

EFFECTS OF HOT FILTER MEDIA ON THE YIELD AND PROPERTIES OF FUEL OBTAINED FROM THE PYROLYSIS OF RUBBER DUNG

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Abstract

This research aimed to study the effect of hot filter media on the yield and properties of fuel obtained from the pyrolysis of rubber dung in a fixed bed reactor under a reaction temperature of 300°C for 2 hours. The hot filter media used in this study consisted of dolomite, charcoal, charcoal pellets, rice husks, and rice husk pellets. The hot filter operates at a reaction temperature of 100°C. The results indicated that pyrolysis of rubber dung without filter media yielded a maximum fuel content of 70 wt%. When the filter media was placed in the hot filter, the yield of fuel significantly reduced. Dolomite resulted in a minimum reduction in fuel yield of 49 wt%. However, the fuel obtained using different types of filter media exhibited improved properties. Dolomite increased the heating value of the fuel to a maximum of 42.4 MJ/kg and reduced viscosity by up to two times. Therefore, it can be concluded that using hot filter media in pyrolysis reduces the yield of fuel but improves its properties, and is suitable for producing fuel oil from rubber waste through pyrolysis. Further research should be conducted to expand the application of this process to real-world community use.

Keywords: Hot Filter; Fuel; Pyrolysis; Rubber Dung

Introduction

Rubber dung includes rubber that is stuck in cut marks; rubber at the bottom of the cup; rubber that falls on the ground; rubber stuck in the container; rubber from wastewater treatment ponds; rubber left over from the processing of raw rubber sheets, foam rubber, and smoked rubber sheets; and concentrated latex scraps. This rubber dung can be used as raw material to produce low-quality block rubber. However, it has a disadvantage, which is a foul smell that creates odor pollution problems.

If there is proper management of rubber dung to reduce odor problems, it will help reduce this environmental and community problem. Transforming rubber dung into fuel by pyrolysis may be one process that can help increase value and reduce odor problems for the environment and the community.

For example, in a study of bio-oil production using a pyrolysis machine, the best pyrolytic bio-oil yield RSC (Rajia *et al.*, 2023) showed that

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the pyrolysis process is often used in research with rubber. Pyrolysis is the thermochemical decomposition of particles in an oxygen-free environment, so there is no internal combustion in the system and no odor effects. It has a short vapor residence time and then condenses the vapor rapidly (Bridgwater *et al.*, 1999) to obtain a liquid product, which is fuel. Most of the raw materials that are popularly pyrolyzed are in the form of solids. Therefore, rubber dung has characteristics that are suitable for pyrolysis. In the past, there has been research on the pyrolysis of plastic waste, which has similar characteristics to rubber dung. It was found that plastic waste can be converted into fuel up to 70 wt% (Pannucharoenwong *et al.*, 2023a). The factors that affect the yields and properties of the fuel include: the pyrolysis temperature (Duanguppama *et al.*, 2019; Janarthanan and Sivanandi, 2022; Vellaian, 2024); the type of plastic waste (Turakarn *et al.*, 2021; Chaiphet *et al.*, 2022; Al-Rumaihi *et al.*, 2023; Pannucharoenwong *et al.*, 2023a); the type of catalyst (Sasena *et al.*, 2021; Chaiphet *et al.*, 2022; Fu *et al.*, 2022; Sridevi *et al.*, 2022; Pannucharoenwong *et al.*, 2023a); and the condensation temperature (Pannucharoenwong *et al.*, 2022).

