proportion of feedstock in reaction slurries, sub-optimal heat transfer, and product separation.

Summary ~~of the Invention~~

In light of the disadvantage/s associated with current methodologies including those described above, a need exists for improved biofuel production processes.

A number of existing methods utilise aqueous solvents (e.g. water and/or aqueous alcohols) at high temperature and pressure to produce bio-oils from organic matter. It has been unexpectedly determined that the addition of oil to these solvents (e.g. combining oil and/or water and/or aqueous alcohol) provides a means of increasing the efficiency of bio-oil production.

In a first aspect the present disclosure~~invention~~ provides a method for producing biofuel, the method comprising:

producing a slurry comprising organic matter feedstock, water and oil;

treating the slurry in a reactor apparatus at a temperature of between about 200°C and about 450°C and a pressure of between about 180 bar and about 350 bar; and

cooling the slurry and releasing said pressure thereby providing a product comprising said biofuel.

In one embodiment of the first aspect, the slurry comprises between about 20% and about 60% by weight of said oil.

In one embodiment of the first aspect, the slurry comprises between about 20% and about 40% by weight of said organic matter.

In one embodiment of the first aspect, the slurry further comprises an aqueous alcohol.

In one embodiment of the first aspect, the aqueous alcohol is ethanol or methanol.

In one embodiment of the first aspect, the slurry comprises a percentage by weight of said alcohol of: between about 5 wt% and about 40 wt%, between about 5 wt% and about 30 wt%, between about 5 wt% and about 25 wt%, between about 5 wt% and about 20 wt%, between about 5 wt% and about 15 wt%, or between about 5 wt% and about 10 wt%.

In one embodiment of the first aspect, the organic matter is lignocellulosic matter.

In one embodiment of the first aspect, the organic matter is lignite.

In one embodiment of the first aspect, said treating comprises heating and pressurising the slurry in at least one vessel or chamber of said reactor apparatus.

In one embodiment of the first aspect, said treating comprises generating subcritical or supercritical steam independently of the slurry and contacting the slurry with the subcritical or supercritical steam in at least one vessel or chamber of said reactor apparatus.

In one embodiment of the first aspect, the slurry is at ambient or near ambient temperature and pressure prior to said contacting with the subcritical or supercritical steam.

In one embodiment of the first aspect, said treating comprises: heating the slurry to a temperature selected from the group consisting of at least about 100°C, at least about 150°C, at least about 200°C, at least about 250°C, at least about 300°C, at least about 350°C, between about 200°C and about 250°C, between about 200°C and about 400°C, between about 250°C and about 400°C, between about 250°C and about 350°C, and between about 250°C and about 350°C; generating subcritical or supercritical steam independently of the slurry; and contacting the slurry with the subcritical or supercritical steam in at least one vessel or chamber of said reactor apparatus. The slurry may be pressurised prior to and/or after said contacting.

In another embodiment, the present disclosure~~a second aspect the invention~~ provides a method for producing a biofuel, the method comprising treating organic matter with an oil-based solvent comprising less than about 50 wt% water at a temperature of between about 200°C and about 450°C, and a pressure of between about 180 bar and about 350 bar.

In a second~~third~~ aspect the present disclosure~~invention~~ provides a method for producing a biofuel, the method comprising treating organic matter with an oil-based solvent comprising less than about 50 wt% water at a temperature of between about 200°C and about 400°C, and a pressure of between about 100 bar and about 300 bar.

In another embodiment~~a fourth aspect~~ the present disclosure~~invention~~ provides a method for producing a biofuel, the method comprising treating organic matter with an oil-based solvent comprising less than about 50 wt% water at a temperature of between about 200°C and about 400°C, and said pressure is between about 50 bar and about 300 bar.

In one embodiment of the above embodiments and second~~second, third and fourth~~ aspects, said treating comprises heating and pressurising a slurry comprising said organic matter in at least one vessel or chamber of a reactor apparatus.

In one embodiment of the above embodiments and second~~second, third and fourth~~ aspects, said treating comprises contacting a slurry comprising said organic matter with subcritical or supercritical steam.

In one embodiment of the above embodiments and second~~second, third and fourth~~ aspects, the slurry is at ambient or near ambient temperature and pressure prior to said contacting with the subcritical or supercritical steam.

