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Study of Cassava Peel Biomass and Spent Bleaching Earth (SBE) as Raw Material for Refused Derived Fuel (RDF)

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Abstract

Cassava, a widely used raw material in Indonesia's food industry, amounted to 14.9 million tons in 2022. Typically, cassava peel, comprising 2-5% of the plant, is discarded in landfills or left untreated. However, recent research suggests its potential as a source of refuse-derived fuel (RDF), given its high calorific value of 4253 kcal/kg and 12.55% fixed carbon. Another potential RDF source is spent bleaching earth (SBE), a by-product of oil treatment, containing 20-40% oil. This study explores the impact of different compositions of cassava peel, SBE, and various binders on RDF characteristics. Binders like tapioca flour, durian seed, and rejected papaya were tested in ratios ranging from 70:20:10 to 90:0:10. The findings reveal that the 90:0:10 composition with rejected papaya binder yielded RDF with the highest calorific value and volatile matter content. Specifically, RDF from 90% cassava peel exhibited a calorific value of 5320 kcal/kg, fixed carbon of 13.9%, volatile matter of 80%, ash content of 5.7%, and moisture content of 0.3%. These results meet Indonesia's RDF standards, which mandate a calorific value above 3000 kcal/kg and volatile matter between 50-80%.

Keywords: Biomass; Cassava Peel; RDF; Renewable Energy; SBE

1. Introduction

In recent years, the rising need for fossil fuels, driven by industrial growth and urbanization increase, has become a significant concern regarding greenhouse gas emissions and resulting global warming [1]. Fossil energy continues to play a crucial role in several industries, especially the cement sector, which is the third-largest consumer of fossil energy [2]. The cement manufacturing process, particularly during calcination and clinker formation, exhibits significant energy demands, requires approximately 400 tonnes of coal per 100 tonnes of cement production [3]. As a result, there is a growing need for sustainable alternatives like refuse-derived fuel (RDF) to replace fossil fuels in cement manufacturing.

Numerous studies have investigated the viability of RDF derived from biomass waste as a renewable energy source. Kan et al. [4] demonstrated that RDF generated from palm fronds, rubber and plastic bag exhibited a calorific value of 5872 cal/g, while [5] reported a calorific value of 6298.86 cal/g for RDF sourced from oil sludge, coconut shell, and rice husk. The calorific value represents a critical characteristic of RDF, serving as an indicator of its energy yield. Spent bleaching earth (SBE), a by-product of the oil processing industry, is characterized by a moisture content of 4.46%, ash content of 36.05%, volatile matter of 52.70%, and fixed carbon content of 5.89% [6]. Additionally, it contains 20-40% oil, whose hydrocarbon constituents have the potential to enhance the calorific value of fuels like RDF [7]. Besides spent bleaching earth, biomass waste plays a crucial role in optimizing RDF characteristics.

Cassava peel waste emerges as a promising biomass feedstock for RDF production, constituting up to 5% of total cassava yield [8]. Notably, cassava peel exhibits a characteristic ash content of 3.75%, within the prescribed RDF standard (<10%), along with volatile matter at 62.70%, fixed carbon at 17.35%, and a calorific value of 12,870 cal/g, surpassing the RDF standard requirement of >3000 cal/g [9]. Earlier research has highlighted cassava peel's ability to increase the calorific value of RDF above the standard.

Binders play a crucial role in RDF production by facilitating the cohesion of raw materials, thus enhancing combustion efficiency. Tapioca flour, containing around 17% amylose, acts as a potent binding agent by absorbing water and forming a thick gel with high viscosity, enhancing water and moisture retention [10]. Similarly, durian seeds, rich in amylose (36.8%) and amylopectin (63.68%), can produce a binder mixture yielding RDF with a calorific value of 6063 cal/g [11]. Furthermore, rejected papaya, characterized by its natural sugar and fiber content, serves as a viable biomass binder, offering a calorific value of 435.02 cal/g [12] and contributing to an RDF calorific value of 4822.06 cal/g [13]. Therefore, the objective of this research is to analyze the effect of the SBE and cassava peel ratio and the optimum binder type on the characteristics of RDF.

2. Method

1.1. Preparation of Raw Materials and Binders

Bleaching earth (BE) is utilized in oil purification processes for its ability to modify and neutralize color through the absorption of gum content from the oil. Once utilized, it transforms into spent bleaching earth (SBE). SBE was sourced from an oil treatment and palm oil industry in Balikpapan, characterized by high solid and oil content. Subsequently, SBE underwent drying in an oven for 24 hours followed by carbonization in a furnace at 400°C. This carbonization process aimed to enhance the calorific value and increase the carbon content of SBE, with the resulting carbon subjected to characteristic testing.

