat/oil. These may comprise sludge palm oil, such as palm effluent sludge (PES) or palm oil mill effluent (POME), used cooking oil (UCO), acid oils (ASK) from edible oils, brown grease (BG), sludge palm oil, spent bleaching earth oil (SBEO), technical corn oil (TCO) or lignocellulosic based oils, municipal solid waste-based oils, and/or algae-based oils.

10 In an embodiment, the renewable feedstock comprises as an impurity at least one of: organo-phosphorus compound(s), organo-nitrogen compound(s), and free fatty acids.

In an embodiment, the method for pretreating a renewable feedstock 100 comprises subjecting the renewable feedstock 100 to at least one pretreatment process for reduction of at least one impurity in the renewable feedstock, and to an *in situ* measurement with an online analyzer 50 thereby obtaining real time information on a quantity of said at least one
15 impurity.

In an embodiment, the renewable feedstock 100 can be subjected to said at least one pretreatment process and to the *in situ* measurement with an online analyzer 50 in any preferred order.

20 In an embodiment, said at least one pretreatment process of the renewable feedstock 100 can comprise one pretreatment process, or more than one pretreatment processes.

In an embodiment, the renewable feedstock 100 is subjected to said at least one pretreatment process:

- a. before, after or during the *in situ* measurement with an online analyzer 50; or
- b. between two or more separate *in situ* measurements with an online analyzer 50.

25 In an exemplary embodiment, as set out in e.g. figure 1, the renewable feedstock 100 being subjected to the *in situ* measurement with an online analyzer 50 means the measurement (M1 or M3) is made directly from the renewable feedstock stream, which is entering or exiting the at least one pretreatment process, or the measurement (M2) is made directly from the renewable feedstock stream which is under the at least one pretreatment process,
30 i.e. being processed.

In an embodiment, the method comprises that the renewable feedstock 100 is subjected to said at least one pretreatment process before conducting the *in situ* measurement with an online analyzer 50.

In an embodiment, the method comprises that the renewable feedstock 100 is subjected to said at least one pretreatment process after conducting the *in situ* measurement with an online analyzer 50.

5 In an embodiment, the method comprises that the renewable feedstock 100 is subjected to said at least one pretreatment process during conducting the *in situ* measurement with an online analyzer 50.

In an embodiment, the method comprises that the renewable feedstock 100 is subjected to said at least one pretreatment process between two or more separate *in situ* measurements with an online analyzer 50.

10 In an embodiment, the method comprises:
- subjecting the renewable feedstock 100 to a first *in situ* measurement (M1) with an online analyzer 50, followed by
- subjecting the renewable feedstock 100 to the at least one pretreatment process; followed by
15 - subjecting the pretreated renewable feedstock 200 to a second *in situ* measurement (M3) with an online analyzer 50.

In an embodiment, the method comprises at least two sequential or consecutive *in situ* measurements with an online analyzer 50. In an embodiment, measuring the renewable feedstock 100, or the pretreated renewable feedstock 200 *in situ* with an online analyzer 50
20 means quantifying the amount of at least one impurity in the renewable feedstock 100, or in the pretreated renewable feedstock 200. In an embodiment wherein the method comprises two or more separate *in situ* measurements with an online analyzer 50, the same impurity/impurities are quantified in all *in situ* measurements made. In some other embodiments, only some of the same impurities, or none of the same impurities are
25 quantified in a 1st *in situ* measurement as in a 2nd *in situ* measurement with an online analyzer 50.

In an embodiment, the method comprises providing a pretreatment system or unit comprising parts wherein the at least one pretreatment processes can take place and any pipelines delivering the renewable feedstock 100 therein and further delivering the
30 pretreated renewable feedstock 200 therefrom.

In an embodiment of Fig. 1, the method for pretreating a renewable feedstock comprises the steps:

- 1) delivering the renewable feedstock 100 to said at least one pretreatment process (A) along an infeed line 12;

- 2) pretreating the renewable feedstock in said at least one pretreatment process (A);
and
3) delivering the pretreated renewable feedstock 200 away from said at least one pretreatment process (A) along an outlet line 13;
- 5 wherein at least one *in situ* measurement (M1, M2, M3) with an online analyzer 50 is obtained in real time at least in one of the steps 1) – 3) of the method.

In an embodiment an outlet line 13 is configured to deliver the pretreated renewable feedstock 200 to at least one subsequent treatment process, i.e. post-treatment process. In an alternative embodiment the outlet line 13 is configured to deliver the pretreated
10 renewable feedstock 200 to storage, such as a tank or other vessel, to wait for possible subsequent treatment process(es).

In an embodiment, the method comprises at least one *in situ* online measurement of the renewable feedstock with the online analyzer 50 but may also comprise more than one *in situ* online measurements.

- 15 In an embodiment, the measuring of the renewable feedstock 100 or the pretreated renewable feedstock 200 is done *in situ*, which means, the measurement is taken directly from the line delivering renewable feedstock 100 or pretreated renewable feedstock 200 or taken directly from said at least one pretreatment process (A). In an embodiment, the online analyzer 50 is configured to obtain measurements directly from a feedstock line delivering
20 the renewable feedstock, which is either pretreated or not. In an embodiment, measuring (M1) the renewable feedstock 100 *in situ* in the pretreatment system is done directly from the infeed line 12 configured to deliver the renewable feedstock 100 to said at least one pretreatment process (A) (Fig.1). In an embodiment, measuring (M2) the renewable feedstock 100 *in situ* in the pretreatment system is done directly from said at least one pretreatment process (A), wherein the pretreatment reactions take place (Fig. 1). In an embodiment, measuring (M3) the renewable feedstock 200 *in situ* in the pretreatment system is done directly from the outlet line 13 configured to deliver the pretreated renewable feedstock 200 from said at least one pretreatment process (A) (Fig.1). In an embodiment,
25 the method comprising the *in situ* measurement (M1) and/or (M2) and/or (M3) is beneficial, as this allows continuous and fast adjustment of the pretreatment process, quickly accommodating the pretreatment to any alterations in the composition of the renewable feedstock 100. Irrespective of the exact location of the measurement, the online analyzer 50 is configured to provide the measurement of the renewable feedstock *in situ*.
30

Measuring the renewable feedstock 100 or the pretreated renewable feedstock 200 *in situ* has several advantages, such as the analysis taking place in real time, thus providing data of the characteristics and composition of the feedstock quickly and enabling a fast response to altered impurities in the renewable feedstock with changes in the pretreatment. Any
5 delays in providing an impurity measurement of a feedstock, will potentially allow a larger volume of a feedstock with too high impurity levels to pass through the pretreatment process, and decrease the life cycle of the catalysts used in subsequent post-treatment processes. Measuring the renewable feedstock 100 or the pretreated renewable feedstock 200 *in situ* is further advantageous, as the feedstock purity can be verified quickly and
10 accurately after the pretreatment process, thereby also indicating the need for adjustment of the pretreatment.

Further, measuring *in situ* is non-destructive, as such measurements can be performed without altering or damaging the feedstock, which is particularly beneficial when continuous monitoring of the feedstock is required. Yet further, the *in situ* measured portion of the
15 renewable feedstock can be directed forward and utilized for production i.e. it is not removed from the process. Moreover, by measuring the feedstock directly at its source, *in situ* measurements can minimize potential errors or biases that may occur during sample collection, handling, time delay and transportation, thus leading to more accurate and representative data. Therefore, with more accurate *in situ* measurement data, excessive
20 pretreatments, which unavoidably lead to increased processing cost and yield loss, can be diminished. Measuring *in situ* a feedstock is also cost and time efficient as the need for sample transportation and laboratory analysis is eliminated.

In an embodiment, the method comprises subjecting the renewable feedstock 100 to said at least one pretreatment process after the *in situ* measurement with an online analyzer 50
25 and selecting said at least one pretreatment process based on the result of the *in situ* measurement provided with the online analyzer 50.

In an embodiment, the method allows selecting at least one suitable pretreatment process for the renewable feedstock, based on at least one *in situ* measurement of the renewable feedstock 100 with an online analyzer 50. In an embodiment, the method comprises:
30 selecting a pretreatment based on the information provided by the *in situ* measurement with the online analyzer 50, and subjecting the renewable feedstock 100 to the pretreatment, thereby obtaining a pretreated renewable feedstock 200 having a reduced quantity of the said least one impurity. Accordingly, in some embodiments, the method for pretreating a renewable feedstock is a method of selecting a pretreatment for a renewable feedstock 100
35 for reduction of at least one impurity in the renewable feedstock 100.

In an embodiment, the method reduces said at least one impurity in the renewable feedstock, via a selection of a specific pretreatment process for the renewable feedstock, wherein the selection is done based on at least one *in situ* measurement of the renewable feedstock 100 with an online analyzer 50. In an embodiment, the measurement with the
5 online analyzer 50 provides information of one or more impurities in the renewable feedstock 100, based on which information, the selection for a specific at least one pretreatment process can be made. In an embodiment, the pretreatment process(es) can be tailored for specific feedstock compositions when selecting said at least one pretreatment process, wherein the selection is based on the composition of the renewable
10 feedstock 100 and on the amount and type of impurities in the feedstock, as measured *in situ* with the online analyzer in real time.

Measuring the renewable feedstock 100 *in situ* prior to said at least one pretreatment process allows a quick adjustment of said at least one pretreatment process. The information obtained from the *in situ* measurement can thus be used to optimize process
15 conditions, ensure quality control, and enhance overall efficiency of the reduction of said at least one impurity at said at least one pretreatment process. Measuring the renewable feedstock 100 *in situ* thus enables a fast selection of a suitable pretreatment process for the renewable feedstock 100 at the subsequent step. The real time *in situ* measurement of the renewable feedstock 100 is done with the online analyzer 50. The selected pretreatment
20 process can be modified quickly when needed if the renewable feedstock 100 composition changes.

In an embodiment, selecting a suitable pretreatment process for the renewable feedstock 100 can take place immediately after the *in situ* measurement with the online analyzer 50, without any significant delays, i.e. selecting suitable pretreatment process can take place in
25 real time. This means, selecting a suitable pretreatment process for the renewable feedstock 100 takes place seamlessly, without any breaks or interruptions once the *in situ* measurement with the online analyzer 50 is made. In this respect, without any significant delays means that the selection of the suitable pretreatment takes place within less than 20 minutes, such as from 10 sec to 20 min, or such as from 10 sec to 10 min, from the *in situ*
30 online measurement. In an embodiment, the selection is automated, via integration into automated control and operation systems. In an embodiment, the selection is done by an operator manually. The current method comprising selecting a suitable pretreatment process(es) for the renewable feedstock 100 immediately after the *in situ* measurement with the online analyzer 50 is beneficial, as the *in situ* measurement allows a quick and accurate
35 selection of suitable pretreatment of the renewable feedstock. The current method

comprising selecting a suitable pretreatment process(es) for the renewable feedstock 100 immediately after the *in situ* measurement with the online analyzer 50 is further beneficial, as the pretreatment process must not be halted to obtain the measurement results, and/or the flowthrough of non-optimally pretreated/purified renewable feedstock can be reduced, thereby decreasing/delaying catalyst poisoning of a downstream process catalyst.

In an embodiment, measuring (M1) the renewable feedstock 100 *in situ* is done directly from the inlet line 12, configured to deliver the renewable feedstock 100 to said at least one pretreatment process (A) (Fig.1).

In an embodiment, a method for selecting at least one pretreatment process of a renewable feedstock 100 for reduction of at least one impurity in the renewable feedstock is provided, the method comprising the steps:

- providing the renewable feedstock 100;
- measuring the renewable feedstock *in situ* with an online analyzer 50, thereby obtaining real time information on a quantity of said at least one impurity in the renewable feedstock 100; and
- selecting at least one pretreatment process based on the information provided by the *in situ* measurement and subjecting the renewable feedstock to the at least one pretreatment process, thereby obtaining a pretreated renewable feedstock 200 having a reduced quantity of the said least one impurity.

In an embodiment, the method also comprises a step:

- measuring the pretreated renewable feedstock 200 *in situ* with the online analyzer 50, thereby obtaining information on a quantity of at least one impurity in the pretreated renewable feedstock 200.

In some embodiments, the method also comprises quantifying the amount of at least one impurity in the renewable feedstock 100 prior to providing said renewable feedstock 100 to the present method for pretreating a renewable feedstock.

In some embodiments, the method also comprises subjecting the renewable feedstock 100 to at least one additional pretreatment process prior to providing said renewable feedstock 100 to the present method for pretreating a renewable feedstock.

In an embodiment, the method comprises subjecting the renewable feedstock 100 to said at least one pretreatment process before the *in situ* measurement with an online analyzer 50, thereby obtaining information on a quantity of said at least one impurity in the pretreated renewable feedstock 200.

In an embodiment, the method comprises subjecting the renewable feedstock 100 to said at least one pretreatment process before the *in situ* measurement with an online analyzer 50, the measurement thereby providing a confirmation of the reduced quantity of said at least one impurity in the pretreated renewable feedstock 200. In an embodiment, measuring
5 the pretreated renewable feedstock 200 is done *in situ*, which means, the measurement is conducted directly in the pretreatment system wherein the pretreated renewable feedstock 200 is obtained.

In an embodiment, method comprises measuring the pretreated renewable feedstock 200 *in situ* with the online analyzer 50, thereby obtaining information of a quantity of said at least
10 one impurity in the pretreated renewable feedstock 200. In an embodiment, the measuring the pretreated renewable feedstock 200 means quantifying the amount of at least one impurity in the pretreated renewable feedstock 200.

In an embodiment, the measuring of the pretreated renewable feedstock 200 *in situ* is done similarly or the same way as the measurement of the renewable feedstock 100 *in situ*
15 described herein. Therefore, what has been disclosed concerning the *in situ* measurement of the renewable feedstock 100 applies also for the *in situ* measurement of the purified renewable feedstock 200, and *vice versa*. In an embodiment, the method is a continuous process, and the online analyzer 50 is configured to provide continuous online measurement in real time of said at least one impurity in the pretreated renewable feedstock
20 200.

In an exemplary embodiment, measuring (M3) the purified renewable feedstock 200 *in situ* is done directly from the outlet line 13, configured to deliver the pretreated renewable feedstock 200 from said at least one pretreatment process (A) (Fig.1). In an exemplary
25 embodiment, measuring (M2) the pretreated renewable feedstock 200 *in situ* is done directly from the pretreatment process (A) wherein the pretreatment takes place (Fig. 1).

