

Co-pyrolysis product analysis of coffee husk and LDPE plastic mixture

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Abstract. The main energy source in Indonesia is fossil fuels, but this energy source has a detrimental impact on the environment such as global warming. One solution to reduce fossil fuel consumption is to use alternative energy sources derived from biomass. Coffee husks are one of the biomass that is abundantly available and has the potential as an alternative energy. To optimize coffee husk waste as an alternative fuel, it is mixed with low-density polyethylene (LDPE) plastic which has a high calorific value, thereby improving the quality of the mixed product. In this research, the slow pyrolysis method without a condenser was used with a temperature of 600 °C, a grain size of 60 mesh, with variations in the treatment of raw coffee husks without the addition of LDPE plastic, the addition of 25% LDPE, and the addition of 50% LDPE plastic. Pyrolysis without the addition of LDPE obtained a yield of 35.9% solid material, 19.9% liquid, and 44.2% gas. Pyrolysis results with the addition of 25% LDPE obtained solid yield of 28%, liquid 21.1%, and gas as much as 50.9%. Meanwhile, the addition of 50% LDPE obtained a solid yield of 19.6%, liquid 42.4%, and gas as much as 38.1%.

1 Introduction

Jember Regency is one of the third largest robusta coffee producing regions in East Java province [1]. According to data from the Central Statistics Agency (BPS) of Jember Regency, the distribution of coffee areas in Jember Regency in 2023 reached 18,318 hectares spread across almost all sub-districts. The total coffee plantation area produces a production of 8,901.60 tons/year with coffee husk waste of 3,115.56 tons/year. Some coffee husks are currently used as animal feed, but most cannot be processed so that when the coffee harvest season arrives there is an accumulation of coffee husk waste.

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Coffee husk waste produced from the coffee processing process is not utilized and is often just piled around forest areas. This accumulation of waste has the potential to produce methane gas due to anaerobic decomposition [2]. Methane gas is a greenhouse gas that has a negative impact on the environment because it can contribute to global warming and climate change [3].

Besides the problem of coffee husk waste, the problem of waste accumulation in the Jember Regency city area is 72,817.79 kg/day with an LDPE plastic composition of around 11-15% [1]. LDPE represents the second biggest portion of plastic waste with the approximate consumption of 415 million in 2015. This value is expected to increase by 4 % in the following years. LDPE is widely used as plastic bags and packaging due to its excellent characteristics of flexibility, ease of processing and low cost [5]. Compared to HDPE, LDPE has more branching (2 % of carbon atom) and weaker intermolecular forces. Low Density Polyethylene (LDPE) is a type of plastic that is often found in various applications and often ends up as waste. This type of plastic has a very high calorific value of 11,758 cal/g and has the potential to be used as a raw material for making briquettes [6]. However, unfortunately, the volatile matter content of up to 98.53% makes LDPE plastic tend to burn out more quickly, so it is necessary to mix the composition with other materials that are known to have good enough quality to be made into briquettes [7]. Suriapparao and Vinu, [8] examined the co-pyrolysis of LDPE with five different biomass and found that the experimental bio-oil yield (13.2 – 32.3 wt%) was less than the theoretical value (42–47.5 wt%). One of biomass material that has the potential to be used as a raw material for LDPE plastic mixtures is coffee husk.

The problem of coffee husk waste reaching 11,547.31 tons/year and LDPE plastic waste in Jember district reaching 3,115.56 tons/year, as well as the potential for energy conversion from the consortium of these two materials, the pyrolysis method is used [9]. Waste pyrolysis is a recycling method that converts plastic into fuel [10]. Waste pyrolysis not only produces high-energy fuel but also reduces waste [10]. Among these modes of conversions, pyrolysis is considered an efficient process because the ratio of feedback to fuel is higher than then other modes of conversions [11].

The aim of this research is to produce pyrolysis products from a mixture of coffee skins and with the addition of LDPE plastic, it can produce solid, liquid and gas products that have the potential to be raw materials for energy conversion or products that have other useful values.

2 Materials and Methods

The method used in this research consists of two stages, namely raw material preparation and the pyrolysis process.

2.1 Preparation Raw Material

The raw materials were prepared by drying the coffee husks obtained from the Sumber Kembang Farmers Group in Jember Regency in the sun for two days. The husks were then ground using a grinder and sieved through a 60-mesh sieve.

