中欧农业废弃物循环利用国际会议 , October 22-24,2018

Bio-oil Production from Biomass Fast Pyrolysis and its Upgrading

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There are 8 main parts

1.Introduction to Shanghai JiaoTong University(SJTU)

2.Mechanism of biomass pyrolysis

3.Rotating cone reactor

4.Fluidized bed reactor for biomass fast pyrolysis for bio-oil production developed by SJTU

5. Performance of a commercial-scale biomass fast pyrolysis plant for bio-oil production

6.Hydrodeoxygenation (HDO) of Bio-oil

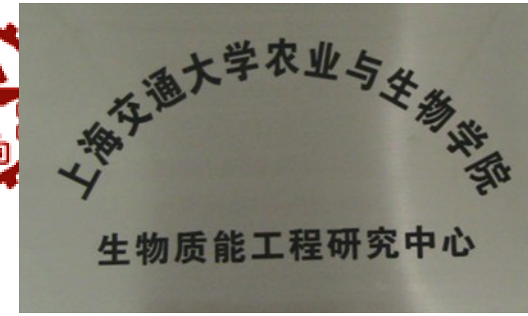
7.Other Biomass Energy Research in SJTU

8. Selected Publications(SCI)

上海交通大學
Shanghai Jiao Tong University

1.Introduction to Shanghai JiaoTong University(SJTU)

- **Established in 1896**
- There are 29 schools, including school of Agriculture and Biology, School of Mechanical and Power Engineering, etc.
- Students:49,838(Undergraduate16,221,graduate30,895, foreign student2,722); Teachers:3,014
- Area of campus: about 333 ha.



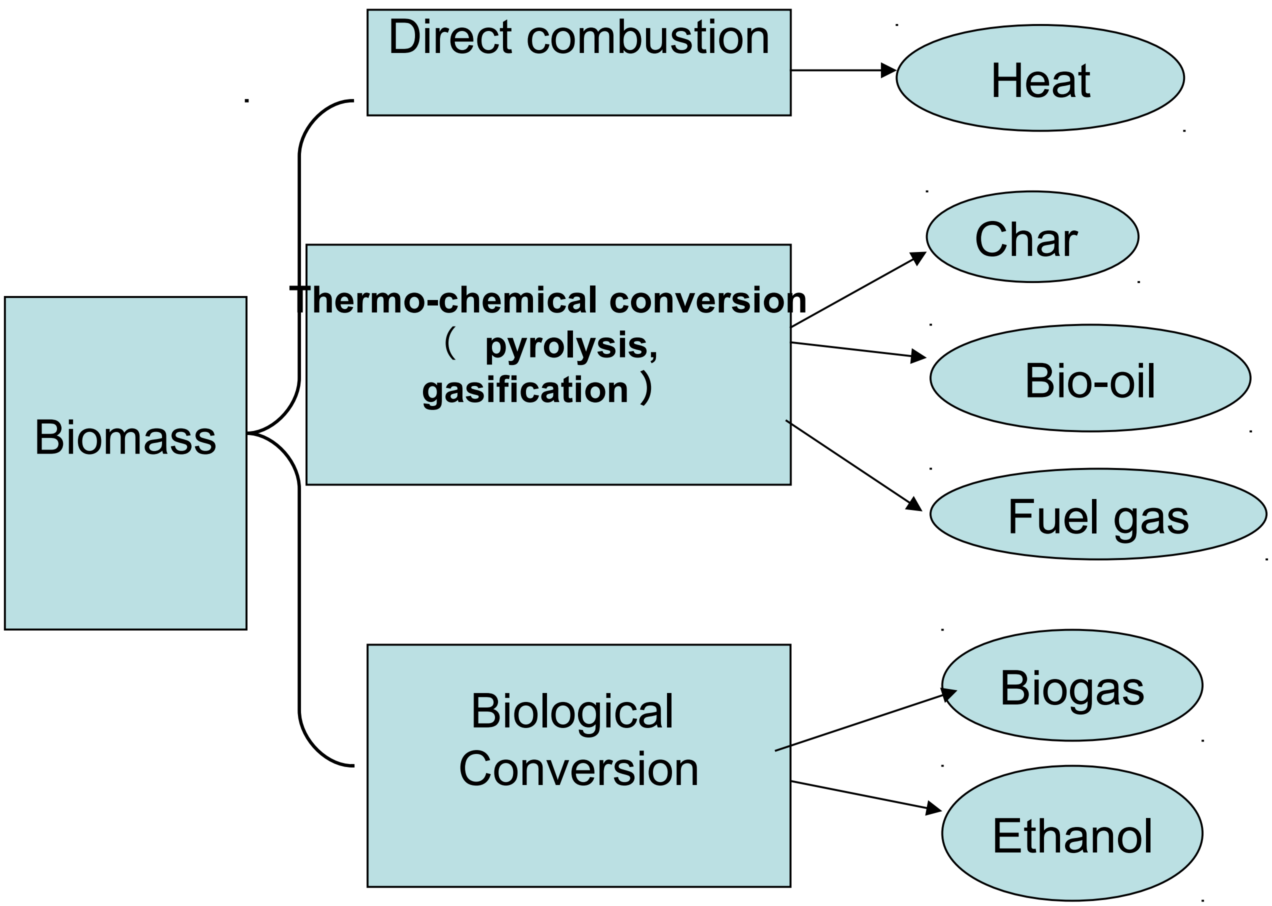
School of Agriculture and Biology (SJTU)

Biomass Energy Engineering Research Centre,

School of Agriculture and Biology , Shanghai JiaoTong University has a lot of experiences in the field of biomass energy and environment,

including characterization of biomass, biomass pyrolysis, biogas ,biochar, gasification, bioethanol, etc.