In an exemplary embodiment, the method comprises at least two *in situ* measurements (M1) and (M3), wherein (M1) takes place before subjecting the renewable feedstock 100 to said at least one pretreatment process (A), and (M3) takes place after subjecting the renewable feedstock 100 to said at least one pretreatment process (A) . In an embodiment, the method
30 comprising the *in situ* measurements (M1) and (M3) is beneficial, as with the *in situ* measurement (M3), the quantity of said at least one impurity in the pretreated renewable feedstock 200 can be accurately verified, the measurement (M3) thereby providing information whether the selected pretreatment was suitable for the impurity in question and able to lower the amount of the impurity below a predefined target value.

In an embodiment, wherein the method comprises measuring renewable feedstock at more than one separate locations, said measurements are done with separate online analyzers 50. In an embodiment, the present method comprises two or more *in situ* measurement with two or more online analyzers 50.

- 5 Measuring the renewable feedstock 100 *in situ* after said at least one pretreatment process allows a quick verification of the obtained reduced level of said at least one impurity in the pretreated renewable feedstock 200. Thus, pretreatment process efficacy and the quantity of at least one impurity can be verified from the pretreated renewable feedstock 200. Measuring the pretreated renewable feedstock 200 *in situ* after said at least one
10 pretreatment process also allows a quick adjustment and/or modification of the at least one pretreatment process in case the level of said at least one impurity in the pretreated renewable feedstock 200 is not adequately low. Measuring the pretreated renewable feedstock 200 *in situ* after said at least one pretreatment process is further beneficial, as based on the *in situ* measurement, the feedstock 200 can be directed to any necessary
15 subsequent pretreatment process(es) or post-treatment process(es), or optionally recycled back to the same pretreatment process. In an embodiment, the method for pretreating a renewable feedstock 100 comprises obtaining a pretreated renewable feedstock 200 having a reduced quantity of said at least one impurity.

- In an embodiment, the pretreated renewable feedstock 200 is obtained from said at least
20 one pretreatment process wherein the pretreated renewable feedstock 200 has a reduced quantity of one or more impurities, but at least a reduced quantity of one impurity. In an embodiment, a pretreated renewable feedstock 200 having a reduced quantity of said at least one impurity is obtained from the method for pretreating a renewable feedstock 100.

- In an embodiment, said at least one impurity is selected from phosphorus (P), nitrogen (N),
25 H₂O, sulfur (S), silicon (Si), total acid number (TAN) increasing acids, metals, polyethylene, chlorine (Cl), and combinations thereof. In an embodiment, said at least one impurity is selected from phosphorus (P), nitrogen (N), oxygen (O), H₂O, sulfur (S), silicon (Si), total acid number (TAN) increasing acids, metals, polyethylene, chlorine (Cl), compounds with C=C double bonds, and combinations thereof. The amount of compounds with C=C double
30 bonds may be expressed through an iodine index or a bromine index, such as defined by e.g. Bailey's Industrial Oil and Fat Products, 6th ed., vol. 1, p. 172, or ASTM D-1159, and combinations thereof.

In an embodiment, said at least one impurity is selected from phosphorus (P), nitrogen (N), oxygen (O), H₂O, sulphur (S), silicon (Si), total acid number (TAN) increasing acids, metals, chlorine (Cl), compounds with C=C double bonds, and combinations thereof.

5 In a preferred embodiment, said at least one impurity of the renewable feedstock 100 is P-containing materials, wherein the P-containing material comprises elemental phosphorus and/or phosphorus containing compounds, such as organophosphorus compounds or phospholipids. Removal of P-containing materials from the renewable feedstock via a pretreatment process is beneficial for a catalytic post-treatment process, as removal of phosphorus reduces the deactivation of a catalyst and/or plugging of a catalyst bed, and
10 thereby increases the catalyst lifetime.

In an embodiment, said at least one impurity of the renewable feedstock 100 is N-containing materials, wherein the N-containing material comprises elemental nitrogen and/or nitrogen containing compounds. Removal of N-containing materials from the renewable feedstock via a pretreatment process is beneficial for a catalytic post-treatment process, when the
15 pretreated renewable feedstock 200 is exposed to a post-treatment process, such as HDO. An HDO catalyst can remove some of the nitrogen present in a renewable feedstock, but it will lower the oxygen removal efficiency of the reaction. Moreover, if directed to a post-treatment process such as isomerization, an isomerization catalyst may not be able to withstand nitrogen comprised by the renewable feedstock, leading to catalyst passivation.

20 In an embodiment, said at least one impurity of the renewable feedstock 100 is H₂O. In an exemplary embodiment, the renewable feedstock comprises water, the quantity of which can be reduced in a pretreatment process comprising the drying step. Removal of H₂O from the renewable feedstock via a pretreatment process is beneficial, as it can cause e.g., a steam explosion when it is fed to the next process step at high temperature.

25 In an embodiment, said at least one impurity of the renewable feedstock 100 is S-containing materials, wherein the S-containing material comprises elemental sulfur and/or sulfur-containing compounds. Removal of S-containing materials from the renewable feedstock via a pretreatment process is beneficial, when the pretreated renewable feedstock 200 is exposed to a catalytic post-treatment process utilizing a catalyst which is sensitive to
30 catalyst deactivation by sulfur, such as noble-metal catalysts.

In an embodiment, said at least one impurity of the renewable feedstock 100 is Si-containing materials, wherein the Si-containing material comprises elemental silicon and/or silicon containing compounds. Removal of Si-containing materials from the renewable feedstock via a pretreatment process is beneficial, as this can prevent catalyst poisoning and

deactivation in downstream reactions, as well as enhance the final product quality. Removal of Si-containing materials from the renewable feedstock via a pretreatment process is also beneficial, as it can minimize equipment corrosion, scaling, fouling, and plugging.

5 In an embodiment, said at least one impurity of the renewable feedstock 100 is total acid number (TAN) increasing acids, such as free fatty acids (FFAs). Other TAN increasing acids may include but are not limited to, light acids, such as formic acid, acetic acid and citric acid, resin and rosin acids, other organic acids, cellulose/hemicellulose- derived acids, lactic acid, tannins and/or phenolic compounds. In an embodiment, majority of the TAN increasing acids comprised by renewable feedstocks are FFAs. Removal of TAN increasing acids, or
10 at least FFAs from the renewable feedstock via a pretreatment process is beneficial, as it reduces the total acid number of the renewable feedstock, and thus mitigates corrosion of the equipment.

In an embodiment, said at least one impurity of the renewable feedstock 100 is one or more metals. In an embodiment, the metal impurities comprised by renewable feedstocks include
15 but are not limited to alkali metals, alkaline earth metals and other metals like Fe, Mn, Cu, Co, Cr, Hg, Mo, Al, or Ni, typically Fe and Mn. In an embodiment, the metal impurities of renewable feedstocks include but are not limited to sodium, potassium, iron, magnesium, and calcium. Removal of metals from the renewable feedstock via a pretreatment process is beneficial, as metal impurities in feedstocks can lead to deactivation of the catalyst,
20 plugging of the catalyst bed, undesirable byproducts, reduced process efficiency, and thus, to lower yields and reduced product quality.

In an embodiment, said at least one impurity of the renewable feedstock 100 is polyethylene. Removal of polyethylene from the renewable feedstock via a pretreatment process is important for the product's safety and quality.

25 In an embodiment, said at least one impurity of the renewable feedstock 100 is Cl-containing materials, wherein the Cl-containing material comprises elemental chlorine and/or chlorine containing compounds. Removal of Cl-containing materials from the renewable feedstock via a pretreatment is beneficial, as this can prevent catalyst poisoning, corrosion of downstream equipment as well as enhance the final product quality.

30 In one embodiment, the feedstock comprises the impurities in solid form, whereby the solid impurities may be distributed within the renewable feedstock in various impurity containing compounds. Removal of these solid impurities, which can be separated from the renewable feedstock, for example, by a pretreatment comprising filtering, is beneficial for the operation

of heat exchangers which tend to collect the solid particles onto their surfaces thus reducing their efficacy.

The renewable feedstock 100 may comprise various amounts of different impurities depending on the origin of the feed. Some of the impurities, especially those in low quality waste and residue materials, may be very difficult to remove and demand complex combinations of different pretreatment processes and parameters. Likewise, the quality within one type of feedstock may vary depending on e.g. place of origin, duration of transportation or handling in storage.

The renewable feedstock 100 provided in the method typically comprises a quantity of said at least one impurity, which is at or above the detection level of the online analyzer 50. Similarly, the pretreated renewable feedstock 200 obtainable from the method typically comprises a quantity of said at least one impurity, which is at or above the detection level of the online analyzer 50. However, occasionally the amounts are very low and cannot be detected (i.e., the impurity amount is beyond the detection limits of the analyzer).

In an embodiment, the online analyzer 50 is configured to detect quantity of said at least one impurity selected from: at least 0.5 wt-ppm of P; at least 20 wt-ppm of N; at least 100 wt-ppm of H₂O; at least 2 wt-ppm of S; at least 0.2 wt-ppm of Si; at least 0.3 wt-% of TAN increasing acids; and at least 0.2 wt-ppm of metals, at least 50 wt-ppm of polyethylene, at least 5 wt-ppm of chlorine, or combinations thereof.

In an embodiment, the method for pretreating a liquid renewable feedstock is used for producing at least one renewable fuel component or a renewable chemical, and the method comprises:

- providing the renewable feedstock 100;
- subjecting the renewable feedstock to at least one pretreatment process for reduction of at least one impurity in the renewable feedstock, and to an *in situ* measurement with an online analyzer 50 thereby obtaining real time information on a quantity of said at least one impurity, wherein the renewable feedstock is subjected to said at least one pretreatment process before, after or during the *in situ* measurement with an online analyzer; and wherein the at least one impurity is selected from phosphorus (P), nitrogen (N), H₂O, sulfur (S), silicon (Si), total acid number (TAN) increasing acids, metals, polyethylene, chlorine (Cl), and combinations thereof; and
- obtaining a pretreated renewable feedstock having a reduced quantity of said at least one impurity,

wherein said at least one pretreatment process is configured to render the pretreated renewable feedstock suitable for use in a catalytic hydrotreatment process.

Therefore, the renewable feedstock 100 comprises a quantity of said at least one impurity which the online analyzer is capable of detecting.

5 It should be appreciated, that different online analyzer 50 equipment have various capabilities in detecting different impurity levels, Therefore, the present method is not bound to any one specific online analyzer 50, but instead, the method may be performed with any suitable analyzer, capable of providing the online *in situ* measurement of said at least one impurity in real time, at the impurity level critical for post-processing of the feedstock.

10 In an embodiment, the renewable feedstock 100 may originally comprise a high amount of one or more impurities depending on the origin of the feedstock. Based on prior knowledge of the effectiveness of typically used pretreatment processes, the best suited method may be selected. However, the anticipated removal efficiency may diverge from the obtained actual result depending on the quality and amount of impurity compounds and impurity
15 profile of the renewable feedstock 100.

The target for pretreatment is to minimize the quantity of impurities in the renewable feedstock before it enters further processing e.g. into catalytic hydrotreatment. In an embodiment, the at least one pretreatment process is configured to render the pretreated renewable feedstock suitable for use in a catalytic hydrotreatment process. Depending on
20 the available feedstock quality, the life cycle stage of the catalyst of the subsequent hydrotreatment, and the like, a predefined value for the impurity/impurities may be set and aimed at. This predefined value may be used as criteria for adjusting the pretreatment parameters to obtain a better result, fulfilling said predefined criteria. Some of the feedstock may have unexpected surprisingly high single impurity values even after a typically used
25 pretreatment process.

In an embodiment, the pretreated renewable feedstock 200 needs to fulfill one or more of the following predefined impurity criteria, to be directed into catalytic hydrotreatment:

- less than 2 wt-ppm of P, such as less than 1 wt-ppm, calculated as elementary phosphorus, and/or
- 30 • less than 1000 wt-ppm of N, such as less than 500 wt-ppm, such as less than 150 wt-ppm, such as less than 50 ppm, such as less than 5 wt-ppm, calculated as elementary nitrogen, and/or
- less than 10000 wt-ppm of H₂O, and/or

- less than 100 wt-ppm of S, such as less than 50 wt-ppm, such as less than 30 wt-ppm, such as less than 5 ppm, calculated as elementary sulfur, and/or
- less than 10 wt-ppm of Si, such as less than 5 wt-ppm, such as less than 1 wt-ppm, calculated as elementary silicon, and/or
- 5 • less than 10000 wt-ppm of TAN increasing acids, such as 1000 wt-ppm, and/or
- less than 5 wt-ppm of one or more metals, such as less than 1 wt-ppm, calculated as elementary metals, and/or
- less than 500 wt-ppm of polyethylene, and/or
- less than 50 wt-ppm of chlorine, such as less than 20 wt-ppm, such as less than 10
- 10 wt-ppm of chlorine, calculated as elementary chlorine; and/or
- any combination thereof.

In an embodiment, the pretreated renewable feedstock 200 comprises less than 10000 wt-ppm of free fatty acids (FFAs), such as 1000 wt-ppm of free fatty acids (FFAs).

- 15 In an embodiment, the online analyzer 50 is configured to provide continuous online measurement on a quantity of said at least one impurity.

20 In an embodiment, the online analyzer 50 is configured to provide reliable and accurate continuous online measurement of very low quantities of said at least one impurity. In an embodiment, the online analyzer 50 is configured to provide continuous online measurement of more than one impurity, such as two, three, or more impurities simultaneously.

In an embodiment, the online analyzer 50 is configured to provide continuous online measurement *in situ* of at least the one impurity in the renewable feedstock 100, and/or in the pretreated renewable feedstock 200, before, after or during it is entered into the at least one pretreatment process.

- 25 In an embodiment, the online analyzer 50 may be any analytical equipment capable of determining the amount of at least one impurity in a feedstock material, as described in this disclosure, and making this determination online, *in situ*, and providing real time information on said at least one impurity.

30 In an embodiment the online analyzer comprises specifically tailored gas chromatography (GC), GC coupled with mass spectrometry (GC-MS), UV fluorescence (UVF), chemiluminescence detection (CLND), X-ray fluorescence (XRF), such as ED-XRF (Energy Dispersive X-Ray Fluorescence), NMR (Nuclear Magnetic Resonance), such as ³¹P-NMR or ¹⁴N-NMR, LIBS spectrometer (Laser-Induced Breakdown Spectroscopy), Raman spectrometer, infrared spectrometer such as FTIR (Fourier transform infrared spectrometer)

35 or mid-FTIR, inductively coupled plasma (ICP-MS), inductively coupled plasma combined

with mass spectrometry (ICP-MS). In another exemplary embodiment, a mid-FTIR with Sagnac interferometer can be used as the online analyzer 50, which is able to carry out the collection of spectral data *in situ*, online in real time.

In an embodiment the online analyzer is a spectrophotometric analyzer.