In 2023, Pannucharoenwong *et al.* (Pannucharoenwong *et al.*, 2023a) pyrolyzed plastic waste in a fixed-bed reactor with a reaction temperature of 300°C produced fuel exhibited physical characteristics similar to those of petroleum-based fuel. Analysis of the chemical composition revealed that it resembled diesel. Additionally, Danguppama *et al.* (Duanguppama *et al.*, 2019) studied pyrolysis at a temperature of around 300°C and tested how well biodiesel made from rubber seed (BKB) worked in diesel engines. In this research, RSB was produced in a double-shell reactor using KOH catalyst according to ASTM standard. In the pyrolysis reactor at 300°C, the plastic pyrolysis oil was first distilled to separate the diesel and gasoline fractions. According to (Bisrul *et al.*, 2024), the pyrolysis of plastic waste using dolomite and kaolin catalysts increased the fuel's heating value to 42 MJ/kg. The catalyst is expensive, resulting in high operating costs. In addition, there is research that has studied the potential of low-quality rubber waste as a raw material for the production of liquid biofuels through the pyrolysis process, which can be converted to fuel by 65-70%. The TGA test results indicated that WRPO has evaporation and thermal decomposition characteristics similar to B10 diesel, starting to evaporate at temperatures below 40°C and completely decomposing at 300°C, which showed the potential of WRPO as an efficient and environmentally friendly biofuel. (Preecha

et al., 2025). Moreover, cleaning the catalyst after pyrolysis is a crucial step in the production process. If other materials can be used to replace the catalyst, it will help reduce costs and steps in the production process.

In 2025, Muhammad *et al.* (2015) conducted a study on the pyrolysis of discarded car tires and inner tubes using SiO₂ as a catalyst. They found that the optimal conditions were a temperature of 350°C, a catalyst weight of 1.5 grams, and a heating time of 1 hour. They found the resulting oil to have properties similar to diesel, suggesting its potential as an alternative fuel.

Our research focused on the production of fuel from rubber dung by pyrolysis at a reaction temperature of 300°C in a fixed-bed reactor. The rate of rubber dung was 1 kg per experiment. Dolomite, charcoal, charcoal pellets, husk, and husk pellets were the five types of solid materials to be studied. They were put in the hot filter position to see how they changed the amount and properties of fuel. The key properties of the fuel that were measured included its high heating value, density, viscosity, flash and fire points, and ash content.

Materials and Methods

Feedstock

The experiment utilized rubber dung, as shown in Figure 1, which was sourced from discarded waste at storehouses in Sakon Nakhon province. Prior to collection, the rubber dung underwent sun-drying. According to proximate analysis, the material had a moisture content of less than 5 wt% and a high heating value (HHV) of 27.31 MJ/kg. The material was passed through both a natural filter, which served as a blank filter, and a synthetic filter. The filter material is a catalyst.



Figure 1. The rubber dung sample

Pyrolysis of rubber dung

Figure 2 illustrates the pyrolysis system used for rubber dung processing. The setup included a fixed-bed reactor, a hot air filter, a primary condenser operating with R134a refrigeration, and two additional condensers (Condenser 2 and 3) that functioned with air cooling. Automatic controls equipped the entire system, incorporating sensors for measurement and safety mechanisms.

The diagram also presents actual images of the equipment used. The reactor featured an internal diameter of 300 mm and a height of 500 mm. The hot air filter measured 200 mm in diameter and 600 mm in height. The primary condenser had an internal diameter of 200 mm and a height of 300 mm. The second and third condensers were designed as cylindrical units, each with a 300 mm diameter and a 500 mm height. All components were constructed from stainless steel, specifically grade 304, ensuring durability and resistance to corrosion.

The characteristics of the five catalysts included round, cylindrical, elliptical, and prismatic shapes. The pellet types had the following sizes: rice husk pellets with a thickness of 0.8 cm and a length of 0.8 cm, dolomite with a thickness of 0.40 cm and a length of 0.41 cm, and compressed charcoal with a thickness of 1.1 cm and a length of 9.1 cm. The densities of each type were as follows: Rice husk had a density of 0.00014 kg/m³, compressed rice husk had a density of 0.00054 kg/m³, charcoal had a density of 0.00007 kg/m³, compressed charcoal had a density of 0.00087 kg/m³, and dolomite had a density of 0.0002 kg/m³.