Cassava peel, sourced from the food industry in Balikpapan, underwent initial cleaning to remove impurities, followed by cutting into small pieces (4x5cm) and drying in an oven for 24 hours. Subsequently, carbonization was conducted at 350°C for 1 hour. The carbonized cassava peel underwent sieving using a 50-mesh sieve before analysis. Various binders, such as tapioca flour, underwent preparation by sieving with a 100-mesh sieve and mixing with a 1:6 water ratio. Durian seeds were dried in an oven for 24 hours and ground into powder using a 100-mesh sieve. Rejected papaya underwent squashing and filtration to separate solids from moisture content. Upon completion of all preparations, the binder was mixed with SBE and cassava peel for pellet formation.

Figure 1. (a) cassava peel (b) spent bleaching earth (c) durian seed (d) carbonization process

1.2. Pellet Production

Pellet production began with the preparation of raw materials, including cassava peel charcoal, SBE charcoal, and binder. Each binder was mixed with different combinations of cassava peel and SBE charcoal. Table 1 illustrates the variations in the composition of cassava peel charcoal, SBE charcoal, and binder.

All composition variations are subjected to the same process, wherein raw materials are blended with binder. Once thoroughly mixed, the material blend is shaped using a small tube-shaped mold, measuring 1.2 cm in diameter and 2.5 cm in length. Subsequently, the resulting RDF is left to air dry in the sun for 1-2 days to reduce its moisture content. Figure 2 shows RDF generated from different compositions of cassava peel, SBE, and binder.

Table 1. composition of raw materials of RDF

Types of Binder	**Composition**				
	Cassava peel Charcoal: SBE Charcoal: Binder				
Durian Seeds	90:0:10 DS1	85:5:10 DS2	80:10:10 DS3	75:15:10 DS4	70:20:10 DS5
Tapioca Flour	90:0:10 TF1	85:5:10 TF2	80:10:10 TF3	75:15:10 TF4	70:20:10 TF5
Rejected Papaya	90:0:10 RP1	85:5:10 RP2	80:10:10 RP3	75:15:10 RP4	70:20:10 RP5

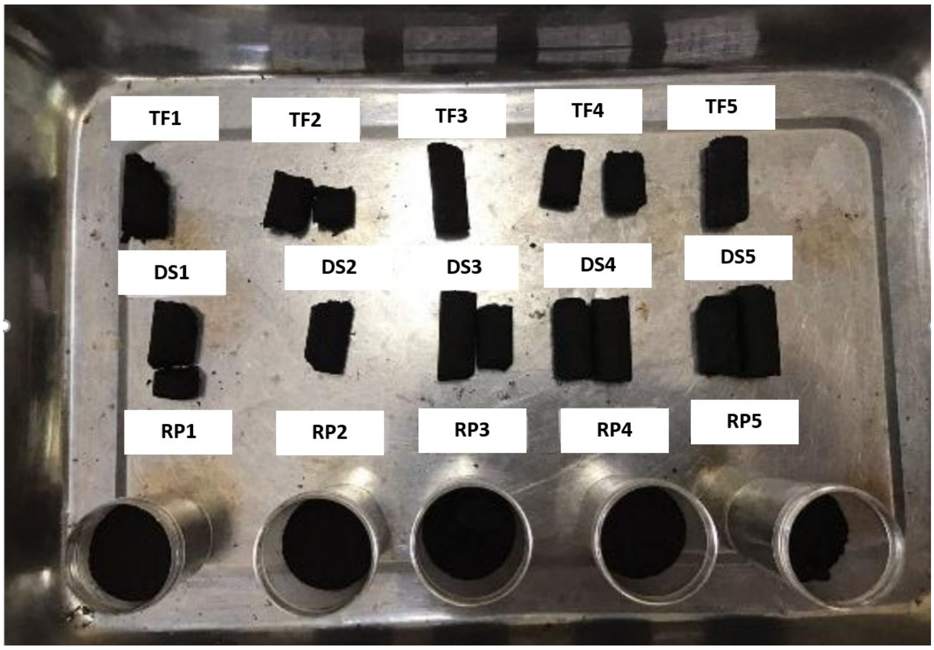

Figure 2. RDF made of SBE, cassava peel, and binder

1.3. RDF Characterization

1.3.1. Proximate analysis

The proximate analysis encompasses a series of examinations aimed at determining the characteristics of raw materials and binders, adhering to ASTM standards. The parameters subjected to testing include moisture content, volatile matter, fixed solid, ash content, and calorific value. Detailed explanations of the calculation methods are provided below:

1) Moisture Content

The moisture content refers to the quantity of water present within a substance, typically denoted as a percentage. Determining the moisture content within RDF follows the guidelines outlined in the ASTM D-3173-17 standard. The calculation formula is detailed below [14]:

$$Moisture\ Content\ (\%) = \frac{A-B}{C} \times 100\% \tag{1}$$

In this equation, A represents the initial mass of the sample before drying, while B denotes the mass of the sample after the drying procedure.

