ISSN 2355-8776

The Effect of Coffee Dregs Addition on the Manufacture of Corn Cob Briquettes with Variation of Adhesive Type

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ARTICLE INFO

Article history
Received June 10, 2024
Revised November 20, 2024
Accepted November 22, 2024

Keywords
Briquettes
Coffee grounds
Corncobs
Type of adhesive

ABSTRACT

Energy demand is rising while the availability of fossil fuels is declining. To reduce the use of fossil fuels, it is necessary to utilize biomass energy as an alternative. Agricultural waste, such as corn cobs and husks, is used as raw materials for making briquettes. This study uses the carbonization method to convert raw materials into charcoal. Tapioca flour and sago flour are used as binders in the briquettes. This research aims to evaluate the composition of carbon sources in the form of corn cobs and coffee shells, the type of adhesive in producing briquettes, and the quality of briquettes produced. Research has begun by making briquettes from variations of the composition of mixture and coffee grounds (80:20; 70:30; 60:40; 50:50%) with variation adhesive (Sago and tapioca starch). The resulting briquettes were evaluated for calorific value, ash content, and moisture content according to SNI 01-6235-2000. The results of the analysis of briquettes from a variation of the composition of mixture and coffee grounds (80:20; 70:30; 60:40; 50:50%) with variation adhesive (Sago and tapioca starch) conform to SNI 01-6235-2000. The best briquettes were obtained on the composition of a 50% ratio of corn cobs and coffee husks with sago flour as an adhesive, have a moisture content of 4.93%, ash content of 2.22%, and calorific value of 5404.27 Cal/gram.

1. Introduction

The demand for domestic fuel increases annually while the fuel crisis worsens. Most fuel is derived from fossil fuels, classified as nonrenewable natural resources. Due to the reliance on fossil fuels and the depletion of fossil fuel reserves, the price of fossil fuels has increased [1], [2], [3], [4]. Finding and developing conventional fuels into alternative fuels can improve the usefulness of these natural resources. Biomass is an alternative fuel that uses renewable natural resources. In Indonesia, biomass is one of the alternative energy sources with enormous potential. Biomass consists of wood waste, agricultural waste, plantation waste, forest waste, and organic components from industry and households, allowing for the simple production of alternative energy and the economically valuable utilization of waste [4], [5], [6]. Corncob waste is agricultural waste biomass used to manufacture alternative fuels.

In Indonesia, corn stover is one of the abundant lignocellulosic waste products. Lignocellulosic waste is an agricultural material composed of cellulose, hemicellulose, and lignin [7]. Each of these compounds has the potential for biotransformation into another substance. Corn stover can be used as a substrate in cellulase enzyme fermentation with the support of microorganisms such as *Aspergillus niger*.

Cellulose is a carbon source that microorganisms can use as a substrate in the fermentation process to produce products with high economic value; a high lignin and cellulose content will also make products with high calorific value. The levels of lignin complex compounds in corn stover range from 6.7% to 13.9%, hemicellulose from 39.8% to 45.5%, and cellulose from 32.3% to 45.5%. Rarely is cellulose found in its purest form; it is always bound to other substances, namely lignin and hemicellulose. Corn stover also has a relatively high crude fiber content of 33%, a cellulose content of approximately 44.9%, and a lignin content of roughly 33%, making it used as a primary material for charcoal briquettes[8]. Essentially, corncob waste is abundant but underutilized. With it comes the concept of maximizing its value. Briquetting is an efficient method for transforming solid raw materials into compacted forms that are more effective, efficient, and user-friendly. The choice of corncobs as the primary material is due to the abundance of the material, which is not optimally utilized. Soaked corn cobs have a silica concentration of 52.32 % [9].

