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(54) Title: PROCESS FOR PRODUCING ALCOHOL AND OTHER BIOPRODUCTS FROM BIOMASS EXTRACTS IN A KRAFT PULP MILL

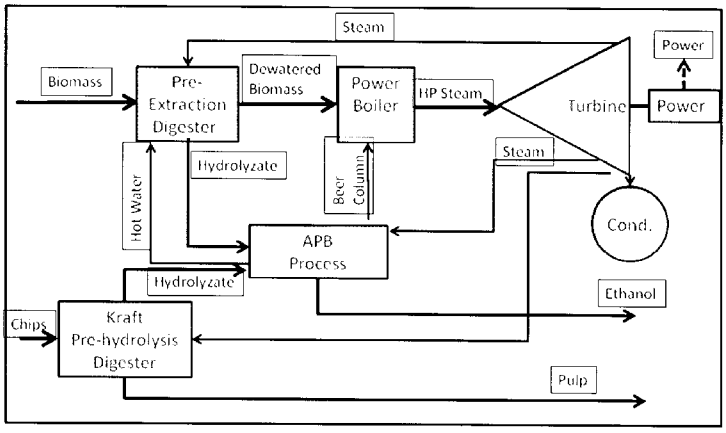

Figure 1. An overall flow sheet example of the invention process.

(57) Abstract: A method for the production of alcohol and other bioproducts from power boiler woody biomass extract containing hemicelluloses, with or without combining extract from wood prior to Kraft cooking. The process is integrated with the host Kraft pulp mill plant process to minimize the heat loss from extracting hemicelluloses and the energy used in the process.

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INVENTION TITLE

PROCESS FOR PRODUCING ALCOHOL AND OTHER BIOPRODUCTS FROM BIOMASS EXTRACTS IN A KRAFT PULP MILL

DESCRIPTION

FIELD OF THE INVENTION

[Para 1] This invention relates, in general, to the process extracting and treating of extracts of biomass prior to a biomass boiler, potentially combined with extract from biomass prior to Kraft process, and treatment of this extract for production of alcohol and other bioproducts in a Kraft pulp mill.

BRIEF DESCRIPTION OF THE DRAWINGS

A more complete understanding of the present invention may be obtained by reference to the following detailed description when read in conjunction with the accompanying drawings wherein:

Figure 1. illustrates a conceptual flow sheet example of the invention process.

Figure 2. illustrates a typical general arrangement of the unit operations for mixed biomass derived extract by steam explosion prior to a power plant combustor.

BACKGROUND OF THE INVENTION

[Para 2] Renewable power generation from forest residues is commonly practiced in the forest products industries. The U.S. forest products industry consumed 27.1 million tons of wood derived biomass, called "hog fuel", in the generation of steam. By comparison, the power generation industry used 11.9 million tons of biomass of which 80% is wood derived. The biomass

consumption in power generation is expected to double in every 10 years until 2030.

[Para 3] The major wood components are lignin, hemicelluloses and cellulose. The steam explosion process dissolves predominantly hemicelluloses in temperatures above 160 °C. Hemicelluloses fraction removed in this process is termed "extract". A concentration of the extract through evaporation is energy intensive, although it is currently practiced to produce molasses.

[Para 4] Previous research indicates that ethanol, acetic acid and their byproducts can be derived from the wood extract. Especially hardwood produces an extract rich in acetic acid and sugars as taught by Amidon et al. in (U.S. Patent Application No. 2007/0079944 A1, April 12, 2007).

[Para 5] The current inventors, Retsina; et al. (United States Patent Filing Number 61175588) have previously described a steam extraction and hydrolysis process, in which an alkaline acetate product is concentrated in reverse osmosis membrane from evaporator condensate. The clean permeate is further recycled to the host mill to achieve zero effluent operation. Furthermore, the current inventors Retsina; et al. (U.S. Patent Application Number 61219764) have described the process integration of the waste heat to temper power boiler feed water.

[Para 6] The current inventors found an alternative method to produce fermented alcohol, ethanol or butanol, from biomass extraction using steam explosion, followed by vapor recompression evaporation, acid hydrolysis, fermentation and distillation. The present inventors have now developed a process, wherein the hemicelluloses in the power plant biomass extract can be converted to chemical products in an energy efficient process.

