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Design and Construction of Microwave-Assisted Pyrolysis of Waste Coconut Shell for the Isolation of Pyroligneous Acid

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Abstract

As a country with a large amount of natural resources, Indonesia should be able to convert this material into more value added product. However, most of the natural resources were sold as a raw material. Process system engineering research center is one of the solution to overcome this problem by developing an integrated and systematic technology. Through this research center, output of the research can be scaled up for large scale production and also can be commercialized to increase the community welfare. One of natural resources which has not been optimally utilized is waste coconut shell (WCS). Indonesia is the largest coconut producer in the world with areal production of 3.88 ha and 3.2 million ton of coconut products. Several problems are faced by coconut agroindustry, i.e. the lack of coconut based product diversification and also the large number of WCS. WCS is one of organic waste, however it is quite hard to be decomposed by the microorganism due to its hard texture. This problem may gave high potential in the environmental pollution. In this research, WCS is going to be used as a raw material for pyroligneous acid through pyrolysis process. Pyrolysis is a method that is usually used to convert a biomass waste sources into a valuable product through thermal decomposition process without the presence of oxygen. This process will produce solid (char), liquid (bio-oil, tar and pyroligneous acid) and gas. Pyroligneous acid is commonly obtained as a side product from the production of active carbon and to date it has not been utilized economically. In the other hand, pyroligneous acid can be used as an anti-oxidant, antimicrobial, antifungal, anti-biofilm and also as an anti inflammatory. This properties are available due to the presence of organic matter and phenolic compound in the pyroligneous acid. This characteristics showed that pyroligneous acid is highly potential as raw material in drugs and pharmacy industries. Pyrolysis process requires high temperature which has range between 500 – 600 °C. In this paper, it will be discussed a pyrolysis equipment design and production of pyroligneous acid from WCS by using microwave-assisted pyrolysis (MAP).

Keywords: Coconut Shel, Pyroligneous Acid, Pyrolysis, Microwave, Pharmacy

1. Introduction

Indonesia is a country with huge amount of renewable and non-renewable resources. Otherwise, most of its resources were only exported as a raw material without any added value. Based on this condition, natural resources of Indonesia were only exploited without considering the optimal improvement of community welfare. This challenge needs an integrted and systematic technology improvement to optimally utilized natural resources of Indonesia into a more valuable product with high economic value.

Waste coconut shell is one of Indonesia natural resources which has not been optimally used as a high value product. Indonesia is one of the world leader in coconut production with plantation area around 3.88 ha with copra production of 3.2 million in 2005. Coconut plant can easily grow in almost part of Indonesia since it does not require any special treatments for its growth. There are several downstream industry as a result of coconut processing industries such as cocochemical, cocofiber, coconut oil, dessicated cconut, nata de coco, active carbon and etc (Hendaryati and Arianto). The problems that arise in coconut agro-industry is the lack of diversification development of coconut-based product with high added value. In the other hand, coconut-based products demand both in the domestic and in the world are still quite prospective and keep growing. Therefore, it needs an action to conduct a continuous research in the diversifcation and development of coconut-based product.

One of coconut plant part that has not been utilized optimally is waste coconut shell. It usually considered as a waste and disposed in the coconut processing both in industrial and domestic scale. It has a hard texture and due to this physical properties, WCS can not be easily decomposed by the microorganism. Therefore, the accumulation of WCS is highly potential to pollute the environment. WCS is commonly used as a raw material for craft industry and mannufacturing of active carbon (Pugersari et al., 2013). However, there are still a lot of WCS that has not been optimally utilized. Consequently, diversification of WCS into more value added product is needed. This article is going to review the utilization of WCS as a raw material of pyroligneous acid production through pyrolysis process.

2. Biomass

Indonesia is an agricultural country, therefore it has a big potential of lignosellulosic biomass sources (Figure 1). In line with the Energy National policy, one of the potential renewable energy sources is obtained from energy of biomass. WCS is one of potential biomass sources in Indonesia.