- 5 In an embodiment, when considering the typical impurities to be determined, possible analyzers may comprise e.g. specifically tailored XRF, such as ED-XRF (Energy Dispersive X-Ray Fluorescence), NMR (Nuclear Magnetic Resonance), such as ^{31}P -NMR or ^{14}N -NMR, LIBS (Laser-Induced Breakdown Spectroscopy), Raman spectroscopy or infrared spectroscopy. The online analyzer 50 is only limited by its capability to determine the
- 10 amount of at least one impurity in a feedstock material, and making this determination online, *in situ*, and providing real time information on said at least one impurity. Thus, the online analyzer 50 is suitable to determine the amount of at least one impurity in a feedstock material, and making this determination online, *in situ*, and providing real time information on said at least one impurity. In an embodiment, the online analyzer 50 is configured to
- 15 determine a wt-ppm quantity of the at least one impurity, and making this determination online, *in situ*, and in real time. However, as the quantity of impurities to be detected may be low, even less than 1 wt-ppm, and the matrix for the impurity is complicated, such as triglycerides and heteroatoms and organometallic compounds, or including varying chain length hydrocarbons, the analyzer needs to have specific capabilities for being able to
- 20 detect said impurities, especially online with a short period of time available for probing.

The measurement with the online analyzer 50 can be considered a continuous online measurement as the speed of a single measurement, and the frequency of measuring is very fast. In an exemplary embodiment, an FTIR spectrophotometer may be used as the online analyzer 50, which is able to carry out the collection of spectral data in just a few

25 seconds or less. Moreover, a suitable online analyzer 50, such as a mid-FTIR spectrophotometer, needs to have a high signal to noise ratio for detection of the spectral differences associated with the modest absorption changes originating from the impurity interactions within the renewable feedstocks.

In an embodiment, the online analyzer 50 is configured to provide continuous *in situ*

30 measurement of at least one impurity, as opposed to providing an offline measurement wherein samples of the renewable feedstock 100, 200 are taken out of the pretreatment for measurement and transferred to a suitable equipment in the analysis laboratory with appropriate antecedent sample handling. In practice, the *in situ* measurement is made in-

line directly from the line delivering the feedstock, or directly from the at least one pretreatment process.

In an embodiment, the online analyzer 50 is configured to provide the measurement of said at least one impurity in real time. In an embodiment, the online analyzer 50 is configured to provide real time data of the quantity of at least one impurity without significant delays.

In an embodiment, the online analyzer 50 is configured to provide the information on the quantity of the at least one impurity in wt-ppm.

In an embodiment, the online analyzer 50 provides a measurement continuously in real time, thus providing immediate feedback of any deviations in the quantity of said at least one impurity, allowing a fast action to modify the selection of the pretreatment process. Providing the measurement of said at least the one impurity *in situ* in real time is thus beneficial as the fast measurements enable operator and/or systems to react quickly with regard to adjustment of said at least one pretreatment process, to ensure that impurity levels in the pretreated renewable feedstock 200 remain below the predefined specific values. The real time measurement provides accurate and precise measurement results. In an embodiment, the online analyzer 50 provides a measurement continuously in real time, thus also allowing an immediate action to direct the purified renewable feedstock 200, to necessary subsequent pretreatment process(es) and/or to post-treatment processing.

In an embodiment, measurement with the online analyzer 50 is automated, via integration into automated control and operation systems.

In an embodiment, the online analyzer 50 is a spectrophotometric analyzer 50.

In an embodiment, the online analyzer 50 is configured to provide continuous online measurement of said at least one impurity by collecting spectral data continuously. In an embodiment, the online analyzer 50 is configured to provide continuous *in situ* online measurement in real time of said at least one impurity selected from phosphorus (P), nitrogen (N), oxygen (O), H₂O, sulfur (S), silicon (Si), total acid number (TAN) increasing acids, metals, chlorine (Cl), compounds with C=C double bonds, and combinations thereof. In an embodiment, the online analyzer 50 is configured to provide continuous online measurement of said at least one impurity selected from phosphorus (P), nitrogen (N), oxygen (O), H₂O, sulfur (S), silicon (Si), total acid number (TAN) increasing acids, chlorine (Cl), compounds with C=C double bonds, and combinations thereof.

In an embodiment, the renewable feedstock 100 is subjected to said at least one pretreatment process before, after or during the *in situ* measurement with an online analyzer 50, wherein the measured at least one impurity is selected from phosphorus (P), nitrogen

(N), H₂O, sulfur (S), silicon (Si), total acid number (TAN) increasing acids, metals, chlorine (Cl), and combinations thereof.

In an embodiment, the online analyzer 50, i.e. a spectrophotometer, operates in a spectral region of IR radiation, UV radiation, visible light, or combinations thereof (see e.g. https://en.wikipedia.org/wiki/Fourier-transform_infrared_spectroscopy).

A spectrophotometric online analyzer 50 operating in a specific spectral region means that it is configured to measure the absorption of electromagnetic radiation within a particular range of wavelengths or frequencies. In a preferable embodiment, the spectrophotometer is operating in spectral region of infrared (IR) radiation. Regardless of the exact type of the online analyzer 50, the online analyzer 50 needs to be suitable for providing the *in situ* online measurement of said at least one impurity in real time. This means, the measurement is provided with high enough data collection rate to be considered a continuous measurement, and the online analyzer 50 having adequately high signal to noise ratio for detection of the relevant signals associated with the characteristic data of the impurity compound(s) in the renewable feedstock.

In an embodiment, the online analyzer 50 is a Fourier-transform infrared (FTIR) spectrophotometer, preferably a mid-FTIR spectrophotometer operating at a wavenumber range of 500 – 4000 cm⁻¹, such as 800 – 1800 cm⁻¹. In an embodiment, the online analyzer 50 is a Fourier-transform infrared (FTIR) spectrophotometer. Utilizing an FTIR spectrometer is especially beneficial in the current method, as spectral information may be obtained accurately and fast, to determine the quantity of impurities in the renewable feedstock. In an embodiment, the online analyzer 50 is a mid-FTIR spectrophotometer. When making measurements in mid-infrared region, absorption of photons takes place and molecular vibrations get excited which results in achieving a characteristic absorption pattern, a fingerprint for the detection and quantification of the analyte. Several FTIR and mid-FTIR spectrophotometers having varying performance properties are currently commercially available.

In an embodiment, the *in situ* measurement with the online analyzer 50 comprises measuring spectral data from the renewable feedstock and converting said spectral data via a predefined model and impurity calibration data to the information of the quantity of said at least one impurity. In an embodiment, the predefined model is a predefined chemometric model. In an embodiment, the online analyzer is a spectrophotometric analyzer, and the predefined model is a predefined chemometric model.

As the *in situ* measurement is done the same way regardless of the composition of the measured feedstock, the expression “measuring spectral data from the renewable feedstock” can refer to both/either of the renewable feedstock 100 and/or the pretreated renewable feedstock 200. In an embodiment, the *in situ* measurement comprises
5 quantifying the amount of one impurity, or several different impurities in the renewable feedstock 100, and/or the pretreated renewable feedstock 200. In an embodiment, the *in situ* measurement comprises measuring spectral data *in situ*, directly from the renewable feedstock 100, and/or the pretreated renewable feedstock 200 .

Concerning FTIR spectroscopy, as the intensities of the absorption band in an IR spectrum
10 are directly proportional to concentration of the studied impurity materials and when coupled with chemometric techniques (i.e., a predefined model) and calibration data, FTIR spectroscopy serves as means for quantitative study of impurities present in the feedstock. Thus, the area under the measured absorption band and/or intensity of the signal provides information regarding the concentration of the selected impurity. This information together
15 with calibration data (against band intensity) allows impurity concentration to be construed from measurements obtained from reference samples. FTIR with suitable chemometrics, i.e. a predefined model, and calibration data has proven to be a powerful tool to obtain quantitative information about the described impurities in renewable feedstocks.

In an embodiment, the *in situ* measurement comprises measuring spectral data from the
20 renewable feedstock 100 or the pretreated renewable feedstock 200 and converting said spectral data via an impurity-specific calibration data and a predefined chemometric model to the information of the quantity of said at least one impurity. Therefore, said at least one impurity in the renewable feedstock can be quantified. The use of predefined chemometric models with FTIR spectroscopy is known in the art and there are several statistic
25 multivariate chemometric techniques available depending on the type of samples to be studied see, e.g. article by Kumar K. 2021 (Kumar, Keshav. (2021). Partial Least Square (PLS) Analysis: Most Favorite Tool in Chemometrics to Build a Calibration Model. Resonance. 26. 429-442. 10.1007/s12045-021-1140-1), and Christou et al. 2018 (Christou C, Agapiou A, Kokkinofa R. Use of FTIR spectroscopy and chemometrics for the classification of carobs origin. J Adv Res. 2017 Dec 24;10:1-8. doi:
30 10.1016/j.jare.2017.12.001), and in particular for use of PLS-regression (partial least squares regression) chemometric models, Wold et al. 2001 (S. Wold, M. Sjöström, L. Eriksson; PLS-regression: a basic tool of chemometrics, Chemometrics and Intelligent Laboratory Systems, Volume 58, Issue 2, 2001, p. 109-130, ISSN 0169-7439), which are
35 hereby incorporated by reference. Typically, producers of online analyzers offer predefined

chemometric models compatible with their respective analyzers. Producers also provide analysis of the measured results obtained from these analyzers. However, the purpose of this disclosure is not to specify a particular online analyzer for use with a specific chemometric model. Instead, the described process can be performed with any suitable
5 online analyzer capable of determining the amount of the at least one impurity in a feedstock material, which determination is made online and *in situ*, providing real-time information on the at least one impurity. Various online analyzers that meet these criteria are available.

In an embodiment, the predefined chemometric model utilized in the measurement obtained using PLS-regression (partial least squares regression) chemometric models. Thus, when
10 using the online analyzer 50, the skilled person can select any suitable chemometric model and calibration, depending on the online analyzer used and the specific impurity measured.

In an exemplary embodiment, the calibration of the online analyzer 50 for a specific impurity can be done using PLS-regression chemometric models, such as the one published by Wold et al. 2001.

- 15 In an exemplary embodiment, the method for pretreating a renewable feedstock comprises:
- providing the renewable feedstock;
 - subjecting the renewable feedstock to at least one pretreatment process for reduction of at least one impurity in the renewable feedstock, and to an *in situ* measurement with an online analyzer thereby obtaining real time information on a quantity of said at least one
20 impurity, wherein the *in situ* measurement comprises measuring spectral data from the renewable feedstock and converting said spectral data via a predefined chemometric model and impurity calibration data to the information of the quantity of said at least one impurity, and wherein the predefined chemometric model and impurity calibration data are obtained using PLS-regression chemometric model; and
- 25 - obtaining a pretreated renewable feedstock having a reduced quantity of said at least one impurity.

In an embodiment, said at least one pretreatment process is configured to reduce the quantity of two or more impurities in the renewable feedstock 100.

In an embodiment, the *in situ* measurement with the online analyzer 50 provides real time
30 information of the quantity of two or more impurities in the renewable feedstock 100, thereby allowing to select a suitable pretreatment process(es) reducing the quantity of two or more impurities in the renewable feedstock 100, preferably simultaneously. In an embodiment, the pretreatment process(es) is/are configured to reduce the quantity of two or more impurities in the renewable feedstock 100 simultaneously and/or sequentially.

In an embodiment, said at least one pretreatment process comprises a pretreatment selected from heat treatment (HT), heat treatment with adsorbent (HTA), degumming, bleaching, deodorization, removal of solids, removal of volatiles, water washing, distillation, extraction, blending, and charge balancing, or any combination thereof.

- 5 In an embodiment, the pretreatment process comprises heat treatment (HT) optionally followed by evaporation of volatiles and/or filtration. In an embodiment wherein the pretreatment process comprises a heat treatment, the renewable feedstock 100 is heated at a temperature of from 80 °C to 400 °C, preferably from 80 °C to 325 °C, preferably from 180 °C to 300 °C, more preferably from 200 °C to 295 °C, most preferably from 200 °C to 10 280 °C and has a residence time from 1 to 300 min. In one embodiment, the heat treatment is made at a high temperature, such as from 300 °C to 400 °C, or from 350 °C to 400 °C, in presence of water, 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, the absolute pressure is from 4000 to 6500 kPa. A heat treatment followed by an evaporation step is an especially beneficial 15 pretreatment process for e.g. feedstocks comprising silicon containing compounds and/or lipophilic phosphorus containing compounds, as these are removed efficiently in such pretreatment process. In an embodiment the pretreatment process comprises HT followed by bleaching. In an embodiment the pretreatment process comprises HT with alkali addition and bleaching. An example of heat treatment of a renewable feedstock as a pretreatment 20 process is disclosed in WO 2020/016405, which is hereby incorporated by reference. Another example of a heat treatment of a renewable feedstock as a pretreatment process is disclosed in WO2019129933A1, which is hereby incorporated by reference.

- In an embodiment, the pretreatment process comprises heat treatment with adsorbent (HTA), wherein the adsorbent is a filter aid for removal of impurities. In an embodiment, the 25 heat treatment with adsorbent is performed in a temperature from 180 °C to 325 °C, preferably from 200 °C to 300 °C, more preferably from 240 °C to 280 °C, optionally in the presence of an acid. In an embodiment, the adsorbent is selected from alumina silicate, silica gel and mixtures thereof, and is typically added in an amount of 0.1 wt-% to 10 wt-%, such as 0.5 wt-%. In an embodiment, both HT and HTA can be performed under absolute 30 pressure of 0.01 to 8000 kPa, such as from 50 to 5000 kPa. A heat treatment aided with adsorbent is an especially beneficial pretreatment process for feedstocks comprising crude tall oil (CTO) and tall oil pitch (TOP). A heat treatment, with or without adsorbent, optionally followed by filtration and/or bleaching, is an especially beneficial pretreatment process for feedstocks comprising, for example, brown grease. In one embodiment the pretreatment 35 process comprises HTA followed by a flash evaporation. In one embodiment, the

pretreatment process comprises HTA followed by bleaching, or optionally followed by flash evaporation and bleaching. An example of HTA can be found in WO 2020/016410, which is hereby incorporated by reference.

In an embodiment, the pretreatment process comprises degumming. In an embodiment, degumming is performed using water and optionally acid, preferably citric acid or phosphoric acid. In an embodiment, the pretreatment process comprises degumming followed by a solid removal by centrifugation and/or a bleaching step. In an embodiment, degumming (e.g. acid degumming) included in a pretreatment process is especially beneficial for feedstocks comprising palm effluent sludge (PES) or palm oil mill effluent (POME).