In one embodiment of the above embodiments and second~~second, third and fourth~~ aspects, said treating comprises: heating a slurry comprising said organic matter to a temperature selected from the group consisting of at least about 100°C, at least about 150°C, at least about 200°C, at least about 250°C, at least about 300°C, at least about 350°C, between about 200°C and about 250°C, between about 200°C and about 400°C, between about 250°C and about 400°C, between about 250°C and about 350°C, and between about 250°C and about 350°C; generating subcritical or supercritical steam independently of the slurry; and contacting the slurry with the subcritical or supercritical steam in at least one vessel or chamber of said reactor apparatus. The slurry may be pressurised prior and/or after to said contacting.

In one embodiment of the above embodiments and~~first, second, third and fourth~~ aspects, the temperature is between about 300°C and about 380°C, and the pressure is between about 200 bar and about 300 bar.

In one embodiment of the above embodiments and~~first, second, third and fourth~~ aspects, the treating comprises use of at least one additional catalyst.

In one embodiment of the above embodiments and~~first, second, third and fourth~~ aspects, the least one additional catalyst is an additional base catalyst.

In one embodiment of the above embodiments and~~first, second, third and fourth~~ aspects, the additional base catalyst is an alkali metal hydroxide catalyst or a transition metal hydroxide catalyst.

In one embodiment of the above embodiments and~~first, second, third and fourth~~ aspects, the additional base catalyst is sodium hydroxide or potassium hydroxide.

In one embodiment of the above embodiments and~~first, second, third and fourth~~ aspects, the treating is performed under conditions of continuous flow.

In one embodiment of the above embodiments and~~first, second, third and fourth~~ aspects, the treating comprises use of at least one additional catalyst that enhances incorporation of hydrogen into said organic matter.

In one embodiment of the above embodiments and~~first, second, third and fourth~~ aspects, the catalyst that enhances incorporation of hydrogen is selected from the group consisting of alkali metal formate catalysts, transition metal formate catalysts, reactive carboxylic acid catalysts, transition metal catalysts including their hydrides, sulphide catalysts, noble metal catalysts including their hydrides, water-gas-shift catalysts, and combinations thereof.

In one embodiment of the above embodiments and~~first, second, third and fourth~~ aspects, the catalyst is sodium formate.

In one embodiment of the above embodiments and~~first, second, third and fourth~~ aspects, the catalyst is a low-valent iron species including their hydrides, zero-valent iron homogeneous species, and zero-valent iron heterogeneous species.

In one embodiment of the above embodiments and~~first, second, third and fourth~~ aspects, the treating comprises use of at least one additional catalyst that enhances removal of oxygen from said organic matter.

In one embodiment of the above embodiments and~~first, second, third and fourth~~ aspects, the catalyst that enhances removal of oxygen from said organic matter is selected from the group consisting of alkali metal formate catalysts, transition metal formate catalysts, reactive carboxylic acid catalysts, transition metal catalysts, including their hydrides, sulphide catalysts, noble metal catalysts, including their hydrides, water-gas-shift catalysts, and combinations thereof.

In one embodiment of the above embodiments and~~first, second, third and fourth~~ aspects, the organic matter is fossilised organic matter having a carbon content of at least 50%, and said solvent is an oil comprising less than 50 wt% water.

In one embodiment of the above embodiments and~~first, second, third and fourth~~ aspects, the organic matter is fossilised organic matter having a carbon content of at least 60%, and said solvent is an oil comprising less than 50 wt% water.

In one embodiment of the above embodiments and~~first, second, third and fourth~~ aspects, the organic matter is lignite, the temperature is between about 330°C and about 350°C, and the pressure is between about 160 bar and about 250 bar.

In one embodiment of the above embodiments and~~first, second, third and fourth~~ aspects, the organic matter is lignocellulosic biomass, the temperature is between about 330°C and about 350°C, and the pressure is between about 160 bar and about 250 bar.

In one embodiment of the above embodiments and~~first, second, third and fourth~~ aspects, the treating is for a time period of at least about 5 minutes.

In one embodiment of the above embodiments and~~first, second, third and fourth~~ aspects, the treating is for a time period of between about 5 minutes and about 25 minutes.

In one embodiment of the above embodiments and~~first, second, third and fourth~~ aspects, the treating is for a time period of between about 5 minutes and about 60 minutes.

In one embodiment of the above embodiments and~~first, second, third and fourth~~ aspects, the treating is for a time period of between about 10 minutes and about 20 minutes.

In one embodiment of the above embodiments and~~first, second, third and fourth~~ aspects, the treating is for a time period of about 15 minutes.