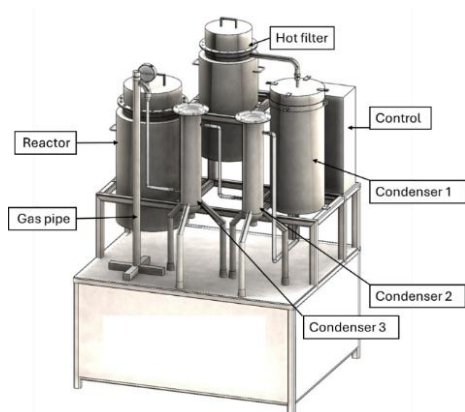


Figure 2. The pyrolysis diagram of rubber dung

The pyrolysis began by placing 1 kg. of rubber dung in the reactor and then tightly capping the reaction temperature at 300°C. The hot filter unit temperature was controlled at 100°C. The first

condenser employed a refrigeration technique with R134a working fluid by setting a reaction temperature of 10°C. The second condenser operated using air, maintaining a reaction temperature of approximately 30°C. Following this, the hot filter and reactor were activated, reaching the preset reaction temperature with heat supplied by LPG. The pyrolysis process lasted for two hours, during which the rubber dung underwent chemical and thermal decomposition. After completion, the control system was deactivated, allowing the equipment to cool naturally to room temperature.

Mass Balance

The pyrolysis of rubber dung resulted in three main products: fuel, ash, and gas. The first fuel yield was determined by measuring the weight increase in fuel pot 1. The second fuel yield was obtained by summing the weight increase in fuel pots 2 and 3. The ash yield was calculated based on the weight gain observed in the reactor and the hot filter. Lastly, the gas yield was estimated by subtracting the total fuel and ash yields from the initial material input.

$$Y_{\text{Fuel}} = \frac{(W_{\text{Fuel pot 1}} + W_{\text{Fuel pot 2}} + W_{\text{Fuel pot 3}})(\text{g})}{W_{\text{rubber dung}}(\text{g})} \times 100 \quad (1)$$

$$Y_{\text{Ash}} = \frac{(W_{\text{Reactor}} + W_{\text{Hot filter}} + W_{\text{Gas line}})(\text{g})}{W_{\text{rubber dung}}(\text{g})} \times 100 \quad (2)$$

$$Y_{\text{Gas}} = 100 - Y_{\text{Fuel}} - Y_{\text{Ash}} \quad (3)$$

When

Y_{Fuel} = Yields of fuel, wt%

Y_{Ash} = Yields of ash, wt%

Y_{Gas} = Yields of gas, wt%

$W_{\text{Fuel pot 1}}$ = Wet of fuel pot 1, g

$W_{\text{Fuel pot 2}}$ = Wet of fuel pot 2, g

$W_{\text{Fuel pot 3}}$ = Wet of fuel pot 3, g

$W_{\text{rubber dung}}$ = Wet of rubber dung, g

W_{Reactor} = Wet of reactor,

$W_{\text{Hot filter}}$ = Wet of hot filter, g

$W_{\text{Gas line}}$ = Wet of gas line, g

Fuel properties analysis

High heating value analysis

The fuel's heating value was measured following the DIN 51900 standard using an S.M.D. Torino bomb calorimeter. The analysis involved placing a 1 g fuel sample into a bomb cup, which was then pressurized with oxygen to 25 bar. The bomb cup was subsequently submerged in a bucket containing 2 liters of water to conduct the test.

When all parts were ready, the analyzer was started for about 5 min, then the switch pressed to ignite the fuel with a conductive wire. After about 20 mins, the computer analyzed the high heating value (HHV).

Kinetic viscosity analysis

The viscosity analysis was ASTM D445 for the standard analysis of the fuel. The viscosity was analyzed under 40°C in a glass tube, size 350 (Cannon-Fenske Viscometer).

Density analysis

The fuel density was determined in accordance with ASTM D4052. A 5 mL fuel sample was placed in a measuring cup and weighed at a controlled room temperature of 15°C.