Biomass energy conversion technologies



2. Mechanism of biomass pyrolysis

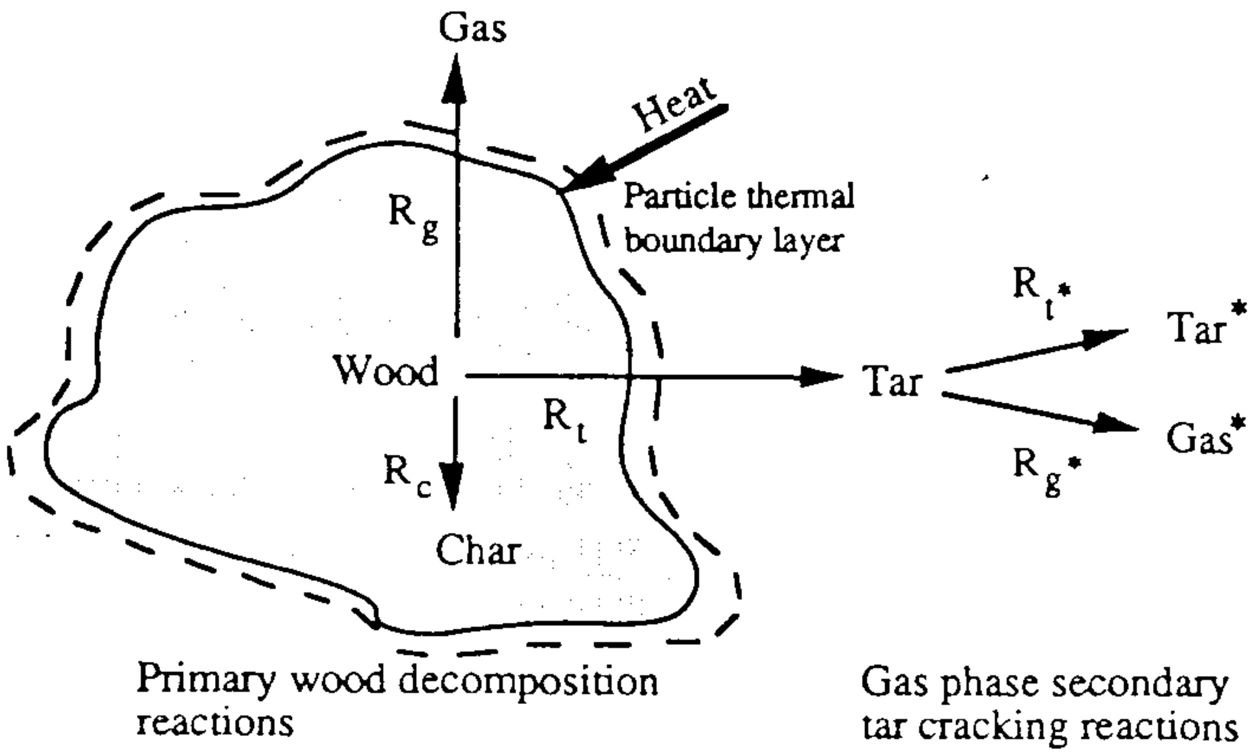


Fig. 1 Sketch of a Decomposing Wood Particle Including the Reaction Paths Involved

If the pyrolysis conditions are proper, 100kg biomass can produce 70 kg bio-oil.

3.Rotating Cone Reactor

- It was key project of Ministry of Science &Technology of China. Professor Ronghou Liu was Vice coordinator.

- The biomass throughput: 50 kg/h
- The bio-oil yield : 53%

4.Fluidized bed reactor for biomass fast pyrolysis for bio-oil production developed by SJTU

- Biomass throughput:1-5 kg/h;
- Reactor Temperature:400-600°C
- Biomass particle size: <2mm

*Effect of hot vapor filtration on the characterization of bio-oil from rice husks with fast pyrolysis in a fluidized-bed reactor

Bioresource Technology 102 (2011) 6178–6185

Contents lists available at ScienceDirect

Bioresource Technology

journal homepage: www.elsevier.com/locate/biortech

Effect of hot vapor filtration on the characterization of bio-oil from rice husks with fast pyrolysis in a fluidized-bed reactor

Tianju Chen [a], Ceng Wu [a], Ronghou Liu [a,*], Wenting Fei [a], Shiyu Liu [b]

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Fuel Processing Technology 161 (2017) 204–219

Contents lists available at ScienceDirect

Fuel Processing Technology

journal homepage: www.elsevier.com/locate/fuproc

Research article

Effect of temperature of ceramic hot vapor filter in a fluidized bed reactor on chemical composition and structure of bio-oil and reaction mechanism of pine sawdust fast pyrolysis