SUMMARY OF THE INVENTION

The present invention describes a process for the production of alcohol and other bioproducts from power boiler biomass extract, combined or not, with extract from the pretreatment of wood chips prior to Kraft process digestion. Treatment of hemicelluloses in the extract through hydrolysis, evaporation, fermentation and distillation steps is used to recover and concentrate alcohol and acetate products. The process is integrated with the host plant to reuse water and to minimize process energy and water consumption.

DETAILED DESCRIPTION OF THE INVENTION

[Para 7] The first step of the process is biomass extraction. Woody biomass is charged in a batch or continuous reactor vessel along with steam and heated to between 5 and 30 atmospheres pressure for 2 or more minutes to obtain 10-30% of wood as dissolved solids. In one manifestation, this extract is combined with extract from the Kraft mill digester. In the Kraft mill digester, a first stage of steam extraction is practiced prior to the Kraft cooking.

[Para 8] The second step of the process is washing of biomass. The heated biomass is washed with hot water or condensate and drained to recover dissolved wood components. The wash filtrate contains dissolved xylan, glucan, mannan, arbinan, galactan and acetyl groups in oligomers of hemicelluloses as well as lignin. The wash filtrate has low organic solids concentration in between 1% and 15%. The majority of the water must be removed before an economic treatment of hemicelluloses is possible.

[Para 9] The third step of the process is compaction of the biomass. The remaining solid biomass is subjected to mechanical pressure through a plug screw feeder. This compaction dewaters the biomass to uniform moisture of 60% or less, which is similar to delivered biomass from the forest.

[Para 10] The fourth step of the process is low solids evaporation. Evaporation of the wash filtrate or extract using mechanical vapor

recompression is suitable for low solids concentration up to around 25%, because the boiling point rise is small. Evaporated vapor is compressed and condensed in the hot side of the evaporator to produce more evaporation. If the wash filtrate or extract feed concentration is over 5%, this step may be omitted. When the pH is kept below acetic acid dissociation point at 4.8, acetic acid, a fermentation inhibitor, is volatilized to vapor fraction.

[Para 11] The fifth step of the process is hydrolysis. Sulfuric acid or enzymes can be used to hydrolyze the sugars, which were concentrated in the low solids evaporator. Oligomeric hemicelluloses are converted into monomer sugars and acetyl groups are released. The hydrolyzate pH is controlled following the hydrolysis to maintain acetic acid in the unassociated form. Hydrolysis can be performed in batch or continuous mode. As an option at the end of this step, the pH may be adjusted with lime or another chemical and any precipitated solids may be washed and treated separately.

[Para 12] The sixth step of the process is post hydrolysis evaporation. Evaporation using mechanical vapor recompression is performed to concentrate the hydrolyzate to 15% - 35% solids. More of the remaining acetic acid and water is evaporated in this step. Under the appropriate economic criteria, this step could be done with steam evaporation.

[Para 13] The seventh step of the process is fermentation of wood sugars. The sugars in the evaporated hydrolyzate are fermented in continuous or batch tanks with one or more micro-organisms capable of converting five and six-carbon sugars into alcohol and carbon dioxide. The majority of acetic acid, which may inhibit fermentation, was removed in the previous evaporation step. Some additional acetic acid may be formed in the fermentation steps. Nutrients and pH adjustment chemicals, as well as make-up fermentative organism, are added in the fermentors as and if needed. Carbon dioxide is removed from the fermentors and scrubbed with cool water for alcohol recovery. This purified gas can be further compressed and sold as industrial grade carbon dioxide. The fermentation broth, commonly termed "beer", from the fermentation step is sent to a distillation column.

[Para 14] The eighth step of the process is distillation of alcohol. The beer from the fermentation processes is sent to a distillation column to separate the alcohol from the solids and residual sugars. Alcohol leaving as the overhead from the distillation column is recovered at approximately 50 mass-% strength. The final concentration of the alcohol product is performed in a rectifying column and molecular sieve to obtain over 99-mass % alcohol. In one manifestation, the beer column is integrated in the existing Kraft mill multiple-effect evaporator train so that it runs as an effect and avails itself of the multiple effect economy of the Kraft evaporator.