In an embodiment, the pretreatment process comprises bleaching. In an embodiment, the pretreatment process comprises two separate bleaching steps. In an embodiment, bleaching is conducted by acid addition in an amount of from 500 to 5000 wt-ppm, calculated from the total weight of the renewable feedstock 100. In an embodiment, the pretreatment process comprising bleaching comprises bleaching with an acid, preferably bleaching the liquid phase of the renewable feedstock with an acid. In an embodiment the bleaching is carried out by mixing the renewable feedstock with an acid, such as citric acid or phosphoric acid or malic acid, and bleaching earth. In an embodiment, bleaching comprises a strong acid treatment, such as treatment using strong mineral acid(s). In an embodiment, bleaching treatment is performed in a temperature from 60 °C to 90 °C, and includes a drying step at a temperature from 110 °C to 130 °C. In an embodiment, after bleaching, a filtration step is performed to remove formed solids and possible filter aids. In an exemplary embodiment, the bleaching includes the sequence: (1) acid addition 1000-4000 wt-ppm citric acid (50 wt-% water) 85 °C, 10 min; (2) adsorbent/filter aid addition 0.1-1 wt-%, 85 °C, 800 mbar, 20 min; (3) drying 120 °C, 80 mbar, 25 min (4) filtering 120 °C, 2.5 bar. Bleaching included in a pretreatment process is especially beneficial for feedstocks comprising large quantities of colorants.

In a preferred embodiment said at least one pretreatment process is a sequence of process steps. In an embodiment, bleaching is the last step of the pretreatment process. Bleaching can be considered as polishing treatment leaving the pretreated feedstock ready, for example, for a hydrotreatment. However, bleaching alone cannot remove very high impurity levels from feedstocks, and therefore it is combined with other pretreatment process steps. In one embodiment, the pretreatment process comprises bleaching and deodorization.

In an embodiment, the pretreatment process comprises removal of volatile impurities from the liquid renewable feedstock 100, for example through evaporation, such as flash evaporation. In an embodiment, the evaporation, e.g. performed by flashing, can be performed after HT or HTA or any other pretreatment process stage and can be performed
5 at about 160 °C, such as from 150 °C to 225 °C, in a pressure of 10 to 1000 mbar (1 to 100 kPa). In an embodiment, a pretreatment process comprising an evaporation step is especially beneficial in pretreatment processes wherein light components comprising silicon and phosphorus containing compounds are removed.

In one embodiment deodorization is a steam distillation process carried out under vacuum,
10 such as at a pressure from 100 Pa to 700 Pa, and at temperatures ranging from 210 °C to 270 °C. The steam acts as a carrier that removes volatile compounds and results in a cleaner effluent.

In an embodiment, the pretreatment process comprises removal of solid impurities from the renewable feedstock 100 through filtration of solids, centrifugation and/or
15 sedimentation/settling. In an embodiment, the pretreatment process removing solids from the renewable feedstock 100 is filtration. In an embodiment, pretreatment process comprises removal of solids before and/or after HT or HTA. In an embodiment, the pretreatment process comprises HT or HTA, followed by filtration as an addition or an alternative to evaporation. In an embodiment, the pretreatment process comprising heat
20 treatment (with or without adsorbent) followed by a filtration and optionally bleaching, is especially beneficial with renewable feedstocks comprising, for example, brown grease. In an embodiment, the pretreatment process comprises more than one steps to remove solids and more than one bleaching step.

In an embodiment, the pretreatment process comprises solvent extraction and/or
25 evaporation.

In an embodiment, water can be added before or during HT and HTA to a level of up to 5 wt-%, such as 1 wt-% - 3 wt-%, calculated from the total weight of the feedstock. Therefore, in some embodiments, the pretreatment process comprises water washing. Water washing is especially beneficial for renewable feedstocks comprising, for example, high
30 concentration of hydrophilic phospholipids.

In an embodiment, the pretreatment process comprises distillation. A pretreatment process comprising distillation is beneficial in removing impurities from a feedstock in many different pretreatment processes, thus providing the bottom product as the at least partly pretreated feedstock. In an embodiment, a pretreatment process comprising distillation comprises

deodorization. A pretreatment process comprising distillation is also beneficial in removing impurities along a remaining bottom product, thus providing the distillate product as the at least partly pretreated feedstock. For example, the pretreated renewable feedstock comprising free fatty acids (FFAs) can be obtained as the distillate in a pretreatment process
5 comprising distillation.

In an embodiment, the pretreatment process comprises HT or HTA, followed by an evaporation step. In an embodiment, the pretreatment process comprises HT or HTA, followed by an evaporation step and a bleaching step. In an embodiment, the pretreatment process comprises HT or HTA, and bleaching. In an embodiment, the pretreatment process
10 comprises HT with alkali addition and bleaching. In an embodiment, the pretreatment process comprises HT, bleaching and deodorization.

In an embodiment, the pretreatment process comprises a method including charge balancing of the feedstock with subsequent filtering. In an embodiment, said at least one pretreatment process comprises charge balancing and filtering of the feedstock prior to
15 subjecting the feedstock to other pretreatment process(es), as depicted in e.g. FI20225301, which is hereby incorporated by reference.

In an embodiment, the purified renewable feedstock 200 is subjected to the *in situ* measurement with an online analyzer 50 after said at least one pretreatment process, and the method further comprises one or more of the following steps:
20 - directing at least part of the pretreated renewable feedstock 200 back to the same or different pretreatment process based on the information obtained from the *in situ* measurement; and/or
- blending at least part of the pretreated renewable feedstock 200 with the renewable feedstock 100.

25 In an embodiment, the method comprises directing the pretreated renewable feedstock 200 after the *in situ* measurement with an online analyzer 50 back to the same at least one pretreatment process. Such an embodiment is beneficial, when the measured quantity of said at least one impurity in the pretreated renewable feedstock 200 is still too high for the pretreated renewable feedstock 200 to be used in a selected post-treatment process, such
30 as catalytic hydrotreatment. Repeating the same at least one pretreatment process twice is in some embodiments followed by a new subsequent *in situ* measurement, for verifying the measured quantity of said at least one impurity has decreased to the desired level.

In an exemplary embodiment, after the *in situ* measurement (M3) of the pretreated renewable feedstock 200 with the online analyzer 50, at least part of the pretreated

renewable feedstock 200 is directed back to the pretreatment process (A) along a feedstock line 14, and blended with the renewable feedstock 100, as shown in Fig. 2.

In an embodiment, the method comprises blending the pretreated renewable feedstock 200 with the renewable feedstock 100 which has not yet been exposed to the at least one pretreatment process. Blending the pretreated renewable feedstock 200 with the renewable feedstock 100 is beneficial when the quantity of said at least one impurity in the untreated renewable feedstock 100 is very high, the pretreated renewable feedstock 200 thereby diluting the concentration of said at least one impurity, thus improving efficacy of the at least one pretreatment process.

10 In an embodiment, the process comprises directing the pretreated renewable feedstock 200 to a different pretreatment process based on the information obtained from the *in situ* measurement. In an exemplary embodiment, the pretreated renewable feedstock 200 is provided along a feedstock line 15 to a re-selected (i.e. different) pretreatment process (B), as shown in Fig. 2. In an embodiment, the pretreated renewable feedstock 200, which has
15 undergone the re-selected pretreatment process (B), can be provided along the feedstock line 16 to any post-treatment process desired, or, for example, blended with the renewable feedstock 100, as shown in Fig. 2. In an embodiment, the pretreated renewable feedstock 200, which has undergone the re-selected pretreatment process (B), can be measured (M4) *in situ* with the online analyzer 50, for example from the re-selected pretreatment process
20 (B) and/or from a feedstock line 16 delivering the pretreated renewable feedstock 200, as shown in Fig. 2. In an embodiment, the present method comprises the *in situ* measurement (M4) with an online analyzer 50.

In an embodiment, subsequent renewable feedstock 100 is directed to an adjusted pretreatment process based on the information obtained from the *in situ* measurement. In
25 an embodiment, the adjusted pretreatment process is carried out by changing the process conditions used in respect to the originally used pretreatment process conditions, in said adjusted pretreatment process. With the term "subsequent renewable feedstock 100" is meant the remaining portion or volume of the renewable feedstock 100, which has not yet entered the pretreatment process. In a preferred embodiment, if the *in situ* measurement
30 with the online analyzer 50 reveals that the pretreatment process should be adjusted, the remaining, i.e. subsequent, untreated renewable feedstock 100 which has not yet entered the pretreatment process, is treated with an adjusted pretreatment process. In such an embodiment, the already pretreated renewable feedstock 200 is not recycled to pretreatment(s), but rather directed to post-processing. As the *in situ* measurement allows

a fast adjustment of the pretreatment process, the volume of non-optimally pretreated renewable feedstock 200 entering post-treatment process(es) remains small.

In an exemplary embodiment, the method comprises directing the subsequent untreated renewable feedstock 100 after the *in situ* measurement (M3) with an online analyzer 50 to an adjusted pretreatment process, which is not identical to said at least one pretreatment process to which the previously pretreated renewable feedstock 200 has already been subjected to. In an embodiment, directing the subsequent untreated renewable feedstock 100 after the *in situ* measurement to an adjusted pretreatment process allows adjusting the pretreatment process to improve the removal of said at least one impurity. Directing the subsequent untreated renewable feedstock 100 after the *in situ* measurement with an online analyzer 50 to the adjusted pretreatment process is beneficial, as pretreatment adjustment to the needs of the renewable feedstock composition is fast, and no resources or time needs to be utilized for laboratory measurements and/or recycling any feedstock.

In an embodiment, the method further comprises adjusting said at least one pretreatment process based on the information obtained from the *in situ* measurement with the online analyzer 50.

In an embodiment, the adjusted pretreatment process is carried out by changing the process conditions used in said adjusted pretreatment process, in respect to the originally used pretreatment process conditions. With the term the originally used pretreatment process conditions is meant here the conditions of the pretreatment process which were applied in the pretreatment process previously, before the *in situ* measurement and before the subsequent adjustment of the pretreatment process.

In an embodiment, wherein the *in situ* measurement reveals the quantity of said at least one impurity is too high in the pretreated renewable feedstock 200, the pretreatment process can be adjusted. In an embodiment, wherein the *in situ* measurement reveals the ratio of two or more impurities is too high in the pretreated renewable feedstock 200, the pretreatment process can be adjusted.

Thus, in an embodiment, the remaining volume of the renewable feedstock 100, which has not yet entered the pretreatment process is directed to an adjusted pretreatment process based on the information obtained from the *in situ* measurement, wherein the adjusted pretreatment process is adjusted in respect of the at least one pretreatment process to which the previously pretreated renewable feedstock 200 has already been subjected to.

In an embodiment, the adjustment of the pretreatment process means re-selecting a suitable pretreatment process or process sequence or process parameters based on the

information obtained from the *in situ* measurement. In such an embodiment, the re-selected pretreatment process may comprise different pretreatment(s) than the previously utilized pretreatment process. In an embodiment, the adjusting of the pretreatment process comprises reselecting a suitable pretreatment sequence. In an embodiment, the adjusting
5 of the pretreatment process comprises modification of the pretreatment process by adding at least one pretreatment and/or removing at least one pretreatment from the sequence of different pretreatments. In an exemplary embodiment, wherein the quantity of said at least one impurity is observed to be too high in the *in situ* measurement, the pretreatment process sequence can be adjusted by including further pretreatment steps or changing one or more
10 pretreatment steps. For example, a second HT, bleaching, washing and/or filtration step can be added to the pretreatment process sequence.

In an embodiment, the adjusting of the pretreatment process is configured to decrease at least the amount of phosphorus in the pretreated renewable feedstock 200, thereby obtaining a pretreated renewable feedstock 200 having a reduced phosphorus content. In
15 an exemplary embodiment, the amount of phosphorus in the pretreated renewable feedstock 200 can be decreased by a pretreatment comprising filtering, heat treatment and bleaching.

In a preferred embodiment, the adjustment of the pretreatment process means adjusting the previously selected pretreatment process (A), based on the information obtained from
20 the *in situ* measurement. A skilled person is able to select a suitable adjustment of the pretreatment process based on the knowledge of the impurity (or impurities) in the renewable feedstock, the quantity of the impurity (or impurities), and the available selection of suitable adjustable processes and process conditions thereof. The adjustment may even be automated based on predefined impurity profiles.

25 In an embodiment, the adjustable process conditions of the pretreatment process comprise at least residence time of the renewable feedstock, pretreatment reaction temperature, dosing of at least one substance, and selection of a suitable pretreatment process sequence. In an embodiment, changing the process conditions used in the adjusted pretreatment process means changing materials used in the adjusted pretreatment process.

30 In an embodiment, the adjusted pretreatment process is carried out by adjusting one or more of:

- residence time of the renewable feedstock;
- pretreatment temperature;

- dosing of at least one substance, preferably selected from a bleaching clay, adsorbent, acid, and water; and
- selection of a suitable pretreatment or a suitable pretreatment sequence.

In an embodiment, the adjusting of the pretreatment process comprises modification of residence time of the renewable feedstock 100 during the pretreatment process. In an exemplary embodiment, adjusting the pretreatment process by increasing the residence time of the renewable feedstock 100 during the pretreatment process, the removal of said at least one impurity from the pretreated feedstock is increased. In another exemplary embodiment, adjusting the pretreatment process by decreasing the residence time of the renewable feedstock 100 during the pretreatment process, the energy efficiency and scalability of the pretreatment process can be improved, and the risk of thermal or chemical decomposition of the renewable feedstock is reduced.

In an embodiment, the adjusting of the pretreatment process comprises adjusting the pretreatment process reaction temperature. For example, in some embodiments, the temperature of the heat treatment is not high enough to precipitate the desired impurities and should thus be increased. Therefore, in an embodiment, adjusting the pretreatment process reaction temperature by increasing the temperature, the removal of said at least one impurity is improved. In another exemplary embodiment, adjusting the pretreatment process reaction temperature by decreasing the temperature, the thermal degradation of the renewable feedstock can be reduced and/or prevented and reaction selectivity of the feedstock improved.

In an embodiment, the adjusting of the pretreatment process comprises adjusting the dosing of at least one substance selected from a bleaching clay, adsorbent, citric acid, and water. In an embodiment, adjusting the dosing of bleaching clay in the pretreatment process is beneficial as the removal of impurities, such as phosphorus, metal, sulfur and nitrogen compounds, color pigments, residual contaminants, and undesirable odors, from the renewable feedstock is improved. In an embodiment, adjusting the dosing of adsorbents, such as activated carbon or silica gel, in the pretreatment process is beneficial as the adsorption of impurities, such as metals, from the renewable feedstock is improved. In an embodiment, adjusting the dosing of acid, such as citric acid, in the pretreatment process is beneficial as acid adjusts the pH of a feedstock, and acts as a chelating agent binding with metal ion contaminants in a feedstock. In an embodiment, adjusting the dosing of water in the pretreatment process is beneficial as water can aid in hydration, swelling, and softening of the feedstocks, making it more amenable to subsequent processing steps.