CrossMark

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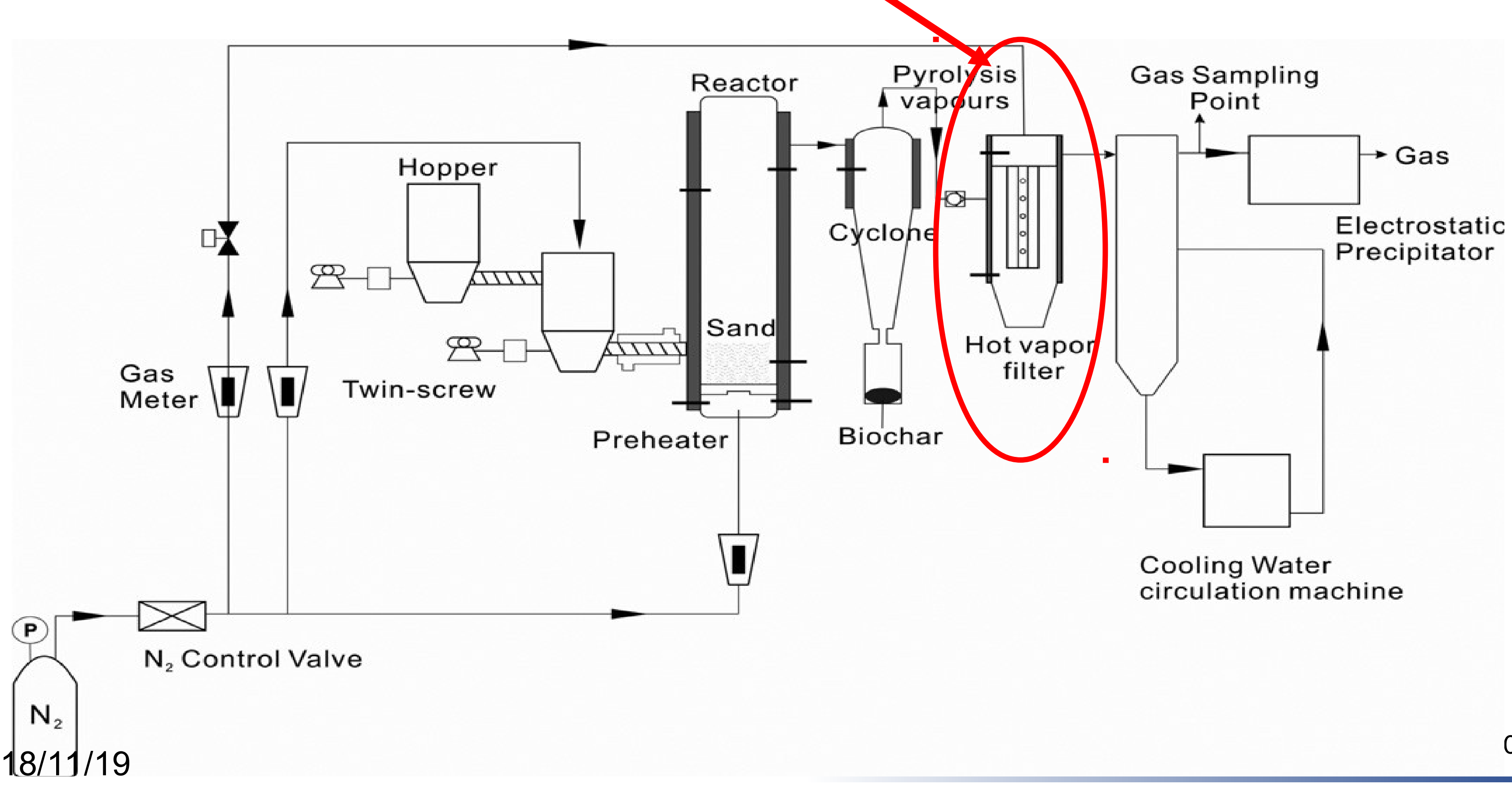
*Effect of hot vapor filtration on the characterization of bio-oil from rice husks with fast pyrolysis in a fluidized-bed reactor



Yield and physicochemical properties of bio-oil at condenser

Yield and physicochemical properties of the bio-oil at the condenser and the EP.

	C_1[c]	C_2[c]	F_1[c]	F_2[c]
Water content(wt.%)	64.41 ± 0.16	10.77 ± 0.10	75.09 ± 0.42	9.19 ± 0.08
Yield of bio-oil (wt.%)	57.3	42.7	60.5	39.5
Ratio of collected water content of oil[a]	88.9	11.1	92.7	7.3
C (wt.%)	17.07	60.95	10.67	66.56
H (wt.%)	10.76	7.26	11.23	7.50
N (wt.%)	<0.3	0.94	<0.3	1.30
O[b] (wt.%)	71.87	30.85	77.80	24.65
pH	2.84	4.10	3.37	4.40
Density (g/cm^3)	1.0705	1.1550	1.0392	1.1766
High heating value (MJ/kg)	–	22.06	–	23.86
Na content (ppm)	46	38	19	36
K content (ppm)	19	116	13	41
Ca content (ppm)	82	60	57	23
Mg content (ppm)	8	8	8	1

[a] The total water yield during the reaction process is equal to the sum of the product of mass and water content at each condenser. The ratio of the collected water content of oil for each condenser is equal to the collected water yield at each condenser divided by the total water yield.

[b] By difference.

[c] C_1, C_2 were the bio-oil condensed in the condenser and EP when using the cyclone only to remove the solid particle, and F_1, F_2 were the bio-oil condensed in the condenser and EP when using the cyclone coupled with HVF.

Conclusion:

It was found that the total bio-oil yield decreased and that the bio-oil has a higher water content, higher pH value, and lower alkali metal content when a HVF is used in the system.

