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Palm Oil Sludge as a Binding Agent for Briquette Production

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Abstract— *This study included the production of biomass briquettes from discarded cotton flock, an industrial byproduct. To boost densification, cotton flock was mixed with palm oil sludge at a ratio of 1:1. The quality factors include the shatter index, calorific value, water boiling test, flash point, and density of the final briquette was examined. Test results indicate that the free fatty acid percentage of sludge palm oil at room temperature was 32%. The moisture content of sludge palm oil was discovered to be 8%. The raw material was fed to the manual briquetting machine to densify by 50% to achieve a final height of 4 cm. It was determined that the briquette's shatter index was 99.5%. The calorific value of the briquette has been calculated to be 39.5MJ/kg. The density of the briquette, which was measured to be 816 kg/m3. It was established that the moisture percentage and ash content of the briquette were 5.8% and 15.1%, respectively. The cotton flock with sludge palm oil as the binding agent produce high quality fire briquette to replace the biomass requirement in the industrial combustion process.*

Keywords— *Briquette; Binding agent; Biomass; Palm oil sludge*

I. INTRODUCTION

The commonly utilized fossil fuels, such as coal, oil, and natural gas, drive the global energy process and account for more than 80% of the market value [1]. The depletion of fossil fuels has significantly impacted the energy crisis and the sustainability of the energy supply. Even though fossil fuels were the cornerstone of the industrial revolution, the environmental harm caused by air pollution and the resulting decline in public health has sparked a great interest in renewable energy sources [2]. In 2020, the atmospheric carbon dioxide (CO_2) concentration reached 417 ppm, frightening the global community into pursuing renewable energy sources [3].

Most enterprises and families in developing nations generate energy from biomass because it is easily accessible and inexpensive compared to fossil fuel [4]. Moreover, biomass is the third most excellent energy resource on the planet [5]. Even though biomass is considered an essential energy source, its environmental effect, deforestation, and air pollution are considerable. Biomass boilers are one of the primary uses of biomass in industrial processes since they generate steam. By converting biomass waste into briquettes by densification [6], inefficient biomass use, heat losses, and incomplete combustion may be reduced. In addition, novel waste-to-energy technologies can mitigate the adverse effects of conventional biomass utilization.

Briquetted biomass is a known technique for efficiently generating energy from biomass since it produces more excellent heat with fewer raw materials [7]. Several types of trash have been used as the raw material for briquettes to combat the issues connected with solid waste management. Decades ago, sawdust, agricultural crop residue, solid waste, and industrial wastewater sludge were used to produce briquettes [8]. Additionally, biological waste, cotton dust, waste flocks, sawdust, and charcoal may be used to produce briquettes with a binder [9]. Water was used as a lubricant in the production process to promote the consistent mixing of the raw materials. To improve bulky materials' density and calorific value, briquetting may be achieved by manual hand pressing and mechanical compaction. However, the binding agent is required in many cases to densify the raw material and generate a long-lasting final product [10].

Briquette binder

Typically, biomass contains structural binders and chemicals that stabilize its structure. During biomass densification, which happens at very high temperatures and pressures, structural binders or stabilizing chemicals, such as lignin and proteins, are released and activated [11, 12]. Therefore, the structural particle bonding of biomass briquettes is greatly strengthened. In some instances, additional binders may be necessary to achieve the appropriate degree of briquette hardness and durability, either because the biomass does not contain a sufficient quantity of natural binder (lignin) or because of the circumstances of the densification process necessitate their usage [13]. The three unique types of briquette binder [14, 15] are organic binders, inorganic binders, and compound binders, based on their diverse material compositions. However, these many kinds of binders have their own benefits and drawbacks.

However, including specific binders during the densification and combustion phases of briquette production can have deleterious consequences on the final product. These adverse effects include a decrease in the compaction of the briquettes, less-than-ideal combustion characteristics, and airborne pollutants when used in large quantities [16]. Binders with higher cellulose content, such as bio solids and microalgae, produce briquettes with a weaker compaction effect, less durability, and lower energy contents [17, 18]. This is because briquettes with a higher cellulosic content are more difficult to compact. Therefore, the selection of binders that will be utilized in the production of briquettes is crucial and should be carefully evaluated before production. This is because the briquettes will be utilized to hold other components together.