[Para 15] The ninth step of the process is the solids concentration from the stillage. The solids, commonly termed stillage, from the distillation beer column bottom can be further evaporated in an optional mechanical vapor concentrator to achieve zero-liquid discharge operation. The concentrated sludge can be burned in a biomass boiler to increase steam generation. Alternatively, this concentration can happen by injecting the distillation bottoms in the weak black liquor of the existing Kraft mill, so that it is evaporated using multiple-effect economy in the existing Kraft evaporator.

[Para 16] The tenth step of the process is combustion of biomass. The compacted biomass from the third step and concentrated solids from the ninth step are fed to a traditional biomass combustion unit. The heat of combustion is used to raise steam, which drives a steam turbine to generate electricity, or the steam can be used for the process.

[Para 17] In one manifestation of the invention, hydrolysis and fermentation (the seventh and tenth steps) may be combined in one step by using a third party proprietary microorganism.

CLAIMS

Claim 1. A method for the production of alcohol and other bioproducts from power boiler woody biomass extract containing hemicelluloses combined with extract from wood prior to Kraft cooking.

Claim 2. A process according to claim 1, where the alcohol is ethanol.

Claim 3. A process according to claim 1, where the alcohol is butanol.

Claim 4. A process according the claim 1, where the extract from wood prior to Kraft cooking is not practiced.

Claim 5. A process according the claim 1, where the alcohol plant is integrated with the host Kraft pulp mill plant process to minimize the heat loss from extracting hemicelluloses and the energy used in the process.

Claim 6. A process according the claim 1, where steam is used for extracting hemicelluloses from biomass.

Claim 7. A process according the claim 1, where the biomass is compressed to a moisture content of 60% or less after the extraction.

Claim 8. A process according the claim 1, where the biomass extract is concentrated using vapor compression evaporation.

Claim 9. A process according the claim 1, where the hydrolyzed extract is evaporated using vapor compression evaporation.

Claim 10. A process according the claim 1, where the vapor compression evaporation is performed below acetic acid dissociation pH of 4.8.

Claim 11. A process according the claim 1, where the acetate product is recovered.

Claim 12. A process according the claim 1, where a multiple-effect evaporator is integrated with an alcohol distillation beer column.

Claim 13. A process according the claim 1, where distillation column bottoms are evaporated and combusted to achieve zero-liquid discharge.

