



Characteristics of Refuse-Derived Fuel (RDF) at The Waste Processing Facility (WPF) of The Faculty of Engineering, Untirta

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ABSTRACT

Landfill in Cilegon City has an impact on the environment, so processing is needed, one of which is converting waste into RDF fuel. The conversion of waste into RDF provides benefits by reducing the amount of waste sent to landfills and utilizing renewable energy as fuel. The composition of mixed materials in RDF has potential characteristics that affect the quality of the resulting RDF. The study objective is to study the effect of the composition of a mixture waste of organic (leaves) and LDPE plastic on the characteristics of RDF. The research was conducted with composition ratios of organic waste (leaves) and LDPE plastic waste at 95:5, 90:10, 85:15, and 80:20 (% wt.). The results showed that the optimal RDF product was produced with a composition of 85:15 and with the addition of 10% starch. These results indicate the characteristics of RDF, including an ash content of 14.681%, moisture content of 11.215%, volatile matter of 54.465%, fixed carbon of 19.469%, calorific value of 4598.017%, bulk density of 0.706 g/cm³, and compressive strength of 6.69 kg/cm². It has the potential to be a good alternative for using RDF as fuel in boilers.

Keywords : *composition, calorific value, organic waste, inorganic waste, RDF*

1. INTRODUCTION

Waste is the residue of human daily activities and natural processes, primarily in solid form (Mulhidin, 2022). Waste can be divided into two types: organic waste and inorganic waste. Organic waste refers to waste generated from living organisms, which can be easily decomposed by microbes. Examples include twigs, leaves, food waste, and so on. On the other hand, inorganic waste is waste that is resistant to decomposition by microbes, requiring special processing. Examples of inorganic waste include plastic waste, canned waste, glass waste, and other non-biodegradable materials (Nurhaliza, 2021).

The Law of the Republic of Indonesia Number 18 of 2008 concerning Waste Management states that waste management in Indonesia is not aligned with environmentally sound methods and perspectives, thus having the potential to cause environmental pollution. Improper waste disposal can lead to various

environmental issues, including water pollution, air pollution, and the spread of diseases (Rania et al, 2019).

Cilegon City has been experiencing an increasing amount of waste every year. In 2019, the amount of waste sent to landfills in Cilegon City was 135,211 tons per year. This amount increased to 136,458 tons per year in 2020. The waste composition in Cilegon City consists of organic waste (27.37%), glass (7.81%), plastic (41.41%), and other materials (27.68%) (The Ministry of Environment and Forestry, 2023).

Plastic waste is one of the materials used in food packaging and can take a long time to decompose, such as through combustion and other processes (Putra et al., 2010). Plastic waste can be utilized as Refuse Derived Fuel (RDF) for fuel purposes (Lucky et al., 2018). RDF is the product of a separation process that separates combustible solid waste from non-combustible solid waste (Caysa, 2012). The stages involved in producing RDF include waste separation, cutting, mixing materials, drying, packaging, and storage (Fauzie, 2017).

The composition of waste used in the production of RDF can have an impact on the quality of the resulting RDF. LDPE plastic waste, for example, has a calorific value of 12,318.4 cal/g (Anggun et al., 2014). The composition of mixed materials in RDF can influence the calorific value of the RDF produced (Garcia et al., 2021) as well as the presence of aldehyde compounds in the plastic (MarEdo et al., 2016). For instance, RDF with a composition of 40% organic waste and 60% inorganic waste has a calorific value of 5674 cal/g (Rithy et al., 2017). The quality and characteristics of RDF are dependent on the type of waste and the waste characterization process. The characteristics of RDF can be observed through its physical properties, calorific values, and proximate parameters.

The utilization of organic and inorganic waste in the production of RDF has the potential to reduce environmental pollution caused by landfills. Therefore, further management processes can be implemented in a specific area as an effort to minimize environmental pollution. Hence, this study aims to decrease the amount of waste sent to landfills and determine the RDF characteristics by using a mixture of organic waste (*Terminalia catappa* and coconut shell) and inorganic waste (multilayer LDPE plastic packaging). The study focuses on examining the proximate characteristics and RDF calorific value, in accordance with the relevant national standard (SNI).

2. METHODS

2.1 Materials

In this study, the waste materials used were sourced from the campus of the Faculty of Engineering, Sultan Ageng Tirtayasa University. The waste consisted of organic waste (*Terminalia catappa* and coconut shell) as well as inorganic waste (multilayer LDPE plastic packaging)."