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*Effect of Selective Condensation on the Characterization of Bio-oil from Pine Sawdust Fast Pyrolysis Using a Fluidized-Bed Reactor

Energy Fuels **2010,** *24,* 6616–6623 · DOI:10.1021/ef1011963
Published on Web 11/11/2010

energy&fuels
article

Effect of Selective Condensation on the Characterization of Bio-oil from Pine Sawdust Fast Pyrolysis Using a Fluidized-Bed Reactor

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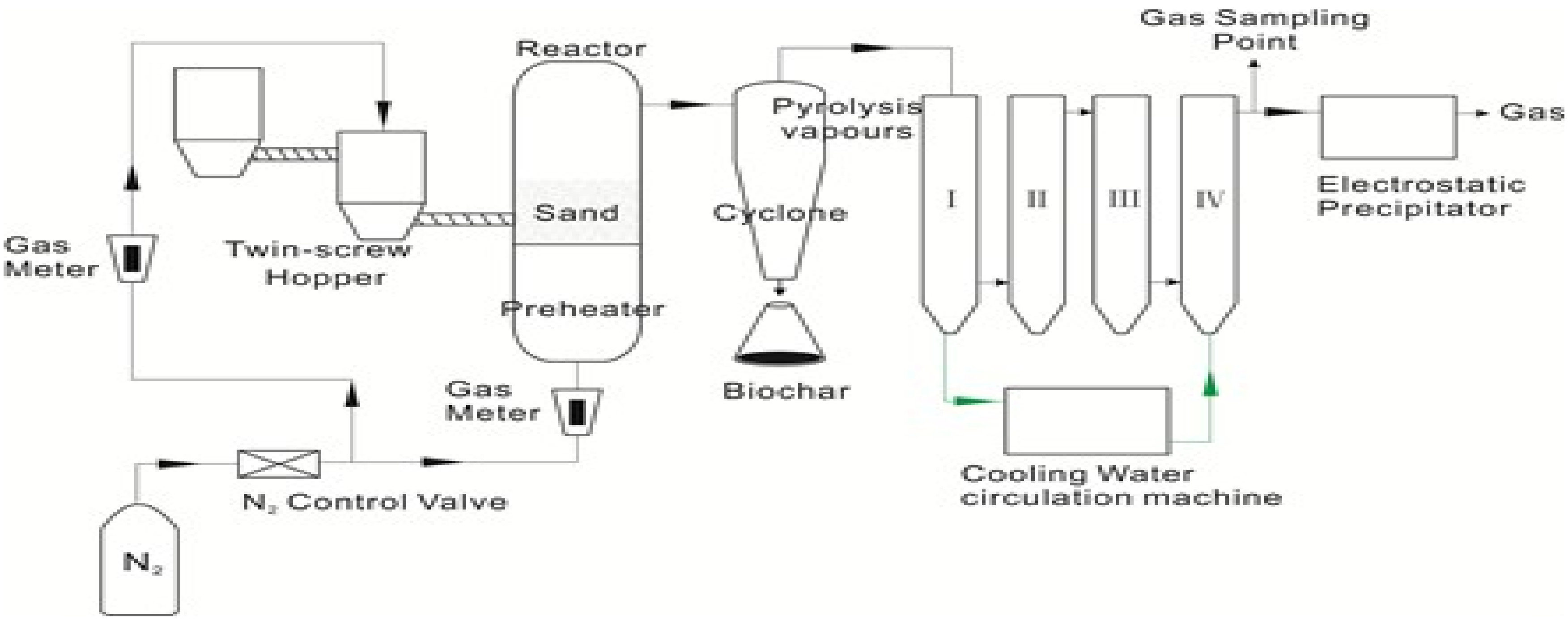
Received September 4, 2010. Revised Manuscript Received October 25, 2010



The flow chart of the fluidized bed reactor fast pyrolysis system

Results

(1) Yield and the Water Content of the Bio-oil at Different Condensers

Yield and the Water Content of the Bio-oil at Different Condensers

	Condenser 1#	Condenser 2#	Condenser 3#	Condenser 4#	Condenser 5#
Yield of bio-oil **(wt/%)**	65.3	1.8	1.2	11.3	20.4
Water content**(wt/%)**	33.21	7.82	7.45	7.35	7.45
Ratio of collected water content of oil [a]	86.2	0.6	0.4	3.3	9.5

Note: [a] The total water yield during the reaction process was equal to the sum of the product of mass and water content at each condenser. The ratio of the collected water content of oil for each condenser is equal to the collected water yield at each condenser divided by the total water yield .

Conclusion 1 : The total bio-oil, the gases and the char yields were 41.5%, 43.3%, 15.2% respectively ;
and 86.2 wt % water steam was condensed in condenser 1.

(2) Other properties

pH Value of the Bio-oil

	1#	2#	3#	4#	5#
pH	2.66	2.73	2.78	2.78	2.78

Higher Heating Value (HHV) of the Bio-oil

	1#	2#	3#	4#	5#
HHV **(MJ/Kg)**	14.9	22.6	22.9	22.7	23.5

The Effect of Temperature on the Viscosity of Bio-oil

	20 ℃	30 ℃	40 ℃	50 ℃	60 ℃	70 ℃	80 ℃	90 ℃
Viscosity of bio-oil 1# **(mm^2/s)**	9.10	1.95	1.35	1.21	0.94	0.63	0.54	0.53
Viscosity of bio-oil 4# **(mm^2/s)**	938.13	326.09	142.38	69.25	38.01	12.93	7.26	5.80
Viscosity of bio-oil 5# **(mm^2/s)**	1210.97	397.44	175.48	82.50	46.87	26.88	17.48	12.62

Conclusion 2: The bio-oil condensed in the later condensers has a lower water content, higher pH value, higher heating value, higher kinetic viscosity compared to the first one.

