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(54) Title: FRACTIONATION PROCESS OF LIGNOCELLULOSIC BIOMASS PRODUCING RICH BIOGENIC CARBON PRODUCTS

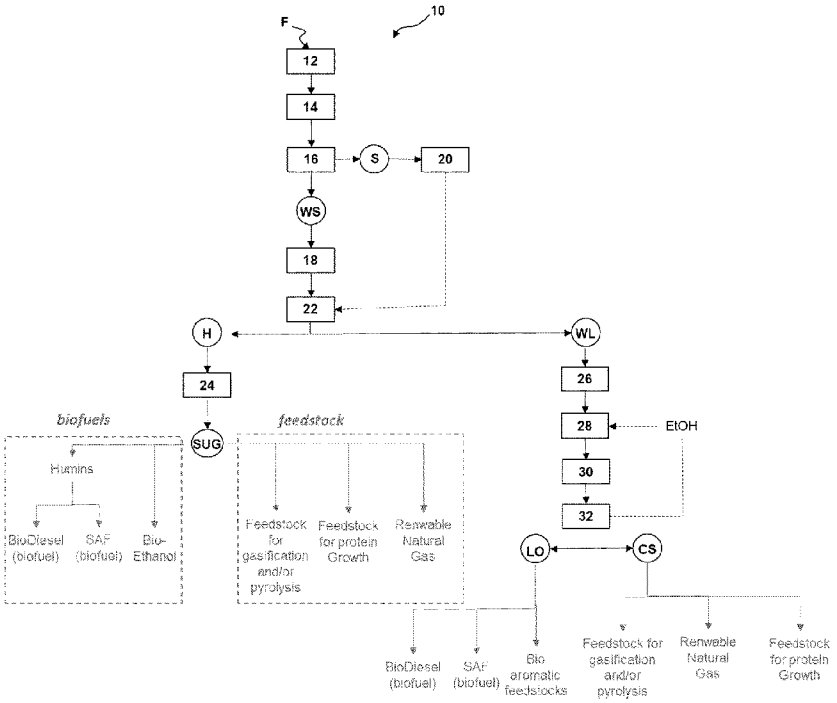

Fig. 1

(57) Abstract: It is provided a fractionation process of a lignocellulosic biomass feedstock producing biogenic carbon products comprising impregnating the lignocellulosic biomass feedstock with water producing an impregnated wet solid fraction after draining the liquid; raising the temperature of the impregnated wet solid fraction by adding steam producing steamed wet solids; adding water to said steamed wet solids to a ratio of liquid to solids below 16 obtaining a mixture of liquid and steamed wet solids; filtering the mixture of liquid and steamed wet solids producing an hydrolysate fraction and a wet solid fraction; concentrating the hydrolysate fraction to obtain a concentrated sugar solution which can be converted into humins; drying the wet solid fraction and mixing the dried wet solid fraction in an ethanol solution containing a mineral acid producing a slurry; heating the slurry and filtering the heated slurry producing a liquid phase, a solid cake containing lignin oligomers convertible into biofuels and an acid-impregnated cellulose-rich residue.

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FRACTIONATION PROCESS OF LIGNOCELLULOSIC BIOMASS PRODUCING RICH BIOGENIC CARBON PRODUCTS

CROSS-REFERENCE TO RELATED APPLICATION

[0001] The present application is claiming priority from U.S. Provisional Application No. 63/491,542 filed March 22, 2023, the content of which is hereby incorporated by reference in its entirety.

TECHNICAL FIELD

[0002] It is described a fractionation process for producing biogenic carbon product and/or intermediates from a lignocellulosic biomass feedstock.

BACKGROUND

[0003] Lignocellulosic biomass being 100% biogenic, represent a desirable feedstock, and a CO_2 source for conversion to diversified marketable bioproducts. Lignocellulosic biomass brings to the market numerous common biomaterials (lumber, pulp fibers and particle boards), and biomass-derived chemicals produced by bio-catalytic and/or thermo-catalytic synthesis. Such biomass-derived chemicals will be, progressively, part of a new generation of sustainable products (plastics, composites, surfactants, etc.) incorporating biogenic carbon (from the lignocellulosic biomass) and/or recycled carbon (from postconsumer plastics today made from fossil-only feedstock.