2.2 Pyrolysis Process

Pyrolysis was carried out on three variations, namely without adding LDPE (100% coffee skin), adding 25% LDPE plastic, and adding 50% LDPE plastic three times. Pyrolysis was carried out at 600°C using a fixed-bed pyrolysis reactor, as shown in Figure 1. The products resulting from the pyrolysis process are solid materials in the form of charcoal, liquid materials and gas.

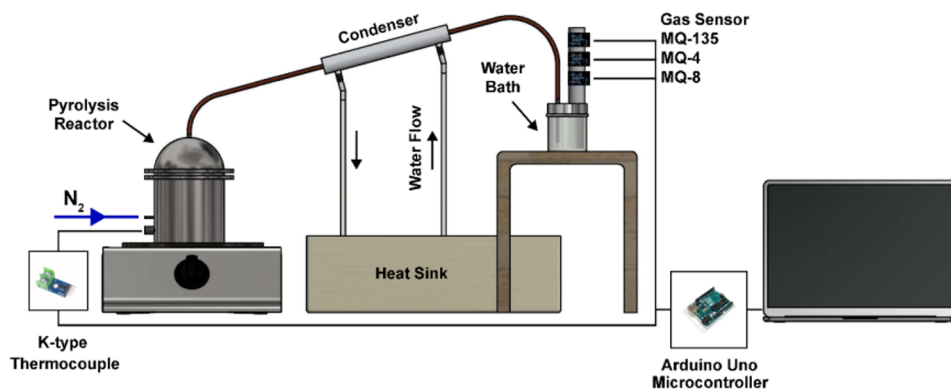


Fig. 1. Fixed-bed pyrolysis reactor [12]

3 Results and Discussion

In this study, three treatments were conducted in the co-pyrolysis process between coffee husks and the addition of LDPE plastic. The first treatment was a pyrolysis process without the addition of LDPE plastic. The second treatment was a pyrolysis process with the addition of 25% LDPE plastic, and the second treatment was a pyrolysis process with the addition of 50% LDPE plastic. The results of the study are presented in the following sub-chapters.

3.1 Without Added LDPE

Based on Table 1, which is the result of pyrolysis of coffee skin without the addition of LDPE plastic, it is known that the product yield is dominated by gas material, namely 44.2%, then char or solid material is 35.9%, and liquid material is 19.9%. Other products resulting from the pyrolysis process of coffee skin without the addition of LDPE plastic are the aqueous phase of 77.63%, and crude oil as much as 23.37%. For crude oil and wax, wax, and heavy fractions were not found.

Table 1. Results of coffee husk

Pyrolysis Product	Unit	Value
Char	%	35.9
Liquid	%	19.9
Gas	%	44.2
Aqueous phase	%	77.63
Crude oil	%	23.37
Crude oil + Wax	%	-
Wax	%	-
Heavy Fraction	%	-

3.2 Addition of 25% LDPE

Based on Table 2. Which is the result of pyrolysis of coffee skin with the addition of 25% LDPE plastic, it is known that the yield of the resulting product in the form of gas is 38.1%, then the char or solid material is 28%, and the liquid material is 21.1%. Other products resulting from the pyrolysis process of coffee husk with the addition of 25% LDPE plastic are the aqueous phase of 59.52%, and crude oil as much as 30.28%, wax is 6.52, and heavy fraction is 3.68%. Meanwhile, the mixture of crude oil and wax was not found.

Table 2. Results addition of 25% LDPE

Pyrolysis Product	Unit	Value
Char	%	28.0
Liquid	%	21.1
Gas	%	38.1
Aqueous phase	%	59.52
Crude oil	%	30.28
Crude oil + Wax	%	-
Wax	%	6.52
Heavy Fraction	%	3.68

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3.3 Addition of 50% LDPE

The results of pyrolysis of coffee skin with the addition of 50% LDPE plastic are known to be dominated by liquid material yield of 42.4%, then gas material of 38.1%, and char or solid material of 19.6%. Other products resulting from the pyrolysis process of coffee skin with the addition of 50% LDPE plastic are aqueous phase of 17.85%, a mixture of crude oil and wax of 75.52%, and heavy fraction of 6.63%. Crude oil and wax were not found. The pyrolysis results are presented in Table 3.

