# Producing Bio-Oil from Coconut Shell by Fast Pyrolysis Processing

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# Producing Bio-Oil from Coconut Shell by Fast Pyrolysis Processing

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**Abstract.** The utilization of biomass as a source of new and renewable energy is being carried out. One of the technologies to convert biomass as an energy source is pyrolysis which is converting biomass into more valuable products, such as bio-oil. Bio-oil is a liquid which produced by steam condensation process from the pyrolysis of coconut shell. The composition of biomass such as hemicellulose, cellulose and lignin will be oxidized to phenol as the main content of the bio-oil. Production of bio-oil from coconut shell was investigated via fast pyrolysis reactor. Fast pyrolysis was carried out at 500 °C with a heating rate of 10 °C and 1 hour holding time at pyrolysis temperature. The Bio-oil chemical composition was investigated using GC-MS. Percentage value of phenol, 2-methoxy phenol, 3-methoxy 1,2-benzenediol, and 2,6-dimethoxy phenol was 45.42%, 13.37%, 10.09%, and 11.72% respectively.

## 1 Introduction

Along with the depletion of world oil reserves and environmental issues, various researches on renewable energy are being actively conducted by various parties. Therefore, new technology needed to be able to overcome those issues. One of the technology that can be used is pyrolysis technology where the raw material comes from organic waste (biomass). The pyrolysis technology also has the potential to tackle organic waste problem and convert it into valuable end product.

Pyrolysis is a thermal conversion process for turning biomass into a more valuable product such as bio-oil. Bio-oil is dark-colored liquid fuel, smells like smoke that condensed from pyrolysis vapors product from ingredients that contain lots of lignin, cellulose, hemicellulose and other carbon compounds. Bio-oil consists of carbon, hydrogen, and oxygen with little nitrogen and sulfur. Sulfur and nitrogen content in bio-oil can be eliminated because of its little impact towards bio-oil performance. The largest organic components in bio-oil are lignin, alcohol, organic acids, and carbonyls. These characteristics make bio-oil an environmentally friendly fuel, and potentially have a greater caloric value than other oxygen fuels (such as methanol) and are only slightly lower in caloric value than diesel and other light fuel oils [1].

The biomass used to produce bio-oil can be obtained from agricultural, forest, plantation, industrial and household waste. Tropical countries like Indonesia generally have abundant biomass resources. Biomass raw materials which potentially used as raw materials for making bio-oils are

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durian leather [2], oak [3], corn cobs [4], powder / sawmills and wheat bark [5], jathropa [6], fruit pulp [7], coconut shell [8].

Coconut shell waste caused many problems in waste management that usually had been left to rot, stacked, and burned. Those handling will have a negative impact on the environment. One alternative that can be taken to overcome those problems are to convert it into valuable products with applicative and cheap technology so that the results are easily applied to the society.

The aim of this research is to convert waste of biomass into new raw materials or products that have an economic value such as Bio-oil (as an alternative energy resources).

This next research needs to be done to extract phenolic compounds as the main component of bio-oil which is corrosive, unstable and so difficult to be upgraded into ideal fuels [1]. Phenolic compounds are useful for disinfectant or floor cleaner. For the rubber industry, phenol is used to increase the quality of the rubber.

## 2 Materials and Method

### 2.1 Materials

The coconut shell was obtained from local market at Semarang, Central Java, Indonesia. Materials for supporting the fast pyrolysis process are distilled water. glasswool and $N_2$ gas.

### 2.2 Experimental

Coconut shell was washed using distilled water and then cut into small pieces and dried in an oven at 110°C for 1 hour. Dried coconut shell was crushed using hammer mill and separated by size using a sieve shaker.

The 1000 g prepared coconut shell is fed into a fixed bed reactor. The $N_2$ gas is fed into a vertical reactor (the schematic experimental is shown in Fig.1) at a rate of 200 ml / min from below until it passes through the top of the reactor. The $N_2$ gas serves as a substitute for air of the reactor, allowing the conditions when the pyrolysis reaction is anaerobic because there is no $O_2$ gas in the reactor. The steam formed during the pyrolysis process is the bagasse that flows with the N2 gas toward the top of the reactor, then cooled with a water-filled condenser. From the condenser, the vapor containing the mixed gas turns into a liquid with a temperature drop to 50°C. The liquid product from the condenser is collected in a 500 ml sample bottle, while the non-condensable gas, collected in a gas bag.

The schematic experimental of coconut shell reactor pyrolysis is shown in Fig. 1.