[0004] Good quality biomass (acceptable in traditional sectors and in chemical/fuel sectors) is expensive. In the North-East of North America the cost of clean chips entering any type of conversion system, is in the range of 100 – 120 USD/metric ton, dry basis (hence-to-forth: metric ton = t; dry basis = d.b.). This translates into 5.6 – 6.7 USD/GJ, lower than the trading cost of crude oil and significantly lower than refined hydrocarbons given that naphta, kerosene and diesel have trading market prices typically 30% above those of crude oil (with no distribution costs or taxes considered).

[0005] Postconsumer biomass is available in populated areas of North-America, albeit in limited quantities, as low-cost shredded biomass-rich material from sorting centers. Mainly used for co-generation (via combustion with air to achieve complete oxidation of the feedstock) to produce heat and power in plants where contaminants can be handled conveniently in the flue gas. It can also be converted (via partial oxidation) into “producer gas” (an old terminology for low calorific value gas). Such “producer gas”,

when derived from O_2 / steam - driven gasification is known as syngas. The syngas can be cleaned, conditioned, and further converted into synthesis gas (CO and H_2) which, once free of contaminants, can be used as clean gaseous feedstock as developed by Enerkem Inc. which uses this route to produce e.g. methanol.

[0006] Current technologies to convert lignocellulosic residues into biofuels are still conceived on the notion of large availability of biomass (0.5 – 1.0 million tonnes/y, dry basis). However, a new reality is emerging: the need to focus on sustainable agro-forestry, regional development, diversification of biomass species, and prudent capital markets.

[0007] It is thus highly desired to be provided with a conversion process that will be financially and commercially attractive by efficiently using the biogenic feedstock in a sustainable manner.

SUMMARY

[0008] In accordance with the present description, there is provided a fractionation process for producing biogenic carbon product comprising providing a lignocellulosic biomass feedstock; impregnating the lignocellulosic biomass feedstock with water producing an impregnated wet solid fraction after draining the free liquid, the latter is reused for the next impregnation step; raising the temperature of the impregnated wet solid fraction by adding steam producing steamed wet solids; adding water to said steamed wet solids to a ratio of liquid to solids below 25 obtaining a mixture of liquid and steamed wet solids; filtering the mixture of liquid and steamed wet solids producing an hydrolysate fraction and a wet solid fraction; concentrating the hydrolysate fraction to obtain a concentrated sugar solution; drying the wet solid fraction and mixing the dried wet solid fraction in an ethanol solution containing a mineral acid producing a slurry; heating the slurry and filtering the heated slurry producing a liquid phase, a solid cake containing lignin oligomers and acid-impregnated cellulose-rich residue; and removing the liquid phase.

[0009] In an embodiment, the lignocellulosic biomass feedstock is mechanically pretreated by debarking and chipping the biomass to produce a fraction of clean chips or shreds and a fraction of fines.

[0010] In a further embodiment, the fraction of clean chips or shreds are of a dimension of up to 50 mm and the fraction of fines are of a dimension of less than 6 mm. In an embodiment, the fines can be added to the clean chips or shreds.

[0011] In a further embodiment, the lignocellulosic biomass feedstock is between 6 mm and 50 mm in dimension.

[0012] In a further embodiment, the lignocellulosic biomass feedstock is impregnated at a temperature between 20 to 70°C.

[0013] In another embodiment, the lignocellulosic biomass feedstock is impregnated with water at a weight ratio of the water to the solid below 12.

[0014] In an embodiment, the pH of the lignocellulosic biomass feedstock and water is adjusted by the addition of an acid or base during the impregnating step.

[0015] In another embodiment, the impregnated wet solid fraction is charged in a vessel for raising the temperature by adding steam.

[0016] In a further embodiment, the temperature of the impregnated wet solid fraction is raised up to 230°C for less than 5 mins.

[0017] In another embodiment, the vessel is decompressed by discharging the steam and the mixture of liquid and steamed wet solids into a reservoir.

[0018] In an embodiment, the mixture of liquid and steamed wet solids is maintained at a ratio of liquid to solids below 16 in the reservoir.

[0019] In a further embodiment, the discharged steam is further separated via a cyclonic device and condensed producing condensed water which is recycled.

[0020] In another embodiment, wherein the mixture of liquid and steamed wet solids is filtered in a filter press to recover a liquid (hydrolysate) and a wet solid fraction.

[0021] In an embodiment, the wet solid fraction is dried to a 5-10 wt% moisture.