2.2 Preparation of Raw Materials

The process procedure in the preparation of raw materials begins with the collection of waste, which consists of organic waste (coconut husk, leaves, and shells) and inorganic waste (multilayer LDPE plastic). After the waste is collected, it is then separated into organic and inorganic waste. The organic waste is dried until it reaches a moisture content of approximately 11% by weight. Next, the waste is placed in a crusher and sifted to achieve a particle size of 40 – 60 mesh.

2.3 Process of Making RDF

The process procedure for RDF begins with the mixing of organic waste (coconut husk, leaves, and shells) and inorganic waste (multilayer LDPE plastic) in various composition ratios (% weight) such as 95:5, 90:10, 85:15, and 80:20. The mixed waste is then supplemented with 10% starch adhesive by weight and placed into a cylindrical RDF printer container with a diameter of 4 cm. It is then compressed with a pressure of 66 N/cm² and

heated at a temperature of 80 – 90 °C. The printed material is subsequently dried until it reaches a moisture content of approximately 11%. Afterward, the RDF products are analyzed for bulk density, compressive strength, proximate composition, calorific value, and FTIR analysis. The RDF press equipment is presented in Figure 1.



Fig. 1. RDF press equipment

Table 1. The variations composition of RDF mixed materials

NO	Sampel	Compositions
1	TD-RDF 1	95% organic waste : 5% inorganic waste
2	TD-RDF 2	90% organic waste : 10% inorganic waste
3	TD-RDF 3	85% organic waste : 15% inorganic waste
4	TD-RDF 4	80% organic waste : 20% inorganic waste

3. RESULTS AND DISCUSSION

3.1 Process of Making RDF

RDF is a fuel obtained from the process of separating solid waste. In the production of RDF, the waste is first cut into small sizes and then dried. Organic waste, such as coconut testa leaves and skin, is mixed with inorganic waste, namely LDPE multilayer plastic packaging. The mixture is then supplemented with 10% starch adhesive. The addition of starch adhesive helps to bind the waste mixture into RDF briquettes with good adhesion. After the mixing process, the RDF mixture is molded under a pressure of 66 N/cm² using a cylindrical RDF mold with a diameter of 4 cm. The molded RDF is then heated at a temperature of 80-90 °C. The heat transfer process occurring during molding can be observed in Figure 2.

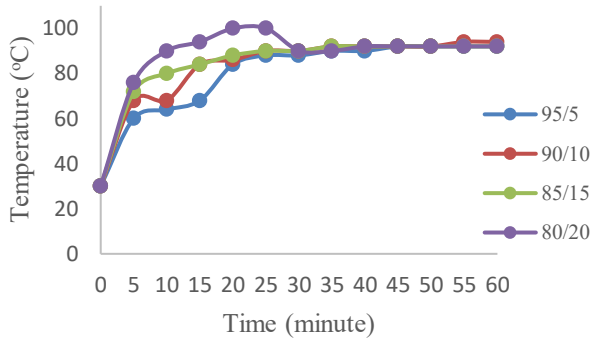


Fig. 2. Profile of heat transfer in RDF pressing

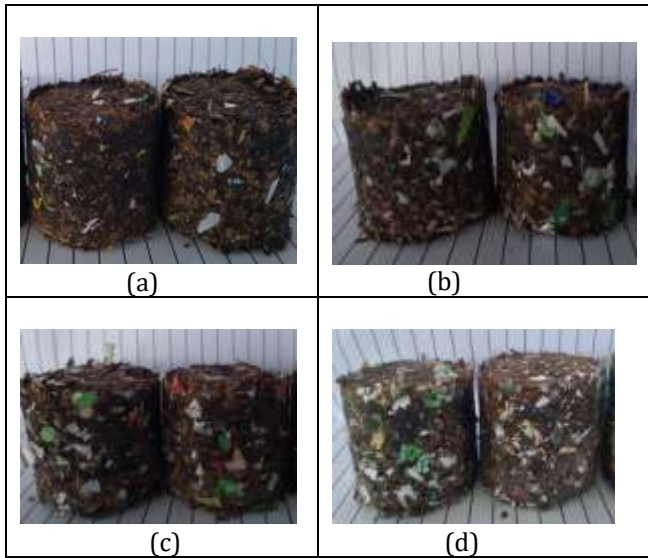


Fig. 3. RDF Results (a) TD-RDF 1 (b) TD-RDF 2 (c) TD-RDF 3 (d) TD-RDF 4

Heat transfer is carried out for 60 minutes. During the first 30 minutes, the mold is heated to warm the outer surface of the RDF. In the next 30 minutes, the heat is transferred throughout the RDF to ensure a good density. This process is crucial as it helps to dilute the lignin content in organic waste, allowing it to serve as a natural adhesive for forming RDF (Danang et al., 2012). The molded RDF is then dried until it reaches a moisture

content of approximately 11%. The drying process is conducted to enhance the hardness and calorific value of the RDF, resulting in high-quality RDF briquettes. The results of the RDF briquettes has been presented in Figure 3.