Table 3. Results addition of 50% LDPE

Pyrolysis Product	Unit	Value
Char	%	19.6
Liquid	%	42.4
Gas	%	38.1
Aqueous phase	%	17.85
Crude oil	%	-
Crude oil + Wax	%	75.52
Wax	%	-
Heavy Fraction	%	6.63

3.4 Discussion

The results of co-pyrolysis between coffee husks with the addition of LDPE plastic are presented in Figure 4.1. The combination treatment of adding coffee husks with 20% and 50% LDPE plastic, as well as without treatment, showed different trends in results. Judging from the solid product (char) produced, it is known that the highest yield was obtained from pyrolysis of coffee husks without the addition of LDPE plastic, namely with a yield of 35.9%. The second highest yield was obtained from the variation of co-pyrolysis of coffee husks with the addition of 25% LDPE plastic, and the smallest value was obtained from co-pyrolysis of coffee husks with the addition of 50% LDPE, namely 19.6%. The content of coffee husks contains 39.2 ± 0.2 wt% cellulose, 12.6 ± 0.1 wt% hemicellulose, 23.3 ± 0.1 wt% Klason lignin, and 2.9 ± 0.4 wt% acid-soluble lignin [13]. High cellulose and hemicellulose content can produce a lot of char. On the other hand, for the liquid product, the highest co-pyrolysis yield was obtained from coffee skin with the addition of 50% LDPE plastic, namely 42.4%. Furthermore, for the co-pyrolysis yield of coffee skin with the addition of 25% LDPE plastic, namely 21.1%, and the lowest liquid product yield was obtained from the pyrolysis of coffee skin without the addition of LDPE plastic, namely 19.9%. The pyrolysis yield between coffee husk and LDPE plastic both have the potential for high gas products, so that when condensed, they will produce high liquid products.

Meanwhile, for gas products, the highest yield was obtained from the co-pyrolysis of coffee skin with the addition of 25% LDPE plastic, namely 50.9%, followed by the pyrolysis yield without the addition of LDPE plastic, namely 44.2%, and the smallest yield was obtained from the co-pyrolysis of coffee husk with the addition of 50% LDPE plastic, namely 38.1%. According to Alamsyah et al., [14], the quality of smoke contains high tar, namely 51.82%, so that the gas produced from the pyrolysis of coffee skin is quite high when compared to the co-pyrolysis of coffee skin with a mixture of LDPE plastic. To produce a dominant solid product (char), the pyrolysis process can be carried out without a mixture of LDPE plastic, but to produce a product dominated by liquid materials, a composition of 50% LDPE can be used, while to produce a product dominated by gas materials, an addition of 25% LDPE plastic can be used.

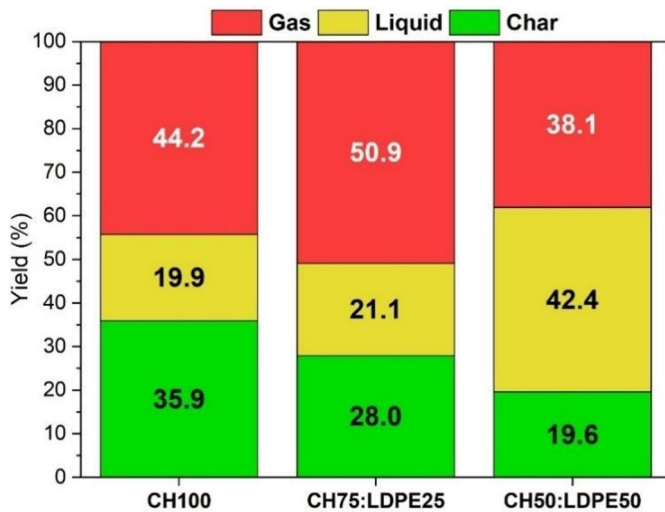


Fig. 2. Analysis graph of solid, liquid, and gas products from co-pyrolysis of coffee husk and LDPE plastic