2) Ash Content

Ash content refers to the residual matter left after combustion. Higher ash content indicates a greater amount of residue produced. The calculation of ash content values is conducted according to ASTM D-3174-04. The formula is detailed below [14]:

$$Ash\ Content\ (\%) = \frac{A}{B} \times 100\% \tag{2}$$

In this context, A represents the amount of ash residue following carbonization, while B indicates the initial mass of the sample before the carbonization process.

3) Volatile Matter

Volatile matter includes combustible gases like hydrogen (H_2), methane (CH_4), and carbon monoxide (CO) [15]. Increased volatile matter content facilitates easier combustion and ignition of RDF. The determination of volatile matter values adheres to the procedures outlined in ASTM D-3175-02, outlined as follows [14]:

$$Volatile\ Matter\ (\%) = \left(\frac{B}{A} \times 100\%\right) - MC(\%) \tag{3}$$

In this context, A represents the initial mass of the sample before carbonization, B denotes the mass of the sample after carbonization, and MC indicates the moisture content of the sample.

4) Fixed Carbon

The fixed carbon value indicates the quantity of carbon (C) fractions present in the RDF, excluding the fractions of water, volatile substances, and ash. The determination of the fixed carbon value follows the guidelines outlined in ASTM D3172-13, as detailed below [16]:

$$Fixed\ Carbon\ (\%) = 100\% - (water\ content - ash\ content - volatile\ matter) \tag{4}$$

1.3.2. Calorific Value

The calorific value represents the heat energy present within a fuel. In the case of RDF, the calorific value signifies the utmost heat energy liberated during a full combustion process. Determining the calorific value typically involves utilizing a bomb calorimeter and the subsequent equation [16]:

$$Hg = \frac{t.w - I_1 - I_2 - I_3}{M} \tag{5}$$

In this equation, Hg denotes the calorific value in Kcal/Kg, M represents the sample's mass, t stands for the temperature differential in degrees Celsius, w signifies 2426/°C, I_1 indicates the quantity of sodium employed for titration, I_2 represents the value of 3.7 x 10.2 x M, and I_3 denotes the length of wire utilized.

2. Result and Discussion

2.1. Characteristics of Cassava Peel and SBE Charcoal

The properties of raw materials underwent analysis, encompassing various parameters including moisture content, volatile matter, ash content, fixed carbon, and calorific value. Table 2 shows the characteristics of a cassava peel and SBE charcoal.

Table 2. raw material characteristics

No.	Parameter	Charcoal Characteristics		Unit
		Cassava Peel	SBE	
1.	Moisture content	0.16	0.1	%
2.	Ash Content	4.25	65.19	%
3.	Volatile Matter	85.48	32.64	%
4.	Fixed Carbon	10.42	2.05	%
5.	Calorific Value	5336	4779	kcal/kg

The examination outcomes reveal that the moisture content in charcoal derived from spent bleaching earth (SBE) and cassava peel is recorded at 0.1% and 0.16%, respectively. The reduced moisture content is due to pre-drying the raw materials. The moisture level is a crucial factor influencing the heating value, efficiency of combustion, ignition ease, and the amount of smoke generated during the combustion process [17]. Volatile matter assessment is essential due to its influence on combustion dynamics, with elevated volatile matter content correlating with heightened smoke production [18]. Cassava peel exhibits a volatile matter content of 85.48%, surpassing that of SBE charcoal, which registers at 32.64%.

Ash content analysis shows the existence of inorganic materials that do not evaporate easily [19]. SBE charcoal demonstrates a higher ash content compared to cassava peel charcoal, indicating a predominance of non-volatile aluminum silicates in SBE [20]. During carbonization, cassava peel's organic parts produce more fixed carbon than SBE, as organic matter breaks down into carbon. The calorific value assessment of charcoal derived from spent bleaching earth (SBE) and cassava peel reveals that cassava peel charcoal exhibits a higher calorific value of 5,336 kcal/kg, while SBE charcoal yields a calorific value of 4,779 kcal/kg. The relatively increased calorific value of SBE charcoal can be attributed to the presence of hydrocarbon content mixed with oil within the SBE material [21]. The substantial calorific values observed in both cassava peel and SBE charcoal signify their potential significance as primary contributors to the calorific value of RDF.