In an embodiment, the adjusting of the pretreatment process takes place continuously during the pretreatment process and during the method for pretreating a renewable feedstock. In an embodiment, the current method is a continuous process, and thus, with the information obtained from the *in situ* measurement(s), the pretreatment process can be quickly modified, to meet the requirements set for the outgoing pretreated renewable feedstock 200 impurity composition. Thus, in an embodiment, the adjusting of the pretreatment process takes place continuously, each time after an *in situ* measurement is provided.

In an exemplary embodiment, method for pretreating a renewable feedstock comprises the steps:

- a) providing the renewable feedstock 100;
- b) optionally measuring the renewable feedstock 100 *in situ* with an online analyzer 50, thereby obtaining information on a quantity of at least one impurity in the renewable feedstock 100;
- c) subjecting the renewable feedstock 100 to a pretreatment process, thereby obtaining a pretreated renewable feedstock 200 having a reduced quantity of said at least one impurity;
- d) measuring the pretreated renewable feedstock 200 *in situ* with an online analyzer 50, thereby obtaining information of a quantity of said at least one impurity in the pretreated renewable feedstock 200;
- e) adjusting the pretreatment process in the step c) based on the information obtained from the step d) and optionally directing at least part of the pretreated renewable feedstock 200 back to the step c).

In an embodiment, the pretreatment process is adjusted if the pretreatment process is not removing said at least one impurity from the renewable feedstock adequately well. In an embodiment, the pretreatment process is also adjusted if the pretreatment process is removing said at least one impurity from the renewable feedstock more efficiently than what is actually needed. In such an embodiment, the pretreatment process is adjusted to be less efficient, to save materials used in the pretreatment process, such as bleaching clay.

In an exemplary embodiment, the pretreated renewable feedstock 200 is collected to a tank prior to post-processing steps. In an embodiment, wherein the pretreated renewable feedstock 200 is collected to a tank after the pretreatment process, the pretreated renewable feedstock 200 can be blended with subsequent pretreated renewable feedstock 200 which has gone through an adjusted pretreatment process (thus having an adjusted composition), prior to post-processing steps. Consequently, in some embodiments, two

different pretreated renewable feedstocks 200 having gone through different pretreatment processes and thus having different compositions, are collected to a tank after the pretreatment process and blended. Such blending of different batches of pretreated renewable feedstock 200 is beneficial, if the earlier pretreatment process resulted in too high level of said at least one impurity, the subsequent batch of pretreated renewable feedstock 200 (which has gone through the adjusted pretreatment process) thus adjusting the blend composition of the combined pretreated renewable feedstock 200 in the tank, to be suitable for post-treatment processes such as HDO.

In an embodiment, with "pretreated renewable feedstock 200" is meant a blend of two different batches of pretreated renewable feedstock 200, the two different batches having different composition, preferably having different concentration of said at least one impurity. In an embodiment, the method further comprises directing the pretreated renewable feedstock 200 to at least one post-treatment process suitable for producing at least one renewable fuel component or a renewable chemical, said at least one post-treatment process comprising a catalytic hydrotreatment, preferably comprising a hydrodeoxygenation (HDO). In an embodiment, said at least one post-treatment process comprises a catalytic hydrotreatment. In an embodiment, said at least one post-treatment process preferably also comprises, in addition to said catalytic hydrotreatment, at least one of stabilization and fractionation.

In an embodiment, said at least one pretreatment process is configured to render the pretreated renewable feedstock 200 suitable for use in a catalytic hydrotreatment process, such as hydrodeoxygenation (HDO) process.

In an embodiment, the pretreated renewable feedstock 200 is used in a catalytic hydrodeoxygenation (HDO) process. In an embodiment, the pretreated renewable feedstock 200 is provided to a catalytic HDO process directly after said at least one pretreatment process. In an alternative embodiment, the pretreated renewable feedstock 200 is provided to a catalytic HDO process after the *in situ* measurement with an online analyzer 50.

In an embodiment, the method for pretreating the renewable feedstock is configured to render the pretreated renewable feedstock 200 suitable for use in a catalytic hydrotreatment process, when the method comprises the steps:

- a) providing the renewable feedstock 100;
- b) subjecting the renewable feedstock to at least one pretreatment process for reduction of at least one impurity in the renewable feedstock 200,

c) subjecting the renewable feedstock to an *in situ* measurement with an online analyzer 50 thereby obtaining real time information on a quantity of said at least one impurity in the pretreated renewable feedstock 200;

5 e) adjusting the pretreatment process in the step b) based on the information obtained from the step c). Therefore the present process renders the pretreated renewable feedstock 200 suitable for use in a catalytic hydrotreatment, by adjusting said at least one pretreatment process, the adjusted pretreatment thus rendering the pretreated renewable feedstock 200 suitable for use in a catalytic hydrotreatment.

10 In an embodiment, said at least one pretreatment process is configured to reduce the quantity of at least one impurity in the pretreated renewable feedstock 200, reducing said quantity of at least one impurity to a level that is sufficiently low for the renewable feedstock 200 to be introduced into a catalytic HDO process without inducing significant catalyst poisoning. In an embodiment, said at least one pretreatment process being configured to render the pretreated renewable feedstock 200 suitable for use in a catalytic 15 hydrodeoxygenation (HDO) process means, the quantity of said at least one impurity in the pretreated renewable feedstock 200 is configured to be reduced to or below a selected predefined target value for the particular pretreatment process.

In a preferred embodiment, said at least one pretreatment process is configured to reduce the quantity of phosphorus containing materials and metals in the pretreated renewable 20 feedstock 200 to a level low enough for the renewable feedstock 200 to be used in a catalytic HDO process. In an embodiment, said at least one pretreatment process is configured to reduce the quantity of phosphorus containing materials and/or metals in the pretreated renewable feedstock 200, thereby avoiding HDO catalyst poisoning, when directing the pretreated renewable feedstock 200 to a catalytic HDO process. In an 25 embodiment, said at least one pretreatment process is configured to render the pretreated renewable feedstock 200 suitable for use in a catalytic HDO process, by reducing the level of phosphorus to 2 wt-ppm or less, calculated as elemental phosphorus. In an embodiment, said at least one pretreatment process is configured to render the pretreated renewable feedstock 200 suitable for use in a catalytic HDO process, by reducing the level of metals 30 to 2 wt-ppm or less, calculated as elemental metals.

In an embodiment, said at least one pretreatment process is configured to reduce the nitrogen (N) content of the pretreated renewable feedstock 200 to a level of 500 wt-ppm or less, calculated as elemental N. In an embodiment, said at least one pretreatment process is configured to reduce the water content of the pretreated renewable feedstock 200 to a 35 level of 5000 wt-ppm or less. In an embodiment, said at least one pretreatment process is

configured to reduce the sulfur (S) content of the pretreated renewable feedstock 200 to a level of 100 wt-ppm or less, calculated as elemental S. In an embodiment, said at least one pretreatment process is configured to reduce the silicon (Si) content of the pretreated renewable feedstock 200 to a level of 10 wt-ppm or less. In an embodiment, said at least one pretreatment process is configured to reduce the chlorine (Cl) content of the pretreated renewable feedstock 200 to a level of 20 wt-ppm or less, calculated as elemental Cl.

In an embodiment, the *in situ* measurement with the online analyzer 50 is configured to verify the reduced quantity of said at least one impurity in the pretreated renewable feedstock 200.

10 In an embodiment, the method further comprises directing the pretreated renewable feedstock 200 to at least one post-treatment process comprising hydrotreatment.

In an embodiment, after the *in situ* measurement with the online analyzer 50, at least part of the pretreated renewable feedstock 200 is directed to a post-treatment process.

In an embodiment, the method for pretreating a renewable feedstock comprises the steps:

- 15 a) providing the renewable feedstock 100;
- b) optionally measuring the renewable feedstock 100 *in situ* with an online analyzer 50, thereby obtaining information on a quantity of at least one impurity in the renewable feedstock 100;
- c) subjecting the renewable feedstock 100 to a pretreatment process, thereby obtaining
- 20 a pretreated renewable feedstock 200 having a reduced quantity of said at least one impurity;
- d) measuring the pretreated renewable feedstock 200 *in situ* with an online analyzer 50, thereby obtaining information of a quantity of said at least one impurity in the pretreated renewable feedstock 200; and
- 25 f) directing the pretreated renewable feedstock 200 to at least one post-treatment process suitable for producing at least one renewable fuel component.

In an embodiment, the pretreated renewable feedstock 200 is directed to at least one post-treatment process when the pretreatment process has removed said at least one impurity from the renewable feedstock adequately well.

30 In an embodiment, the pretreated renewable feedstock 200 is directed to a catalytic hydrodeoxygenation (HDO) process. In an embodiment, the pretreated renewable feedstock 200 is provided to a catalytic HDO process directly after said at least one pretreatment process or directly after the *in situ* measurement with an online analyzer 50.

In an embodiment, the pretreated renewable feedstock 200 is provided to a catalytic HDO process after being collected and optionally blended in a collection tank.

In an embodiment, the pretreatment process renders the pretreated renewable feedstock 200 suitable for use in a catalytic hydrodeoxygenation (HDO) process, which is confirmed
5 in the *in situ* measurement of the pretreated renewable feedstock 200 after the pretreatment process.

In an embodiment, at least part of the pretreated renewable feedstock 200 is directed to a catalytic hydrodeoxygenation (HDO) process. In an embodiment, the pretreated renewable feedstock 200 is fractionated before directing at least one of the fractions of the pretreated
10 renewable feedstock 200 to a HDO process.

In an embodiment, the catalytic HDO process is carried out at a temperature of 250 - 450 °C, preferably the temperature is 250 - 380 °C, such as 260 - 360 °C, or even 280 - 350 °C; and/or a pressure of 1 - 20 MPa, preferably the pressure is 1 - 15 MPa, such as 2 - 10 MPa. In an embodiment, the catalytic HDO process is carried out at a H₂ feed ratio of 50 - 2000
15 nl H₂/ liter of feed, preferably 100 - 1000 nl H₂/ liter of feed, more preferably 150 - 500 nl H₂/ liter of feed. In an embodiment, the catalytic HDO process is carried out in the presence of the HDO catalyst comprising at least one group VIII and/or VIB metal of the Periodic Table, preferably selected from nickel, molybdenum, tungsten, cobalt, and any combinations thereof, preferably selected from NiMo, CoMo, and NiW. In an embodiment, the HDO
20 catalyst further comprises at least one support selected from zeolite, silica, alumina, amorphous silica alumina (ASA), and any combination thereof. In another embodiment, the catalyst may be supported on any convenient support, such as alumina, silica, zirconia, titania, amorphous carbon, zeolite, molecular sieves or combinations thereof. In one embodiment the HDO is performed in the presence of one or more catalyst(s) selected from
25 hydrogenation metal on a support, such as a metal selected from a group consisting of Pd, Pt, Ni, Co, Mo, Ru, Rh, W or any combination thereof, preferably a catalyst comprising one or more metals selected from CoMo, NiMo, NiW, and CoNiMo on a support, such as alumina, silica and/or zeolite containing support. Usually, metal is impregnated or deposited on the support as metal oxides and then typically converted into their sulphides. Also, other
30 known catalysts known in the art can be used.

In a preferable embodiment, the catalytic hydrodeoxygenation (HDO) reaction is catalyzed by a heterogeneous HDO catalyst. The hydrodeoxygenation may be performed at liquid hourly space velocities of 0.2 h⁻¹ to 10 h⁻¹. During a hydrodeoxygenation step using a sulphided catalyst, the sulphided state of the catalyst may be maintained by the addition of

sulphur in the gas phase or by using a feedstock having sulphur containing mineral oil blended with the feedstock of biological origin. Effective conditions for hydrodeoxygenation may reduce the oxygen content of the renewable feedstock to less than 1 wt-%, such as less than 0.5 wt-% or less than 0.2 wt-%. In some cases, the conditions may be selected to yield partial hydrodeoxygenation corresponding to a deoxygenation of at least 40 wt-%, at least 50 wt-% or at least 75 wt-%.

Hydrodenitrogenation, hydrodesulphurization, hydrodearomatization and hydrodehalogenation may take place simultaneously or separately from hydrodeoxygenation. The reaction conditions, such as temperatures, pressures, residence times and flow rates and ratios, and especially catalysts, may be adjusted to favor the reduction of amount of nitrogen, sulphur, aromates or halogens, particularly. The reaction conditions may be tuned for particular feedstock abundant with particular impurities or heteroatoms. For example, the catalysts for hydrodenitrogenation typically comprise of cobalt and nickel as well as molybdenum disulfide, sometimes e.g. tungsten disulfide supported on alumina. The precise composition of the catalyst, such as Co/Ni and Mo/W and Ni/W ratios, may be tuned for particular feedstocks. For the hydrodesulphurization, the catalyst are typically transition metals, or for example Ru based compounds or binary combinations of Co and Mo, Ni or W. In hydroaromatization noble metal catalysts, such as Pd, Pt catalysts supported on USY zeolite, alumina and/or zeolite have been applied with varying Pd/Pt mass ratios.

In an embodiment, the method for pretreating a renewable feedstock includes also a catalytic hydrotreatment of the pretreated renewable feedstock, and therefore, the method is a method for pretreating and hydrotreating a renewable feedstock.

In an embodiment, the method comprises the pretreated renewable feedstock 200 is used in a catalytic hydrotreatment process comprising one or more of the following: hydroprocessing, hydroisomerization, hydrocracking, and/or dewaxing.

