

Improved process for manufacture of liquid fuel components from renewable sources

Field of the invention

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The invention relates to an improved process for the manufacture of fuel hydrocarbons, particularly light fuel components from renewable oil sources such as biological oils and fats. More specifically, the invention relates to manufacture of purified light fuel components from source material containing phosphorus and metal impurities.

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Background of the invention

Environmental interests and an increasing demand for diesel fuel, especially in Europe, encourage fuel producers to employ more intensively available renewable sources. In the manufacture of diesel fuels based on biological raw materials, the main interest has concentrated on vegetable oils and animal fats comprising triglycerides of fatty acids. Long, straight and mostly saturated hydrocarbon chains of fatty acids correspond chemically to the hydrocarbons present in diesel fuels. However, neat vegetable oils display inferior properties, particularly extremely high viscosity and poor stability, and therefore their use as such in transportation fuels as components is limited.

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Conventional approaches for converting vegetable oils or other fatty acid derivatives into liquid fuels comprise, for example, transesterification into fatty acid methyl ester (FAME). Unfortunately, the obtained product offers poor low-temperature properties and results in undesirably high emissions of NO_x in comparison to conventional diesel fuels.

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One approach is to convert the fatty acids or their esters to hydrocarbons by deoxygenation reactions. The deoxygenation of oils and fats based on biological material may be carried out by catalytic hydroprocessing, such as hydrocracking, or in a more controlled manner using hydrotreating conditions. During hydrotreating, in particular hydrodeoxygenation, oxygen containing groups are

reacted with hydrogen in the presence of a catalyst, and oxygen is removed through formation of water.

However, due to the typically high amount of phosphorus and metal impurities in vegetable or animal oil or fat ash containing material will be formed, the probability of side reactions will be increased and deactivation of the catalyst is likely. Metals in biological oil may additionally form metal soaps which promote plugging of preheating section and decrease catalyst activity and operating life. Therefore, the content of impurities in the crude oil to be treated should be decreased prior to further processing.

The impurity quality and quantity of biological oils and/or fats varies considerably in feedstock from varying origin. Different impurities require different purification procedures. In this respect, animal fats provide the most challenging source material which is very difficult to purify. On the other hand, animal fat is a highly desirable feedstock for fuel production, since animal fat is considered a waste stream requiring proper treatment to be discharged. Animal fat has shorter fatty acids chain lengths compared to many vegetable oils resulting in excellent properties in renewable fuels produced by hydrogenation thereof.

Biological raw material often contains, in addition to metals and phosphorus, metal compounds, organic nitrogen and sulphur which are known catalyst inhibitors and poisons, inevitably reducing the catalyst service life and necessitating more frequent catalyst regeneration or replacement. Metals in biological oils and/or fats tend to build up on catalyst surface and change activity and selectivity of the catalyst. Moreover, metals frequently promote side reactions such as ash forming and blocking of catalyst. These kinds of phenomena typically increase the pressure drop over catalyst beds and further decrease the activity of the catalysts. Especially, metals such as Na, Ca, Mg and Fe are particularly detrimental and should be removed as efficiently as possible.

The need for purification of biological oils and fats before subjecting them to hydrotreatment and formation of renewable fuel components is recognized in

several publications. US2006/0264684 describes several pre-treatment methods for purification of biological oils. US2007/0010682 suggests degumming and/or bleaching of biological oils in order to reduce the phosphorous and total metal content of the biological oils prior to the hydrotreatment process.

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Summary of the invention

An object of the present invention is to provide an improved oil purification process when treating oil obtained from a renewable oil source.

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A further object of the invention is to decrease the harmful impurity content of renewable oil to be further processed into liquid fuel component.

A yet further object of the invention is to purify oil from renewable oil source efficiently with a high throughput.

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The present invention relates to a method for producing liquid fuel components from renewable oil as depicted by claim 1.

20 In a process comprising first preliminary pretreatment of impure oil feedstock and subsequently post-treatment of purified oil, for example, with hydrotreatment and isomerisation in order to obtain liquid fuel components, it was surprisingly found that by diluting the oil to be purified the amount of impurities in the intermediate oil fraction to be subjected to further processing steps is efficiently lowered
25 simultaneously increasing the resulting purified oil throughput. Especially, using fresh oil feedstock with high amount of impurities the overall purification performance was considerably enhanced.

The present invention offers several advantages to the processing. The lowering
30 of the cloud point of the used oily material results in increased purification capability and suppression of side-reactions. The decrease in solution viscosity aids in related separation processes enhancing the throughput. The decreased plugging tendency results in extended maintenance cycles.

Figures

Figure 1 shows a schematic flow chart of one embodiment of the present invention.

- 5 Figure 2 shows a schematic flow chart of a preferred embodiment of the present invention.

Figure 3 shows the flow chart of the degumming treatment performed in example 1

Figure 4 shows the cloud point depression due to dilution as discussed in example 2.

- 10 Figure 5 depicts the effect of dilution to pressure drop in filtering as discussed in example 3.

Figures 6 A and B show the influence of dilution to viscosity and density.