This research was conducted with several data collection trials in the manufacture of RDF briquettes. The first trial involved using 10% starch adhesive and pressing for 60 minutes at a temperature of 80-90 °C. In the next experiment, pressing was done at the same temperature and duration without using starch adhesive. Another experiment involved using 10% starch adhesive and pressing for 60 minutes without applying heat. The results of the RDF briquettes using starch and heaters were satisfactory, as the produced briquettes had good density and were not easily destroyed. However, when heating was applied without additional starch, the RDF briquettes obtained had lower density and were prone to breakage. In the case of RDF briquettes with unheated starch, they initially exhibited tightness, but broke after a few minutes, resulting in poor density. This is because the addition of starch in the waste mixture helps bind organic waste and plastic waste together. However, if a heater is not used, the density of the RDF briquettes can crack. Therefore, a heater is essential to achieve optimal adhesion between the organic waste and plastic waste. Based on these findings, this study utilized 10% starch adhesive and applied 60 minutes of pressing with a heater at a temperature of 80-90 °C. The resulting RDF briquettes exhibited good density and shape, making them resistant to damage during storage or transportation.

3.2 RDF Characteristics

The results of the proximate, bulk density, and compressive strength tests of RDF are presented in Table 2, indicating that the produced RDF complies with the SNI standards for Solid Jump Fuel and falls into class 2, with a calorific value of ≥ 3582.688 cal/g (SNI 8966:2021 about BBJP).

Table 2. RDF characteristics

Sample	Proximate Analysis					Bulk density (g/cm ³)	Coppressive strength (kg/cm ²)
	Ash Conten (%)	Water content (%)	Volatil matter (%)	Fixed carbon (%)	Caloric value (cal/g)		
TD-RDF1	13.404	12.205	52.424	21.968	3955.088	0.631	10.49
TD-RDF2	13.765	11.469	53.523	21.216	4102.900	0.681	13.04
TD-RDF3	14.681	11.215	54.465	19.469	4598.017	0.706	6.69
TD-RDF4	14.699	11.984	54.537	18.780	4591.528	0.730	12.96
TD-RDF1 without press	15.968	10.980	54.447	22.605	4080.237	-	-
SNI 8966:2021	<8	<8	<15	>77	>5000	-	-

The resulting RDF has a bulk density value ranging from 0.631 to 0.730 g/cm³, which corresponds to the bulk density value of RDF briquettes, ranging from 0.57 to 0.65 g/cm³, indicating good density (Rithy et al., 2017). The

addition of starch adhesive provides strong durability to the RDF, with values ranging from 6.69 to 13.04 kg/cm², which is higher than the compressive strength values of RDF composed of organic waste and inorganic waste in

the study conducted by Rithy et al. (2017), which ranged from 2.01 to 2.32 kg/cm². The durability and density of RDF briquettes influence the combustion process, leading to increased combustion length and temperature.

The best RDF is produced in RDF 3, with a composition of 85% organic waste by weight and 15% inorganic waste by weight, exhibiting the highest calorific value of 4,598.017 cal/g. It also has an ash content of 14.699%, moisture content of 11.215%, volatile matter of 54.465%, and fixed carbon of 19.469%. The greater the composition of inorganic waste (multilayer LDPE plastic packaging), the higher the calorific value produced. This is because packaging waste has a calorific value of 6,687-8,837 cal/g, while leaf waste has a calorific value of 3,753.22 cal/g (Rithy et al., 2017). Therefore, the addition of plastic waste can increase the calorific value of RDF. Furthermore, the inclusion of coconut testa peel in the organic waste mixture can enhance the calorific value of RDF.

3.3 Profile Temperature to Time in the RDF Combustion Process

RDF burning is conducted directly using an RDF combustion process assisted by a blower. The temperature profile of the RDF combustion process is depicted in Figure 4.



Fig. 4. Process of RDF Combustion

The RDF combustion process is carried out using RDF samples with a composition of 85:15% by weight. the temperature rise that occurs in the combustion process is shown in Figure 5.