[0022] In a further embodiment, the dried wet solid fraction is mixed in an ethanol solution comprising 0.25 M HCl.

[0023] In another embodiment, the slurry is heated to a temperature of 180 to 220 °C.

[0024] In an embodiment, the process described herein further comprises converting the hydrolysate or sugars into humins.

[0025] In a further embodiment, the humins are high calorific value feedstock for gasification and/or pyrolysis.

[0026] In another embodiment, the humins are feedstock to derive hydrocarbon biofuels.

[0027] In another embodiment, the hydrocarbons are in the naphtha, kerosene, and diesel ranges.

[0028] In an embodiment, the process described herein further comprises converting the hydrolysate or sugars into bioethanol.

[0029] In an embodiment, the process described herein further comprises converting the concentrated sugar solution into a substrate for protein growth

[0030] In an embodiment, the process described herein further comprises converting the hydrolysate into a substrate for mycoprotein growth.

[0031] In an embodiment, the process described herein further comprises converting the lignin oligomers and humins into biofuels by de-oxygenation and hydrocracking step.

[0032] In a further embodiment, wherein the biofuels are bionaphtha, biokerosene (known as SAF) or middle distillate (known as biodiesel).

[0033] In an embodiment, the process described herein further comprises converting the lignin oligomers into a bio-aromatic feedstock.

[0034] In an embodiment, the process described herein further comprises converting the cellulose-rich residue into renewable natural gas.

[0035] In an embodiment, the process described herein further comprises converting the cellulose-rich residue into a feedstock suitable for protein growth.

[0036] In a further embodiment, at least 90 %, preferably 96.1% of the carbon present in the lignocellulosic biomass feedstock is recycled.

BRIEF DESCRIPTION OF THE DRAWINGS

[0037] Reference will now be made to the accompanying drawings.

[0038] Fig. 1 illustrates a flow-chart diagram of the process described herein in accordance to an embodiment.

[0039] It will be noted that throughout the appended drawings, like features are identified by like reference numerals.

DETAILED DESCRIPTION

[0040] In accordance with the present disclosure, there is provided an energy self-sustaining process that can use any lignocellulosic biomass at its natural moisture content.

[0041] It is described a fractionation process for producing biogenic carbon product from a lignocellulosic biomass feedstock.

[0042] Lignocellulosic biomass feedstock can be forestry and/or agricultural (i.e. agro-forestry) feedstocks or residues (i.e. waste materials) such as ICI (industrial, commercial, and institutional) wood biomass, or energy crops.

[0043] The process described herein has the option of not requiring the use of fossil fuel energy to provide the heat and power needed by the conversion process, and provides a mean to use available low-cost biomass that, economically, can compete with fossil alternatives.

[0044] In an embodiment, the fractionation process described herein comprises providing a lignocellulosic biomass feedstock; impregnating the lignocellulosic biomass feedstock with water, an acid and/or a base producing an impregnated wet solid fraction after draining the liquid; raising the temperature of the impregnated wet solid fraction by adding steam producing steamed wet solids; adding said steamed wet solids to a ratio of liquid to solids below 25, preferably below 12, obtaining a mixture of liquid and steamed wet solids; filtering the mixture of liquid and steamed wet solids producing an hydrolysate fraction and a wet solid fraction (ligno-cellulose); concentrating the hydrolysate fraction to obtain a concentrated sugar solution (hemicellulose-rich) which can be upgraded to humins or fermented to ethanol or used as a substrate for fungal protein growth or upgraded to renewable natural-gas (RNG); drying the wet solid fraction and mixing the dried wet solid fraction in an ethanol solution or other solution with appropriate polarity and solvency, containing a mineral acid producing a slurry; heating the slurry and filtering the heated slurry producing a liquid phase, a solid cake containing lignin oligomers which can be upgraded to bio diesel and/or sustainable aviation fuel (SAF), and acid-impregnated cellulose-rich residue which can be upgraded to renewable natural gas or used as a substrate for fungal protein production; and removing the liquid phase. Sugars (from hemicelluloses and from cellulose) are upgraded into humins using a thermal dehydration treatment followed by a filtration step. Alternatively, sugars can be purified for

fermentation into bioethanol, and a residual substrate for microbial protein production, or purified and upgraded for RNG production.

[0045] As illustrated in Fig. 1, the process **10** described herein comprises a first step **12** of impregnating a lignocellulosic biomass feedstock **F** with water followed by a steam treatment **14**.