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The selection of binders from numerous varieties is heavily influenced by various parameters, such as the required bonding strength, low emissions, and the effect on the briquette's combustion performance, environmental friendliness, and economic and sustainable availability [13]. The important properties of a briquette binder are a) strong bond, b) pollution-free, c) no influence on the heat release and combustibility of the coal, d) no effect on the use of the coal, e) ecologically acceptable, and f) economically accessible [19]. Binders significantly influence the quality and characteristics of briquettes. In recent years, efforts have been undertaken to manufacture less expensive, more accessible, and environmentally friendly binders and optimize the binder-to-briquette mix ratio [20, 21]. The quality of the briquettes produced is significantly affected by the varying conditions under which the binders are processed.

Due to the inherent material bonding methods of the various raw materials, however, different binders are required for use with these materials [22]. Even while binders are used to enhance the bonding between biomass particles during densification, the specific mechanism of the bonding process is not entirely understood [23]. Several hypotheses [24, 25, and 26] have been proposed due to previous research to explain particle bonding processes in biomass densification. These hypotheses consist of forces of attraction between biomass particles, adhesion and cohesion forces, solid bridges and mechanical interlocking linkages, interfacial forces, and capillary pressure.

Palm oil sludge or sludge palm oil (SPO), also known as palm oil mill effluent, is a brownish-colored, viscous liquid produced during manufacturing. According to the earlier investigation, palm oil sludge comprises 4 to 5% particles, 0.5 to 1% oil, and the rest as water [27]. Due to its high concentration of free fatty acid (FFA), SPO often has little potential for use as a byproduct or raw material in other industries. Due to the effluent composition, the FFA percentage of the SPO is often greater than 20% [28]. SPO is recognized as the binder for the briquette in this experiment because to its better liquid-to-solid transition quality. The SPO is often solid at room temperature owing to the large quantity of saturated fatty acids represented by the FFA percentage. However, when the temperature rises, it becomes liquid at around 40°C. This is because of the crystallization and melting characteristics of palm kernel oil. The change of the binding agent from solid to liquid is essential to the briquetting process.

II. Materials and Method

Pre-treatment

The collected SPO is heated on a hot plate equipped with a temperature sensor to determine the melting point at which the solid-to-liquid transition occurs. The SPO is a semi-liquid-solid combination at room temperature, as seen in Figure 1. After being exposed to warmth, SPO began to transition into a liquid state at 32°C and became liquid at 40°C. Figure 2 depicts the liquid palm oil sample at 40°C, which was ready for further testing.

Fig. 1. SPO at room temperature (28°C).

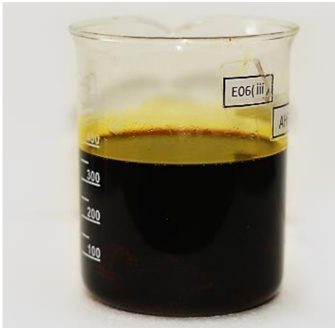

Fig. 2. SPO at 40°C.

FFA% analysis

The FFA of the melted SPO was analyzed with the titration method. The acid number means the KOH mass in milligrams required to neutralize one gram of oil. The one gram of SPO was added to a titration flask containing 125ml of isopropyl alcohol along with 5-6 drops of indicator, which is phenolphthalein. The mixture was titrated with 0.1M KOH solution to get the color change from colorless solution to pale pink and recorded the required KOH volume (V1). A similar procedure was followed for the blank sample, which did not contain SPO, and recorded the KOH volume (V2). The entire procedure was performed three times to minimize the errors. The acid value and the FFA% were calculated with Equations 1 and 2.

$$\text{Acid Value} = 56.1 \times 0.1 \times (V1 - V2) / 1 \quad (1)$$

$$\text{FFA\%} = (\text{Acid Value}) / 2 \quad (2)$$

SPO quality Analysis

The quality of the SPO was analyzed to check the amount of water content of the oil sample. A known amount of SPO sample was placed in a laboratory oven at 130°C for 1 hour. After that, the remaining weight was calculated to find the sample's moisture content.