2.2. Characteristics of Binders

The binder must exhibit robust adhesion to raw materials, devoid of any polluting effects or alterations to the fuel, easily accessible, and cost-effective [22]. Durian seeds, tapioca flour, and rejected papaya meet these binder criteria while augmenting the characteristic attributes of RDF. Detailed results of characteristic tests are provided in Table 3.

Table 3. binder characteristics

No.	Parameter	Characteristics			Unit
		Durian Seeds	Tapioca flour	Rejected Papaya	
1.	Moisture Content	9.49	7.32	2.46	%
2.	Ash Content	2.96	0.22	2.91	%
3.	Volatile Matter	96.62	99.43	96.4	%
4.	Fixed Carbon	0.055	0.0009	0	%
5.	Calorific Value	3743	3557	2178	kcal/kg

In Table 3, durian seeds exhibit the highest moisture content at 9.42%, followed by tapioca flour at 7.32%, and rejected papaya at 2.46%. The increased moisture content in durian seeds and tapioca flour can be attributed to the presence of amylose and amylopectin in both binders. Durian seeds and tapioca flour require water addition to facilitate raw material bonding The application of boiling water to these binders induces hydrogen bond formation between amylose and amylopectin, leading to gelatinization. In contrast, the rejected papaya binder was utilized without additional water, resulting in lower moisture content compared to durian seeds and tapioca flour. The volatile matter content of the binder ranges from 96% to 99%. The predominant organic composition of the binder, such as tapioca flour containing amylose and amylopectin, is responsible for this high volatile matter content [10].

Binders that undergo non-carbonization exhibit increased volatile matter values due to the decomposition of organic constituents during volatile matter measurement. The ash content produced by the binder ranges from 0.22% to 2.91%, primarily due to the substantial evaporation of organic content. Durian seeds possess a calorific value of 3743 Kcal/Kg, while tapioca flour and rejected papaya exhibit values of 3557 Kcal/Kg and 2178 Kcal/Kg, respectively.

2.3. Effect of Biomass Composition and Binder Type on RDF Characteristics

2.3.1. Moisture Content

Moisture content is crucial for RDF quality. Lower moisture means better RDF quality. Higher moisture means using more energy to evaporate water from RDF, which reduces its ability to burn well [17]. The findings of the RDF moisture content examination are depicted in Figure 3. The graph illustrates that RDF, composed of 90% cassava peel, 0% SBE, and 10% durian seed binder, yields a moisture content of 1.1%. Conversely, RDF comprising 70% cassava peel, 20% SBE, and 10% durian seed binder exhibits a higher moisture content percentage of 1.7%. Changes in the composition of SBE can affect moisture levels, although the increase isn't very large. These fluctuations may occur due to the presence of silica sand in SBE, which is known for its ability to absorb and retain water [20].

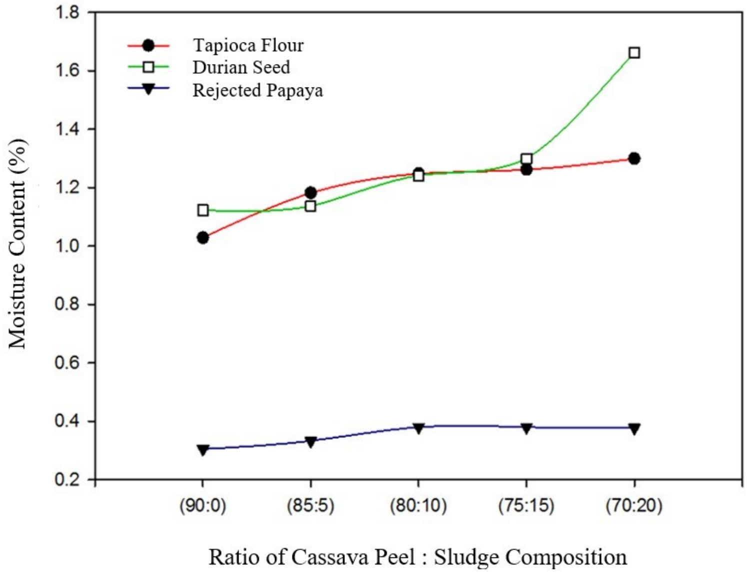

Figure 3. Effect of raw material composition and binder types on moisture content

2.3.2. *Volatile Matter*

Volatile matter consists of organic compounds that evaporate as vapor, containing water, tar, oil, and gas, due to the decomposition of compounds present in RDF [23]. A higher volatile matter content indicates a shorter ignition time needed for RDF. This correlation suggests that RDF with more volatile matter ignites faster, showing increased reactivity [24]. The outcomes of the RDF moisture content examination, categorized by composition and binder type, are depicted in Figure 4.