In an embodiment, the method comprises use of the pretreated renewable feedstock 200 in a catalytic hydrotreatment process for producing renewable fuels, the method comprising the steps:

- iii. subjecting the pretreated renewable feedstock 200 to hydroprocessing to obtain a hydroprocessed stream, preferably comprising more than 90 wt.-% of paraffins;
- iv. subjecting the hydroprocessed stream to stripping to remove light components thereby providing a stripped liquid stream;

- v. measuring in situ, online the stripped liquid stream and monitoring in real time using an online analyzer the information of the amount of at least one impurity selected from: C=C double bonds, oxygen, nitrogen and sulphur, in the stripped liquid stream from step (iv), and determining the amount of the at least one impurity in the stripped liquid stream;
- 5 vi. optionally adjusting reaction conditions of the hydroprocessing of step (iii) until the determined amount of the at least one impurity in the stripped liquid stream is at or below a predefined target purity value;
- vii. subjecting the stripped liquid stream from step (iv) to hydroisomerization, hydrocracking, and/or dewaxing to obtain a hydroisomerized stream, a hydrocracked
- 10 stream and/or a dewaxed stream;
- viii. stabilizing and fractionating the hydroisomerized stream, the hydrocracked stream and/or the dewaxed stream from step (vii) to obtain an effluent containing at least a renewable aviation fuel component and a heavier fraction, such as renewable diesel fuel component;
- 15 ix. optionally recycling at least partly the heavier fraction from step (viii) to step (vii); and/or
- x. optionally recycling at least part of the hydroisomerized stream, the hydrocracked stream and/or the dewaxed stream obtained from step (vii) to step (iii).
- In an embodiment of the method, the pretreated renewable feedstock 200 is used in a
- 20 catalytic hydrotreatment process comprising the steps iii.-x.
- In an embodiment the catalytic hydrotreatment comprises hydroprocessing, which comprises hydrodeoxygenation, hydrodenitrogenation, hydrodesulphurization, hydrodearomatization and/or hydrodehalogenation, preferably at least hydrodeoxygenation.
- 25 The hydroprocessing reaction produces also light gasses or by-products. Decarboxylation reactions produces carbon oxides, such as CO₂ by removal of a carboxyl group, and hydrodeoxygenation produces oxygen as H₂O. Occasionally, some light hydrocarbons, such as C1-C4 may be formed as well as other gaseous compounds. These lights may be removed by stripping. In stripping, light components are removed from the hydroprocessed
- 30 stream to obtain a stripped liquid stream which comprises heavier hydrocarbons, such as C5+ hydrocarbons.
- In an embodiment, the stripped liquid stream from step (iv) has the amount of C=C bonds expressed by a bromine index less than 320 mg Br₂/100g, such as less than 50 mg

Br₂/100g; oxygen less than 20 ppm-wt, such as less than 10 ppm-wt, or less than 5 ppm-wt, such as less than 1 ppm-wt; nitrogen less than 6.2 ppm-wt, such as from 0.5 to 0.7 ppm-wt; and/or sulphur less than 1.7 ppm-wt, such as less than 0.2 ppm-wt.

5 In an embodiment, amount of at least one impurity in the hydroprocessed stream and/or stripped liquid stream is determined. The determination is performed directly, preferably continuously in real time, from the stream using an online analyzer. Preferably, *in situ*, online determination is made at least from the stripped liquid stream.

10 In an embodiment the online analysis comprises measuring *in situ*, online the hydroprocessed stream and/or stripped liquid stream and monitoring in real time using an online analyzer the information of the amount of at least one impurity selected from: C=C double bonds, oxygen, nitrogen and sulphur, in the stripped liquid stream from the step iv., and determining the amount of the at least one impurity in the stripped liquid stream.

15 In an embodiment the online analysis comprises measuring *in situ*, online the hydroprocessed stream and/or stripped liquid stream and monitoring in real time using an online analyzer the information of the amount of at least oxygen and additionally at least one other impurity selected from: C=C double bonds, nitrogen and sulphur, in the stripped liquid stream, and determining the amount of oxygen and the at least one other impurity in the stripped liquid stream.

20 In an embodiment the online analysis comprises measuring *in situ*, online the stripped liquid stream and monitoring in real time using an online analyzer the information of the amount of at least one impurity selected from: C=C double bonds, oxygen, nitrogen and sulphur, in the stripped liquid stream from step, and determining the amount of the at least one impurity in the stripped liquid stream.

25 In an embodiment, the hydroprocessed stream is subjected to stripping after conducting the *in situ*, online determination of the amount of at least one impurity with an online analyzer. In an embodiment the hydroprocessed stream is subjected to stripping during conducting the *in situ*, online determination of the amount of at least one impurity with an online analyzer. In an embodiment, the method comprises at least two sequential or consecutive *in situ*, online determination of the amount of at least one impurity with an online analyzer.

30 In an embodiment, continuously determining the amount of at least one impurity such as compounds including C=C double bonds, oxygen, nitrogen and/or sulphur in the in the stripped liquid stream provides a determined amount of the at least one impurity in the hydroprocessed stream and/or in the liquid stripped liquid stream.

In an embodiment, wherein the method comprises two or more separate *in situ* online determinations with an online analyzer, the same impurity/impurities are quantified in all *in situ*, online determinations made. In some other embodiments, only some of the same impurities, or none of the same impurities are quantified in a 1st *in situ*, online determination
5 as in a 2nd *in situ*, online determination with an online analyzer.

Determining impurity levels of the stripped liquid stream has several advantages. Since the determining takes place in real time, characteristics and composition of the stripped liquid stream are provided quickly. This in turn enables a fast response to altered impurity levels in the stripped liquid stream by adjusting hydroprocessing reaction conditions. Any delays
10 in impurity determinations may allow a stripped liquid stream with too high impurity level to enter the downstream process reactor(s) such as a hydroisomerization reactor, which in turn has a negative effect on the hydroisomerization reaction. Determining the impurity level of the stripped liquid stream *in situ*, online allows for adjusting reaction conditions of the hydroprocessing of step so that the impurity level is adjusted to a predefined target value
15 or below.

Further, *in situ*, online determination is non-destructive. The determinations can be performed without altering or damaging the hydroprocessed stream and/or the stripped liquid stream, which is particularly beneficial when continuous monitoring impurity levels of the hydroprocessed stream and/or stripped liquid stream is required. Therefore, with more
20 accurate online data on non-optimal hydroprocessing and/or stripping, which unavoidably leads to increased processing cost and yield loss, can be diminished.

In an embodiment, the present method comprises determining or measuring the stripped liquid stream *in situ*, online with the online analyzer, thereby obtaining information on a quantity of at least one impurity in hydroprocessed stream. In an embodiment, the
25 measuring is continuous, and the online analyzer is configured to provide continuous online measurement in real time of at least one impurity in the stripped liquid stream.

In an embodiment, wherein the method comprises determining amount of at least one impurity in the hydroprocessed stream and/or in the stripped liquid stream at more than one separate location, said determinations are done with separate online analyzers. In an
30 embodiment, the present method comprises two or more online determinations with two or more online analyzers.

Determining amount of at least one impurity in the stripped liquid stream online after said stripping process allows a quick verification of the obtained reduced level of said at least

one impurity in the stripped liquid stream. Thus, hydroprocessing and stripping efficacy and the quantity of at least one impurity can be verified from the stripped liquid stream.

In an embodiment, the hydroprocessed stream and/or the stripped liquid stream needs to fulfill one or more of the following predefined impurity criteria, to be directed into hydroisomerization, hydrocracking, and/or dewaxing reactor: a bromine index less than 320 mg Br₂/100g, such as less than 50 mg Br₂/100g; oxygen less than 20 ppm-wt, such as less than 10 ppm-wt, or less than 5 ppm-wt; nitrogen less than 6.2 ppm-wt, such as from 0.5 to 0.7 ppm-wt; and/or sulphur less than 1.7 ppm-wt, such as less than 0.2 ppm-wt.

In an embodiment the stripped liquid stream from step (iv) has a bromine index less than 320 mg Br₂/100g, such as less than 50 mg Br₂/100g; oxygen less than 20 ppm-wt, such as less than 10 ppm-wt, or less than 5 ppm-wt; nitrogen less than 6.2 ppm-wt, such as from 0.5 to 0.7 ppm-wt; and/or sulphur less than 1.7 ppm-wt, such as less than 0.2 ppm-wt.

In an embodiment the online analyzer 50 is configured to provide continuous online in situ measurement on at least compound containing one or more C=C double bonds, oxygen, nitrogen and/or sulphur.

In an embodiment the *in situ*, online measurement with the online analyzer comprises measuring spectral data from the stripped liquid stream of step (iv) and for determining amount of the at least one impurity in said stream, converting said spectral data via a predefined chemometric model and impurity calibration data to the information of the amount of said at least one impurity.

In an embodiment, the online analyzer is configured to provide reliable and accurate continuous online measurement of very low quantities of said at least one impurity. In an embodiment, the online analyzer is configured to provide continuous *in situ*, online measurement of more than one impurity, such as two, three, or more impurities simultaneously.

In an embodiment, the online analyzer is configured to provide continuous online determination of amount of at least the one impurity in the hydroprocessed stream and/or in stripped liquid stream.

In an embodiment, the light components, such as light gaseous compounds or hydrocarbons, or by-products which are formed during hydroprocessing and removed thereafter by stripping may also be subjected to online measurement. These light gaseous compounds, such as NH₃, H₂S, H₂O, and/or carbon oxides, such as CO and CO₂, or even methane, may be determined in real time providing further information on the reactions

taking place during the hydrotreatment. The amount of the formed light gaseous compounds give information, for example, on the following:

- ammonia, NH_3 , provides information on the possible conversion of the nitrogen containing compounds, and nitrogen therein,
- 5 • hydrogen sulphide, H_2S , provides information on the possible conversion of the sulphur containing compounds, and sulphur therein, and about the sulphur conversion,
- water or gaseous steam, H_2O , provides information on the possible conversion of the oxygen containing compounds, and oxygen therein, and about the oxygen
10 conversion,
- carbon oxides, CO and/or CO_2 , provide information on the possible amount of decarboxylation or decarbonylation reactions, and conversion of oxygen,
- methane, CH_4 , may be formed, as well.

The *in situ*, online determination of the amount of the at least one impurity with an online
15 analyzer may be performed directly from the stripped liquid stream.

In an embodiment the online determination of the amount of the at least one impurity with an online analyzer is made from the light gaseous compounds removed from hydroprocessed stream during the stripping step. Since the impurities are in gaseous phase the analysis and determination of the amount of the compounds is straightforward.

20 In an embodiment, the online analyzer provides a determination of the amount of the at least one impurity continuously in real time, thus providing immediate feedback of any deviations in the quantity of said at least one impurity, allowing a fast action to modify the hydroprocessing. Providing the determination of the amount of the at least the one impurity online in real time is thus beneficial as the fast determinations enable operator and/or
25 systems to react quickly with regard to adjustment of said hydroprocessing, to ensure that impurity levels in the hydroprocessed stream or in the stripped liquid stream remain below the predefined specific values.

In an embodiment, determination of the amount of the at least one impurity in the stripped liquid stream with the online analyzer is automated, via integration into automated control
30 and operation systems.

In an embodiment, the online analyzer is configured to provide continuous online measurement of the at least one impurity by collecting spectral data continuously. In an embodiment, the online analyzer, i.e. a spectrometer, operates in a spectral region of IR radiation, UV radiation, visible light, or combinations thereof.

A spectrometric online analyzer operating in a specific spectral region means that it is configured to measure the absorption of electromagnetic radiation within a particular range of wavelengths or frequencies. In a preferable embodiment, the spectrometer is operating in the spectral region of infrared (IR) radiation. Regardless of the exact type of the online analyzer, the online analyzer needs to be suitable for providing the online determination of the at least one impurity in real time. This means, the determination is provided with a high enough data collection rate to be considered a continuous determination, and the online analyzer having an adequately high signal to noise ratio for detection of the relevant signals associated with the characteristic data of the impurity compound(s) in the hydroprocessed stream and/or in the stripped liquid stream.

In an embodiment, the *in situ*, online measurement with the online analyzer comprises measuring spectral data from the hydroprocessing stream and/or from the stripping stream and converting said spectral data via a predefined model and impurity calibration data to the information of the quantity of said at least one impurity.

The reduction of impurities formed in the catalytic hydrotreatment comprising hydroprocessing step is performed by adjusting the hydroprocessing reaction conditions until the impurity level in hydroprocessed stream and/or in the stripped liquid stream is at a predefined target value. If the predefined value for sufficient purity in the hydroprocessed stream or in the stripped liquid stream is met, adjusting of the hydroprocessing reaction conditions is not needed.

If the predefined value for sufficient purity in the hydroprocessed stream is not met, reduction of impurities during hydroprocessing is improved by adjusting the hydroprocessing reaction conditions based on the impurity analysis.

In an embodiment the hydroprocessing is adjusted for improving the reduction of impurities in step (iii) by modifying at least one of following: reactor temperature, reactor pressure, weight hourly space velocity (WHSV), residence time, hydrogen to oil ratio, hydrogen flow rate, the feedstock composition, the feedstock introduction location into a catalyst bed arrangement in the hydroprocessing reactor, the dilution or recycle stream introduction location into a catalyst bed arrangement, the number of catalyst beds or guard beds in the hydroprocessing reactor, the number of hydroprocessing reactors and/or recycling of the hydroprocessed stream back to the hydroprocessing reactor.

In an embodiment, the reactor temperature is modified by increasing or decreasing it, depending on the targeted impurity reduction, the quality of the feedstock and other reaction conditions. Even a specific temperature profile may be created across the reactor. Typically,

increasing the reaction temperature increases the reaction rates and conversion, thus reducing the amount of impurities. However, the used catalyst may suffer from the temperature increase, and the tendency of cracking may be increased. Increasing the temperature may further induce oligomerization and formation of aromatics depending on the feed quality. Decreasing the temperature leads to the opposite phenomena.

In an embodiment, the reactor pressure is modified by increasing or decreasing it, similarly depending on the targeted impurity reduction, the quality of the feedstock and other reaction conditions. Typically increasing reactor pressure leads to increased cracking, hydrogenation reactions may be facilitated by favoring liquid phase and reaction rates may change. Ability to change reactor pressure may complicate reactor design depending on the magnitude of the needed adjustment.

In an embodiment, the weight hourly space velocity (WHSV) is modified, thus affecting the residence time and contact time of the reacting species. This may change the reaction kinetics of the catalytic reactions. Similarly, modifying the feed flow rate changes the residence time inversely.

In an embodiment, the hydrogen to oil ratio, NL/L, or the hydrogen flow rate is modified. A too low value may result in local depletion, whereas a too high value is not beneficial economically. Typically, the range is from 1.5 - 4-fold.

The quality of the feedstock, such as successful pretreatment before hydroprocessing influences the reaction selectivity, formation of by-products or side products, consumption of reactants such as hydrogen, performance of the catalyst such as activity and life cycle of the catalyst, and the like.

In an embodiment, the introduction location of the feedstock into the hydroprocessing reactor may be varied i.e. infeed to various positions of the catalyst bed arrangements. The catalyst beds may have varying thicknesses, activity profiles, particle shapes and quality. Moreover, the use of e.g. guard beds may affect the flow characteristics and reactions taking place inside the reactor.

In an embodiment, an introduction of diluents into the reactor or to the catalyst bed arrangements may change the reaction kinetics by affecting the temperature profiles and local reactant concentrations. Similarly, recycling the hydroprocessed stream back to the hydroprocessing reactor affects the reaction kinetics.

A person skilled in the art is capable of choosing the needed values for the adjustments based on the feedstock used and availability of the equipment.

Furthermore, the hydroprocessing reactor set up may comprise several reactors of different types, the operating parameters of which may be independently adjusted. In specific hydroprocessing schemas there may be combined guard bed reactors with hydrodeoxygenation reactors, hydrodeoxygenation reactors combined with polishing
5 reactors or just multiple hydrodeoxygenation reactors, or hydrodeoxygenation reactors with several catalysts beds with varying catalyst materials providing varying reactions.