(3) GC-MS Results

Table 8. Components of Bio-oil from Pine Sawdust Pyrolysis and Their Relative Mass Contents Detected by GC-MS

				Relative mass content (%)		
Peak NO.	Main identified compounds	RTA(min)	mol mass	1#	4#	5#
1	Ethynyl isopropyl ketone	3.552	96	0.15		
2	1,3-dione-4-Cyclopentene	3.642	96	1.21	0.21	0.2
3	Cyclopentanone	3.883	84	4.98		
4	2(5H)-Furanone	3.896	84		3.5	2.67
5	2-Methyl-2-cyclopentenone	4.124	96	3.92	1.41	1.24
6	1-(2-furanyl)-Ethanone,	4.227	110	1.18	0.32	0.38
7	3-methyl- 2,4-Pentanedione	4.314	114		0.27	
8	3-methyl- 2,5-Furandione	4.308	112	0.73		0.45
9	2-methyl-Cyclopentanone	4.448	98	9.98	6.68	6.11
10	Bicyclo[3.1.0]hexan-2-one	4.5	96			0.24

Conclusion 2: GC-MS showed that 102 types of chemical compounds were detected and most of the compounds were condensed at different condensers. The selective condensation is useful to separate the water and chemical compounds from bio-oil compared with direct contacting condensing.

5.Performance of a commercial-scale biomass fast pyrolysis plant for bio-oil production

Fuel 182 (2016) 677–686

Contents lists available at ScienceDirect

Fuel

journal homepage: www.elsevier.com/locate/fuel

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Full Length Article

Performance of a commercial-scale biomass fast pyrolysis plant for bio-oil production

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ARTICLE INFO

Article history:
Received 18 January 2016
Received in revised form 3 June 2016
Accepted 7 June 2016

Keywords:
Fast pyrolysis
Bio-oil
Downdraft circulating fluidized bed reactor
Rice husks

ABSTRACT

A commercial-scale biomass fast pyrolysis plant, based on downdraft circulating fluidized bed technology with biomass throughput of 1–3 T h^{-1}, has been developed for bio-oil production and its performance has been investigated. The technological process consists of six parts: a feeding system, a heat carrier system, a reactor system, a cyclone system, a condensation system and a carbon separating system. The plant has four circulation systems: circulation of a heat carrier, quenching materials (bio-oil), cooling water and non-condensable gas. The bio-oil, raw material (rice husks), char and non-condensable gas samples were analyzed using GC–MS, FTIR, and SEM to characterize the physical properties and chemical composition. Results showed that the operation of the plant was stable. At 550 °C, the highest yield of bio-oil obtained was 48.1 wt% with char, and non-condensable gas yields of 26.0 wt% and 25.9 wt%, respectively. GC–MS results revealed that the composition of bio-oil was complicated and the most abundant compound category was phenolics (14.92%). The char had complex pore structure by SEM analysis, which can be collected as a resources for further comprehensive utilization.

Fuel Processing Technology 171 (2018) 308–317

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Research article

Bio-oil production from fast pyrolysis of rice husk in a commercial-scale plant with a downdraft circulating fluidized bed reactor

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Key Laboratory of Urban Agriculture (South), Ministry of Agriculture, 800 Dongchuan Road, Shanghai 200240, PR China

ARTICLE INFO

Keywords:
Fast pyrolysis
Bio-oil
Downdraft circulating fluidized bed reactor
Rice husk
Commercial-scale plant

ABSTRACT

Bio-oil, a promising candidate to replace fossil fuels, has received considerable attention for its sustainability, resource diversity and environmental benefits. Industrial production of bio-oil is urgently needed. In this study, a downdraft circulating fluidized bed reactor commercial-scale fast pyrolysis plant with biomass throughput of 1–3 t h^{-1} is studied. Rice husk was processed at a fast pyrolysis temperature of 550 °C to evaluate the plant operation status. The system was continuously operated for 80.42 h. The thermal properties of the feedstock (rice husk), dust (separated from feedstock), char and heat carrier were analyzed and the bio-oil properties such

5.1 Financial support

Project Title： Development of Equipment for Biomass Fast Pyrolysis for Bio-oil Production and its Demonstration in Thousand Ton Scale

Project type :The National Science and Technology Supporting Plan;

Ministry of Science and Technology of China

Organizer: Shanghai JiaoTong University

Partners:1) Zhejiang University

2)Shandong University of Technology

3)Guangzhou Institute of Energy Conversion, Chinese Academy of Science

4)University of Science and Technology of China

5) University of Science and Technology of South China

6) Company

Coordinator of the project: Ronghou Liu

Period： January 2011-December 2013

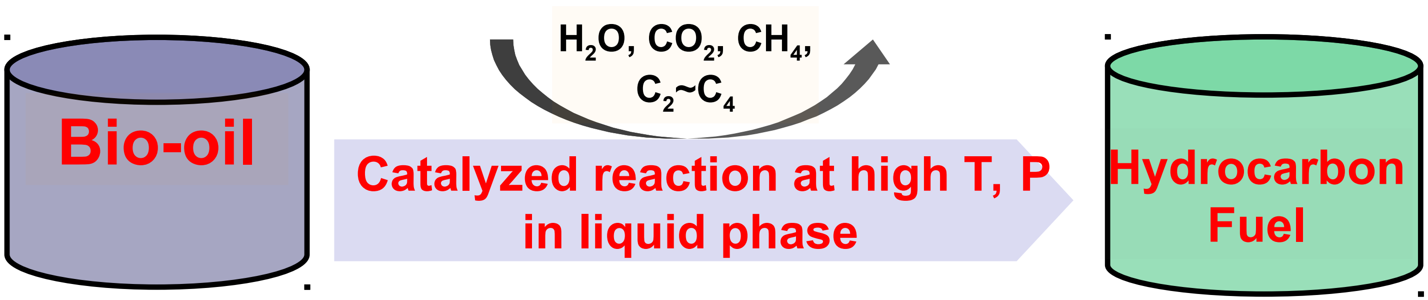
5.2 Pyrolysis plant

A commercial-scale biomass fast pyrolysis plant, based on downdraft circulating fluidized bed technology with biomass throughput of 1–3 T /h(Bio-oil yield:10000 t/a) has been jointly developed and built in Company and Shanghai Jiao Tong University, China for bio-oil production.