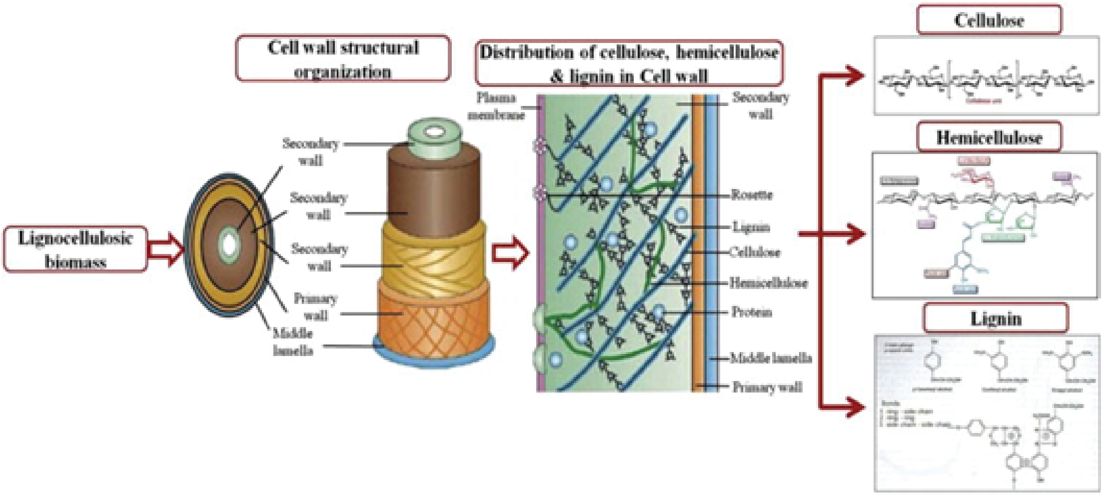

Figure 1: Structure of lignocellulose.

WCS is also a prospective biomass waste resources in Indonesia. In the world, Indonesia has the largest coconut plantation area with 3.8 million ha and the second largest coconut fruit producer in the world. The average production of Indonesian coconut fruit is 15.5 billion grains per year with follow-up ingredients, such as 3.75 million tons of coconut water, 0.75 million tons of shell charcoal, 1.8 million tons of coconut fiber and 3.3 million tons of dust fiber. In 2016, the coconut production area was 3,544,002 hectares with a total production of 2,922,584 tons. This data shows the high potential of WCS. Biomass can be used as bioenergy through direct combustion, thermochemical conversion or biochemical conversion.

3. Pyrolysis

Pyrolysis is the best method for biomass waste conversion into high economic value products through thermal decomposition in the absence of oxygen. Thermochemical conversion is widely used to decompose biomass into bioenergy. Through this method, biomass decomposition is carried out through the pyrolysis or gasification. Pyrolysis is thermal decomposition process in the absence of air, while gasification process decomposition is carried out in the presence of small amount of air. Pyrolysis can be categorized as slow, fast, and flash pyrolysis. Slow pyrolysis is carried out at temperatures of 300-700 ℃ with a residence time of 7.5 minutes, this process will produce bio-oil, char, and gas are with composition of 30%, 35%, and 35%. Fast pyrolysis is run at a temperature of 600-1000 ℃ with a residence time of 10 minutes and produced bio-oil, char, and gas products as much as 50%, 20%, and 30%. Flash pyrolysis is carried out at a temperature of 800-1000 ℃ with a residence time of less than 0.5 seconds and produced bio-oil, char, and gas products with composition of 75%, 12%, and 13% respectively. If pyrolysis process is carried out at low temperatures (300-400 ℃) with a very slow residence time, a large amount of solids of bio-charcoal will be produced. Meanwhile, if pyrolysis of biomass is carried out at high temperatures with sufficient residence time (900-1000 ℃), it can be obtaned a large amount of bio-hydrogen gas.