Fuels including branched hydrocarbons have better cold flow properties than fuels including merely n-paraffins. Better cold flow properties refer to e.g. a lower temperature value of a pour point (PP), lower cloud point (CP) and/or lower cold filter plugging point (CFPP). The
10 formed isoparaffins may have one or more side chains, or branches, typically methyl or ethyl groups, possibly even longer chained branches.

Isomerization may take place in varying forms depending on the catalysts and operating conditions. Not only hydroisomerization, but also hydrocracking and dewaxing enable branching of hydrocarbon chains of the hydroprocessed feedstock and decreasing the
15 carbon chain length.

The hydroisomerization may be carried out in the presence of a hydroisomerization catalyst, optionally in the presence of hydrogen added to the hydroisomerization process. Suitable hydroisomerization catalysts may contain a molecular sieve and/or a metal selected from Group VIII of the periodic table and optionally a carrier. Preferably, the isomerization
20 catalyst contains SAPO-11, or SAPO-41, or ZSM-22, or ZSM-23, or ferrierite, or EU-2, and the like, with noble metals, such as Pt and Pd, or Ni, and a support of e.g. Al₂O₃, or SiO₂. Typical isomerization catalysts are, for example, Pt/SAPO-11/Al₂O₃, Pt/ZSM-22/Al₂O₃, Pt/ZSM-23/Al₂O₃, and Pt/SAPO-11/SiO₂. There are available various types of ZSM catalysts, such as e.g. hierarchical ZSM-23 catalysts, providing modified capability to
25 branch different chain length hydrocarbons with varying temperatures. The catalysts may be used alone or in combination. The presence of added hydrogen is particularly preferable to reduce catalyst deactivation. In a preferred embodiment, the hydroisomerisation catalyst is a noble metal bifunctional catalyst, such as Pt-SAPO and/or Pt-ZSM-catalyst, which is used in combination with hydrogen.

30 In an embodiment temperature in the hydroisomerization is 200-500°C, such as 280-370 °C, and pressure is 10-150 bar, such as 20-50 bar.

In an embodiment the hydroisomerization is performed in the presence of one or more catalyst(s) comprising a Group VIII metal on a support, where the support is selected from

silica, alumina, clays, titanium oxide, boron oxide, zirconia, which can be used alone or as a mixture, preferably silica and/or alumina.

In one embodiment the hydroisomerization is performed in the presence of one or more catalyst(s) comprising Pt, Pd, Ru, Rh, W, Ni, Co, Mo or any combinations thereof on an
5 acidic support, preferably amorphous silica, alumina, zeolite, clays or mixtures thereof, wherein the zeolite is MFI, MTT, TON, AEF, MWW, FER, BEA, FAU or MOR zeolites, such as EU-2, ZSM-5, ZSM-11, ZSM-12, ZSM-23, ZSM-22, ZSM-35, ZSM-48, SAPO-11, MCM-22, ferrierite, beta, Y-and X-zeolites and/or mordenite.

In an embodiment, the hydrocracking is carried out in the presence of a bifunctional
10 hydrocracking catalyst comprising a metal site and an acid site. In an embodiment, the bifunctional hydrocracking catalyst is selected from one or more of: platinum, palladium, ruthenium, nickel, molybdenum, cobalt, tungsten, or any combination thereof. In an embodiment, the bifunctional hydrocracking catalyst comprises a noble metal or a group VIA metal, such as molybdenum or tungsten, together with a group VIIIA metal, such as
15 cobalt or nickel. In an embodiment, the hydrocracking catalyst is Ni/W, Ni/Mo, Co/Mo, Pt Ru or Pd.

In an embodiment, the hydrocracking is carried out in the presence of an acidic hydrocracking catalyst support. Acidity of the hydrocracking catalyst support is important for the function of the hydrocracking process. In an embodiment, the said acidic support is
20 selected from one or more of alumina/chlorided alumina, amorphous silica alumina (ASA), zeolite and a binder. In an embodiment, the said acidic support is selected from one or more of SiO₂, Al₂O₃ and zeolites, such as beta-zeolites.

In an exemplary embodiment, the hydrocracking catalysts are sulphurized NiMo/NiW or noble metal on zeolite-based catalysts on acid support. In an embodiment, additional
25 hydrogen gas is fed into the hydrocracking process. Said additional hydrogen may be produced e.g. by electrolysis.

The hydrocracking can also be carried out at mild hydrocracking reaction conditions, such as at a pressure of about 35 - 150 bar, a temperature of about 325 - 375 °C, a WHSV of about 0.5 - 3.0 h⁻¹, and a H₂ feed ratio of about 250-500 nl H₂/ liter of the feed.

30 In an exemplary embodiment, the hydrocracking typically comprises hydrogen pressure above 5 MPa and reaction temperatures are above 350°C.

Hydrocracking conversion can be set to about 95 wt-% of the total weight of the feed to be hydrocracked. Hydrocracking selectivity to SAF component boiling range is set to at least 50 wt-% of the total weight of converted hydrocracked effluent.

In some embodiments the hydrocracking conditions are selected to allow mild hydrocracking. In hydrocracking, the fatty acid molecules will split to hydrocarbons that have lower carbon number compared to fatty acid in the presence of hydrogen and a catalyst. Depending on the choice of the catalyst, the hydrocarbon distribution can be adjusted.

- 5 Besides hydrocarbons, water and carbon oxides are formed. Typical hydrocracking catalysts are sulphurized NiMo/NiW or noble metal on zeolite-based catalysts on acid support. The hydrogen pressure is typically above 5 MPa and reaction temperatures are above 350 °C. With the selection of reaction conditions and catalyst properties, hydrocracking reactions can be enhanced and the distribution of hydrocarbons to broaden
10 carbon number range is achieved. Further, hydrocracking of fatty acids forms cyclic (naphthenic and aromatic) compounds that have beneficial impact to SAF properties.

In an embodiment temperature in the hydrocracking is 300-450 °C, such as 350-450 °C, and pressure is 100-200 bar, such 120-200 bar.

- 15 In an embodiment the hydrocracking is performed in the presence of one or more bifunctional hydrocracking catalyst(s) comprising a metal site and an acid site.

The goal in hydrocracking conversion is the reduction of the average carbon number and the production of shorter chain length branched hydrocarbons. Branching isomerization of linear paraffins is desired to improve the cold properties of fuel fractions.

- 20 Typically, branching and cracking reactions occur on a bifunctional catalyst consisting of a noble metal supported on an acid zeolite and can be rationalized with the bifunctional reaction scheme. In this reaction scheme feed molecules are dehydrogenated on the noble metal producing unsaturated hydrocarbons which in turn undergo protonation on the acid centers of the zeolite with formation of carbenium ions as reaction intermediates. These carbenium ions undergo skeletal rearrangements and β -scission reactions followed by
25 deprotonation and hydrogenation of the resulting olefins. For hydrocracking of n-paraffins the classical bifunctional catalysts such as noble metal loaded Y-zeolites exhibit a considerable amount of cracking at high conversions limiting the yield of the branched isomers of C8–C12 paraffins. High yields of branched isomers together with limited hydrocracking can be obtained using a shape-selective zeolite like Pt/ZSM-22 on which
30 cracking reactions are strongly hindered because of steric effects in the micropores. This type of zeolite belongs to the family of 10-membered ring zeolites and contains very narrow parallel pores. The most important characteristics of the members of this family of molecular shape selective zeolites in hydrocracking are the low yield of tribranched isomers, the low yield of feed isomers with ethyl and propyl side chains and the low yield of branched cracked

products. One example is Pt/ZSM-22 which exhibits shape selectivity through pore mouth catalysis in the conversion of pure paraffinic and naphthenic model components.

Different dewaxing methods, catalysts, and/or catalyst precursors allow for production of diesel boiling range fuels with improved cold flow properties at desirable yields. The catalysts and/or catalyst precursors can correspond to supported metal catalysts and/or catalyst precursors at least one Group 8-10 base metal, preferably a non-noble Group 8-10 base metal, such as Ni and/or Co along with a Group 6 metal, such as Mo and/or W as supported metals. The support can include a zeolitic framework structure. The catalyst precursors can be formed, for example, by impregnating a support including a zeolitic framework structure with impregnation solution(s) that also includes a dispersion agent. Typically, dewaxing catalysts can tolerate sulphur well, and necessarily no gas stripping after HDO is necessary. However, the isomerization ability may be more modest than with e.g. noble metal catalysts.

In an embodiment temperature in the dewaxing is 300-400 °C, such as 325-375 °C, and pressure is 30-75 bar, such 35-70 bar.

In an embodiment the dewaxing is performed in the presence of one or more catalyst(s) comprising supported Ni, NiMo, CoMo or NiW catalyst, the support being alumina, silica or zeolite, or mixtures thereof. Preferably, the catalysts are selected from NiMo/Al₂O₃, NiMo/SiO₂, NiMo/Al₂O₃-zeolite, NiMo/zeolite, NiW/Al₂O₃, NiW/SiO₂, NiMo/Al₂O₃-zeolite NiW/zeolite.

The hydroisomerized stream, the hydrocracked stream and/or the dewaxed stream is subjected to stabilization thus removing the remaining unwanted gaseous and light components. Thereby an effluent containing the fuel range branched hydrocarbons is obtained. This effluent may be fractionated, typically by distillation, into at least a renewable aviation fuel component and a heavier fraction, such as renewable diesel fuel component.

The heavier fraction, mainly comprising paraffinic hydrocarbons may be used for recycling, such as recycling at least part of the obtained heavier fraction back to hydroprocessing.

Optionally, at least part of the hydroisomerized stream, the hydrocracked stream, the hydrocracked stream and/or the dewaxed stream obtained is recycled from step (vii) to the hydroprocessing step (iii).

Even if the differences between the catalysts are not pronounced, the combination of a specific catalyst with the operation conditions make a difference for the obtained product properties, and thus minor differences in reaction parameter combinations may result in ability to influence suitably the reactions and adjust the end product quality.

In an embodiment 10-20 wt-% of the heavier fraction, preferably comprising hydrocarbons C17+, from step (viii) is recycled to step (vii).

In an embodiment 10-20 wt% of the hydroisomerized stream, the hydrocracked stream, and/or the dewaxed stream from step (vii) is recycled to step (iii).

- 5 In an embodiment the renewable aviation fuel component complies with the required product properties as set out in the ASTM D7566-22 Annex A2.

In an embodiment the heavier fraction comprises renewable C17+ hydrocarbons. In one embodiment the heavier fraction is renewable diesel fuel component.

- 10 In an embodiment the present method is an industrial method. In another embodiment the industrial method may exclude small scale methods such as laboratory scale methods that are not scaled up to volumes used in industry.

- In an exemplary embodiment of the method of the present disclosure shown in figure 3, the renewable feedstock in the infeed line 12 is directed to at least one pretreatment process (A) and to an in situ measurement with an online analyzer 50 (not shown) to reduce amount
15 of at least one impurity of the renewable feedstock. Subsequently, the pretreated feedstock 200 is delivered along the outlet line 13 and subjected to hydroprocessing 2000. The hydroprocessed stream 3050 is stripped in a stripping unit 3000 to obtain a stripped liquid stream 4050. The method includes measuring *in situ* online at least the stripped liquid stream 4050 in real time using an online analyzer 50 in a measurement (M5), thereby
20 obtaining information of the amount of at least one impurity in the stripped liquid stream and thereby determining amount of the at least one impurity in the stripped liquid stream 4050. If the determined level is above a predefined target purity value, the method includes adjusting the hydroprocessing until the level of the at least one impurity is at or below the target purity value. This ensures that the stripped liquid stream fulfills the purity
25 requirements.

- The stripped liquid stream 4050 is directed to hydroisomerization, hydrocracking and/or dewaxing unit 4000, wherefrom the hydroisomerized stream, the hydrocracked stream and/or the dewaxed stream 5050 is further subjected to stabilizing and fractionating 5000 thereby obtaining a product effluent 6050 containing at least a renewable aviation fuel
30 component and a heavier fraction, such as renewable diesel fuel component.

In an embodiment at least part 8050 of the stream obtained from hydroisomerization, hydrocracking and/or dewaxing 4000 is recycled back to hydroprocessing 2000. Also, the heavier product fraction 7050 may be recycled at least partly from stabilizing and fractionating 5000 to hydroisomerization, hydrocracking and/or dewaxing 4000.

The present method allows an agile pretreatment process for renewable feedstocks having different compositions, thereby removing impurities efficiently from the renewable feedstock 100, as shown in the examples below.

In an embodiment the present method is an industrial method. In another embodiment the industrial method may exclude small scale methods such as laboratory scale methods that are not scaled up to volumes used in industry.

EXAMPLES

Example 1

10 A renewable feedstock comprising poultry fat (85 wt-%) and brown grease (15 wt-%) having a phosphorus content of about 40 wt-ppm was bleached by mixing the feedstock with citric acid in an amount of about 1500 wt-ppm at 85 °C for 10 min, and by adding 0.7 wt-% of bleaching clay. Subsequently, the feedstock was dried and filtered at 120 °C and 2.5 bar for removal of solids. The filtrate was passing a mid-FTIR spectrometer probe at 0.7 WHSV, 15 sampling the feedstock *in situ*. After 50 seconds the spectral data collected was analyzed, and the phosphorus content of the sample was determined based on the predetermined calibration spectra for this kind of feed together with varying P values and a suitable chemometric model. The measured phosphorus content of the pretreated sample was about 0.9 wt-ppm. Compared to the predefined allowable phosphorus content of 1 wt-ppm or less, the measured value was acceptable, rendering the renewable feedstock suitable to be directed into hydrodeoxygenation without a need for further purification. The feedstock was directed to hydrodeoxygenation.

Example 2

Another renewable feedstock batch comprising poultry fat (87 wt-%) and brown grease (13 25 wt-%) was bleached similarly to Example 1. Part of the filtrate was passing a mid-FTIR spectrometer probe at 0.7 WHSV, sampling the feedstock *in situ*. After 50 seconds the spectral data collected was analyzed as described in the Example 1, and the phosphorus content was determined to be about 1.5 wt-ppm. As the predefined allowable phosphorus content for the feedstock was 1.0 wt-ppm or less for not to prematurely deactivate the HDO catalyst, the bleaching needed to be adjusted by increasing the amount of the bleaching 30 clay about 10 % and increasing the concentration of the citric acid to about 1200 wt-ppm. Subsequently, a further mid-FTIR measurement performed on the pretreated effluent *in situ* from the pretreatment unit after the adjustment of the pretreatment process, measured a decreased P content value of about 0.9 wt-ppm.