[0046] The lignocellulosic biomass feedstock can be e.g., but not limited to, pretreated first by debarking and chipping the biomass to produce a first fraction comprising clean chips or shreds and a second fraction comprising bark and fines of smaller sizes. In an embodiment, said first fraction has as characteristic dimension of up to 50 mm. The second fraction of bark and fines is smaller in size, such as e.g. < 6 mm. Debarking and chipping of the biomass produces a fraction of clean chips or shreds having as characteristic dimension, up to 50 mm; and a second fraction of bark and fines (the latter < 6 mm).

[0047] Thus, the lignocellulosic biomass feedstock **F**, once harvested, is reduced in size to the required dimensions for effective heat and mass transfer. Typically, a range comprised between 6 mm and 50 mm is targeted. Such size reduction can be done at the forest or plantation roads or at a “biomass preparation room” of a conversion plant.

[0048] During the impregnation step **12**, the temperature can be between 20 to 70°C with water whose pH can be controlled in an embodiment at 0.30 to 1.00 wt% by the addition of e.g., but not limited to, sulfuric acid. Other mineral acids are also encompassed. As encompassed herein, acid and bases can be added depending on the feedstock constitution. The weight ratio of the water phase to the solids (dry basis) is kept at, or below, 12. The impregnation step **12** can be conducted in a reservoir. In an embodiment, simple reservoirs operating in batch mode (for the biomass) can saturate the chips with the aqueous fraction at the desired acid concentration. An impregnated wet fraction can be recovered after draining the liquid. The latter is reused for subsequent impregnations. A purge is sent to a wastewater treatment plant when needed.

[0049] After draining the liquid, a wet solid fraction is charged into a vessel of appropriate configuration where, once closed, steam is added **14**. Temperature of the wet solids fraction is raised rapidly by the added steam and maintained for a few minutes following a programmed sequence given by a severity factor: $Ro = t \exp[(T-273)/14.75]$, where t is time (min) and T, is temperature (in K). Depending on the programmed sequence, T can be raised up to 230 °C and time t (at T) is maintained for the needed

period to satisfy the programmed choice of Ro, typically comprised between log Ro = 2 and 4.

[0050] Decompression **16** in the vessel is accomplished by e.g. opening a valve, preferentially a ball valve, located at the exit of the bottom section of the vessel. Decompression **16** is essentially instant as the wet solids **WS** or steamed wet solids, and the steam **S** are discharged out of the vessel via a conduit that brings them into a reservoir where the entrained solids plunge **18** and stay into a volume of water. Excess steam, now near atmospheric pressure, is separated via a cyclonic device **20** and condensed in a separate vessel. The condensed water is reused after filtration of the entrained solids. The liquid plus the plunged solids go to a filter press **22** where the separation of the liquid phase, the "hydrolysate" **H**, containing the solubilized hemicelluloses or sugars, and the "wet solids" (i.e., the wet lignocellulose **WL**) is carried out. Liquid can be reused (with some addition of water (fresh or condensed) to maintain the liquid-to-solid ratio at about 10 – 12 for a subsequent charge/discharge cycle.

[0051] A second filtration of a purge of liquid can be used to separate the fines that may be present. Such second filtration produces a clean filtered phase. Fines recovered are part of the "biomass residual fractions" that will eventually make the final biogenic residue, 100% biogenic, to be used once dried to less than 20 wt% moisture, for thermochemical conversion.

[0052] The filtered phase, the hydrolysate, goes to a concentration section **24** that may comprise a reverse osmosis unit and/or a multiple effect evaporator. Concentration of sugars in the liquid phase hydrolysate, yielding a first intermediate, can be readily controlled and molasses having between 10 and 50 wt% sugars obtained. The concentrated sugars solution **SUG** is the first bio-intermediate produced as provided herewith.

[0053] The wet ligno-cellulose recovered from the filter press **22** are dried **26** to 5 – 10 wt% moisture. It is then slurried **28** in an ethanol solution (methanol can be used as well) that contains 0.25 M HCl as mineral acid. The ratio solution/ligno-cellulose = 12-13 wt/wt). The slurry is heated **30** to 180 – 200 °C for, typically 15 min under which hydrolysis occurs and also the lignin becomes solubilized in the ethanol or methanol. After cooling, the slurry is cooled and filtered **32**. The liquid phase containing the lignin and the ethanol (or methanol) is evaporated/distilled. The alcohol is recovered and reused for a new organo-solve cycle. The solid cake are the lignin oligomers **LO**, the second bio-intermediate produced as provided herewith. Their yield is about 20 wt% of

the initial biomass used. The acid-impregnated cellulose-rich residue **CS**, is the third bio-intermediate produced. It contains the insoluble lignin and thus, its calorific value is higher than that of cellulose.

