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<b>Paper-ID</b>	59641
<b>Paper title</b>	A Comparative Study on the Effect of Chemical Composition in Biomass on the Torrefaction
<b>Presentation format</b>	Oral presentation
<b>Date of submission</b>	30.01.2017 20:51 Uhr
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## Content

Torrefaction is a thermal pretreatment method to improve the properties of biomass, particularly an increase in its heating value, and a decrease in moisture content and O/C ratio. Torrefaction is normally operated under inert atmosphere at low temperatures of 200–300°C for several minutes to several hours. Major factors of temperature and residence time, which significantly affect to the severity of the reactions occurred during torrefaction, have been recently focused to investigate the properties of torrefied biomass. However, the complexity of biomass constituents, which mainly consist of cellulose, hemicellulose, and lignin in different composition ratios for each biomass, could play an important role in torrefaction process due to their different characteristics of the thermal decomposition. In this study, several agricultural and forestry biomass wastes, which are abundantly found in Thailand, such as rice husk, rice straw, brown sugarcane leaves, bamboo trash, and oil palm kernel shells, were utilized as biomass samples containing distinct chemical composition ratios of cellulose, hemicellulose, and lignin, which were analyzed by TAPPI standard method [1-4]. The temperature and residence time of the torrefaction were varied in a range of 260–320°C and 0-60 min, respectively, for condition optimization of the torrefaction. Torrefied biomass solids including gaseous products obtained during the torrefaction were further characterized by thermogravimetric analysis (TGA), elemental (CHON) analysis, and gas chromatography. The pyrolysis behaviors of each torrefied biomass were also investigated. The torrefaction at 300–320°C for 60 min resulted in the highest char yield for all biomass after subsequent pyrolysis of the torrefied solids up to 900°C. Moreover, biomasses containing high percentage of cellulose such as bamboo trash significantly showed more percentage increase in their heating values after the torrefaction compared to that of other biomasses. Finally, the relationships between the chemical composition ratios of various biomasses and major properties of torrefied biomass, such as solid yield, percentage increase in heating value, and pyrolysis product distributions, could be systematically postulated.

## References

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- [4] TAPPI standard T 203 om-93, Alpha-, beta- and gamma-cellulose in pulp and wood, 1998.

<b>Paper-ID</b>	67926
<b>Paper title</b>	Simulation, Heat Integration and Rectisol-based Decarbonisation for the Production of Synthetic Natural Gas from Biomass
<b>Presentation format</b>	Oral presentation
<b>Date of submission</b>	01.02.2017 13:11 Uhr
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### Content

The production of synthetic natural gas (SNG) from biomass is currently considered as an alternative to reduce dependency on high-priced natural gas import. Biomass is thermally converted to produce CO<sub>2</sub>, CO, H<sub>2</sub>O and H<sub>2</sub> gases that are cleaned to remove CO<sub>2</sub> before being converted to SNG (methane) via a methanation process.

The focus of this project is to develop a comprehensive simulation framework of heat-integrated decarbonized process suitable for the removal of contaminants from biosyngas to meet SNG production specifications with minimal cost. That resulted in the development of a simulation framework for biomass thermal conversion, water gas shift (WGS) reaction, gas purification by Rectisol process and SNG production via methanation process. The simulation framework was constructed using Aspen HYSYS (V.2006) process simulator. Optimization software (SPRINT) is used for data extraction and analysis of heat integration opportunities across the entire process model.

In this project, straw was initially pyrolyzed to produce a gas stream consisting of CO<sub>2</sub>, CO, H<sub>2</sub>O and H<sub>2</sub> along with tar and char. The gas stream was then mixed with landfill gases containing 40-60% methane. This mixture was further gasified to produce a gas stream consisting mainly of CO<sub>2</sub>, CO, H<sub>2</sub>O, H<sub>2</sub> and H<sub>2</sub>S. The gas stream was then fed to a WGS reactor to increase H<sub>2</sub>/CO ratio to 3.

This gas mixture was cleaned up by a Rectisol process to remove CO<sub>2</sub>, H<sub>2</sub>S and other containments. The cleaned gas (CO, H<sub>2</sub>O, H<sub>2</sub>) was finally fed to a methanation process to convert it virtually to pure methane (i.e. SNG). The Rectisol process used refrigerated methanol as a solvent, where 99% removal of CO<sub>2</sub> and H<sub>2</sub>S was achieved. Two-level refrigeration cycle was developed to maintain the operating temperature of the overall gas purification process.

Methanation is an exothermic reaction and hence, a comprehensive sensitivity analysis was carried out to optimize the process by effective removal of heat of reaction and to achieve maximum CH<sub>4</sub> formation. This analysis showed that four reactors were used to achieve 97.4% maximum conversion of CO to CH<sub>4</sub>. After an in-depth heat integration study of the overall process, 2.5 MW of steam at 320 °C was generated and 0.45 MW process heat recovery was achieved, which resulted in energy savings.