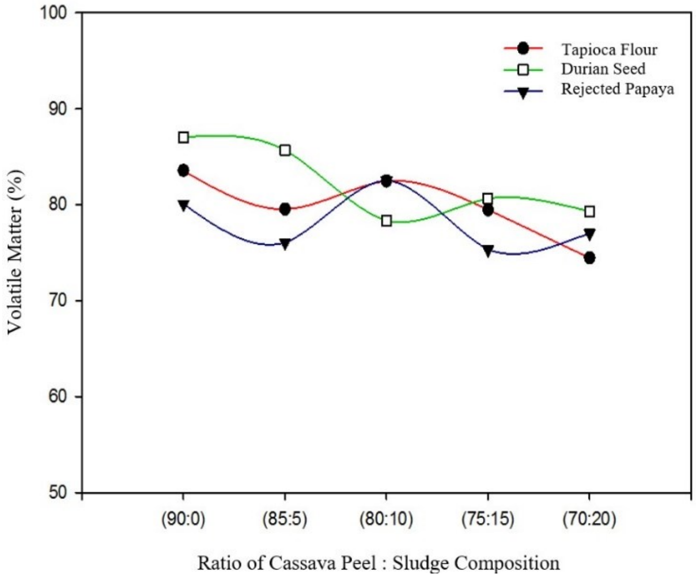

Figure 4. Effect of raw material composition and binder types on volatile matter

Based on Figure 4, volatile matter, with a composition of 90% cassava peel, 0% SBE, and 10% durian seed binder, has the highest value, 85%. In comparison, the composition of 70% cassava peel, 20% SBE, and 10% durian seed binder contains 80% volatile matter. This comparison shows that higher SBE results in lower volatile matter. The higher volatile matter can accelerate combustion and cause smoke [5]. The use of biomass also affects volatile matter. According to Akogun et al. [25], agricultural waste generally has a highly volatile matter, making biomass fuel more reactive than other fuels. Temperature also influences the value of volatile matter when the raw material is well-carbonized at the maximum temperature [26]. In this research, the volatile matter was found within 72 – 87%, while the study by Akogun et al. [25] shows that briquettes with cassava peel biomass produce 81.5% volatile matter. The type of binder used in this study did not significantly affect RDF volatile matter because the composition of the raw material dominates the volatile matter value more than the binder.

2.3.3. Ash Content

Increased ash content is known to reduce the calorific value of RDF. Therefore, reducing ash content results in higher-quality RDF production [27]. Notably, excessive ash content can markedly influence both heat transfer and oxygen diffusion to the RDF surface during combustion [28]. Figure 5 illustrates the outcomes of the ash content assessment for every composition and binder type.

Figure 5 illustrates that with a composition of 85% cassava peel and 5% SBE, the ash content is 9% for the three binders. As the SBE composition decreases to 75% cassava peel and 15% SBE, the ash content increases to 14%. This increase in ash content is attributed to the silica content in SBE [29]. This silica can become a residue similar to fly ash, while the carbonization temperature of SBE charcoal also affects ash content production. During the combustion process, many of the constituents evaporate and leave behind inorganic materials in the SBE charcoal, which become residue [30].