[0054] From the first bio-intermediate, the sugars concentrate **SUG,** biofuels and feedstock can be produced. The C6 sugars can also be fermented to bio-ethanol. Only requirement is to proceed to a purification step.

[0055] In an embodiment, the concentrated sugars (SUG) are preferentially dehydrated thermally under acidic conditions producing humins. The humins structure, made of cyclic nuclei linked through linear -CH_2- fragments is ideal for either catalytic hydroprocessing to hydrocarbons by adding hydrogen or as a high calorific biogenic feedstock for processes such as gasification or pyrolysis.

[0056] The concentrated sugars solution (SUG) can also be used as prime substrates for mycoprotein growth.

[0057] The concentrated sugars solution (SUG) can also be used as prime feedstocks for renewable natural gas production.

[0058] The second bio-intermediate, the lignin oligomers or bio-aromatics can be hydroprocessed, but not limited to, in two catalytic steps: a de-oxygenation step followed by a hydrocracking step to produce biofuels. The marketable products are e.g. but not limited to, naphtha, kerosene and middle diesel distillate. The lignin oligomers can also be converted into a bio-aromatic feedstock, suitable e.g. for a refinery cracker.

[0059] The third bio-intermediate, the cellulose-rich residue, after washing to remove the mineral acid, can be used, but not limited, for the production of heat or renewable natural gas.

[0060] Alternatively, the third bio-intermediate, the cellulose-rich residue, after washing to remove the mineral acid, can also be used as a substrate for mycoprotein growth.

[0061] As provided herewith, it has been estimated that the typical yields, from 1 tonne coniferous biomass, are as example:

-0.26 t hemicellulosic sugars (**SUG**): which can be upgraded to humins, ethanol, or used a substrate for mycoprotein growth;

-0.14 t lignin oligomers (**LO**) which can be converted to drop-in biofuels at a refinery hub;

-0.47 t cellulose, which is directly usable as defibrillated fiber (tissue market), can be depolymerized to C6 sugars and feed for fermentation or for conversion, and usable for anaerobic fermentation producing biogas from which bio-CH_4 and, ultimately "green H_2" can be produced, or a substrate for mycoprotein production.

[0062] As provided herewith, the process described herein allows for a "hub and spoke" approach. It is based on compact "regional satellite plants" deconstructing and fractionating regionally available sustainable biomass (20 - 60 ktonnes biomass/y, dry basis, per plant) into bio-intermediates. The latter are to be produced by a network of regional "satellite plants" or spokes and upgraded in established or new bio-fermentation and thermo-catalytic chemicals plants (hubs). The bio-intermediates can thus be transported or to various specialised plants (hubs) which will use the bio-intermediates and converting them into finished products.

EXAMPLE I

Overall efficiency of the fractionation process of wood

[0063] As provided in Table 1 below, following the process described herein, near 100% or about 96.1% of the carbon is recycled.

Steam Treatment (step 12)	***Hemicellulose (H)***	***Wet solids (WL lignocellulose)***		**Total Solids Balance**	**Carbon Balance**
	26.4% (TS)	*61.7 % (TS))*		88,0%	96,1%
	22.2% (C)	*73.9% (C)*			
Step 25: hemicellulose upgrading to humins	*13.3% (TS)*	-		50,4%	85,1%
	18.9% (C)	-			
Step 25a: humins to SAF	*8.9% (TS)*	-		66,9%	92,1%
	17.4%(C)	-			
WL Separation (steps 26-32)	-	**Lignin**	**Cellulose-rich residue**		
	-	*13.4% (TS)*	44.1% (TS)	93,2%	95,4%
	-	*19.1% (C)*	51.4% (C)		

Note: (i) Basis = 100 TS (49.7% C) of dry biomass (softwood); (ii) TS = total Solids; (iii) C = carbon

[0064] While the present disclosure has been described in connection with specific embodiments thereof, it will be understood that it is capable of further modifications and this application is intended to cover any variations, uses, or adaptations and including such departures from the present disclosure as come within known or customary practice within the art and as may be applied to the essential features hereinbefore set forth, and as follows in the scope of the appended claims.