15 Detailed description of the invention

By the term "impurities" is meant those impurities harmful or undesired in the final liquid fuel component and harmful during processing thereof comprising phosphorus, phosphorus compounds, metals or metal compounds, sulphur and
20 compounds containing sulphur which are dissolved and/or miscible to feed oil or fat.

By the term "pretreatment process" is meant a conventional process or combinations of conventional processes aiming at purification of impure oil feed
25 from the impurities. Preferably these processes comprise degumming, bleaching, centrifugation, filtering or any combination thereof which results in a decreased content of the impurities.

By the term "degumming" is meant a purification process wherein impure oil is
30 treated with acid, water and caustic at elevated temperature with high shear mixing i.e. degummed. The formed gums may subsequently be separated from the oily material preferably by centrifugation and the material may be dried.

By the term "bleaching" is meant a purification process wherein acid and water is added to the impure oil, and the resulting composition is mixed with an adsorbent material at elevated temperature and reduced pressure such as vacuum. Thereafter the oil is dried and separated from said adsorbent typically by filtration.

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By "post-treatment process" is meant process steps aiming at producing paraffins and branched paraffins and rendering them suitable for liquid fuel components.

By the term "hydroprocessing" is meant catalytic processing of organic material by all means of molecular hydrogen.

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By the term "hydrotreatment" is meant a catalytic process; which removes oxygen from organic oxygen compounds as water i.e. hydrodeoxygenation, HDO; which removes sulphur from organic sulphur compounds as dihydrogen sulphide (H_2S) i.e. hydrodesulphurisation, HDS; which removes nitrogen from organic nitrogen compounds as ammonia (NH_3) i.e. hydrodenitrogenation, HDN; and which removes halogens, for example chlorine from organic chloride compounds as hydrochloric acid (HCl) i.e. hydrodechlorination, HDCl; typically under the influence of sulphided NiMo or sulphided CoMo catalysts.

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By the term "hydrodeoxygenation" (HDO) of triglycerides or other fatty acid derivatives or fatty acids is meant the removal of carboxyl oxygen as water by the means of molecular hydrogen under the influence of catalyst.

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.

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By the term "hydrocracking" is meant a catalytic decomposition of organic hydrocarbon materials using molecular hydrogen at high pressures.

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By the term "n-paraffins" is meant normal alkanes or linear alkanes that do not contain side chains.

In the method of the present invention liquid fuel components are produced from renewable oil. The characteristic features of this method are the following:

- 5 • A fresh feedstock comprising saturated fatty acids, and originating from said renewable oil, is subjected to dilution by an organic lipophilic solvent containing less than 5 ppm phosphorus and less than 10 ppm metal, preferably less than 5 ppm, impurities before and/or during purification by at least one pretreatment process for removal of phosphorus and metal
10 impurities. By removal is meant that the concentration of the impurities in the end product i.e. liquid fuel component is lowered to an acceptable level. The metals preferably include at least Fe, Mg and/or Na.
- Subsequently, the resulting purified feed stream is fed into at least one post-treatment process suitable for producing liquid fuel components from
15 the previously pretreated feedstock.

The renewable oil providing the fresh feedstock comprises oils, fats and/or waxes originating from any living biological material. It provides a source of triglycerides such as oils, fats and waxes of vegetable, animal or algae origin which includes
20 saturated fatty acids. Preferably said feed stock comprises saturated fatty acids from plants such as palm, jatropha and the like, animals such as poultry, beef and wild life, fish such as pangasius, microscopic plants such as algae, microalgae, plankton and planarian, and/or oils or fats produced by microbes like yeast, bacteria and mould, or compounds derived therefrom.

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The basic structural unit of a typical plant, or animal oil or fat is a triglyceride which is a triester of glycerol, wherein the esters typically contain alkyl chains of C₅-C₂₃, mainly C₁₁-C₁₉, most typically C₁₅-C₁₇ alkyl groups. These alkyl groups may contain carbon-carbon double bonds and they may be saturated, unsaturated or
30 polyunsaturated. The fresh feedstock from the renewable oil according to the present invention contains at least saturated fatty acids.

The determination of an iodine value from biological oil or fat provides a convenient measure of the degree of saturation which is typically performed according to ISO 3961 standard. Iodine value is a measure of the existing double bonds. A low value means a highly saturated biological fat i.e. low amount of double bonds therein. A high value depicts an unsaturated biological oil i.e. high amount of double bonds. A good numerical estimate for the portion of the saturated fatty acids is obtained by this type of determination.

According to a preferred embodiment the fresh feedstock according to the present invention has an iodine value of 100 or less, preferably less than 75, more preferably less than 60.

The feedstock originating from industrial processes or fresh feed satisfying the iodine value criteria of 100 or less preferably comprises refined or crude palm oil having an iodine value between 50-58; palm kernel oil, hydrogenated soybean oil, olive oil 18-82; microbe oils less than 100; bacterial oils about 70; yeast 50-55; algal oils less than 100; waste liquid of palm stearin 28-61; palm oil fatty acid distillate 42-61; animal fats of high, medium and low qualities 43-100; pangasius fish oil or hydrogenated fish oil 59-73; FAME (fatty acid methyl ester) of animal origin 55-71; jatropha oil 94-116; tallow oil about 40-50; and used cooking or frying oil 37-111.