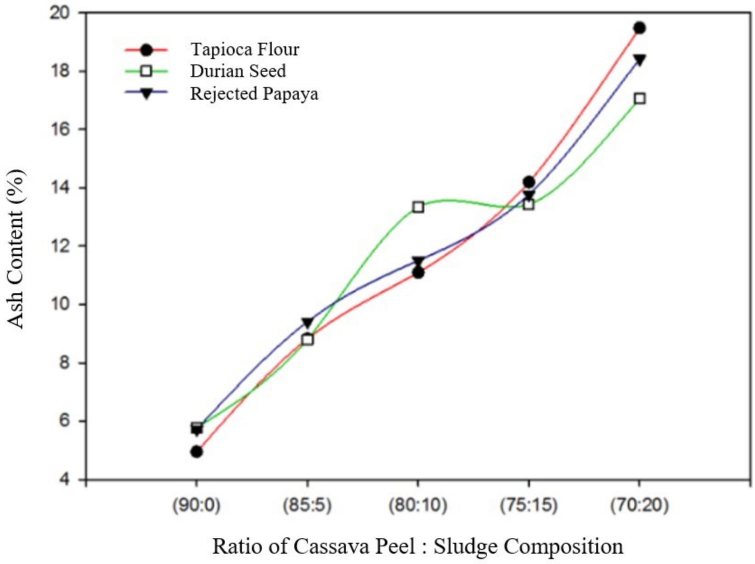

Figure 5. Effect of raw material composition and binder types on ash content

The organic binder used does not significantly affect the ash content of RDF. The composition of 90% cassava peel, 0% SBE, and three binders results in a 5% ash content. Meanwhile, the ash content in the composition of 70% cassava peel and 20% SBE ranges from 17% to 19%. Adding an organic binder does not significantly impact ash content; however, ash content does have an impact on the first ignition of RDF. Based on test results, all RDF compositions meet the Indonesian RDF standard of less than 10% ash content [31].

2.3.4. Fixed Carbon

Fixed carbon in RDF serves as the primary heat producer during combustion [32]. Thus, the higher the fixed carbon value, the better the quality of the RDF produced. The results of the fixed carbon test on RDF are presented in Figure 6. The fixed carbon value with a composition of 90% cassava peel and 0% SBE exhibits the highest fixed carbon content, ranging from 6% to 13%. The elevated fixed carbon in this composition is attributed to the organic content of biomass, which constitutes the primary component of RDF. Fixed carbon is additionally influenced by moisture content, volatile matter, and ash content. A slight decrease in fixed carbon is observed in the composition of 85% cassava peel and 5% SBE due to the increased presence of SBE raw materials. As the SBE composition exceeds 10%, the fixed carbon value decreases, as seen in the composition of 75% cassava peel and 15% SBE, ranging from 3% to 5%.

The organic content in SBE emerges as the main factor in reducing fixed carbon. The presence of binders alongside carbonization positively influenced the physical characteristics of the produced briquettes, such as moisture content, volatile matter, and fixed carbon [18]. Binders do not significantly affect the fixed carbon value. RDF with tapioca flour binder produces fixed carbon ranging from 5% to 11%. The fixed carbon of RDF with durian seeds ranges from 1% to 6%. However, the fixed carbon value is higher than the other two in rejected papaya binders, ranging from 6% to 13%.

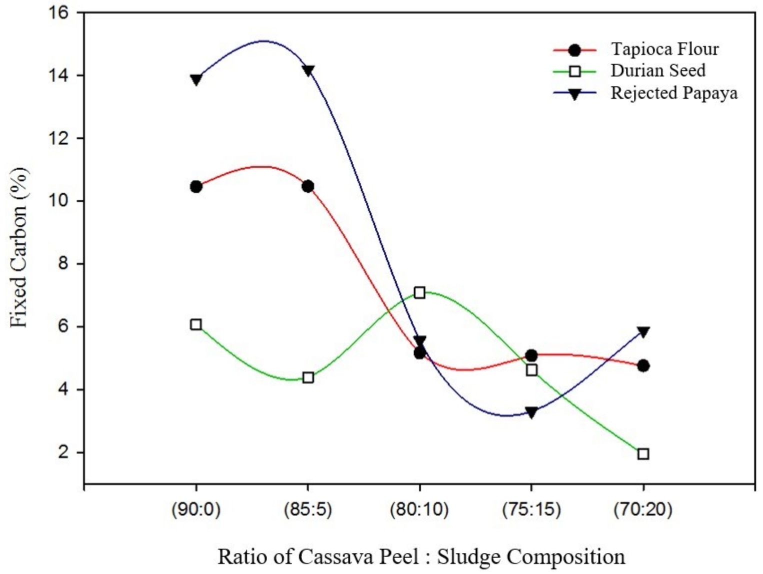

Figure 6. Effect of raw material composition and binder types on fixed carbon

2.3.5. *Calorific Value*

The calorific value denotes the quantity of heat released per unit mass of RDF [33]. Enhancing the calorific value of RDF contributes to its improved quality. A high calorific value is achieved when RDF has low moisture content, ash content, and high fixed carbon [34]. The Indonesian standard for RDF quality specifies a minimum calorific value of ≥ 3,000 kcal/kg. The findings of the calorific value test for RDF are illustrated in Figure 7.