WHAT IS CLAIMED IS:

1. A fractionation process for producing biogenic carbon products comprising:

providing a lignocellulosic biomass feedstock;

impregnating the lignocellulosic biomass feedstock with water producing an impregnated wet solid fraction after draining the liquid, the liquid is reused in a next impregnation step;

raising the temperature of the impregnated wet solid fraction by adding steam producing steamed wet solids;

adding water to said steamed wet solids to a ratio of liquid to solids below 25 obtaining a mixture of liquid and steamed wet solids;

filtering the mixture of liquid and steamed wet solids producing an hydrolysate fraction and a wet solid fraction;

concentrating the hydrolysate fraction to obtain a concentrated sugar solution;

drying the wet solid fraction and mixing the dried wet solid fraction in an ethanol solution containing a mineral acid producing a slurry;

heating the slurry and filtering the heated slurry producing a liquid phase, a solid cake containing lignin oligomers and acid-impregnated cellulose-rich residue; and

removing the liquid phase.

2. The process of claim 1, wherein the lignocellulosic biomass feedstock is mechanically pretreated by debarking and chipping the biomass to produce a fraction of clean chips or shreds and a fraction of fines.

3. The process of claim 2, wherein the fraction of clean chips or shreds are of a dimension of up to 50 mm and the fraction of fines are of a dimension of less than 6 mm.

4. The process of any one of claims 1-3, wherein the lignocellulosic biomass feedstock is between 6 mm and 50 mm in dimension.

5. The process of any one of claims 1-4, wherein the lignocellulosic biomass feedstock is impregnated at a temperature between 20 to 70°C.

6. The process of any one of claims 1-5, wherein the lignocellulosic biomass feedstock is impregnated with water at a weight ratio of the water to the solid below 12.

7. The process of any one of claims 1-6, wherein the pH of the lignocellulosic biomass feedstock and water is adjusted by the addition of an acid or base during the impregnating step.

8. The process of any one of claims 1-7, wherein the impregnated wet solid fraction is charged in a vessel for raising the temperature by adding steam.

9. The process of any one of claims 1-8, wherein the temperature of the impregnated wet solid fraction is raised up to 230°C for less than 5 mins.

10. The process of claim 8, wherein the vessel is decompressed by discharging the steam and the mixture of liquid and steamed wet solids into a reservoir.

11. The process of claim 10, wherein the mixture of liquid and steamed wet solids is maintained at a ratio of liquid to solids below 16 in the reservoir.

12. The process of claim 10, wherein the discharged steam is further separated via a cyclonic device and condensed producing condensed water which is recycled.

13. The process of any one of claims 1-12, wherein the mixture of liquid and steamed wet solids is filtered in a filter press to recover a liquid (hydrolysate) and a wet solid fraction.

14. The process of any one of claims 1-13, wherein the wet solid fraction is dried to a 5-10 wt% moisture.

15. The process of any one of claims 1-14, wherein the dried wet solid fraction is mixed in an ethanol solution comprising 0.25 M HCl.

16. The process of any one of claims 1-15, the slurry is heated to a temperature of 180 to 220 °C.

17. The process of any one of claims 1-16, further comprising converting the hydrolysate or sugars into humins.

18. The process of claim 17, wherein the humins are high calorific value feedstock for gasification and/or pyrolysis.

19. The process of claim 17, wherein the humins are feedstock to derive hydrocarbons biofuels.

20. The process of claim 19, wherein the hydrocarbons are in the naphtha, kerosene, and diesel ranges.

21. The process of any one of claims 1-16, further comprising converting the hydrolysate or sugars into bioethanol.

22. The process of any one of claims 1-16, further comprising converting the concentrated sugar solution into a substrate for protein growth

23. The process of any one of claims 1-16, further comprising converting the hydrolysate into a substrate for mycoprotein growth.

24. The process of any one of claims 1-16, further comprising converting the hydrolysate into a renewable natural gas.

25. The process of any one of claims 1-24, further comprising converting the lignin oligomers and humins into biofuels by de-oxygenation and hydrocracking step.