Processing of the oil such as purification may decrease the iodine value to some extent. Typically, the amount of nonsaponified species and carotene therein tend to increase the iodine value and, for example, chlorophyll comprises double bonds. Yet, most of the double bonds originate from the fatty acids.

In one embodiment of the present invention the fresh feedstock contains triglycerides with C5-C23 alkyl groups, more preferably C11-C19 alkyl groups, and most preferably C15 or C17 alkyl groups. The alkyl chains are at least partly saturated but further comprise unsaturated or polysaturated bonds. The fresh feedstock preferably comprises C12-C24 fatty acids or derivatives thereof, more preferably anhydrides or esters of fatty acids and mixtures of fatty acids with

triglycerides. Fatty acids or fatty acid esters are more preferably produced via hydrolysis of biological oils or by their fractionalization or transesterification reactions of the triglycerides.

- 5 In another embodiment the fresh feedstock originates from plant based oils or fats. Preferably, these plants are selected from the group of palm, soya, olive or jatropa, preferably from palm. Furthermore, the oil may originate from plants bred by means of gene manipulation.
- 10 In a preferred embodiment the fresh feedstock originates from animal based fats, oils and/or waxes, preferably from lard, tallow, train oil, fats contained in milk, recycled fats from the food industry and mixtures thereof which typically have a low iodine value.
- 15 The impurity content of crude plant oil or animal fat is generally high and dependent on the origin of the crude product. Typically, phosphorus amount may be as high as about 1000 ppm for plant oil whereas the amount of metals of about 200 ppm has been observed for animal originating fats. This means that such crude oil or fat is not suitable as such for processing and needs to be purified
- 20 before use. In order to avoid catalyst deactivation and undesired side reactions the crude oil feed should comply with the following impurity requirements: The amount of alkali and alkaline earth metals, calculated as elemental alkali and alkaline earth metals, in the feed is below 10, preferably below 5 and most preferably below 3 ppm. The amount of other metals, calculated as elemental metals, in the feed is
- 25 below 10, preferably below 5 ppm and most preferably below 1 ppm. The amount of phosphorus, calculated as elemental phosphorus is below 30, preferably below 15 ppm, and most preferably below 5 ppm. There are several conventional purification procedures i.e. pretreatment processes available for removal of undesired phosphorus and metals before introducing the crude oil to post-
- 30 treatment processes.

In the present invention there is present at least one pretreatment process for removal of phosphorus and metal impurities. Preferably, the pretreatment process

comprises degumming. The pretreatment may further comprise other purification processes such as centrifugation, wet bleaching, dry bleaching, filtration or any combinations thereof.

- 5 An advantage of dilution in a pretreatment process such as degumming is that dilution changes the feedstock properties and the secondary effect is an enhancement of throughput or efficiency. For example, in degumming the processing temperature for animal fat having a high cloud point must be chosen high enough resulting in degumming at a high temperature. The probability of
- 10 undesired side reactions increases considerably when the processing temperature is increased. For example, the solubility of the formed gums is increased, as well. By diluting the fat feedstock with an organic lipophilic solvent the processing temperature is lowered resulting in a better overall yield.
- 15 Furthermore, the dilution by an organic lipophilic solvent does not interfere with the remaining processing and it is not necessary to remove the diluent from the process after pretreatment. The pretreated feedstock may be introduced as is to the following post treatment sequence.
- 20 A preferred pretreatment process comprising degumming of plant or animal oils results in removal of phosphorus compounds, such as phospholipids. Solvent extracted plant oils often contain significant amounts of gums, typically 0.5-3% by weight, which are mostly phosphatides i.e. phospholipids. Therefore, a degumming stage is needed in order to remove phospholipids and metals
- 25 associated thereto. Especially iron and some further metals may be present in the form of metal-phosphatide complexes. Even a trace amount of iron is capable of catalysing oxidation of the oil or fat. A typical degumming step is performed by washing the feed at 90-105 °C, 300-500 kPa, with H₃PO₄, NaOH and soft water and separating the formed gums. A major amount of metal components, which are
- 30 harmful, for example, for hydrotreatment catalyst in the subsequent post-treatment, are removed from the feedstock during this degumming stage. The moisture content of the degummed oil is preferably reduced in dryer at 90-105 °C, 5-50 kPa.

In another preferred embodiment bleaching is used in addition to degumming in pretreatment process for fresh feed stream. In the bleaching step the feed is heated and mixed with natural or acid-activated bleaching clay. Bleaching
5 removes various impurity traces left from other pretreatment steps like degumming, such as chlorophyll, carotenoids, phospholipids, metals, soaps and/or oxidation products. Bleaching is typically carried out under vacuum to minimize possible oxidation. Generally in food applications, the goal in bleaching is to reduce the color pigments in order to produce an oil of acceptable color and to
10 reduce the oxidation tendency of oil.