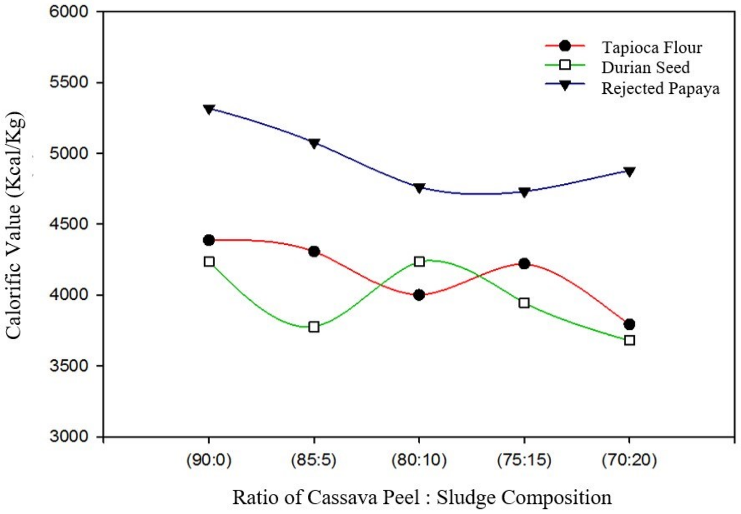

Figure 7. Effect of raw material composition and binder types on moisture content

The highest calorific value was observed in the composition comprising 90% cassava peel and 0% SBE, ranging between 4300 and 5300 Kcal/Kg. A decreasing trend in calorific value is evident in the composition of 75% cassava peel and 15% SBE, ranging from 3700 to 5000 Kcal/Kg. The fixed carbon value can impact the calorific value. For instance, the composition of 70% cassava peel and 20% SBE with durian seed binder yields a fixed carbon value of 1% and a calorific value of 3600 Kcal/Kg. Despite the relatively low fixed carbon value, the resulting calorific value still conforms to the Indonesian RDF standard (>3000 Kcal/Kg) [35]. The calorific value in RDF indicates that the energy obtained arises not only from the produced carbon but also from the hydrocarbon content in the mud. According to Placxedes et al. [7], SBE-containing oil exhibits a high hydrocarbon content, thereby increasing the calorific value. The calorific value of RDF in this study ranges from 3600 to 5300 Kcal/Kg, which closely aligns with the calorific value of briquettes mixed with sludge and cassava peel biomass by Akogun et al. [25], producing a calorific value of 3,716 kcal/kg.

The composition of the raw materials and binder influences the calorific value of RDF. The three binders exhibit different calorific values, particularly rejected papaya. Rejected papaya possesses characteristics such as moisture content (0.3%), volatile matter (77–82%), ash content (5–18%), and fixed carbon (5–13%). RDF with rejected papaya binder yields a calorific value ranging from 4880 to 5,320 Kcal/Kg. Tapioca flour and durian seed binders have calorific values of 3678 to 4388 Kcal/Kg, with all binder types meeting Indonesia RDF standards, which require a calorific value of more than 3000 Kcal/Kg [35].

2.4. Statistical Analysis

Statistical analysis was used to determine the extent to which RDF characteristics are affected by raw material composition and binder type. A method called one-way ANOVA was employed to assess these effects. To utilize one-way ANOVA, the data must be normally distributed and homogeneous. If these criteria are not met by the data, the Kruskal-Wallis method will be used instead. A summary of the tested data can be seen in Table 4 and Table 5.

Table 4. Statistical Test Results: The Effect of Binder Type on RDF Characteristics

Characteristics	Parameter	
	Binder	Information
Moisture Content	Normal and Homogeneous	Binder affects moisture content because the one-way ANOVA value is <0.05 (ρ value: 0.000)
Volatile Matter	Normal and Homogeneous	Binder does not affect volatile matter because the one-way ANOVA value is > 0.05 (ρ value: 0.236)
Ash Content	Normal and Homogeneous	The binder does not affect ash content because the one-way ANOVA value is > 0.05 (ρ value: 1.000)
Fixed Carbon	Kruskal Wallis	There is no difference between fixed carbon and binder because the Kruskal-Wallis value is > 0.05 (ρ value: 0.379)
Calorific Value	Normal and Homogeneous	Binders affect the calorific value because the one-way ANOVA value is <0.05 (ρ value: 0.000)

Table 5. Statistical Test Results: The Effect of Composition on RDF Characteristics

Characteristics	Parameter	
	Composition	Information
Moisture Content	Kruskal Wallis	There is no difference in the moisturecontent of the composition due to the Kruskal Wallis value > 0.05 (ρ value: 0.329)
Volatile Matter	Kruskal Wallis	There is no difference in volatile matter on composition because the Kruskal Walis value is > 0.05 (ρ value: 0.176)
Ash Content	Normal and Homogeneous	Composition affects ash content because the one-way ANOVA value is <0.05 (ρ value: 0.000)
Fixed Carbon	Normal and Homogeneous	The composition does not affect fixed carbon because the one-way ANOVA value is > 0.05 (ρ value: 0.091)
Calorific Value	Kruskal Wallis	There is no difference in calorific value to the composition of the Kruskal walis value > 0.05 (ρ value: 0.675)