6.Hydrodeoxygenation (HDO) of Bio-oil

- **What is HDO?**

  --Hydrodeoxygenation



- **Why HDO?**

- Hydrodeoxygenation is one of the most feasible upgrading method.

7.Other Biomass Energy Research in SJTU

Shanghai

7.1 Bioethanol

7.1 Bioethanol

Available online at www.sciencedirect.com

ScienceDirect

Bioresource Technology 99 (2008) 847–854

BIORESOURCE TECHNOLOGY

Impacts of main factors on bioethanol fermentation from stalk juice of sweet sorghum by immobilized *Saccharomyces cerevisiae* (CICC 1308)

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Received 17 October 2006; received in revised form 17 January 2007; accepted 17 January 2007
Available online 13 March 2007

Abstract

In order to attain a higher ethanol yield and faster ethanol fermentation rate, orthogonal experiments of ethanol fermentation with immobilized yeast from stalk juice of sweet sorghum were carried out in the shaking flasks to investigate the effect of main factors, namely, fermentation temperature, agitation rate, particles stuffing rate and pH on ethanol yield and CO_2 weight loss rate. The range analysis and analysis of variance (ANOVA) were applied for the results of orthogonal experiments. Results showed that the optimal condition for bioethanol fermentation should be $A_4B_3C_3D_4$, namely, fermentation temperature, agitation rate, particles stuffing rate and pH were 37 °C, 200 rpm, 25% and 5.0, respectively. The verification experiments were carried out in shaking flasks and 5 L bioreactor at the corresponding parameters. The results of verification experiments in the shaking flasks showed that ethanol yield and CO_2 weight loss

This paper has been Top 20 Articles, in the Domain of Article 17360181, Since its Publication (2008)

1. Introduction

Ethanol production as an alternative fuel energy resource has been a subject of great interest since the oil crisis of the 1970s (Tao et al., 2005). Therefore, a strong need exists for efficient ethanol production with low cost in raw material and production process. The varied raw materials used in the production of ethanol via fermentation are conveniently classified into three main types of raw materials: sugars, starches, and cellulose materials. Sugars (from sugarcane, sugar beets, sweet sorghum, molasses, and fruits) can be converted into ethanol directly. Starches (from corn, cassava, potatoes, and root crops) must firstly be hydrolyzed to fermentable sugars by the action of enzymes from malt or molds. Cellulose (from wood, agricultural residues, waste sulfite liquor from pulp, and paper mills) must likewise be converted into sugars, generally by the action of mineral acids. Once simple sugars are formed, enzymes from microorganisms can readily ferment them to ethanol (Lin and Tanaka, 2006). As for materials, one of the prime sources being investigated for ethanol is sweet sorghum. Sweet sorghum {*Sorghum biocolor* (L.) Moench} is a high biomass- and sugar-yielding crops (Bryan, 1990), meantime, the stalk of sweet sorghum contains quite a few quantities of soluble (glucose and sucrose) and insoluble carbohydrates (cellulose and hemicellulose) (Jasberg et al., 1983). Therefore, of many crops currently being investigated for energy and industry, sweet sorghum is one of the most promising, particularly for ethanol production (Gnansounou et al., 2005).