In the method of the present invention the removal of phosphorus and metal impurities in the pretreatment processes, such as degumming and bleaching, is facilitated by introduction of low phosphorus and metal content organic lipophilic
15 solvent to the fresh feedstock stream, thus diluting the original phosphorus and metal contents thereof per unit volume entering into the pretreatment step. In order not to increase the original impurity content the organic lipophilic solvent shall contain less than 5 ppm phosphorus impurities and less than 10 ppm metal impurities.

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In the method of the present invention, for example in degumming, the impurities are converted more easily water soluble by dilution by dissociating oil soluble salts and aiding the formation of new microscopic precipitates and gums that are substantially insoluble in oil and/or water. These solid insoluble gums become
25 more easily separated from the aqueous phase and the oil phase by centrifugation which is generally part of the degumming procedure. This separation is enhanced by diluting the occasionally undesirably viscous oil phase.

The extent of the processing difficulties may vary depending on the densities, polarity effects and mass transfer effect of the processed oils/fats. Especially,
30 animal fats have been found particularly difficult to handle and separate. They tend to provide metal or phosphor containing residues into the crude oil after purification in a pretreatment process step which subsequently causes, for

example, plugging in the various processing steps. The quality of some of the animal fats is so poor that it is not possible to purify them using merely the available conventional pretreatment processes.

- 5 In the pretreatment processes typically the final and most critical step is filtration. For example, fresh adsorbent suspended in crude oil feed in bleaching after degumming is recycled through a filter to build up a cake on the surface of the filter mesh. This is followed by a filtration period with a feed from the adsorber and continued until the pressure drop over the cake reaches a maximum ending the
- 10 filtration and resulting in discharging the cake. The filtration is greatly facilitated using a diluted oil feed. This provides a synergistic effect between the particle size requirement and filtration temperature. Viscosity of the crude oil feed including a diluent is lower making the filtration easier. The addition of diluents increases the overall flux through the filter but the cake pressure drop decreases substantially as
- 15 a result of the smaller viscosity. The overall effect or result is that the solid impurities will plug the filter cake more slowly when dilution is provided. As a multiplicative effect the low pressure drop gives more options to material selection, such as clay selection for example, since the filtration is no longer limited by the small size of adsorbent particles. The small particles enhance pore diffusion and
- 20 improve apparent activity of the clay and aid in minimizing oil losses. Due to the lowered viscosity and lowered melting point or cloud point of the mixture the filtration can be carried out at a lower temperature wherein, for example, waxes are less soluble to oil and polyethylene particles are removed more efficiently. Furthermore, associated decrease in temperature minimizes thermal degradation
- 25 and oxidation of oils and fats. Solubility of unwanted polar phospholipids to fat or oil phase is decreased when, for example, non-polar n-paraffin is used as diluent. Surprisingly, it was found that the yield of purified oil per unit time is increased despite of increasing the amount of feedstock to be purified.
- 30 Plant and animal oil, fat or wax may contain typically up to 30% of free fatty acids, which are formed during enzymatic hydrolysis of triglycerides, especially, when e.g. oil seeds are kept in humid atmosphere. Free fatty acids can also be formed during purification of biological oils and fats, especially during caustic wash i.e.

- alkali catalyzed hydrolysis. The amount of free fatty acids present in plant oils is typically lower than in animal fat. Free fatty acids are corrosive in their nature, they tend to attack against the materials of the equipment or catalyst and promote various side reactions. Free fatty acids react very efficiently with metal impurities
- 5 producing metal carboxylates, which further promotes chemical side reactions. Fatty acids may also enhance the formation of heavy compounds. The boiling range of these heavy compounds is different from the range of diesel fuel and may shorten the life of the isomerisation catalyst. Due to the free fatty acids contained in bio oils and fats, the formation of heavy molecular weight compounds is
- 10 significantly increased compared to triglyceridic biological feeds, which have only low amount of free fatty acids, such as less than 1%. Naturally occurring fats and oils containing significant amounts of free fatty acids may be processed without the removal of free fatty acids.
- 15 The diluent, organic lipophilic solvent is preferably a straight chained, branched, cyclic or aromatic hydrocarbon with a carbon number from C3 to C20, with or without substituents. If substituted the substituents are selected from the group of -OH (hydroxy), -HC=O (aldehyde), -COOH (carboxylic acid), -O- (ether), -C(=O)-O- (ester), -NH₂ (amine), -C(=O)-N- (amide), -CN (nitrile), --S(=O)- (sulfoxide) and -
- 20 S(=O)₂ - (disulfoxide).

In one embodiment the organic lipophilic solvent is a product recycle stream i.e. a side stream from such part of the process wherein the amount of impurities, such as phosphorus or metals, have already been reduced to acceptable levels, for

25 phosphorus below 5 ppm and for metals below 10 ppm, preferably below 5 ppm. Preferably, the organic lipophilic solvent is recycled from the post treatment.