Coffee grounds are waste generated from the remaining consumption of coffee beans. This waste can be used as raw material for making briquettes because it has a high calorific value [10]. To create high-quality briquettes, coffee grounds are added and mixed with the appropriate composition to increase the calorific value of briquettes. According to Caetano et al. (2012), coffee grounds have a moisture content of 12.2%, a total carbon content of 52.2%, a total nitrogen content of 2.1%, an ash content of 1.43%, and a cellulose content of 13.8%. [11]. Coffee grounds have a high calorific value of 5764 calories per gram, a high pH, and a high concentration of organic compounds. Making fuel from waste coffee grounds is one of its most significant uses [12]. Caffeine, pectin, proteins, fiber, polyphenols, tannins, and other organic compounds are abundant in coffee grounds [13].

In addition to being burned, biomass waste can be processed into briquettes, increasing the waste's calorific value when it is torched. Briquettes are a renewable alternative energy source that can be utilized to combat the energy crisis [14]. Briquettes are solid fuels derived from the residues of organic materials that, when carbonized, will become alternative fuels with a higher calorific value. Briquettes also have economic benefits due to their simple production and abundant raw materials in Indonesia, allowing them to compete with other fuels. The quality standard for wood charcoal briquettes refers to SNI 01-6235-2000. Good quality briquettes can be utilized for their intended purpose. Briquettes ' important physical and chemical properties that affect fuel quality include moisture, charcoal, volatile matter, and calorific value [15].

Essential briquetting procedures include carbonization and adhesion [16]. Carbonization converts carbon through combustion in a confined space with limited or no oxygen. The material will become charcoal if the combustion process is interrupted while smoldering. The material possesses residual energy that can be used for various purposes, such as heating, baking, and drying. Compared to burning directly into ash, vapor production by charcoaled organic materials is minimal. The energy of organic material is steadily released into the environment as whitish ash during combustion. [17].

The reaction that occurs in the carbonization process [18], namely:

Cellulose decomposition reaction

$$(C_6H_{10}O_5)n \rightarrow CH_3COOH + 3CO_2 + 2H_2O + CH_3OH + 5H_2 + 3CO \quad (1)$$

Lignin decomposition reaction

$$[(C_9H_{10}O_3)(CH_3O)]n \rightarrow C_{18}H_{11}CH_3 + C_6H_5OH + CO + CO_2 + CH_4 + H_2 \quad (2)$$

General reaction of carbon formation

$$(CxHyOz) + O_2 \rightarrow C(graphite) + CO(g) + H_2O\ (g) \quad (3)$$

The subsequent procedure is the bonding procedure, which substantially impacts the briquette's final specifications. The purpose of incorporating adhesives into the production of charcoal briquettes is to ensure that the charcoal particles adhere to one another and are resistant to destruction. Organic adhesives, such as tapioca starch, are effective and generate relatively little ash when burned with briquettes. Using starch adhesives has several benefits, including low cost, simplicity of application, and the ability to develop a solid dry bond [8]. The amylose content of tapioca starch is 27.38%, and the amylopectin content is 87.71% [19]. Sago starch can also be used as an adhesive, similar to tapioca starch, because sago starch is a very productive plant as a starch producer. Sago starch can be used as an adhesive because it contains 27.4% amylose and 72.0% amylopectin [20]. The ratio of amylose to amylopectin affects starch's solubility and degree of gelatinization. The greater the amylopectin content, the stickier and more likely the starch will be to absorb water [21].

This investigation analyzes briquettes regarding their calorific value, moisture, and ash content. The calorific value of an object is the quantity of heat it absorbs or emits. Using an explosive calorimeter, one can calculate calorific values. The calorific value influences the rate of combustion. The calorific value of a briquette is the value of the heat of combustion that the briquette can generate when used as fuel. The quality of the briquette increases as its calorific value increases. Low calorific value and noncompliance with SNI standards disqualify briquettes for use as an alternative energy source [22]. The moisture content of briquettes can be expressed as either unrestricted water vapor or bound water vapor. The amount of water in the charcoal influences the quality of the resulting briquettes. If the moisture content is low, the calorific value and combustion power are high, and vice versa. The calorific value and combustion power are low if the moisture content is high. A briquette is deemed satisfactory if its moisture content is less than or equal to 8 percent. The briquette's quality improves as its water content decreases. The moisture content of briquettes is affected by the surface area of charcoal pores and the amount of carbon bonded in the briquettes. Briquettes contain inorganic substances that are quantifiable as the remaining weight or residue. Ash in briquettes originates from the adhesive, coffee grounds powder, and other mineral substances. Scale formation is highly detrimental to briquettes with a high ash content. Ash content is the combustion residue with no calorific value due to the absence of carbon. The proportion of briquette's inorganic elements to its ash content is proportional. Briquettes with a high ash content are undesirable because they can reduce the calorific value of charcoal briquettes, thereby diminishing the quality of charcoal briquettes [23]. This research aims to evaluate the composition of carbon sources in the form of corn cobs and coffee grounds, the type of adhesive used in the manufacture of briquettes, and the quality of briquettes produced.