Flash and fire point analysis

The fuel sample was tested for its flash and fire points following the ASTM D93 standard. The flash point refers to the minimum temperature at which the fuel's surface can produce a flammable vapor that momentarily ignites. In contrast, the fire point is the lowest temperature at which the fuel sustains continuous combustion.

Ash analysis

In agreement with DIN EN 7 standards, the fuel and its ash components were evaluated. Around 3 g of fuel placed in a container that had already been heated and dried underwent heating for 12 h. at 105°C. This process was to prevent foaming and splashing by eliminating volatile compounds and water. Subsequently, the sample was heated again for 24 h. at 775°C or whenever a constant weight was achieved. The number of rigid sediments during the previous fuel was then tallied up as the ash component.

Results and Discussion

The experimental results of pyrolysis of rubber dung in a fixed bed reactor at a reaction temperature of 300°C, a hot filter temperature of 100°C, a first condenser temperature of 10°C, and second and third condensers of about 30°C found that fuel was obtained from the first condenser, while the second and third condensers did not contain any fuel obtained from condensation. The experiment did not use any filter media and used 5 types of filter media, namely dolomite, charcoal, charcoal pellets, husk, and husk pellets. It was found that there were different quantities and characteristics of fuel as shown in Figure 3, with each bottle of fuel separated into two phases. The fuel obtained from pyrolysis

with dolomite and charcoal pellets was relatively clear in color, while the fuel from pyrolysis with charcoal, husk, and husk pellets was relatively black in color.



Figure 3. The fuel

Effect of the type of hot filter media on product yield

The results of pyrolysis of rubber dung in a fixed bed reactor without filter media (seen in Figure 4.) shows that the highest fuel yield was 70 wt%. When pyrolyzed with five types of filter media, the yield of fuel was significantly reduced. Dolomite filter media resulted in a minimum reduction of 49 wt% in fuel yield. This is because dolomite filter media promotes gas production (Duanguppama *et al.*, 2019; Pannucharoenwong *et al.*, 2023b)

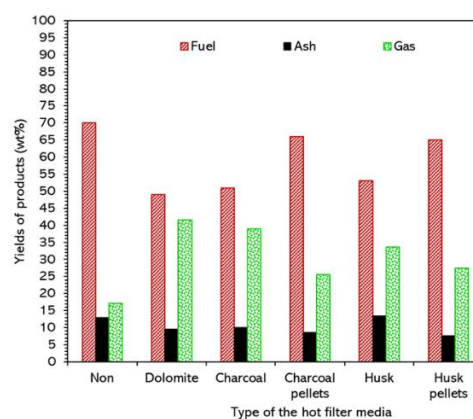


Figure 4. Effect of the type of hot filter media on products yield

Figure 4. shows that dolomite filter media had the highest gas yield, which is 41.5 wt%. What is interesting about this research is that the pellet filter media can increase the yield of fuel. The filter media of charcoal pellets and husk pellets had fuel yields of 66 and 65 wt%, respectively. While the

charcoal and husk filter media had fuel yields of 51 and 53 wt%, respectively. Therefore, it can be concluded that the density of both materials helps increase the efficiency of the pyrolysis vapor filtration to produce more fuel.

The fuel obtained from pyrolysis of rubber dung in a fixed bed reactor had physical characteristics of being separated into two phases. Figure 5. shows that in the case where non-filter media was used, the fuel at the top phase has a higher yield than the bottom phase. When charcoal and husks was used as filtering media, the yield of fuel at the top phase decreases and at the bottom phase increases. The charcoal filter media had a top phase fuel yield of 18.4 wt% and a bottom phase fuel yield of 32.6 wt%. The husk filter media had a fuel yield of 18.7 wt% on the top phase and 34.3 wt% on the bottom phase. Therefore, it can be concluded that a pyrolysis hot filter with low density 5 material can change the fuel ratio better than high density material.