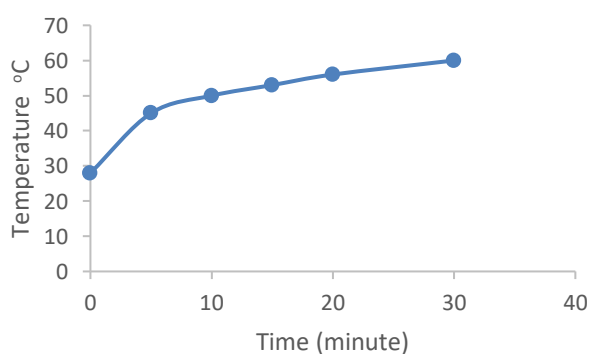


Fig. 5. Profile of RDF Combustion

Figure 5 illustrates the increase in RDF combustion temperature over time. The RDF combustion process is conducted using the optimal RDF composition, which is 85:15% by weight with a calorific value of 4,598.017 cal/g. The temperature reaches its optimum point at 60 °C within 30 minutes. This is attributed to the relatively small quantity of RDF used in the combustion process, which amounts to only 5 pieces (100 grams), resulting in a relatively fast combustion time without excessively high temperatures. The combustion proceeds smoothly as indicated by the minimal amount of ash generated.

3.4 FTIR Analysis

RDF pyrolysis is carried out using a pyrolysis device, where the RDF heating process occurs at a temperature of 400°C for 60 minutes. RDF decomposes into volatile and condensed to give liquid and gaseous products. The results of FTIR analysis on RDF liquid products can be seen in Figure 6 as follows.

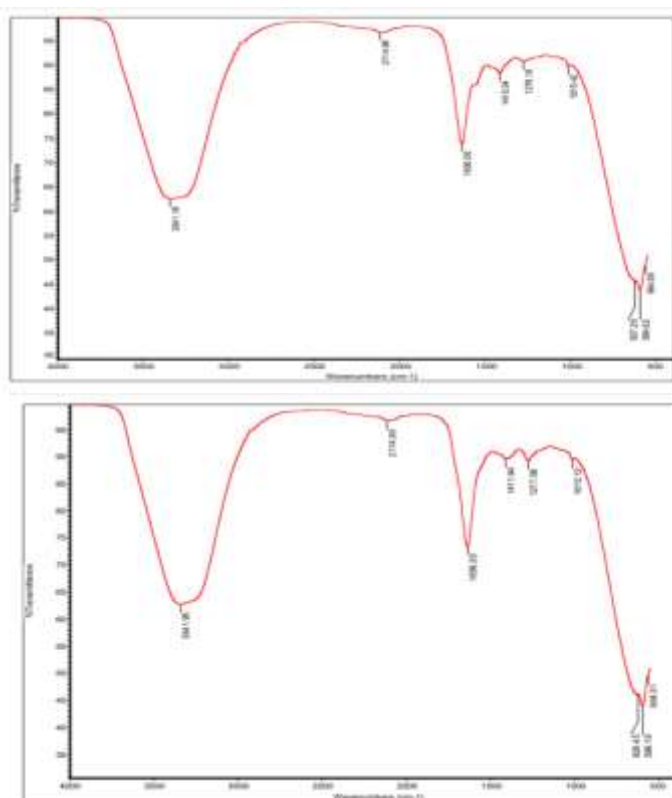


Fig. 6. FTIR analysis of RDF liquid products (a) plastic waste 5 %; (b) plastic waste 20 %.

Based on Figure 6, it is evident that different RDF compositions result in varying absorption peaks. The FTIR spectral curve of the sample displays absorption intensities at wavenumbers 3,341 cm⁻¹, 1,636 cm⁻¹, and 594 cm⁻¹, indicating the presence of CH₄ compounds, CO functional groups (aldehydes and acids), and CO₂ compounds. Additionally, the FTIR graph reveals wave absorption at wavenumber 1,015.42 cm⁻¹, signifying the existence of phenol compounds. There is a difference in absorption peak intensities between the two curves: RDF plastic composition 5% (Fig 6(a)) and RDF plastic composition 20% (Fig. 6(b)). Plastic composition 20%

exhibits a higher absorption peak compared to plastic composition 5%. An increase in plastic content leads to elevated absorption peaks. The FTIR spectral curve also demonstrates absorption intensity at wavenumbers 1,636-2,114.98 cm^{-1} , indicating the presence of aldehyde compounds.

4. CONCLUSION

The best RDF characteristics are achieved with a composition of 85% organic waste by weight and 15% inorganic waste by weight, resulting in a calorific value of 4598.017 cal/g, ash content of 14.681%, moisture content of 11.215%, volatile matter of 54.465%, fixed carbon of 19.469%, bulk density of 0.706 g/cm^3 , and compressive strength of 6.69 kg/cm^2 . During combustion, 100 grams of RDF burns completely within 30 minutes, leaving behind a minimal amount of residual ash. The RDF produced meets the SNI standard for Solid Jump Fuel, making it a suitable alternative fuel to coal and other fossil fuels.

5. ACKNOWLEDGMENTS

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