In summary, the overall efficiency of SNG production depends significantly on the energy content of the biomass feedstock. Moreover, the cost of electricity from steam generation and cost of carbon capture were estimated to be a function of biomass feedstock cost. It is concluded from this study that biomass feedstock cost is absolutely critical in determining the overall operating cost.

**Paper-ID** 93111

**Paper title** Supercritical esterification of fatty acids with supercritical ethanol: kinetics and phase equilibrium analysis

**Presentation format** Poster

**Date of submission** 07.03.2017 23:00 Uhr

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## Content

This work reports on the esterification kinetics of carboxylic acids of different chain lengths (valeric, caprylic, lauric and oleic acids), an industrial mixture of distillate fatty acids (MDFA) and the simultaneous (trans)esterification of synthetic mixtures containing 20% and 40% free fatty acids, prepared using oleic acid in soybean oil in supercritical ethanol. The kinetic experiments were performed in a continuous PFR-type reactor (22 mL). The esterification reactions were carried at under fixed conditions: temperature of 220, 250 and 280 °C, ethanol to fatty acid molar ratio (MR) of 6:1 and 9:1 and fixed pressure of 100 bar. The results showed high conversions (around 90%) for all test samples: valeric, caprylic, lauric, oleic and for the distillate fatty acid mixture at 280 °C, MR of 6:1 and 100 bar for a residence time around 20 min. There was a small difference in the kinetic behaviour of different saturated and unsaturated carboxylic acids at supercritical ethanol conditions and a high similarity was observed among the kinetic of lauric and oleic acids and that of the distillate fatty acid mixture at 250 °C and MR of 9:1. The (trans)esterification reactions were performed at the best condition of oleic acid esterification (280 °C, 100 bar and MR of 6:1). In the acid oil system, the oleic acid conversion was lower than the pure fatty acid system. It is worth mentioning that others reactions such as hydrolysis, esterification and transesterification occur simultaneously. The density of each component and for the mixtures was calculated by PC-SAFT equation of state to estimate the residence time in the reactor at each studied condition. The phase behaviour of reactant reaction mixture was assessed using the Aspen Plus simulator with the PC-SAFT equation of state. The pressure-temperature diagrams showed a single homogeneous reacting phase, which increases the reaction rates once the mass transfer limitation is minimized. The set kinetic data was modelled using an elementary model, considering that the ethylic esterification is self-catalysed. A good agreement between calculated and experimental conversions was observed and this was confirmed by the relatively low RMSD values, even for MDFA esterification systems that were not used for model parameters estimation. These results demonstrate that the kinetics of pure components can be used to represent the kinetics of more complex matrixes, so the model is able to represent MDFA systems and their kinetic parameters, which is important to evaluate the feasibility of such raw materials for the biodiesel production. Additionally, the studied process conditions and the reactor configuration were able to lead all systems to obtain biodiesel from low-cost feedstocks without pretreatment before entering the reactor.

**Paper-ID** 87886  
**Paper title** The removal of heavy metal ions using carbon materials derived from pyrolysis of biomass  
**Presentation format** Oral presentation  
**Date of submission** 28.02.2017 18:04 Uhr  
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## Content

Carbon material (CM) is one of the main bio-based products derived from thermal conversion of biomass including slow pyrolysis, fast pyrolysis, gasification, hydrothermal decomposition. Various biomass-related CM materials have been successfully developed using woods, straws, algae, manure and sediments. It is essential to explore a promising route to utilise the produced carbon materials produced from thermo-chemical conversion of biomass. In this work, we investigated the application of CM as an adsorbent for the removal of heavy metals ( $\text{Cd}^{2+}$ ) from waste water.

Cadmium ions ( $\text{Cd}^{2+}$ ) in aquatic environment, primarily originated from the disposal of industrial effluents in the electroplating, mining industry, petroleum refining and leather manufacturing, have high mobility and biological accumulation, posing severe threats on human health and ecological systems due to their toxicity and carcinogenicity. After prolonged exposure and excessive uptake, cadmium ions would bring about serious damage to bones and kidney causing awful diseases like “itai-itai disease”, anemia, osteoporosis and hypertension.

Our results about using CM to remove cadmium ions show that an increase of initial concentration of heavy metal ions promoted the adsorption capacity. Adsorption was vigorously commenced within the initial contact time of 1 h, accounting for 63.81-76.52% to the total adsorption amount. It is found that the adsorption performance was not significantly influenced by the solution pH (between 3.5 and 5.5) and the ionic strength (between 0 and 0.01 mol/L). The maximum adsorption capacity of the CM prepared from 400, 500 and 600 °C were 32.47, 19.65 and 14.60 mg/g, respectively. Thermodynamics analysis shows that the uptake of  $\text{Cd}^{2+}$  by the CM was subjected to a spontaneous and endothermic process.