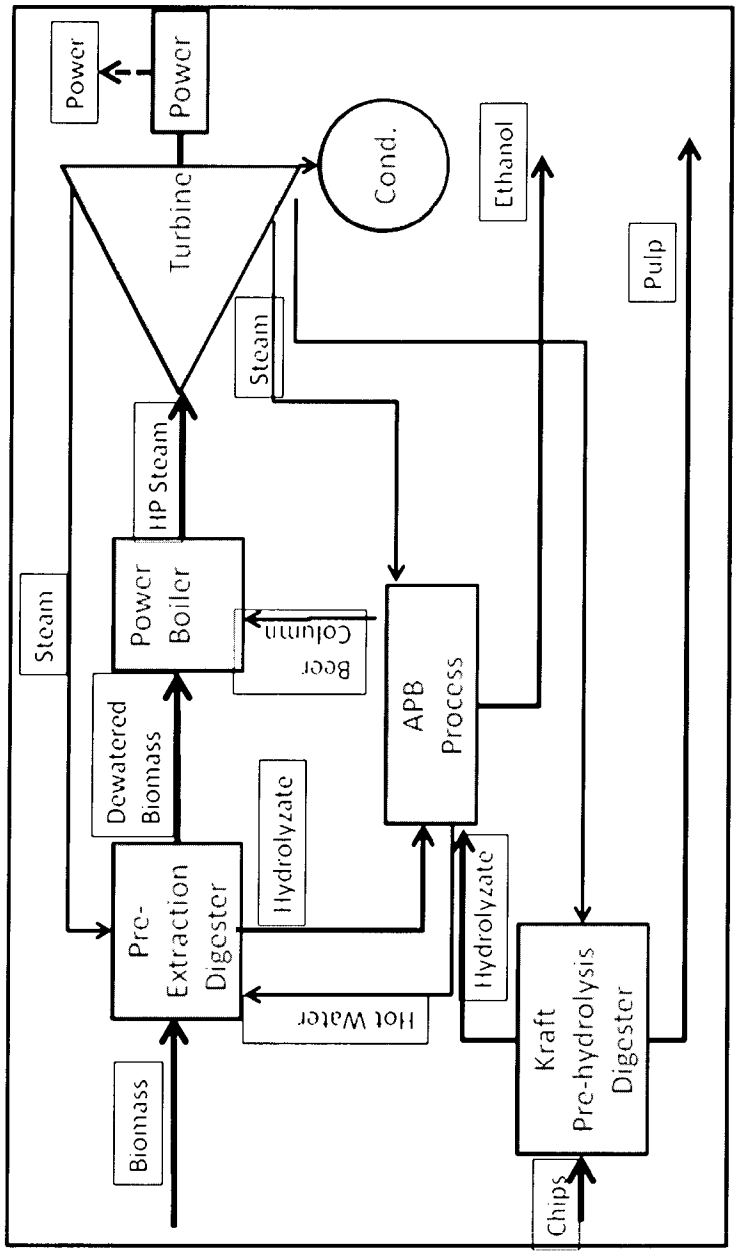

Figure 1. An overall flow sheet example of the invention process.