In one embodiment of the above embodiments and~~first, second, third and fourth~~ aspects, the biofuel comprises an oil component having a gross calorific value of more than 35 MJ/kg.

In one embodiment of the above embodiments and~~first, second, third and fourth~~ aspects, the biofuel comprises an oil component having a gross calorific value of more than 37 MJ/kg.

In one embodiment of the above embodiments and~~first, second, third and fourth~~ aspects, the biofuel comprises an oil component having a gross calorific value of more than 40 MJ/kg.

In one embodiment of the above embodiments and~~first, second, third and fourth~~ aspects, the organic matter is in the form of a slurry comprising at least 30 wt% of said organic matter.

In one embodiment of the above embodiments and~~first, second, third and fourth~~ aspects, the organic matter is in organic matter is in the form of a slurry comprising at least 40 wt% of said organic matter.

In one embodiment of the above embodiments and second~~second, third and fourth~~ aspects, the solvent comprises at least about 30 wt% oil.

In one embodiment of the above embodiments and second~~second, third and fourth~~ aspects, the solvent comprises at least about 40 wt% oil.

In one embodiment of the above embodiments and second~~second, third and fourth~~ aspects, the solvent comprises at least about 50 wt% oil.

In one embodiment of the above embodiments and second~~second, third and fourth~~ aspects, the solvent comprises at least about 60 wt% oil.

In one embodiment of the above embodiments and second~~second, third and fourth~~ aspects, the solvent comprises at least about 70 wt% oil.

In one embodiment of the above embodiments and~~first, second, third and fourth~~ aspects, the oil is selected from the group consisting of paraffinic oil, gas-oil, crude oil, synthetic oil, coal-oil, bio-oil, shale oil, kerogen oil, mineral oil, white mineral oil, and aromatic oil.

In one embodiment of the above embodiments and~~first, second, third and fourth~~ aspects, the oil is recycled from the biofuel.

In one embodiment of the above embodiments and second~~second, third and fourth~~ aspects, said treating provides a biofuel product comprising a first oil phase comprising: oil from said oil-based solvent and bio-oil derived from said organic matter; an aqueous phase comprising dissolved organic compounds; and a solid phase comprising a calorific char.

In one embodiment of the above embodiments and second~~second, third and fourth~~ aspects, said treating additionally provides a gaseous phase.

In one embodiment of the above embodiment~~fourth aspect~~, said cooling and releasing provides a biofuel product comprising a first oil phase comprising: oil from said oil-based solvent and bio-oil derived from said organic matter; an aqueous phase comprising dissolved organic compounds; and a solid phase comprising of a calorific char.

In one embodiment of the first aspect, said releasing additionally provides a gaseous phase.

In one embodiment of the above embodiments and~~first, second, third and fourth~~ aspects, said biofuel product further comprises a second oil phase comprising oil that is more polar than oil of said first oil phase. In another embodiment~~a fifth aspect~~, the present disclosure~~invention~~ provides a biofuel produced by the method of the above embodiments and~~first, second or third~~ aspects.

In one embodiment of the above embodiments and~~first, second, third, fourth and fifth~~ aspects, the biofuel is a bio-oil.

Brief Description of the Drawings

A preferred embodiment of the present invention will now be described, by way of an example only, with reference to the accompanying drawings wherein:

Figure 1 is a schematic flow diagram showing an apparatus for converting organic matter into biofuel in accordance with an embodiment of the invention. Boxed numbers 1-12 correspond to stream nos. 1-12 shown in **Table 1** below (left column) which provide exemplary stream composition characteristics.

Table 1: exemplary stream composition characteristics using a particular biomass feedstock

	Composition as WT%							
stream no.	water	water borne organics	biomass (DB)	oil (DB)	additives	reaction gases	quantity (tonnes/hr)	temp (°C)
1	20	0	79	0	1	0	31.6	25
2	15	0	39.5	45	0.5	0	63.1	90.6
3	15	0	39.5	45	0.5	0	63.1	90.6
4	15	0	39.5	45	0.5	0	63.1	350
5	15	2.4	0	62.4	0.5	20	63.1	350
6	15	2.4	0	62.4	0.5	20	63.1	150
7	10	0	0	0	0	90	13.7	25
8	70.3	24.5	0	0	5.2	0	6.1	150
9	10	0	0	90	0	0	43.3	150
10	70.3	24.5	0	0	5.2	0	6.1	25
11	10	0	0	90	0	0	11.8	25
12	10	0	0	90	0	0	31.6	150