In another preferred embodiment the organic lipophilic solvent is a mixture of straight chained, branched, cyclic or aromatic hydrocarbons. Preferably the

30 solvent is selected from the group of product streams of the process after post-treatment. More preferably it is a hydrotreated vegetable oil product i.e. a middle distillate fraction from a process in which biological oil is hydrodeoxygenated and subsequently isomerised in an isomerisation step to form a mixture of iso-paraffins

typically with a carbon chain length of C14 to C18 (this mixture is referred to as NExBTL), Fischer–Tropsch product fraction, furfural or ethers such as dipropyl ether, dibutylether, dipentylether, MTBE (methyl tert-butylether), ETBE (ethyl tert-butylether), TAME (tert-amyl methylether) and TAEE (tert-amyl ethylether).

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In yet another preferred embodiment the organic lipophilic solvent is a mixture of recycled paraffins from the same process fulfilling the purity criteria.

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In a further preferred embodiment the organic lipophilic solvent is a fresh solvent or a mixture of fresh solvents or a mixture of fresh and recycled solvents fulfilling the purity criteria.

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The organic lipophilic solvent may be a pure fresh solvent which does not itself need to be purified.

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The volume ratio of the organic lipophilic solvent to the fresh feedstock is preferably 0.05-5:1, more preferably 0.1-2:1, most preferably 0.2-1:1. Extensive dilution will lead to an unpractical process including high volumes and increased equipment size.

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According to the present invention there is present at least one post treatment process suitable for producing liquid fuel components. The post-treatment may comprise any conventional processing steps suitable for preparation of the liquid fuel components. Preferably, the post treatment step comprises a hydrotreating process, such as deoxygenation, denitrogenation and desulphurization, and/or isomerisation.

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The organic lipophilic solvent may be introduced into the fresh feed stream before or during the purification i.e. the pretreatment step.

In one embodiment the degumming step of the pretreatment is performed to the fresh feedstock prior to dilution by the organic lipophilic solvent. Subsequently the

degummed and diluted fresh feed is e.g. centrifuged to remove the formed gums before entering into the post treatment step.

A preferred embodiment of the invention is illustrated in figure 2 wherein a pretreatment process including organic lipophilic solvent dilution is linked to post-treatment processing. In this example both pretreatment processes, parallel degumming and bleaching processes utilise dilution before entering the pretreated purified oil feed into the post-treatment processing. The preferred post-treatment processing comprises a hydrotreatment step prior to isomerisation step. The crude biological oil or fat is fed into degumming step comprising first washing the feed at a temperature of 30-115 °C and a pressure of 100-1000 kPa using an acid, preferably H_3PO_4 , and a caustic, preferably NaOH, and soft water for the aqueous phase. Diluting agent is fed into the degumming step liquid in a volume ratio of 0.05-5:1 and subsequently the formed gums are separated by centrifugation. The formation and separation of gums is facilitated compared to centrifugation without any additional diluent due to decrease in forming temperature. Part of the crude biological oil or fat is fed parallel into bleaching step comprising adsorption using clay material and subsequent filtration. The diluent feed addition before filtration aided the filtering by slowing down the development of the filter pressure drop build up and by enhancing the throughput. The purified oil is fed to the post-processing together with the diluent.

In another embodiment of the present invention the degumming step and bleaching steps are in series.

In yet another embodiment of the present invention the diluent is withdrawn from the pretreatment step after purification but before entering the resulting feed into the post-treatment.

In a further embodiment the used organic lipophilic solvent is withdrawn from the post-treatment step during or after hydrotreatment or after isomerisation. Preferably, the formed vapour phase developed during hydrotreatment is removed

from the feed before recycling it as diluents to the pretreatment step or entering the feed into the subsequent isomerisation step.

5 The resulting liquid fuel component is an isomerised product, which is a mixture of branched hydrocarbons, and preferably branched paraffins, boiling in the range of 180 – 350°C, the diesel fuel range, and having one carbon atom less than the original fatty acid chain, are obtained. Additionally some gasoline and gas may be obtained.

10 The invention is further illustrated by the following non-restricting examples.

Examples

Example 1

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Cloud points of ten samples were determined using ISL MPP 5GS MINI analyzer:

Reference sample 1: pure (100%) animal fat (AF) with no added organic lipophilic solvent

20 Sample 2: animal fat 90 % by weight with 10 % by weight of added organic lipophilic solvent wherein the solvent was NExBTL

Sample 3: animal fat 80 % by weight with 20 % by weight of added organic lipophilic solvent wherein the solvent was NExBTL

25 Sample 4: animal fat 60 % by weight with 40 % by weight of added organic lipophilic solvent wherein the solvent was NExBTL

Sample 5: animal fat 20 % by weight with 80 % by weight of added organic lipophilic solvent wherein the solvent was NExBTL

Reference sample 6: pure NExBTL

30 Sample 7: animal fat 90 % by weight with 10 % by weight of added organic lipophilic solvent wherein the solvent was heptane

Sample 8: animal fat 80 % by weight with 20 % by weight of added organic lipophilic solvent wherein the solvent was heptane

Sample 9: animal fat 60 % by weight with 40 % by weight of added organic lipophilic solvent wherein the solvent was heptane

Sample 10: animal fat 20 % by weight with 80 % by weight of added organic lipophilic solvent wherein the solvent was heptane

Animal fat and the organic lipophilic solvent were heated to 45 °C, weighted to 100 ml flasks and mixed vigorously to obtain homogeneous mixture.