The pyrolysis process at high temperatures requires large energy costs. Therefore, in this study biomass pyrolysis innovations were carried out by using the Microwave Assisted Pyrolysis (MAP) method. The basic principle of this method is providing additional energy for a reaction in the form of microwave radiation energy. The effect of heating on microwaves causes organic changes, especially in dielectric polarization.

When a molecule is irradiated by using microwaves, the molecule experienced an electric field modification which causes molecules to consequently transformed and absorb the energy.

Microwave have been applied to accelerate reactions at low or moderate temperatures, but it has not been applied for high temperature pyrolysis. In previous studies, our research group has developed a prototype of the Microwave Assisted Pyrolysis (MAP) equipment that can be operated up to a temperature of 500 ℃ for the biomass conversion into phenolic liquid products. Therefore, MAP needs to be developed which can be operated up to a temperature of 1000 ℃. By using MAP, high temperatures on pyrolysis can be achieved in a short time and also can save a lot of energy.

Researchs on the production of pyroligneous acid from biomass waste through the pyrolysis process have been carried out by Ariffin et al. (2017) for palm oil waste, Pimenta et al. (2018) for eucalyptus plants, and Ibrahim et al. (2014) for mangroves (2014). The pyrolysis process generally requires high temperatures (500-600 ℃) with a low yield (24.4%). This result is not promising from the commercial side. Therefore, to overcome this problems, pyroligneous acid production from microwave-assisted coconut shell waste is needed.

4. Pyroligneous Acid

Pyroligneous acid is one of important compound of liquid product from pyrolysis process which has numerous benefits but has not been widely studied. Piroligneous acid is a by-product of biochar (charcoal) conversion process into activated carbon through the pyrolysis process. Pyroligneous acid is a side product from biochar (active carbon) production from pyrolysis process. Pyroligneous acid is a mixture of water, alcohol, organic acid, phenol, aldehide, ketone, ester, furan, derivatives of pyran, hydrocarbons, and nitrogen compounds. Composition and pyroligneous acid products obtained from pyrolysis process is depend on the biomass raw material as well as the operating condition of the process itself. Generally, pyroligneous acid has a brownish red look and also wood distillate which is soluble in water (Guerrero et al., 2005).

In the active carbon industry, pyroligneous acid can be found as a side product and has not been utilized and it only just treated as a waste. On the other hand, pyroligneous acid contains a component which has high economic potential due to its properties which are an antifungal for plants, herbicides, plant growth boosters, antibacterial, anti-oxidant and anti-inflammatory. All of this properties are prospective to be used in pharmacy (Pimenta et al., 2018; Ma et al., 2014). With the opportunity of pyroligneous acid application in the pharmaceutical, health and medicine industries, the research is focusing on the synthesize of pyroligneous acid from biomass

The most widely used method to obtain pyroligneous acid from biomass is by using pyrolysis process. Several biomass materials have been studied such as palm oil kernel (Arifin et al., 2017), mangroves (Ibrahim et al., 2014), wallut peanut shells, oak tres (Guillen and Manzanos, 2002), eucalyptus plants (Ma et al., 2014) and so on. The pyrolysis methods that have been used are fast, flash and slow pyrolysis. So far, the yield of pyroligneous acid produced from the various pyrolysis method is relatively low whish is below 25%. This process requires a very high temperature which is above 500 °C, so it will cost high energy to achieve this operating condition. This research is going to overcome the problem by applying an innovation in the production of pyroligneous acid as a pharmacy products by using microwave assisted pyrolysis.

The biomass that will be used in this study is coconut shell waste. Coconut shell waste is can be found easily in Indonesia because Indonesia is the largest coconut producer in the world. So far, this coconut shell waste has not been widely used as a strategic product with high added value.