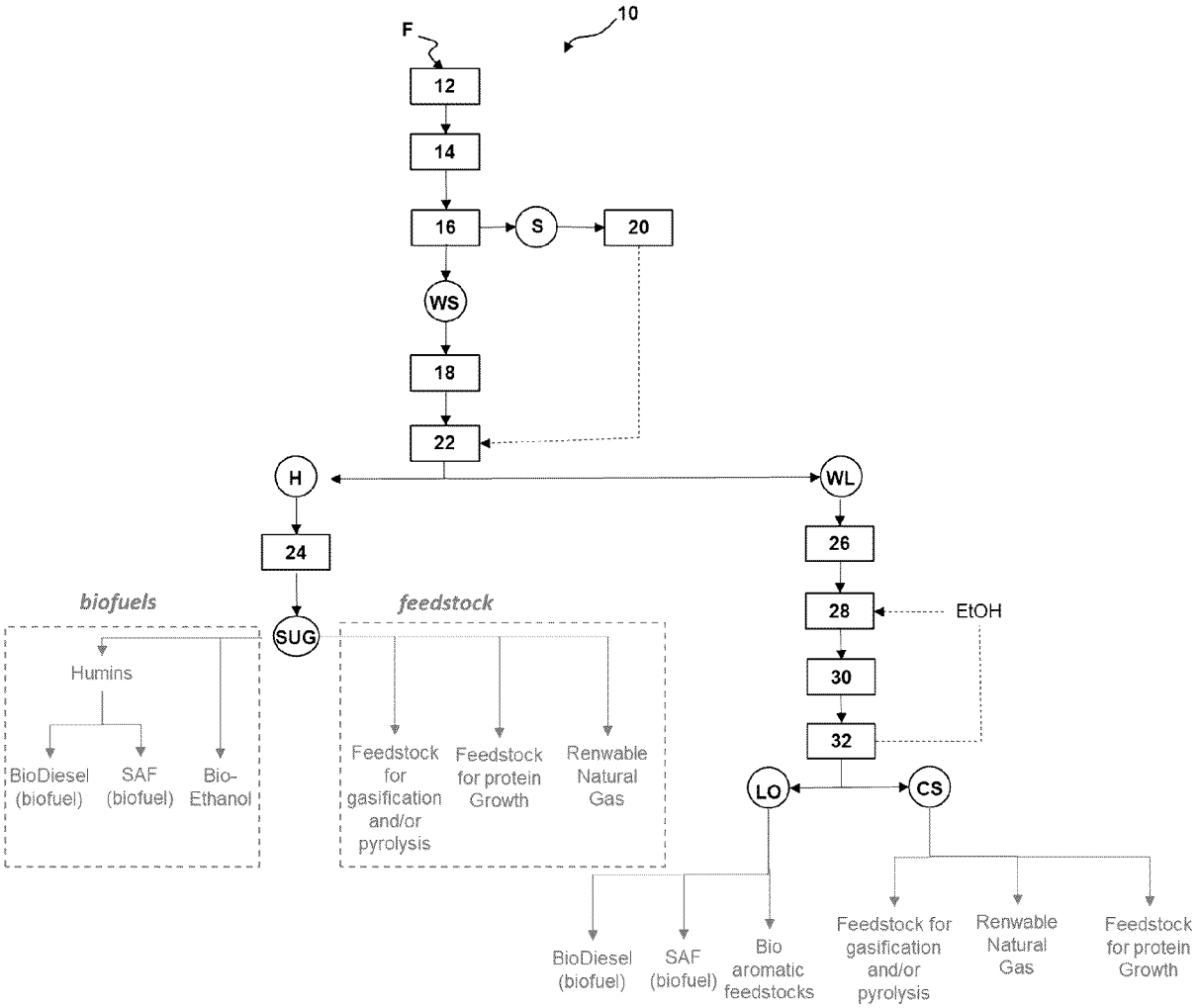
26. The process of claim 25, wherein the biofuels are bionaphtha, biokerosene or middle distillate.

27. The process of any one of claims 1-26, further comprising converting the lignin oligomers into a bio-aromatic feedstock.

28. The process of any one of claims 1-27, further comprising converting the cellulose-rich residue into renewable natural gas.

29. The process of any one of claims 1-27, further comprising converting the cellulose-rich residue into a substrate for protein growth.