The cloud point analysis was measured based on optical detection. A 0.5 ml sample is pipetted to a disposable cuvette, which is installed into the analyzer. The analyzer melts the sample at first by preheating the cuvette. Subsequently, the sample is cooled slowly until first crystals appear at cloud point temperature.

The results in table 1 and figure 4 show that the cloud point decreases considerably when the amount of solvent is increased.

Table 1

% solvent by weight	AF same (°C)	
	NExBTL	heptane
0	29,7	
10	30,2	28,6
20	29,9	26,4
40	24,3	20,0
80	21,1	11,8
100	-48,5	

Example 2

Animal fat (=AF) originating from food industry waste having an iodine value of about 55 was used as feedstock. Three test runs were made by varying the dilution of the fresh feedstock (samples 2-3 according to the invention) before entering it into degumming.

Reference sample 1: pure (100%) animal fat with no added organic lipophilic solvent

Sample 2: animal fat 80 % by weight with 20 % by weight of added organic lipophilic solvent wherein the solvent was NExBTL

5 Sample 3: animal fat 60 % by weight with 40 % by weight of added organic lipophilic solvent wherein the solvent was NExBTL

Reference sample 4: pure NExBTL

10 NExBTL diesel retrieved from the process outlet was stabilized in Rotavapor at 100 mbar pressure and 105 °C temperature. Stabilization was made to remove the light hydrocarbons for safety reasons. Cloud point of the NExBTL diesel was measured to be -48.5 °C.

15 A feedstock sample was taken for metal content analysis and phosphorus analysis (ASTMD5185). Animal fat feedstock samples 2 and 3 were diluted by NExBTL in a flask at 45 °C.

20 Subsequently, degumming was performed. Test run mixture was thermostatically adjusted to 45 °C, and 1000 mg/kg of citric acid was added as a 50% by weight water solution. Silverson high-shear mixer was turned on (8000 rpm) for 2 minutes to create an emulsion. Slow mixing with magnetic stirrer (250 rpm) was continued for 15 minutes after the vigorous mixing. The resulting mixture was cooled to the degumming temperature, 45 °C, 35 °C and 30 °C, and 2 % by weight water and 250 mg/kg lye was added. High-shear mixing was turned on for 2 minutes where
25 after slow mixing was continued for 60 minutes. Finally, the formed gums and water phases were separated from the oil phase by centrifugation (4300 rpm) for 5 minutes at the degumming temperature.

30 A sample for metal, P and nitrogen analyses was taken from the oil product.

Table 2

100% AF, 45 °C		Feed	Product	removal(%)
Water	mg/kg	870	4400	-
Fe	mg/kg	2,8	0,2	93
Na	mg/kg	11,4	3,8	67
Ca	mg/kg	117	1	99
Mg	mg/kg	2,8	0,2	93
P	mg/kg	75,3	8,4	89

20% NExBTL+80%AF, 35 °C		Feed	Product	removal(%)
Water	mg/kg	660	3000	-
Fe	mg/kg	2,6	0,09	97
Na	mg/kg	10,5	1,9	82
Ca	mg/kg	99,1	1,2	99
Mg	mg/kg	2,7	0,07	97
P	mg/kg	70,4	4,5	94

40% NExBTL+60%AF, 30 °C		Feed	Product	removal(%)
Water	mg/kg	470	1800	-
Fe	mg/kg	1,9	0,09	95
Na	mg/kg	8,3	1,5	82
Ca	mg/kg	75,3	0,7	99
Mg	mg/kg	2,0	0,05	98
P	mg/kg	49,4	3,5	93

From Table 2 it can be seen that the removal percentage for phosphorous is increased from 89 % (undiluted) to 94 % and 93 % with 20 % and 40 % dilutions, respectively. The removal percentage (removal(%)) is calculated as the amount of impurities removed from the feed. The removal percentage is also increased for Fe.

Example 3

Undiluted palm oil (CPO) and a mixture of 50 w- % hydrodeoxygenated (HDO) vegetable oil (HDO) and 50 w-% palm oil was filtered through a 4 g cake of
5 BASF/F-160 clay in Dahlmann apparatus (filter surface $\sim 0.001 \text{ m}^2$). The hydrodeoxygenated diluent contained mainly n-paraffinic C_{16} and C_{18} hydrocarbons. The pressure drop ($=dp$) was measured over the cake for the two filtration series and the collected filtrate (g) versus the filtration time is depicted in Figure 5.

10 From the figure it can be seen that for the 50/50 mixture already at 10 min. filtration time more than twice the amount of filtrate is collected (less than 40 g for palm oil compared to more than 80 g for 50/50 mixture). At 20 min. the pressure drop for palm oil has already increased to 2 bar compared to 1 bar at the beginning and the collected filtrate for palm oil is still only half the amount of the 50/50 mixture.