5. Microwave-Assisted Pyrolysis

In this study, the innovation of pyroligneous acid production from waste coconut shell was carried out by microwave-assisted pyrolysis. Microwave technology has been widely applied to accelerate reactions and separation because microwaves will accelerate molecular motion and increase the possibility of contact between molecules, which has an impact on increasing the yield of a process (Handayani et al., 2013). However, so far, the application of micro waves for the process of pyrolysis of coconut shells in the framework of the production of pyroligneous acid has not been studied so that it is a novelty in the field of process technology. The design of the tools developed is shown in Figure 2.

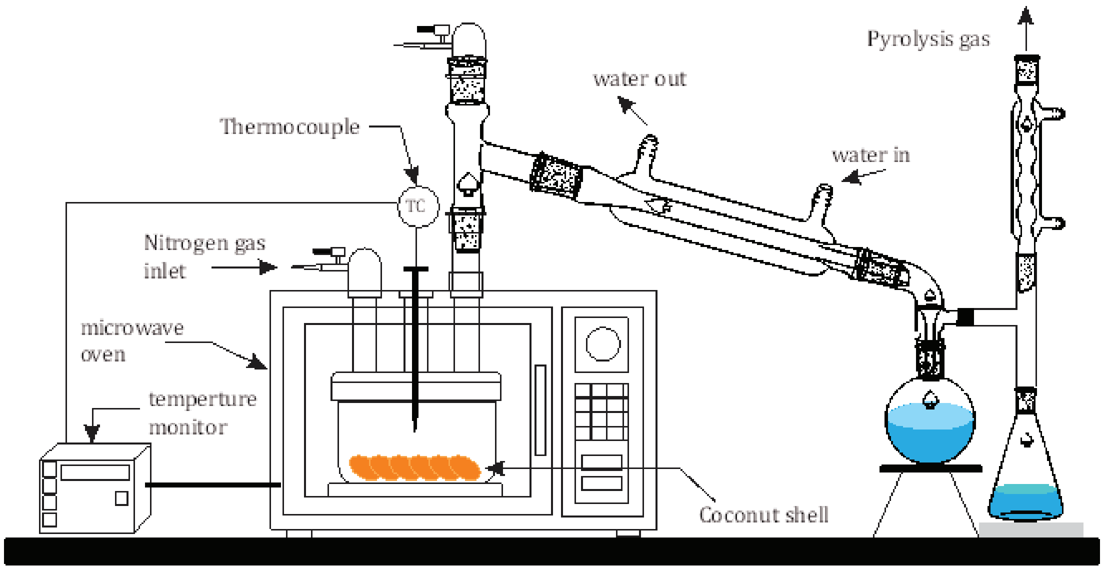

Figure 2: Microwave-Assisted Pyrolysis for Coconut-Shell Based Pyroligneous Acid Production.

The design of the MAP equipment is a new innovation because pyrolysis is integrated with microwaves. The picture of the pyrolysis equipment is shown in Figures 2 and 3.

The waste coconut shell which is going to be pyrolyzed by using MAP need to be pretreated by using the following process, drying, cleaning and size reduction. The size of raw materials needs to be reduced to increase the surface area of the particles so that the pyrolysis reaction will become more effective. The drying process aims to reduce the water content in the raw materials. Raw material with high water content might slow down the pyrolysis reaction. Overall the detail of pretreatment processes are the waste coconut shell is dried under the sun to reduce the water content. Furthermore, the coconut fiber which is attached to the coconut shell is cleaned. Next, the clean and dry waste coconut shell are then reduced into 5 – 7 mm. Finally, this raw material is ready to be pyrolyzed to obtain the pyroligneous acid.

This equipment has been tested to determine the range of operating condition temperatures that can be achieved and the general behavior of the tool and tested the results of pyrolygneous acid.

Figure 3: Equipment installation.

Figure 4: MAP Equipment preliminary test.

Figure 5: Dried waste coconut shell.