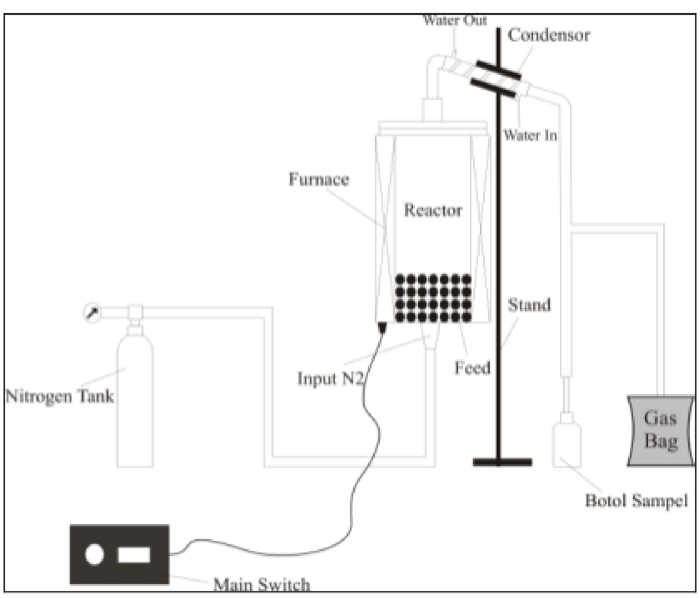

**Figure. 1.** Fast Pyrolysis Equipment for Producing Bio-Oil from Coconut Shell.

Bio-oil are stored in the refrigerator and used for the next step. The compositions of bio-oil from pyrolysis of coconut shell were analyzed by GC-MS (the principal conditions are shown in Table 1).

**Table 1.** Conditions of Gas Chromatograph Mass Spectroscopy

| | | |
|---|---|---|
| GC-MS: Perkin Elmer<br>GC Clarus 680<br>MS Clarus SQ 8T | | |
| Column: | | |
| Inner diameter | [m] | 2.5 x $10^{-4}$ |
| Length | [m] | 30 |
| Carrier gas | - | He |
| Split ratio | [-] | 42.2 : 1 |
| Sample volume | $m^3$ | $1.10^{-6}$ |
| Injection temp. | [K] | 583 |
| Column temp. | [K] | 333 |
| Pressure column | | vacuum |
| Column flow | mL/min | 0.8 |
| MS Scan | [K] | 323 - 573 |
| Hold | min | 5 |

## 3 Results and Discussion

The density of bio-oil obtained in this experiment is 0.961 g/cm$^3$. Based on the standard range proposed by Mohan et al [9], the average density of bio-oil is 0.94-1.2 g/cm$^3$. According to Mohan et al [9] the density value is influenced by the molecular weight of the components contained therein. The higher the molecular weight, the density will also be greater. The bio-oil density value that approximates the water density value shows that bio-oil has a considerable water content. The presence of water comes from moisture levels in the biomass feed and indicates that there is still a small amount of oxygen in the reactor allowing the combustion reactions that produce water and carbon dioxide [10]. The condition of the reactor which is free from oxygen needs to be identified accurately.

The bio-oil viscosity obtained in this study was 4,359 cp. The viscosity of bio-oil obtained in this research generally meets the standard range of bio-oil which is 4-7 cp [9]. According to Mohan et al [9], high viscosity mades the bio-oil difficult to flow during the distribution and storage process.