15 Based on the experiment theoretical densities and viscosities for the pure components and mixtures were calculated. Using C_{18} n-paraffin as hydrodeoxygenated diluent and 891 g/mol as the molar mass of palm oil and 254.5 g/mol as the molar mass of n-paraffin densities and viscosities of the pure components and mixtures
20 were obtained as presented in Figure 6 A and B, respectively.

The theoretical pressure drop (Δp) for palm oil and the diluted mixture were calculated from Ergun equation based on the calculated densities and viscosities and the measured data. From table 3 it can be seen that the agreement between the
25 measured data and calculated pressure drop is good when the cake porosity is adjusted to 0.268. The calculated pressure drop for various mixtures is presented in Table 4 and 5 at 60 °C and 90 °C, respectively. From the tables 4 and 5 it can be seen that significant decrease in pressure drop can be achieved already with 10 to 30 % by weight dilution of palm oil.

30 Table 3 shows the comparison of the measured pressure drop and the calculated pressure drop for pure palm oil and 50/50 mixture with hydrodeoxygenated diluent.

Table 4 shows the effect of diluent addition on pressure drop in filtration at 60 °C and table 5 shows the effect of diluent addition on pressure drop in filtration at 90 °C.

Table 3.

feed	filtration temperature (°C)	mean adsorbent particle diameter (µm)	liquid density (kg/m ³)	liquid viscosity (Pa*s)	cake height (m)	cake porosity &	flux (kg/m ² /h)	measured pressure drop (bar)	calculated pressure drop, Ergun (bar)
RBD palm oil	90	7,6	862	0,0086	6	0,268	74	1,0	0,9
RBD palm oil	90	7,6	862	0,0086	6	0,268	253	3,0	3,0
RBD palm oil	90	7,6	862	0,0086	6	0,268	470	5,0	5,6
RBD palm oil	55	7,6	887	0,0229	6	0,268	168	6,0	5,2
RBD palm oil:HDO-product (50:50 w%)	55	7,6	815	0,0037	6	0,268	232	1,0	1,3

Table 4.

filtration temperature (°C)	mean adsorbent particle diameter (µm)	liquid density (kg/m ³)	liquid viscosity (Pa*s)	cake height (mm)	cake porosity	flux & (kg/m ² /h)	calculated pressure drop, Ergun (bar)	%decrease of pressure drop compared to no diluent case
60	7,6	883	0,0198	15	0,268	230	15,53	0,0
60	7,6	868	0,0105	15	0,268	256	9,29	-40,2
60	7,6	853	0,0069	15	0,268	288	6,96	-55,2
60	7,6	839	0,0051	15	0,268	329	5,97	-61,5
60	7,6	825	0,0040	15	0,268	383	5,65	-63,6
60	7,6	811	0,0034	15	0,268	460	5,77	-62,8

Table 5.

diluent w% of the oil feed	filtration temperature (°C)	mean ad- sorbent particle diameter (μm)	liquid density (kg/m^3)	liquid viscosity ($\text{Pa}\cdot\text{s}$)	cake height (mm)	cake po- rosity	flux & ($\text{kg}/\text{m}^2/\text{h}$)	calculated pressure drop, Ergun (bar)	%decrease of pressure drop com- pared to no diluent case
0	90	7,6	862	0,0086	15	0,268	230	6,90	0,0
10	90	7,6	847	0,0050	15	0,268	256	4,57	-33,8
20	90	7,6	832	0,0035	15	0,268	288	3,66	-46,9
30	90	7,6	818	0,0027	15	0,268	329	3,30	-52,2
40	90	7,6	804	0,0023	15	0,268	383	3,24	-53,1
50	90	7,6	791	0,0019	15	0,268	460	3,40	-50,7

Claims

1. A method for producing liquid fuel components from renewable oil, the method comprising:

subjecting a fresh feedstock of renewable oil comprising saturated fatty acids to dilution with an organic lipophilic solvent containing less than 5 ppm phosphorus impurities and less than 10 ppm metal impurities, wherein the organic lipophilic solvent consists essentially of a mixture of iso-paraffins with a carbon chain length of C14 to C18, wherein the fresh feedstock is subjected to the dilution before and/or during purification of the fresh feedstock by at least one pretreatment process for removal of phosphorus and metal impurities and for forming a purified feedstock, wherein the pretreatment process comprises a degumming process, wherein the fresh feedstock is subjected to the dilution before and/or during the degumming process, and subsequently feeding the purified feedstock into at least one post-treatment process for producing liquid fuel components,

wherein a volume ratio of the organic lipophilic solvent to the fresh feedstock is within a range of from 0.1:1 to 2:1, and

wherein the purified feedstock contains less than 5 ppm phosphorus impurities and less than 10 ppm metal impurities, wherein the metal impurities comprise Fe, Na, Ca, and Mg.

2. The method according to claim 1, wherein the purified feedstock is centrifuged to remove a gum formed from the degumming process.

3. The method according to claim 1, wherein the post-treatment process comprises a hydrotreating step and an isomerization step.

4. The method according to claim 3, wherein the post-treatment process comprises conducting the hydrotreating step including hydrogenation and deoxygenation, and subsequently conducting the isomerization step.