6. Conclusion

Several pyrolysis method to obtain pyroligneous acid have been discussed. An improved equipment of microwave assisted pyrolysis has been developed and pleminary research on the production of pyroligneous acid from coconut shell has been conducted. Chemical Engineering student from UNNES is also going to be sent to Universiti Teknologi Malaysia for the further study on the improvement of pyroligneous acid producion through microwave assited pyrolysis method

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Figure 6: Reduced size of waste coconut shell.

References

[1] Ariffin, S. J., Yahayu, M., El-Enshasy, H., Malek, R. A., Aziz, A. A., Hashim, N. M. dan Zakaria, Z. A. 2017, *Optimization* of *pyroligneous acid production* from *palm kernel shell* and *its potential antibacterial* and *antibiofilm activities*, Indian Journal of Experimental Biology, 55 (7), 427-435

[2] Astuti, W., Sulistyaningsih, T., dan Maksiola, M., 2016, Chemically modified kapok sawdust as adsorbent of methyl violet dye from aqueous solution, Jurnal Teknologi (Science and Engineering) 78 (9), 35-42

[3] Astuti, W., Hermawan, R.A, Mukti, H., and Sugiyono, N.R., 2017, Preparation of activated carbon from mangrove propagule waste by H3PO4 activation for Pb2+ adsorption, AIP Conference Proceedings 1788 (1), 030082

[4] Bilehal, D and Kim, L.L.Y.H., 2012, Gas Chromatography–Mass Spectrometry Analysis and Chemical Composition of the Bamboo-Carbonized Liquid, Food Analytical Methods 5(5):109–112

[5] Fardhyanti, D.S. and Damayanti, A., 2017, Analysis of Bio-Oil Produced by Pyrolysis of Coconut Shell, Journal World Academy of Science, Engineering and Technology, International Journal of Chemical, Molecular, Nuclear, Materials and Metallurgical Engineering, 11(9), 636-639

[6] Ibrahim, D., Kassim, J., Lim, S.H., and Rusli, W., 2014, Evaluation of antibacterial effects of Rhizophora apiculata pyroligneous acid on pathogenic bacteria, Malaysian Journal of Microbiology, 10(3), 197-204

[7] Guillén, M.D. dan Manzanos, M.J., 2002, Study of the volatile composition of an aqueous oak smoke preparation. *Food Chem.*, *79*, 283–292.

[8] Guerrero, M., Ruiz, M.P., Alzueta, M.U., Bilbao, R., and Millera, 2005, A. Pyrolysis of eucalyptus at different heating rates: Studies of char characterization and oxidative reactivity. *J. Anal. Appl. Pyrolysis,* 74, 307–314.

[9] Hendaryati, D.D., dan Arianto, Y., 2016, 2015-2017 Kelapa, Direktorat Jendral Perkebunan Indonesia, Jakarta.

[10] Ma, C., Li, W., and Zu, Y., Yang, L., and Li, J., 2014, Antioxidant Properties of Pyroligneous Acid Obtained by Thermochemical Conversion of *Schisandra chinensis* Baill, *Molecules* 2014, *19*, 20821-20838

[11] Handayani, P.A., Megawati, Sediawan, W.B., 2013, Extraction of P. cubeba Essential Oil by Microwave Assisted Hydrodistillation: Modeling and Process Optimization, Journal American Journal of Oil and Chemical Technologies, 1(10)

[12] Pimenta, A.S., Fasciotti, M., Monteiro, T.V.C., and Lima, K.M.G., 2018, Chemical Composition of Pyroligneous Acid Obtained from Eucalyptus GG100 Clone, Molecules 2018, 23, 426

[13] Pugersari, D., Syarief, A. dan Larasati, D., 2013, Eksperimen Pengembangan Produk Fungsional Bernilai Komersial Berbahan Baku Tempurung Kelapa Berusia Muda dengan Teknik Pelunakan, ITB J. Vis. Art & Des, 5(1), 74-91

[14] Troup, G.M. and Georgakis, C., 2013, Process systems engineering tools in the pharmaceutical industry, Computers and Chemical Engineering 51, 157– 171