In addition to solid, liquid, and gas products in the pyrolysis process of coffee husks, coffee husks and LDPE plastic also produce other products in the form of aqueous phase, crude oil, crude oil + wax, wax, and heavy fraction. The highest aqueous phase results were obtained from the pyrolysis yield of coffee husks, namely 77.63%, then co-pyrolysis of coffee husks and the addition of 25% LDPE plastic, namely 59.52%, and the lowest results were from Co-pyrolysis of coffee husks with the addition of 50% LDPE plastic, namely 17.85%. Coffee husks, which are raw materials from biomass sources, are more dominant in having a high water content compared to LDPE materials. This can be seen from Figure 3, where the more raw materials of coffee husks, the more water phase products there are. Robusta coffee husks in the Jember region have a fairly high water content, namely 8.59% [15]. The highest crude oil yield was obtained from co-pyrolysis of coffee skin with 25% LDPE plastic mixture, namely 30.28%, and the second highest yield was obtained from pyrolysis without LDPE plastic mixture, namely 22.37%. Co-pyrolysis of coffee skin with 50% LDPE plastic mixture did not produce crude oil but produced a very high crude oil + wax mixture, namely 75.52%. Meanwhile, for pyrolysis of coffee skin without the addition of LDPE and co-pyrolysis of skin with a mixture of 25% LDPE plastic did not produce crude oil + wax products, but the treatment of adding 25% LDPE produced a wax yield of 6.52%. The highest yield of heavy fraction products was obtained from co-pyrolysis with the addition of 50% LDPE plastic, namely 6.63%, and co-pyrolysis with the addition of 25% LDPE plastic which

produced a heavy fraction of 3.68%. Heavy fraction, which is one of the products resulting from the decomposition of petroleum, will be obtained from the pyrolysis process of plastic derivatives, whereas it is not found in biomass decomposition.

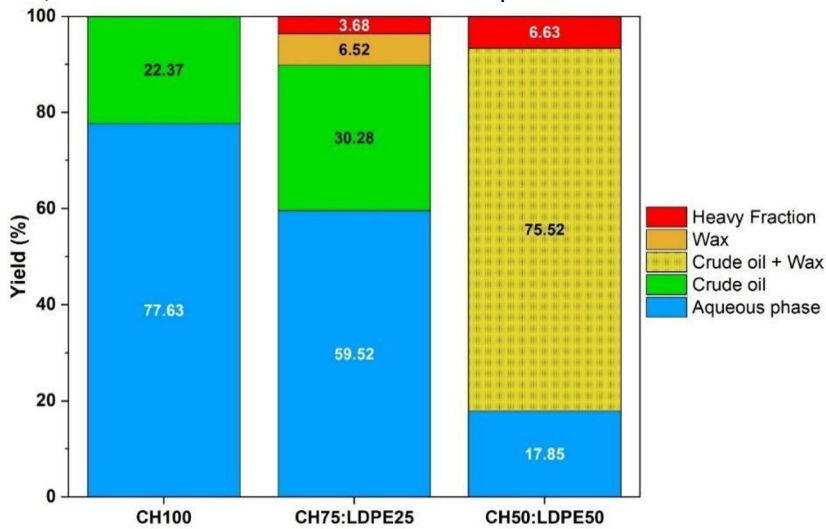


Fig. 3. Analysis graph of additional products from Co-pyrolysis of coffee husk and LDPE plastic

Based on the results of the co-pyrolysis process between coffee skin and the addition of LDPE plastic, it is known that the addition of LDPE plastic with biomass (coffee skin) has the potential to be developed as an alternative material that produces solid products in the form of char as a raw material for briquettes and as a material that can increase its ability to remediate soil quality, has the potential to improve soil structure, and increases microbial activity that plays a role in soil fertility [16]. Liquid products can be developed as raw materials for liquid fertilizers and according to Nurjaya [17] liquid smoke can be used as a preservative that can increase the shelf life of food, and gas materials can also be used as preservatives.

4 Conclusion

Based on the results of the coffee skin pyrolysis process and co-pyrolysis of coffee skin with a mixture of LDPE plastic, three products were produced consisting of solid (char), liquid, and gas. Pyrolysis without the addition of LDPE obtained a yield of 35.9% solid material, 19.9% liquid, and 44.2% gas. Pyrolysis results with the addition of 25% LDPE obtained a solid yield of 28%, liquid 21.1%, and gas as much as 50.9%. Meanwhile, the addition of 50% LDPE obtained a solid yield of 19.6%, liquid 42.4%, and gas as much as 38.1%. From this study, it is known that the co-pyrolysis process between coffee skin and LDPE plastic has the potential to be developed as an alternative material in solid, liquid and gas forms.

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