The advantages of immobilized cells over free cell sys-

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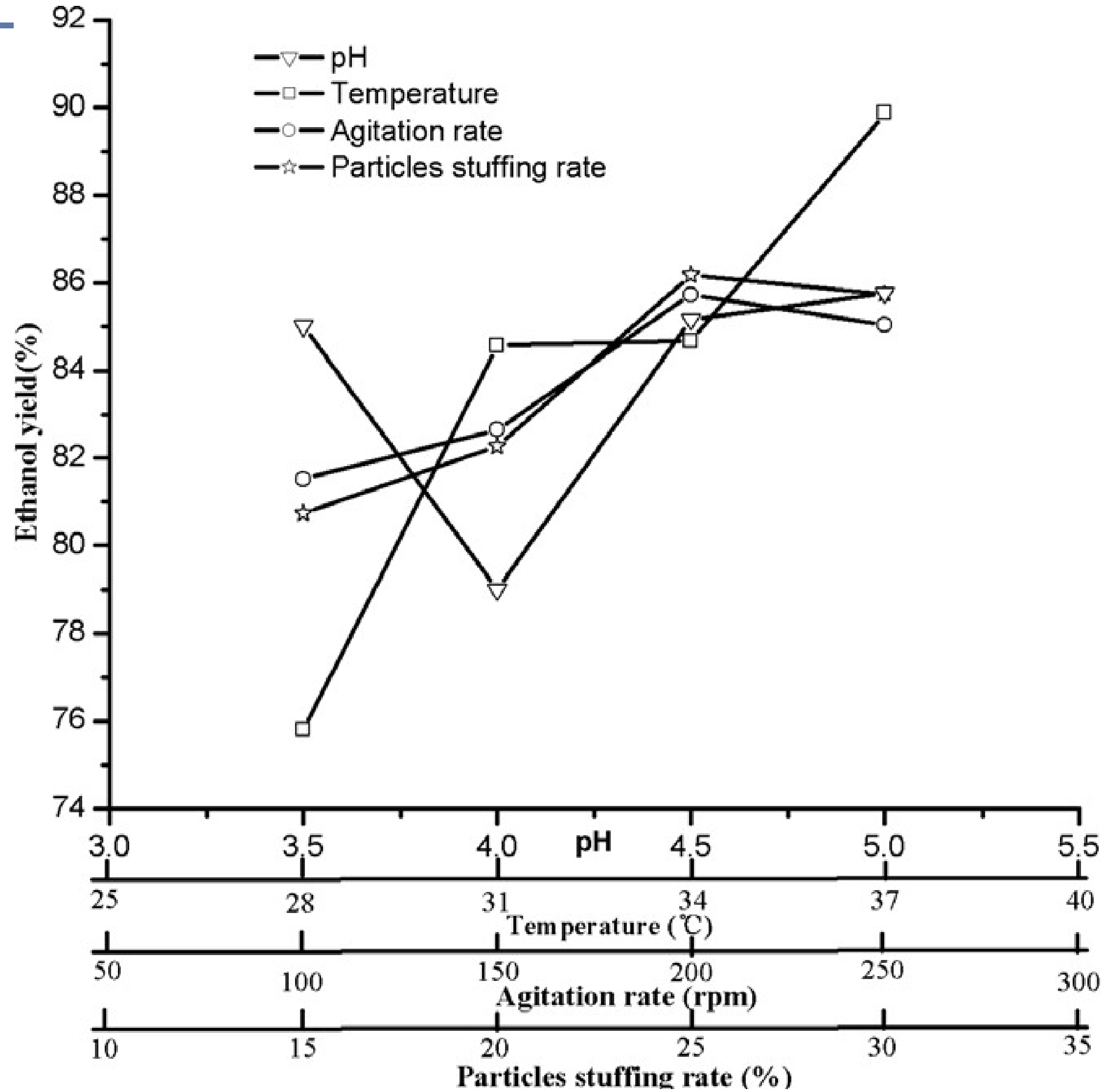
Optimal condition for bioethanol fermentation:

Fermentation temperature:37 °C , Agitation rate: 200 rpm,

Particles stuffing rate:25%,
pH 5.0.
Ethanol yield:98.07%,
Fermentation time: 11 h.



上海交通大学 Shanghai Jiao Tong University

Biogas production from undiluted chicken manure and maize silage: A study of ammonia inhibition in high solids anaerobic digestion

Chen Sun[1,2], Weixing Cao[1], Charles J. Banks[2], Sonia Heaven[2], Ronghou Liu[1,2]*

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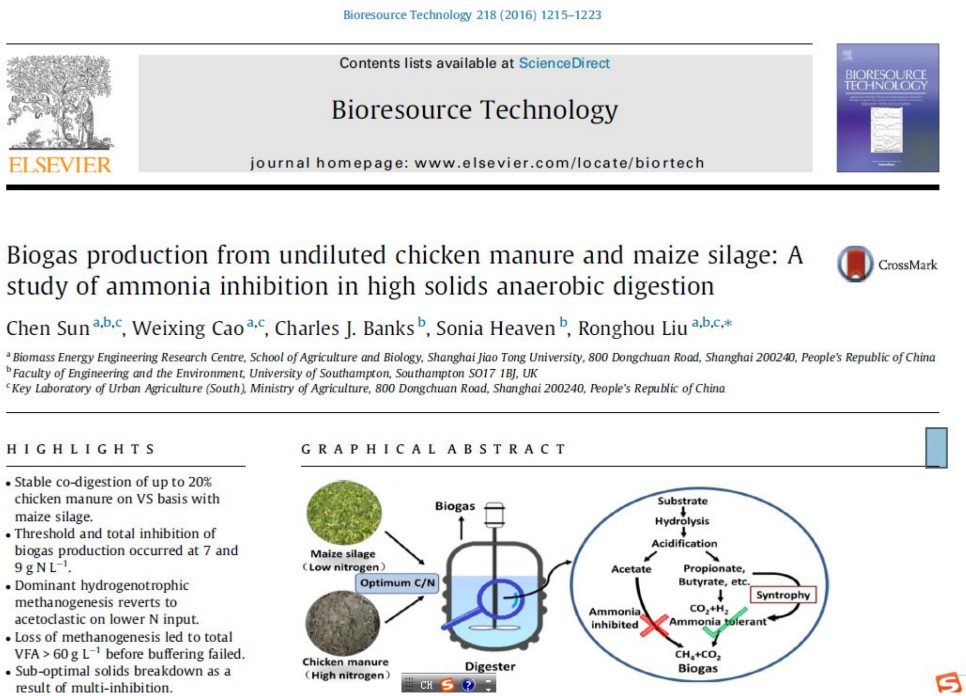
Objectives:

- To evaluate the multi-inhibited AD system using CM and MS as the feedstock without any water addition;
- To determine the thresholds for ammonia inhibition/toxicity;

Conclusions：

- Methanogenesis was totally inhibited at TAN >9 g N L^{-1}. 14C isotope labelling showed the predominant methanogenic pathway at high TAN was hydrogenotrophic.


Bioresource Technology 218 (2016) 1215–1223

Contents lists available at ScienceDirect

Bioresource Technology

journal homepage: www.elsevier.com/locate/biortech

ELSEVIER

Biogas production from undiluted chicken manure and maize silage: A study of ammonia inhibition in high solids anaerobic digestion

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HIGHLIGHTS

- Stable co-digestion of up to 20% chicken manure on VS basis with maize silage.
- Threshold and total inhibition of biogas production occurred at 7 and 9 g N L^{-1}.
- Dominant hydrogenotrophic methanogenesis reverts to acetoclastic on lower N input.
- Loss of methanogenesis led to total VFA > 60 g L^{-1} before buffering failed.
- Sub-optimal solids breakdown as a result of multi-inhibition.