Briquette production with SPO as a binding agent

In the laboratory, a manual pressing machine was employed for briquette manufacture. Figure 3 depicts the manual press equipment that can simultaneously create four briquettes. The initial 8cm height of the material was compressed to 4cm to create the densified briquette.

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Fig. 3. Manual Briquetting machine

As a by-product of the glove manufacturing industry, the discarded cotton flock was employed as the primary raw material for briquette manufacture. SPO was utilized as the adhesive. Maintain a 1: 1 ratio of the cotton flock to SPO for improved densification. After producing the compacted briquette, it was allowed to air-dry for about four hours in the shade. Figure 4 shows the result of the densified briquette.

Fig. 4. Final briquette

Quality analysis of the produced briquette

The final briquette was used for quality analysis such as shatter index, calorific value, moisture content, ash content, and density.

Shatter Index

Shatter resistance is the amount of weight that remains after the 2m drop test, which is conducted to check the stability of the briquette. To calculate the shatter resistance, the final briquette has to drop from 2m height and get the weight loss due to the crash with the floor. Equation 3 was used to calculate the shatter index for the briquette.

$$\text{Shatter Index} = \frac{\textbf{Weight after shatter}}{\textbf{Initial weight before shatter}} * 100\% \quad (3)$$

Calorific Value

The calorific value is the amount of heat released when the unit amount of briquette burns for combustion. The calorific value of the briquette was calculated at the laboratory for the optimized briquette and recorded.

Density

As briquettes with a high energy-to-volume ratio have a high density, density is a crucial characteristic of the briquette production process. It improves the handling, transportation, and storage of briquettes and their physical properties, such as calorific value and flash point. Density was computed with Equation 4.

$$\text{Density of the briquette} = \frac{\textit{mass of the briquette}}{\textit{volume of the briquette}} \quad (4)$$

Moisture Content

The moisture content of the briquettes is one of the most important factors that affect the quality of briquettes. Moisture content influences the strength of the briquettes as well as the durability. The final moisture content of briquettes was analyzed using a laboratory oven at 105°C based on the Equation 5.

$$\text{Moisture content} = \frac{\textit{initial weight} - \textit{final weight}}{\textit{initial weight}} \times 100\% \quad (5)$$

Ash Content

The ash content of briquettes is the quantity of ash created after burning. It is a component of biomass that cannot be burned.

The calorific value is also contingent on the ash content, with a more significant ash content resulting in a lower calorific value. Ash concentration was determined by heating a briquette sample to 550°C in a muffle furnace. The formula for calculating the initial and final weights after three hours is provided in Equation 6.

$$\text{Ash content} = \frac{\textbf{final weight}}{\textbf{initial weight}} \times 100\% \quad (6)$$

III. RESULTS AND DISCUSSION

The FFA percent of the SPO at room temperature was 32%, which is a crucial aspect in choosing the binding agent. The increased FFA percentage suggests that the sludge palm oil is working as a semi-liquid component, which is the cause of the superior binding quality. The SPO's moisture content was measured and found to be 8 percent. The raw material was supplied to the manual briquetting machine up to a height of 8cm, and it was compressed to a height reduction of 50% to achieve a final height of 4cm. The briquette's shatter index was estimated to be 99.95%. The determined calorific value of the briquette is 39.5MJ/kg, which is a lot greater value than the biomass and waste flock. The higher calorific value is due to the calorific value of the palm oil sludge. The density of the briquette, which was found to be 816 kg/m^3, is a significant component in determining its energy content. The briquette's moisture percentage and ash content were measured to be 5.8% and 15.1%, respectively.

IV. CONCLUSION

Cotton flocks created by the glove manufacturing industry must be disposed of in landfills or incinerated to prevent environmental contamination. Similarly, the sludge palm oil produced by the palm oil processing factory is a waste product that requires quick management to prevent environmental contamination. Therefore, the potential of SPO as a binder to manufacture fire briquettes was evaluated, and the briquettes were effectively produced. All measured characteristics are closely aligned with the typical values of the fire briquettes made from different raw materials. Therefore, it may be concluded that sludge palm oil is an ideal semi-liquid binding agent for the briquette sector. This is an urgently required solution for managing trash created by the glove manufacturing and palm oil processing industries.

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