**Paper-ID** 81861  
**Paper title** Torrefaction of coconut shells  
**Presentation format** Oral presentation  
**Date of submission** 28.02.2017 08:40 Uhr  
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**Content**

Torrefaction of coconut shells

The effects of torrefaction in coconut shells with varying temperature and time were investigated. Torrefaction is an emerging thermo-chemical pre-treatment of lignocellulosic biomass for fuel use. The coconut shell was the chosen feed due to its abundance and sustainability in the Philippines. A batch reactor with no inert gas input is used, it can heat the feed to 250C and 300C, and with 30 minutes and 60 minutes as the reaction time. This study aims to provide fuel product characterization on the limited studies on torrefaction of coconut shells. Some of the characterization includes the mass yield, heating value, and proximate analysis.

**Paper-ID** 69766  
**Paper title** Two Stage Gasification of Ligno-cellulosic Waste Biomass  
**Presentation format** Oral presentation  
**Date of submission** 15.02.2017 09:13 Uhr  
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**Content**

Two Stage Gasification of Ligno-cellulosic Waste Biomass

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**Abstract:**

Different types of lingo-cellulosic waste biomass were gasified in a laboratory scale reactor with a secondary reactor for catalytic tar conversion. Wheat straw, corn stalks, corn leaves, sunflowers, wooden chips and hay were gasified under various conditions. Temperature of both primary and secondary reactors varied from 700 to 1000 °C, as gasification agent air, oxygen reached air and poor oxygen were used. Amount and composition of produced gas and gas tar content were determined. All types of waste biomass were studied also by thermogravimetric (TGA) analysis, differential scanning calorimetry (DSC), elemental analysis and bomb calorimetry.

The composition of pyrolysis gases was measured online by a micro-chromatograph. Heating value of gas was calculated based on its composition. A standard method was applied to determine the total amount of tar in produced gas. More detail analysis of tars was provided by GC-MS analysis.

In addition a computer model of the process was developed. As input data the characteristic of raw material estimated in the laboratory was used. The model was verified by experimental measurements from the laboratory and used for modelling of an industrial scale gasification process using a mixed waste biomass stream as raw material. .

**Acknowledgement**

This work was supported by the Grant APVV-15-0148 provided by the Slovak Research and Development Agency

**Paper-ID** 42746

**Paper title** Upgrading of biomass by torrefaction: Pyrolysis behaviors of torrefied leucaena and rice straw

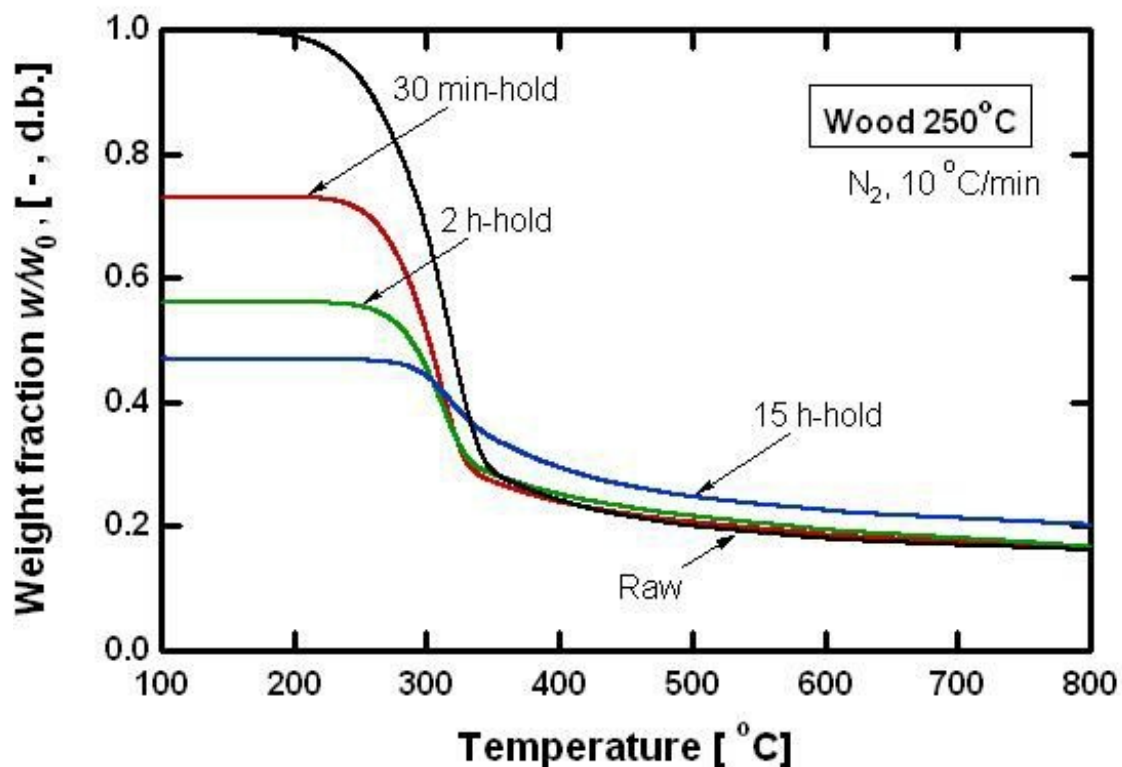
**Presentation format** Oral presentation