GRAPHICAL ABSTRACT

energy&fuels
Article
pubs.acs.org/E

Impacts of Alkaline Hydrogen Peroxide Pretreatment on Chemical Composition and Biochemical Methane Potential of Agricultural Crop Stalks

Chen Sun,[†,‡,§] Ronghou Liu,[*,†,§] Weixing Cao,[§] Renzhan Yin,[∥] Yuanfei Mei,[†,‡,§] and Le Zhang[†,§]


energy&fuels
Article
Impacts of Alkaline Hydrogen Peroxide Pretreatment on Chemical Composition and Biochemical Methane Potential of Agricultural Crop Stalks

Objective:

to increase bio-digestibility and methane yield from crop residues via pretreatment

Results and conclusions:

The AHP pretreatment could:

- break down esterified(酯化） and etherified （醚化） linkage in lignocellulose;
- recover 90% of glucose and 80% of xylose （木糖）；
- remove 30%-50% of lignin;
- increase methane yield and bio-digestibility for certain biomass.

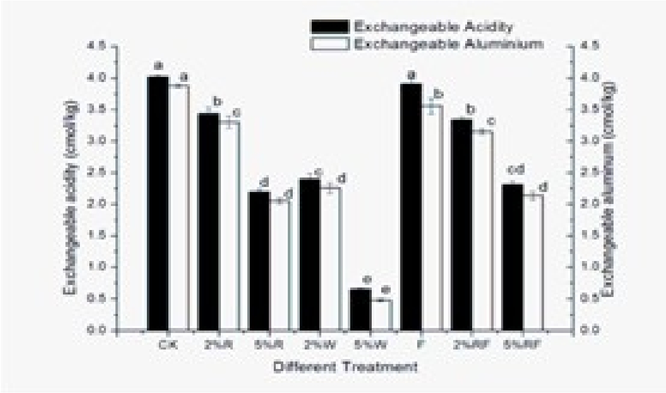
It is necessary to utilize the liquid waste from the pretreatment.

7.3.Biochar Application for Soil Amendment and Heavy metal removal

-863 Project by MOST

1)Developed a biochar application machine:

Scale： 4753.8-34185.2 kg/h



2) The effect of biochar on soil and plant growth

Wood sawdust biochar could reduce the exchangeable acidity and aluminum by 84% and 88%, respectively at the 5% biochar amendment level.

Selected Publications(SCI)

Selected Publications(SCI)

[1]Linzheng Wang, Meiyun Chai, Ronghou Liu*, et al. Synergetic effects during co-pyrolysis of biomass and waste tire: A study on product distribution and reaction kinetics[J]. Bioresource Technology, 2018,268: 363-370. (SCI,IF5.807)

[2]Wenfei Cai, Ronghou Liu*. Performance of a commercial-scale biomass fast pyrolysis plant for bio-oil production[J]. Fuel 2016,182: 677–686. (SCI,IF4.908)

[3]Renzhan Yin, Le Zhang , Ronghou Liu*, et al. Optimization of composite additives for improving stability of bio-oils, Fuel,2016, 170: 1–8.

[4]Chen Sun, Weixing Cao, Charles J. Banks, Sonia Heaven, Ronghou Liu*.Biogas production from undiluted chicken manure and maize silage: a study of ammonia inhibition in high solids anaerobic digestion[J]. Bioresource Technology, 2016, 218: 1215-1223.

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[6] Renzhan Yin, Ronghou Liu*, Yuanfei Mei, et al.Characterization of bio-oil and bio-char obtained from sweet sorghum bagasse fast pyrolysis with fractional condensers[J].Fuel , 2013,112: 96–104.

[7]Le Zhang, Ronghou Liu*, Renzhan Yin, Yuanfei Mei.Upgrading of bio-oil from biomass fast pyrolysis in China: A review[J].Renewable and Sustainable Energy Reviews ,2013,24: 66–72. (SCI ， IF9.184)

[8] Tianju Chen, Ceng Wu, Ronghou Liu*, et al. Effect of hot vapor filtration on the characterization of bio-oil from rice husks with fast pyrolysis in a fluidized bed reactor[J]. Bioresource Technology, 2011, 102: 6178-6185.

[9]Weixing Cao, Chen Sun, Ronghou Liu* ， Renzhan Yin, Xiaowu Wu.Comparison of the effects of five pretreatment methods on enhancing the enzymatic digestibility and ethanol production from sweet sorghum bagasse[J].Bioresource Technology,2012,111: 215–221.

[10] Wenfei Cai, Ronghou Liu*, Yifeng He, et al. Bio-oil production from fast pyrolysis of rice husk in a commercial-scale plant with a downdraft circulating fluidized bed reactor[J].Fuel Processing Technology,2018,171:308-317. (SCI,IF3.956)

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Shanghai Jiao Tong University

Thank You!

Acknowledgment

Financial support from National Natural Science Foundation of China through contracts (Grant no. 51776127, Grant No. 51176121, Grant No.50776059) are greatly acknowledged.

Financial support from The National High Technology Research and Development Program of China (863 Program, Grant 2008AA05Z404, Grant NO.2012AA101808) and financial support from The National Science and Technology Supporting Plan through contract (Grant No.2011BAD22B07) are greatly acknowledged.