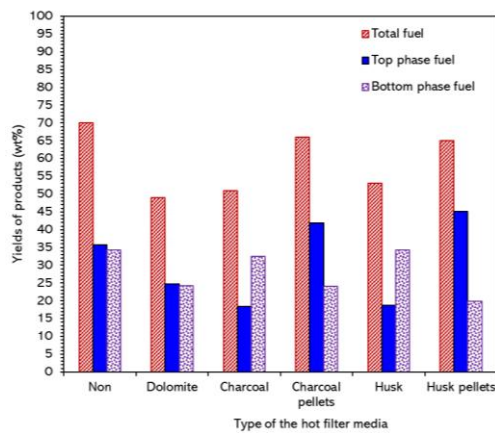


Figure 5. Proportion of fuel

Effect of the type of hot filter media on properties of fuel.

Table 1 shows that the top phase fuel had a lower heating value than the bottom phase fuel. Dolomite filter media can improve the heating value of fuel to the greatest extent. The top phase fuel had an HHV of 39.1 MJ/kg and the bottom phase fuel has an HHV of 42.4 MJ/kg. This figure is in the same range as the heating value of fuel from plastic waste (Pannucharoenwong *et al.*, 2023b). Table 1 also shows that the use of all five-filter media significantly improved the calorific value of the fuel. This is because the filtration of hot vapor before condensing the pyrolysis vapor reduces the ash content in the fuel. Dolomite filter media reduces ash content in the fuel by more than two times, while other filter media can also help reduce the ash content in the fuel. For this reason, the viscosity of the fuel obtained from the hot vapor filter was reduced. However, the fuel obtained from the filtered or unfiltered hot vapor of the rubber dung pyrolysis had the same density, the top being greater than 800 kg/m³. The lower phase fuel had a density in the range of 900 kg/m³. The lower phase fuel had a higher density. Another property of fuel obtained from pyrolysis of rubber dung in all cases is that it could be ignited at a room temperature of approximately 25°C.

Table 1. Properties of the fuel

Properties	Fuel	Type of the hot filter media					
		Non	Dolomite	Charcoal	Charcoal pellets	Husk	Husk pellets
High heating value (MJ/kg)	Top phase	32.0±0.1	39.1±0.4	33.3±0.7	33.7±0.2	33.0±0.5	33.4±0.3
	Bottom phase	34.9±0.5	42.4±0.4	36.1±0.2	40.8±0.4	35.8±0.7	37.1±0.3
Density (kg/m ³)	Top phase	835.3±0.1	800.1±0.0	824.6±0.1	813.7±0.1	805.7±0.1	825.5±0.0
	Bottom phase	994.5±0.0	981.0±0.1	986.5±0.1	989.8±0.0	959.8±0.1	990.5±0.1
Viscosity (cSt)	Top phase	2.4±0.7	1.3±0.5	1.6±0.6	1.4±0.5	1.4±0.5	1.2±0.4
	Bottom phase	4.2±0.5	1.3±0.7	1.5±0.6	1.3±0.6	1.3±0.7	1.1±0.4
Fash-Fire point (°C)	Top phase	Fuels flash and fire at room temperature ~25°C.					
	Bottom phase						
Ash content (wt%)	Top phase	1.4±0.2	0.6±0.1	1.0±0.2	1.0±0.3	1.0±0.4	1.0±0.4
	Bottom phase	1.1±0.6	0.3±0.7	0.7±0.6	0.3±0.1	0.7±0.3	0.8±0.4

Conclusions

Pyrolysis of rubber dung in a fixed bed reactor at a reaction temperature of 300°C and a condensing temperature of 10°C had the highest fuel yield of 70 wt%. When pyrolysis with the addition of hot vapor filter media was conducted, the yield of fuel decreased, but the yield of gas increased. The density of the filter media directly affected the phase separation ratio of the fuel. The hot vapor filter media reduced ash content and viscosity in the fuel. Dolomite filter media increased the heating value of fuel up to 42.4 MJ/kg. Pellet charcoal filter media increased the heating value of fuel to 40.8 MJ/kg. Therefore, it can be concluded that natural filter media can produce higher volumes of fuel than synthetic filter media, and the quality of the produced fuel is like petroleum fuel.

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