5. The method according to claim 1, wherein the renewable oil includes an animal oil or fat, a plant oil or fat, a microscopic plant oil or fat, a microbe oil or fat, or a combination thereof.

6. The method according to claim 1, wherein the fresh feedstock of renewable oil comprising saturated fatty acids has an iodine value of less than 100.

7. The method according to claim 1, wherein the post-treatment process comprises a hydrotreating step and an isomerization step, wherein a vapor phase formed during the hydrotreating step is removed before conducting the isomerization step.

8. The method according to claim 1, wherein the fresh feedstock of renewable oil comprising saturated fatty acids has an iodine value of less than 75.

9. The method according to claim 1, wherein the fresh feedstock of renewable oil comprising saturated fatty acids has an iodine value of less than 60.

10. The method according to claim 1, wherein the volume ratio of the organic lipophilic solvent to the fresh feedstock is within a range of from 0.2:1 to 1:1.

11. The method according to claim 1, wherein the organic lipophilic solvent contains less than 5 ppm metal impurities.

12. The method according to claim 1, wherein the pre-treatment process further comprises a bleaching process, a centrifugation process, a filtering process, or a combination thereof.

13. The method according to claim 1, wherein the dilution is conducted prior to the pretreatment process.

14. The method according to claim 1, wherein the pre-treatment process consists of the degumming process and optionally a centrifugation process.

15. The method according to claim 13, wherein the pretreatment process consists of the degumming process and optionally a centrifugation process.

16. The method according to claim 15, wherein the post-treatment process comprises a hydrotreating step and an isomerization step.

17. The method according to claim 1, wherein a weight ratio of the organic lipophilic solvent to the fresh feedstock is 1:9 to 1:1.5.

18. The method according to claim 1, wherein a weight ratio of the organic lipophilic solvent to the fresh feedstock is 1:9 to 1:4.

19. A method for producing liquid fuel components from renewable oil, the method comprising:

subjecting a fresh feedstock of renewable oil comprising saturated fatty acids to dilution with an organic lipophilic solvent containing less than 5 ppm phosphorus impurities and less than 10 ppm metal impurities, wherein the organic lipophilic solvent consists essentially of a mixture of iso-paraffins with a carbon chain length of C14 to C18, wherein the fresh feedstock is subjected to the dilution before purification of the fresh feedstock by at least one pretreatment process for removal of phosphorus and metal impurities and for forming a purified feedstock, wherein the pretreatment process comprises a degumming process, wherein the fresh feedstock is subjected to the dilution before the degumming process, and

subsequently feeding the purified feedstock into at least one post-treatment process for producing liquid fuel components,

wherein a volume ratio of the organic lipophilic solvent to the fresh feedstock is within a range of from 0.1:1 to 2:1.

20. A method for producing liquid fuel components from renewable oil, the method comprising:

subjecting a fresh feedstock of renewable oil comprising saturated fatty acids to dilution with an organic lipophilic solvent containing less than 5 ppm phosphorus impurities and less than 10 ppm metal impurities, wherein the organic lipophilic solvent consists essen-

- tially of a mixture of iso-paraffins with a carbon chain length of C14 to C18, wherein the fresh feedstock is subjected to the dilution during purification of the fresh feedstock by at least one pretreatment process for removal of phosphorus and metal impurities and for forming a purified feedstock, wherein the pretreatment process comprises a degumming process, wherein the fresh feedstock is subjected to the dilution during the degumming process, and
- subsequently feeding the purified feedstock into at least one post-treatment process for producing liquid fuel components,
- wherein a volume ratio of the organic lipophilic solvent to the fresh feedstock is within a range of from 0.1:1 to 2:1, and
- wherein the purified feedstock contains less than 5 ppm phosphorus impurities and less than 10 ppm metal impurities, wherein the metal impurities comprise Fe, Na, Ca, and Mg.
- 21.** A method for producing liquid fuel components from renewable oil, the method comprising:
- subjecting a fresh feedstock of renewable oil comprising saturated fatty acids to dilution with an organic lipophilic solvent wherein the organic lipophilic solvent consists essentially of a mixture of iso-paraffins with a carbon chain length of C14 to C18, containing less than 5 ppm phosphorus impurities and less than 10 ppm

metal impurities, wherein the fresh feedstock is subjected to the dilution before and during purification of the fresh feedstock by at least one pretreatment process for removal of phosphorus and metal impurities and for forming a purified feedstock, wherein the pretreatment process comprises a degumming process, wherein the fresh feedstock is subjected to the dilution before and during the degumming process, and subsequently feeding the purified feedstock into at least one post-treatment process for producing liquid fuel components, wherein a volume ratio of the organic lipophilic solvent to the fresh feedstock is within a range of from 0.1:1 to 2:1, and wherein the purified feedstock contains less than 5 ppm phosphorus impurities and less than 10 ppm metal impurities, wherein the metal impurities comprise Fe, Na, Ca, and Mg.

22. The method according to claim 1, wherein the organic lipophilic solvent consists of a mixture of iso-paraffins with a carbon chain length of C14 to C18.