30. The process of any one of claims 1-29, wherein at least 90%, preferably 96.1% of the carbon present in the lignocellulosic biomass feedstock is recycled.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Feedstock for protein Growth
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Bio aromatic feedstocks
Feedstock for gasification and/or pyrolysis
Renwable Natural Gas
Feedstock for protein Growth

Fig. 1

INTERNATIONAL SEARCH REPORT

International application No.
PCT/CA2024/050302

A. CLASSIFICATION OF SUBJECT MATTER

IPC: ***C08H 8/00*** (2010.01), ***C08B 1/00*** (2006.01), ***C08H 7/00*** (2011.01), ***C08J 11/14*** (2006.01), ***C10G 1/00*** (2006.01), ***C12P 7/10*** (2006.01) (more IPCs on the last page)

CPC: **C08H 8/00** (2020.01), C08B 1/00 (2020.01), C08H 6/00 (2020.01), C08J 11/14 (2020.01), C10G 1/00 (2020.01), C12P 7/10 (2020.01) (more CPCs on the last page)

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC: ***C08H 8/00*** (2010.01), ***C08B 1/00*** (2006.01), ***C08H 7/00*** (2011.01), ***C08J 11/14*** (2006.01), ***C10G 1/00*** (2006.01), ***C12P 7/10*** (2006.01), ***C12P 19/02*** (2006.01), ***C12P, 21/00*** (2006.01), ***C13K 1/02*** (2006.01), ***D21C 1/02*** (2006.01) (continued on the last page)

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic database(s) consulted during the international search (name of database(s) and, where practicable, search terms used)
Databases: Questel Orbit, STN Caplus
Keywords: lignocellulosic biomass, feedstock, steam, ethanol, filter, mechanical, debarking, chipping, hydrolysate, impregnate, humins, bioethanol, fractionation, separation

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X Y	CA2701194 A1 (Dottori, F. A. et al.) 23 October 2010 (23-10-2010) * Abstract, page 1, pages 7-9 *	1, 5, 6, 8, 13, 14, 16 2-4
Y	WO2013/096698 A1 (Medoff, M. et al.) 27 June 2013 (27-06-2013) * Abstract, paragraphs [0082]-[0085]*	2-4

☐ Further documents are listed in the continuation of Box C. ☒ See patent family annex.

*	Special categories of cited documents:	"T"	later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"A"	document defining the general state of the art which is not considered to be of particular relevance	"X"	document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"D"	document cited by the applicant in the international application	"Y"	document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"E"	earlier application or patent but published on or after the international filing date	"&"	document member of the same patent family
"L"	document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)		
"O"	document referring to an oral disclosure, use, exhibition or other means		
"P"	document published prior to the international filing date but later than the priority date claimed		

Date of the actual completion of the international search 15 May 2024 (15-05-2024)	Date of mailing of the international search report 30 May 2024 (30-05-2024)
Name and mailing address of the ISA/CA Canadian Intellectual Property Office Place du Portage I, C114 - 1st Floor, Box PCT 50 Victoria Street Gatineau, Quebec K1A 0C9 Facsimile No.: 819-953-2476	Authorized officer Yen Truong (873) 355-5080

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		EP2421911B1	18 June 2014 (18-06-2014)
		ES2497568T3	23 September 2014 (23-09-2014)
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		SI2421911T1	30 October 2014 (30-10-2014)
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WO2013096698A1	27 June 2013 (27-06-2013)	AU2012358373A1	05 June 2014 (05-06-2014)
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IPC:
C12P 19/02 (2006.01) , ***C12P 21/00*** (2006.01) , ***C13K 1/02*** (2006.01) , ***D21C 1/02*** (2006.01) , ***D21C 1/10*** (2006.01)

CPC:
C12P 19/02 (2020.01) , C12P 21/00 (2020.01) , C13K 1/02 (2020.01) , D21C 1/02 (2020.01) , D21C 1/10 (2020.01) , C10G 2300/1014 (2020.01)

Continued from Box B
IPC: ***D21C 1/10*** (2006.01)
CPC: **C08H 8/00** (2020.01), C08B 1/00 (2020.01), C08H 6/00 (2020.01), C08J 11/14 (2020.01), C10G (2020.01), C12P 7/10 (2020.01), C12P 19/02 (2020.01), C12P 21/00 (2020.01), C13K 1/02 (2020.01), D21C 1/02 (2020.01), D21C 1/20 (2020.01), C10G 2300/1014 (2020.01)