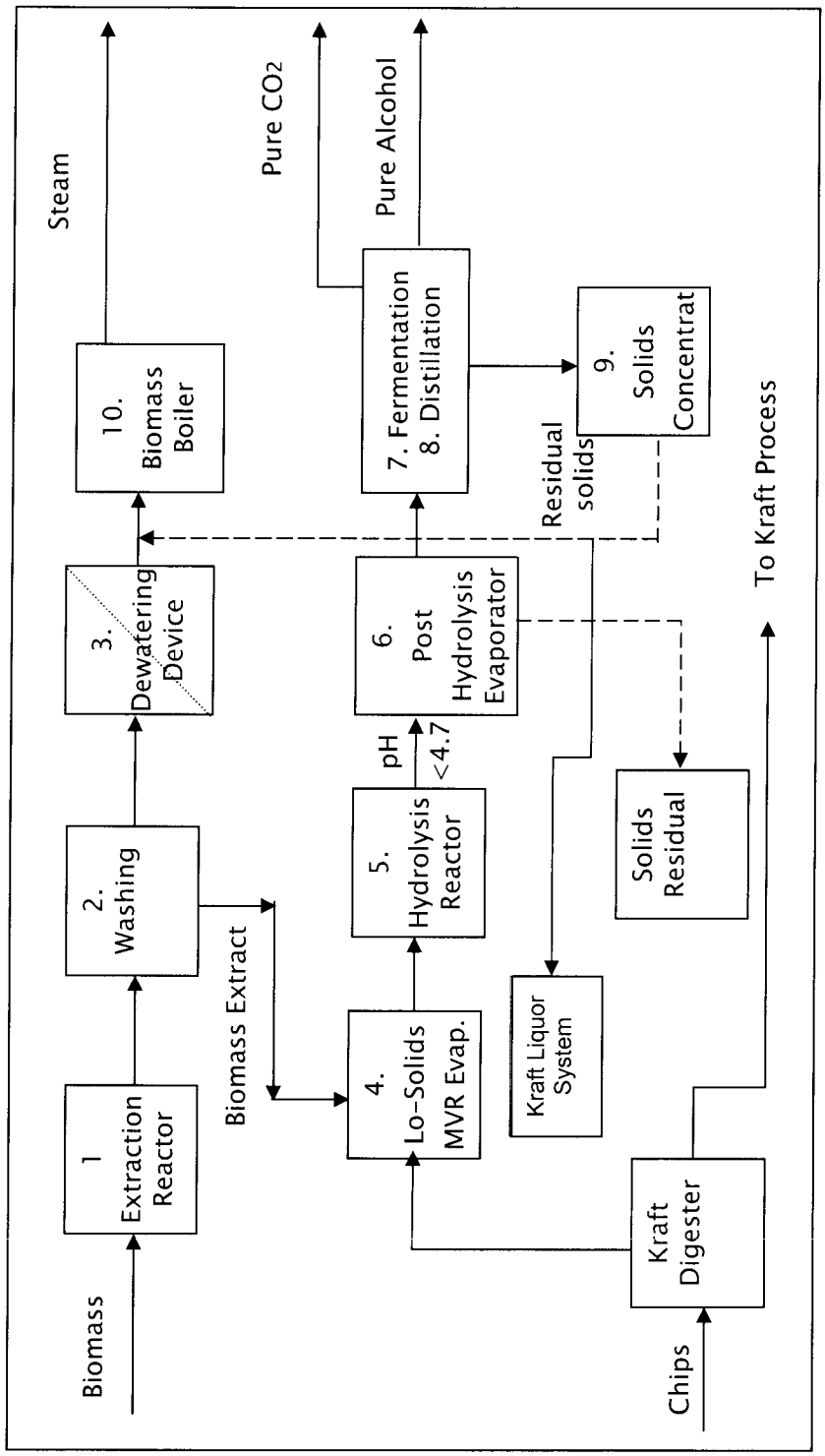

Figure 2. A detailed flow sheet example of the invention process. Process steps may be in other sequences.

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US 10/51759

A. CLASSIFICATION OF SUBJECT MATTER
IPC(8) - D21C 9/00; D21C 11/00 (2010.01)
USPC - 162/16, 14
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(8) -- D21C 9/00; D21C 11/00 (2010.01)
USPC -- 162/16, 14

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
IPC(8) -- D21B; D21C (2010.01)
USPC -- 127/37; 435/161, 165

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
PubWest (PGPB,USPT,USOC,EPAB,JPAB); DialogWeb (File 348 European Patents Fulltext, File 349 WIPO/PCT Patent Fulltext, File 652 US Patents Fulltext (1971-1975), File 654 US Patents Fulltext (1976-present); USPTO; Espacenet; Google Patents; Google Scholar; Google -- please see extra sheet

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X --- Y	US 4,436,586 A (Elmore) 13 March 1984 (13.03.1984) Fig 1; Fig 2; Fig 5; col 31, ln 45; col 4, ln 13-23; col 4, ln 24-59; col 5, ln 37-41; col 11, ln 3-36	1-4 ------- 5-13
Y	US 2007/0051481 A1 (Tan et al.) 08 March 2007 (08.03.2007) para [0020]; [0023]; [0024]	5
Y	US 2008/0057555 A1 (Nguyen) 06 March 2008 (06.03.2008) Fig 1; Fig 3; para [0054]; [0074]; [0106];	6,7
Y	US 2007/0275447 A1 (Lewis et al.) 29 November 2007 (29.11.2007) para [0019]; [0078]	11
Y	WO 2009/053518 A2 (Koistinen et al.) 30 April 2009 (30.04.2009) Page 1, ln 3-9; Page 1, ln 8-10; Page 1, ln 25-26	8-10,12,13
Y	WO 2009/072878 A1 (Kappe et al.) 11 June 2009 (11.06.2009) Page 1, ln 22-26; Page 8, ln 1; Page 8, ln 18-24; Page 9, ln 6-12; Page 9, ln 26 to Page 10, ln 10	8-10,12,13
A	US 2007/0079944 A1 (Amidon et al.) 12 April 2007 (12.04.2007) Fig 3; para [0040]; [0042]; [0043]; [0044]	1-13
A	US 2008/0182305 A1 (Foody et al.) 31 July 2008 (31.07.2008) para [0036]to [0039]	11

☐ Further documents are listed in the continuation of Box C. ☐

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
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"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
"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
"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
"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
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
20 NOVEMBER 2010 (20.11.2010)	15 DEC 2010
Name and mailing address of the ISA/US Mail Stop PCT, Attn: ISA/US, Commissioner for Patents P.O. Box 1450, Alexandria, Virginia 22313-1450 Facsimile No. 571-273-3201	Authorized officer: Lee W. Young PCT Helpdesk: 571-272-4300 PCT OSP: 571-272-7774

INTERNATIONAL SEARCH REPORT

International application No.

PCT/US 10/51759

Search Terms Used:

ACETATE BIOMASS BOILER BURN BUTANOL BUTYL ALCOHOL COMBUST$ DIGEST$ DISTILL$ ETHANOL ETHYL ALCOHOL EXPLOSION EXTRACT$ FERMENT$ HEMICELLULOS$ OR HYDROLYZ$ KRAFT MECHANICAL VAPOR RECOMPRESSION METHANOL MVCE MVR STEAM VAPOR COMPRESSION EVAPORAT$ WOOD CHIPS