2.5. X-Ray Diffraction (XRD) Analysis

X-Ray Diffraction (XRD) analysis was performed to identify the specific minerals present and to determine the mineral characteristics of the material [36]. The XRD tests were performed on three samples with compositions of 90% cassava peel and 0% SBE, 80% cassava peel and 10% SBE, and 70% cassava peel and 20% SBE. The results of the XRD tests are shown in Figure 8. In Figure 8 (a), a peak at $2\theta = 26°$ indicates the presence of graphite in cassava peel. This graphite likely comes from the cassava peel's carbonization process. Figure 8 (b) displays graphite at $2\theta = 26°$, magnesium at $2\theta = 29°$, and quartz at $2\theta = 42°$. This RDF sample, containing 80% cassava peel, 10% SBE, and 10% tapioca flour adhesive, exhibits silica and magnesium, likely originating from the SBE mixture, which contains 55% SiO_2 and magnesium oxide [37].

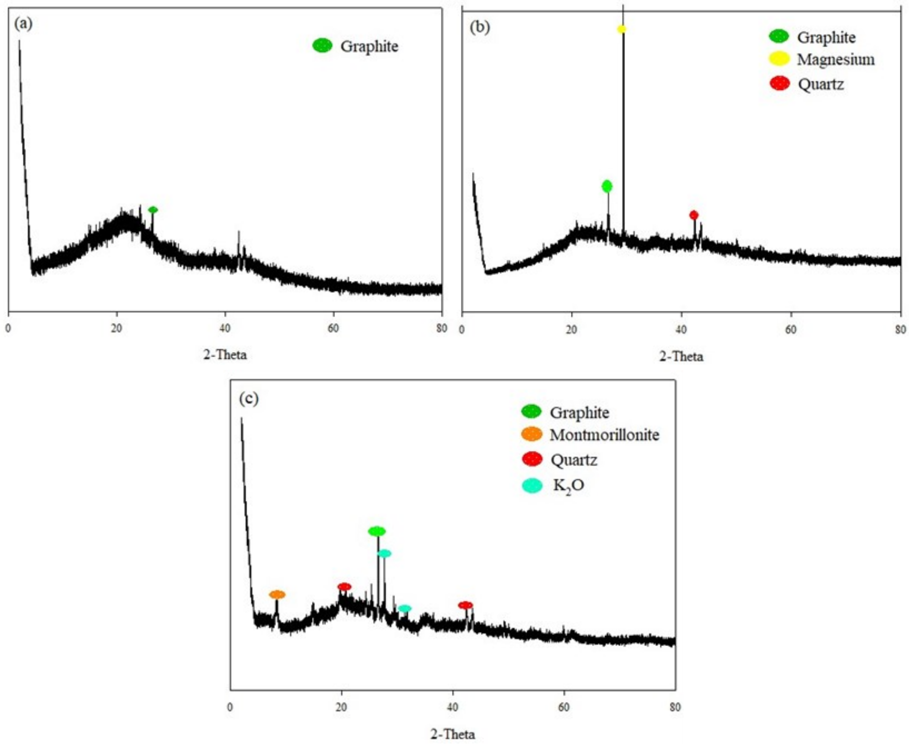

Figure 8. Ratio of (a) 90% Cassava Peel and 0% SBE (b) 80% Cassava Peel and 10% SBE (c) 70% Cassava Peel and 20% SBE

Magnesium in SBE suggests that the RDF ash also contains magnesium. Image (c) reveals montmorillonite at $2\theta = 8°$, quartz at $2\theta = 20°$ and 42°, graphite at $2\theta = 26°$, and K_2O at $2\theta = 28°$ and 31°. Montmorillonite in SBE increases water absorption in RDF, with the study also showing higher moisture content as SBE concentration rises. SBE contains 0.96% K_2O, which is detectable in XRD analysis, with potassium in RDF potentially evaporating as volatile matter [29].

3. Conclusion

Based on the conducted research, it can be concluded that the ratio significantly influences the ash content. The optimal RDF ratio consists of 90% cassava peel, 0% SBE, and 10% binder. The calorific values produced by the tapioca flour binder, durian seed binder, and rejected papaya binder are 4388 Kcal/Kg, 4237 Kcal/Kg, and 5320 Kcal/Kg, respectively. It is evident that the type of binder affects the moisture content and calorific value. Although all three types of binders produce excellent RDF characteristics, it's observed that bonding raw materials with the rejected papaya binder is more difficult than with tapioca flour and durian seed binders.

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