**Date of submission** 30.01.2017 08:39 Uhr

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### Content

Torrefaction is the thermal treatment techniques performed at relatively low temperature ( $< 300\text{ }^{\circ}\text{C}$ ) in an inert atmosphere, which aims to improve the fuel properties attractively. Several studies have been conducted on the properties of torrefied biomass including woody and non-woody biomass by varying temperature and holding time during torrefaction. It was found that the energy density as well as the higher heating value (HHV) was increased progressively at higher torrefaction temperature and at longer holding time. However, few studies have been conducted to examine the effect of torrefaction on the subsequent thermal conversions of torrefied biomass such as pyrolysis, gasification, and combustion. In this study, woody biomass (*Leucaena leucocephala*) and rice straw were torrefied at various temperatures and holding times and the pyrolysis behaviors of the torrefied leucaena and rice straw were examined in detail by using TG-MS technique. It was found that the carbon content and the calorific value of the torrefied leucaena increased significantly when increase the temperature and holding time during the torrefaction. Fig. 1 shows the weight changes during the pyrolysis of raw and torrefied leucaena prepared at  $250\text{ }^{\circ}\text{C}$  and at holding times of 30 min to 15 h. The char yield at  $800\text{ }^{\circ}\text{C}$  for the torrefied leucaena was increased when increasing the holding time during the torrefaction. On the other hand, the tar yield during the pyrolysis decreased significantly with the increase in the holding time during the torrefaction. Through the results from the TG-MS analysis, it was concluded that the structure of leucaena was changed by the torrefaction at temperature below  $275\text{ }^{\circ}\text{C}$  and the cross-linking reactions occurred during the pyrolysis resulting in increase in char yields and decrease in tar yields. It was also suggested that the longer the holding time during the torrefaction, the more the cross-linking reactions proceed during the pyrolysis. The results obtained from the study provide the basic information for the pyrolyser and/or gasifier design by using torrefied biomass as a fuel.





**Paper-ID** 69666  
**Paper title** Value-added chemicals from glycerol by Aqueous Phase Process  
**Presentation format** Poster  
**Date of submission** 14.02.2017 11:29 Uhr  
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## Content

### Value-added chemicals from glycerol by Aqueous Phase Process

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Aqueous Phase Reforming process is considered one of the most promising thermochemical processes to valorize wet residual streams [1], such as cheese whey, glycerol, black liquor,.... The objective of the different research studies present on the literature is in general to produce value-added chemicals with further applications, i.e. , as biofuels additives.

The aim of this research work is to determine the influence of the catalysts characteristics on the gas and liquid products yields and compositions, in order to establish a suitable route map on using of glycerol towards the most valuable compounds [2].

In this context, the catalyst considered for this process has been a supported Ni/CeO<sub>2</sub> catalyst. On the one hand, nickel is proposed in literature as a good active phase for aqueous phase processes and depending on the support, it leads to a high yield of gaseous products or to liquid ones. On the other hand, ceria is a material with high oxygen storage capability, which can be altered by adding dopants into its matrix, such as nickel. For this reason, a study of the Ni/CeO<sub>2</sub> catalysts activity in an aqueous phase process can help us to understand the behavior of this material in aqueous medium. The catalysts were prepared by incipient wetness impregnation. The CeO<sub>2</sub> support was prepared by Ce(NO<sub>3</sub>)<sub>3</sub>·6H<sub>2</sub>O calcination at 500 - 700 °C. Different nickel loads were tested between 10-20 wt. % and the catalysts were calcined at 600-800 °C. The experiments were performed at 227 °C and 33 bar and they lasted a total of three hours. The feeding consisted on a glycerol aqueous solution (5 wt.%) with a flow rate of 1 ml/min.

Under these operating conditions, the glycerol conversion varied between 14-30% and the carbon conversions to liquid and gas are in the range of 11-25 and 1-2% respectively. The main liquid products obtained have been acetol, 1-2 propanediol and ethane-1,2-diol. These last two compounds could be used on the biofuel market, as additives, due to their antifreeze properties.

The authors would like to thank MINECO (project ENE2013-41523-R) for the financial support and the pre-doctoral aid granted to Clara A. Jarauta Córdoba (BES-2014-069165).

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