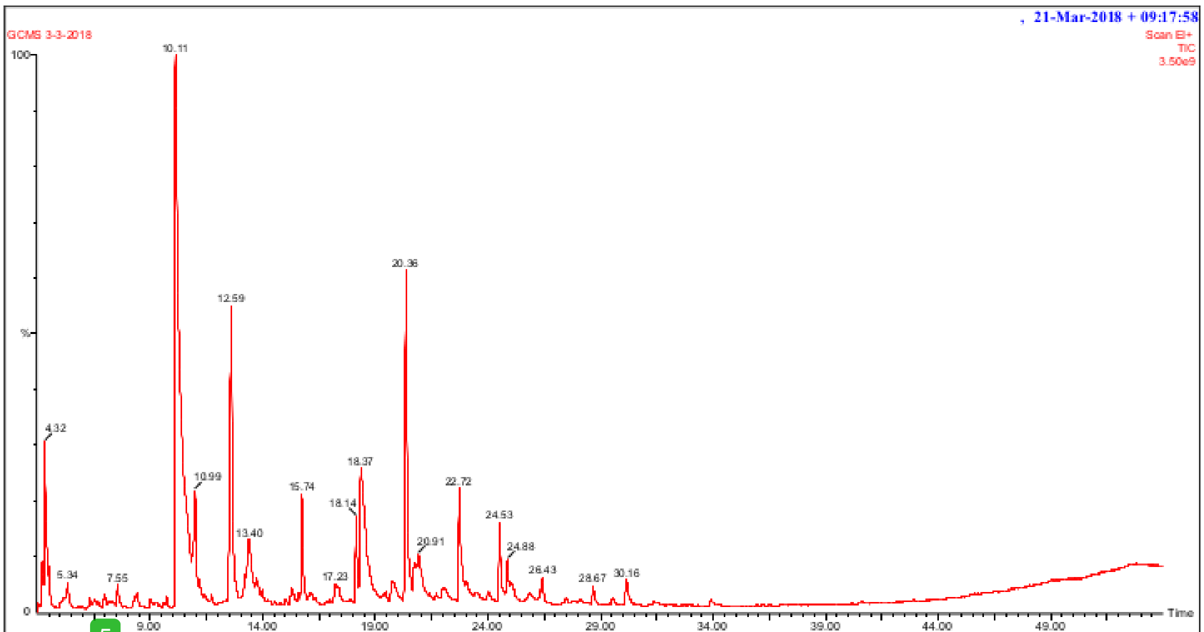


**Figure 2.** GC-MS Chromatograph of Bio-Oil from Coconut Shell.

The chromatogram results shown in Fig. 2 shows that the composition of the most dominant compounds contained in coconut shell bio-oil is 45.42% of phenol, 13.37% of 2-methoxy-phenol, 10.09% of 3-methoxy-1,2-benzenediol and 11.72% of 2,6-dimethoxy-phenol. The overall bio-oil composition is shown in Table 2.

Bio-oil with phenol content more than 50% would be very good if used as fuel [11]. In this research, the dominant chemical compound of coconut shell bio-oil is phenol. This is because the pyrolysis temperature used is 500°C and most of the lignin in the biomass of the coconut shell has been decomposed.

**Table 2.** The Compositions of Bio-Oil from Fast Pyrolysis of Coconut Shell

| Peak Number | Compounds | Percentage (%) |
|---|---|---|
| 1 | Furfural | 3.77% |
| 2 | Phenol | 45.42% |
| 3 | 3-methyl-1,2-Cyclopentanedione | 4.05% |
| 4 | 2-methoxy-Phenol | 13.37% |
| 5 | 2-methoxy-4-methyl-Phenol | 3.23% |
| 6 | 4-ethyl-2-methoxy-Phenol | 2.19% |
| 7 | 3-methoxy-1,2-Benzenediol | 10.09% |
| 8 | 2,6-dimethoxy-Phenol | 11.72% |
| 9 | 4-methoxy-3-methoxymethyl-Phenol | 3.83% |
| 10 | 5-tert-Butylpyrogallol | 2.31% |

## 4 Conclusions

The bio-oil produced from coconut shell with pyrolysis method has density and viscosity of g/cm$^3$ and 4,359 cp, respectively.

The main components contained in the bio-oil are phenol (45.42%), 2-methoxy-phenol (13.37%), 3-methoxy-1, 2-benzenediol (10.09%), and 2,6-dimethoxy-phenol (11.72%).

## References


1. E. Hambali, S. Mujdalipah, A.H. Tambunan, A.W. Pattiwiri, R. Hendroko, *Teknologi Bioenergi.* (Agromedia Pustaka, Jakarta 2007).
2. S. Ismadji, S., *Prosiding Seminar Nasional Teknik Kimia Soebardjo Brotohardjono I* (Prodi Teknik Kimia UPN Veteran Jawa Timur, 2012).
3. C.J. Ellens, R.C. Brown, Biores. Technol. **103**, pp. 374-380 (2012).
4. I. Demiral, A. Eryazici, S. Sensoz, Biomass Bioenergy, **36**, pp. 43-49 (2012).
5. M. Bertero, G. de la Puente, U. Sedran, Fuel, **95**, pp. 263-271 (2012).
6. A. Haryanti, Norsamsi, P.S.F. Sholiha, N.P. Putri, Konversi, **3,** 2 pp.20-29 (2014).
7. M. Ozbay, E. Apaydin-Varol, B. Uzun, A. Putun, Energy, **33**, pp. 1233-1240 (2008).
8. T. Hidayat, Qomaruddin, *Prosiding SNST ke-6* (Fakultas Teknik Universitas Wahid Hasyim, Semarang 2015).
9. D. Mohan, C.U. Pittman, P.H. Steel, Energy and Fuels, **20**, pp. 848-889 (2006).
10. A.O. Ningrum, *Proses Pembuatan Bio-Oil dari Limbah Kelapa Sawit (Tandan, Cangkang, dan Serat) untuk Bahan Bakar Alternatif dengan Metode Fast Pyrolysis* (Skripsi, Universitas Indonesia, Indonesia, 2011).
11. L. Kusmiati, *Pirolisis Kulit Kayu Pinus (Pinus Merkusii) menjadi Bio-Oil menggunakan Katalis Ni/Lempung* (Skripsi, Universitas Riau, Indonesia, 2015).

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