Example 3

A renewable feedstock containing animal fat, mainly cattle and pork fat, having a phosphorus content ranging from 50 to 78 wt-ppm (elementary phosphorus) based on an online *in situ* mid-FTIR spectrometer determination and a verification by an *ex situ* external laboratory measurement was provided. The feedstock was directed to a pretreatment process including bleaching using regularly used bleaching parameters: by adding citric acid in an amount of about 2000 wt-ppm (50 wt-% water) with 0.5 wt-% bleaching earth at a temperature of 85 °C and at 800 mbar, including a drying step at a temperature of about 120 °C and at 80 mbar. After bleaching, the feedstock was filtered at about 120 °C, and at 2.5 bar, for removal of solids. Part of the filtrate was passing a mid-FTIR spectrometer probe sampling the effluent *in situ*. After 60 seconds the spectral data was collected and analyzed, and the phosphorus content of the pretreated feedstock was determined to be on average about 2 wt-ppm. As the acceptable predefined phosphorus content for the feedstock was set to 1.0 wt-ppm or less, the pretreatment needed to be adjusted. The bleaching parameters were adjusted by increasing the residence time by 40 % and the amount of the bleaching clay dosing was increased to 0.7 wt-%. Subsequently, a further mid-FTIR measurement was performed on the pretreated effluent exiting the adjusted pretreatment process, wherein the adjusted residence time and bleaching clay dosing resulted in a decreased average P content value of slightly below 1 wt-ppm. The *ex situ* laboratory measurement obtained the next day verified that the P content of the regularly bleached feedstock, wherein no adjustments in the bleaching process were made, was slightly over 2 wt-ppm.

Example 4

A renewable feedstock batch comprising 100 wt-% of UCO was bleached similarly to Example 1. The obtained pretreated filtrate was passing a mid-FTIR spectrometer probe, sampling the filtrate *in situ*. After 30 seconds the spectral data was collected and analyzed using the calibration for UCO with varying P contents and predefined chemometric model. The phosphorus content of the pretreated filtrate was determined to be about 3.6 wt-ppm. As the acceptable predefined P content for the feedstock was set to 1.0 wt-ppm or less, the bleaching parameters were adjusted by increasing the amount of the bleaching clay about 10 % and increasing the concentration of the citric acid to 1200 wt-ppm. A further mid-FTIR measurement was performed, showing a decrease in the P content to about 1.8 wt-ppm. A part of this feedstock having P content of about 1.8 wt-ppm was blended with another renewable feedstock having a very low P content (less than 0.2 wt-ppm). The blend of these feedstocks was analyzed, and the measured P content was less than 1 wt-ppm.

The rest of the feedstock, which was not used in blending, was subjected to heat treatment with an adsorbent. The heat treatment with adsorbent was performed at a temperature of 245 °C, under a pressure of 1000 kPa, and in the presence of an acid and an alumina silicate adsorbent which was added in an amount of 1 wt-%. A yet further *in situ* mid-FTIR measurement was performed after the heat treatment showing a decrease in the P content of the feedstock to 0.9 wt-ppm.

Example 5

A renewable feedstock containing animal fat was subjected to a pretreatment process containing bleaching, removal of solids and deodorization. The animal fat composition was first bleached by mixing the feedstock with citric acid in an amount of from 1000 wt-ppm at 85 °C for 10 min, and by adding 0.7 wt-% of bleaching clay. Subsequently, the feedstock was filtered at 120 °C and 2.5 bar for removal of solids. Thereafter, the feedstock was directed to the deodorization at a temperature of about 220 °C with a residence time of 10 minutes. After that, a part of the pretreated effluent was passing a mid-FTIR spectrometer probe sampling the effluent *in situ*. Spectral data was collected for 60 seconds and analyzed using a PLS chemometric model and calibration spectra for animal fat compositions with varying TAN values. The pretreated feedstock was measured to have an average TAN value of 15.5 mg KOH/g (ranging between 14-17 mg KOH/g). The TAN value reflects the quantity of TAN increasing acids present in the renewable feedstock. As the predefined allowable TAN value was set to 3 mg KOH/g or less before directing the feedstock into a hydrotreatment reactor, the applied pretreatment process needed to be adjusted for this particular feedstock. The pretreatment process was modified by increasing the temperature of the deodorization to 235 °C and by lowering its absolute pressure by 10 %. Subsequently, further mid-FTIR determination performed on the effluent *in situ* from the pretreatment unit after the adjustment of the pretreatment showed a decrease in TAN value to an average value of about 3 mg KOH/g. The feedstock was subsequently continuously directed into catalytic hydrodeoxygenation, and the level of TAN value was occasionally monitored and found to stay below the predefined allowable TAN value.

Example 6.

A renewable feedstock batch comprising 100 wt-% animal fat was bleached similarly to Example 1. The filtrate was passing a mid-FTIR spectrometer probe sampling the feedstock *in situ*. After 30 seconds the spectral data was collected and analyzed using the calibration spectra for animal fat with varying P and N contents. The phosphorus content based on the

in situ mid-FTIR measurement was about 4.5 wt-ppm, and the nitrogen content was about 200 wt-ppm. As the predefined acceptable limit set for the P content was 1.0 wt-ppm or less, and in this case, the predefined acceptable limit set for nitrogen was 100 wt-ppm or less, the bleaching was adjusted by increasing the amount of the bleaching clay about 10
5 % and by increasing the concentration of the citric acid to 1200 wt-ppm. A further mid-FTIR determination performed *in situ* after the adjustment showed a decrease in the P content to about 1.4 wt-ppm. Part of this pretreated renewable feedstock having P content of about 1.4 wt-ppm and N content of 100 wt-ppm was blended with another renewable feedstock having a very low P and N content (less than 0.2 wt-ppm of P and less than 50 wt-ppm of
10 N). The blend of these feedstocks was analyzed and measured to have a P content of less than 1 wt-ppm, and a N content of less than 100 wt-ppm. The blended feedstock was thus acceptable to be processed in the catalytic hydrodeoxygenation unit.

Example 7

Renewable feedstock samples (100 wt-% animal fat) with varying phosphorus amounts
15 ranging between 0.3-0.7 wt-ppm were subjected to both types of measurements: first, an online *in situ* measurement of P content using a mid-FTIR spectrometer determination including data from calibrations and from predictive chemometric model, and secondly, taking an *ex situ* sample and determining its P content in a laboratory using ICP-MS, according to the ASTM D8110. The level of error in the *in situ* mid-FTIR result vs. the
20 laboratory measurement result was small with RMSECV (root mean square error of cross validation) of 0.1 wt-ppm and $R(CV)^2$ (cross validation coefficient) of 0.87.

Various embodiments have been presented. It should be appreciated that in this document, words comprise, include, and contain are each used as open-ended expressions with no intended exclusivity.

25 The foregoing description has provided by way of non-limiting examples of particular implementations and embodiments a full and informative description of the best mode presently contemplated by the inventors for carrying out the invention. It is however clear to a person skilled in the art that the invention is not restricted to details of the embodiments presented in the foregoing, but that it can be implemented in other embodiments using
30 equivalent means or in different combinations of embodiments without deviating from the characteristics of the invention.

Furthermore, some of the features of the afore-disclosed example embodiments may be used to advantage without the corresponding use of other features. As such, the foregoing description shall be considered as merely illustrative of the principles of the present

invention, and not in limitation thereof. Hence, the scope of the invention is only restricted by the appended patent claims.

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15 description shall be considered as merely illustrative of the principles of the present invention, and not in limitation thereof. Hence, the scope of the invention is only restricted by the appended patent claims.

CLAIMS

1. A method for pretreating a renewable feedstock (100), the method comprising:
 - providing the renewable feedstock (100);
 - subjecting the renewable feedstock to at least one pretreatment process for
 - 5 reduction of at least one impurity in the renewable feedstock, and to an *in situ* measurement with an online analyzer (50) thereby obtaining real time information on a quantity of said at least one impurity; and
 - obtaining a pretreated renewable feedstock (200) having a reduced quantity of said at least one impurity.
- 10 2. The method of claim 1, wherein the renewable feedstock (100) is subjected to said at least one pretreatment process:
 - a. before, after or during the *in situ* measurement with an online analyzer (50), or
 - b. between two or more separate *in situ* measurements with an online analyzer (50).
- 15 3. The method of claim 1 or 2, comprising subjecting the renewable feedstock (100) to said at least one pretreatment process after the *in situ* measurement with an online analyzer (50) and selecting said at least one pretreatment process based on the result of the *in situ* measurement provided with the online analyzer (50).
- 20 4. The method of any preceding claim, comprising subjecting the renewable feedstock (100) to said at least one pretreatment process before the *in situ* measurement with an online analyzer (50), thereby obtaining information on a quantity of said at least one impurity in the pretreated renewable feedstock (200).
- 25 5. The method of any preceding claim, wherein said at least one impurity is selected from phosphorus (P), nitrogen (N), oxygen (O), H₂O, sulfur (S), silicon (Si), total acid number (TAN) increasing acids, metals, chlorine (Cl), compounds with C=C double bonds, and combinations thereof.
6. The method of any preceding claim, wherein the online analyzer (50) is configured to provide continuous online measurement on a quantity of said at least one impurity.
7. The method of any preceding claim, wherein the online analyzer (50) is a
- 30 spectrophotometric analyzer (50).
8. The method of any preceding claim, wherein the online analyzer (50) is a Fourier-transform infrared (FTIR) spectrophotometer, preferably a mid-FTIR spectrophotometer operating at a wavenumber range of 500-4000 cm⁻¹, such as 800 - 1800 cm⁻¹.

9. The method of any preceding claim, wherein the *in situ* measurement with the online analyzer (50) comprises measuring spectral data from the renewable feedstock and converting said spectral data via a predefined chemometric model and impurity calibration data to the information of the quantity of said at least one impurity.
- 5 10. The method of any preceding claim, wherein said at least one pretreatment process is configured to reduce the quantity of two or more impurities in the renewable feedstock (100).
- 10 11. The method of any preceding claim, wherein said at least one pretreatment process comprises a pretreatment selected from heat treatment (HT), heat treatment with adsorbent (HTA), degumming, bleaching, deodorization, removal of solids, removal of volatiles, water washing, distillation, extraction, blending, and charge balancing, or any combination thereof.
- 15 12. The method of claim 4, wherein the purified renewable feedstock (200) is subjected to the *in situ* measurement with an online analyzer (50) after said at least one pretreatment process, and the method further comprises one or more of the following steps:
- directing at least part of the pretreated renewable feedstock (200) back to the same or different pretreatment process based on the information obtained from the *in situ* measurement; and/or
 - blending at least part of the pretreated renewable feedstock (200) with the
- 20 renewable feedstock (100).
13. The method of claim 4, wherein subsequent renewable feedstock (100) is directed to an adjusted pretreatment process based on the information obtained from the *in situ* measurement.
- 25 14. The method of claim 13, wherein the adjusted pretreatment process is carried out by changing the process conditions used in said adjusted pretreatment process, in respect to the originally used pretreatment process conditions.
15. The method of claim 13 or 14, wherein the adjusted pretreatment process is carried out by adjusting one or more of:
- residence time of the renewable feedstock;
 - 30 - pretreatment temperature;
 - dosing of at least one substance, preferably selected from a bleaching clay, adsorbent, acid, and water; and
 - selection of a suitable pretreatment or a suitable pretreatment sequence.
16. The method of any preceding claim, further comprising:

directing the pretreated renewable feedstock (200) to at least one post-treatment process suitable for producing at least one renewable fuel component or a renewable chemical, said at least one post-treatment process comprising a catalytic hydrotreatment, preferably comprising a hydrodeoxygenation (HDO).

- 5 17. The method of any preceding claim, wherein said at least one pretreatment process is configured to render the pretreated renewable feedstock (200) suitable for use in a catalytic hydrotreatment process, such as hydrodeoxygenation (HDO) process.
- 10 18. The method of any preceding claim, wherein said renewable feedstock (100) comprises one or more of: crop plant oil, flowering plant oil, vegetable oil, fungal oil, fish oil, animal fats, algae-based oils, microbial source oil and waste and residues thereof.
- 15 19. The method of any preceding claim, wherein said renewable feedstock (100) comprises at least one component selected from: poultry fat, dry rendered poultry fat (AFP), brown grease (BG), used cooking oil (UCO), acid oils (ASK) from edible oils, sludge palm oil, such as palm effluent sludge (PES) or palm oil mill effluent (POME), crude palm oil (CPO), palm oil, palm seed oil, palm fatty acid distillate (PFAD), babassu oil, carinata 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, archaeal oil, bacterial oil, fungal oil, protozoal oil, algal oil, seaweed oil, mustard seed oil, oils from halophiles, soybean oil (SBO), technical corn oil (TCO), rapeseed oil (RSO), colza oil, 20 canola oil, sunflower oil, hemp seed oil, olive oil, linseed oil, mustard oil, peanut oil, castor oil, coconut oil, lard, tallow, train oil, spent bleaching earth oil (SBEO), lignocellulosic based feeds, municipal solid waste-based oils, and algae-based oils, or any mixture thereof.
- 25 20. The method of any preceding claim, wherein the pretreated renewable feedstock (200) is used in a catalytic hydrotreatment process for producing renewable fuels, the method comprising the steps:
- 30 iii. subjecting the pretreated renewable feedstock (200) to hydroprocessing (2000) to obtain a hydroprocessed stream (3050), preferably comprising more than 90 wt-% of paraffins;
- iv. subjecting the hydroprocessed stream (3050) to stripping (3000) to remove light components thereby providing a stripped liquid stream (4050);
- v. measuring *in situ*, online the stripped liquid stream (4050) and monitoring in real time using an online analyzer (50) the information of the amount of at least one impurity selected from: C=C double bonds, oxygen, nitrogen and sulphur, in the stripped liquid

- stream from step (iv), and determining the amount of the at least one impurity in the stripped liquid stream;
- 5 vi. optionally adjusting reaction conditions of the hydroprocessing of step (iii) until the determined amount of the at least one impurity in the stripped liquid stream (4050) is at or below a predefined target purity value;
- vii. subjecting the stripped liquid stream from step (iv) to hydroisomerization, hydrocracking, and/or dewaxing (4000) to obtain a hydroisomerized stream, a hydrocracked stream and/or a dewaxed stream (5050);
- 10 viii. stabilizing and fractionating (5000) the hydroisomerized stream, the hydrocracked stream and/or the dewaxed stream (5050) from step (vii) to obtain an effluent (6050) containing at least a renewable aviation fuel component and a heavier fraction, such as renewable diesel fuel component;
- ix. optionally recycling at least partly the heavier fraction from step (viii) to step (vii); and/or
- 15 x. optionally recycling at least part of the hydroisomerized stream, the hydrocracked stream and/or the dewaxed stream (5050) obtained from step (vii) to step (iii).