2. Research Methodology

2.1. Materials

Corn stover, coffee grounds, tapioca starch, sago starch, and water were the materials used in this study. Corncob was obtained from Malang Regency. Coffee grounds were obtained from Malang Regency. Tapioca flour and sago flour with commercial grade were obtained from the market in Malang. Tapioca flour and sago flour are commercial grade and obtained from the market in Malang. The used equipment includes a crusher, a furnace, a 60-mesh screen, an explosive calorimeter, an analytical balance, a desiccator, a press, and a heater.

2.2. Procedures

1) Initial Treatment

Ground maize cobs and coffee grounds were baked at 105 °C for two hours. The maize cobs were then carbonized for three hours at 300 °C. The corncob charcoal was sieved through a 60-mesh screen. Then, corncob charcoal and coffee grounds were mixed in proportions of 8:2, 7:3, 6:4, and 5:5 with adhesives made from tapioca and sago starch.

2) Briquetting Process

Water was combined with tapioca starch and sago starch in a ratio of 5:1 to produce the adhesive. The briquette mixture was formed using a press machine after mixing corncob charcoal, coffee grounds, and adhesive. The briquettes were baked for seven hours at 105 °C. The briquettes were then evaluated for calorific, moisture, and ash content.

3) Analysis Process

The calorific value, the moisture content, and the carbon content must be analyzed to determine the quality of the briquettes. Digital bomb calorimeters are used to evaluate calorific value. The calorific value of briquettes can be determined by weighing a sample of 1 gram, placing it in a platinum cup, and putting it on the end of an igniter rod that has been threaded with an igniter thread, followed by placing it in a bomb tube and closing it securely. Submit the Bomb ID number and sample mass and press submit. The increase in thermometer temperature was recorded after waiting 15 minutes for the ignition and chilling processes. The calorific value can be calculated using the following formula about the ASTM D - 2015 method.

$$Calorific\ Value = \frac{(\Delta T \times W - (CVT + CVW))}{M} \quad (4)$$

The moisture content of the briquettes can be determined by placing the cup in an oven at 105°C for one hour, weighing the porcelain cup several times until constant, weighing the porcelain cup empty, and then placing 2 grams of briquette sample into the cup. The sample is flattened and put in an oven at 105 °C for three hours. It is weighed after removing the cup from the oven and letting it chill in a desiccator. The moisture content was determined three times. As a mathematical expression:

$$Moisture\ content = \left(\frac{(m2-m3)}{(m2-m1)}\right) \times 100\% \quad (5)$$

Determination of ash content was carried out by placing the cup into the oven for 1 hour at 105°C and weighing the porcelain cup several times until constant. The cup was then chilled in a desiccator for 30 minutes, and the empty weight was determined. Then, place a 2-gram sample within the vacant cup. The cup containing the sample is then placed in the furnace for two hours at 750 °C until the sample becomes ash. The cup was removed from the stove, cooled in a desiccator, and weighed. The ash content is determined by weighing the residue remaining after the complete combustion of briquettes under standard conditions:

$$Ash\ content\ (\%) = \left(\frac{(m3-m1)}{m2}\right) \times 100\% \quad (6)$$

3. Results and Discussion

3.1. The effect of coffee grounds addition on the calorific value of briquettes

The calorific value is primarily influenced by water, ash, and carbon in the material. The higher the water and ash content, the lower the calorific value of the briquette, while the higher the carbon content, the higher the calorific value [24].

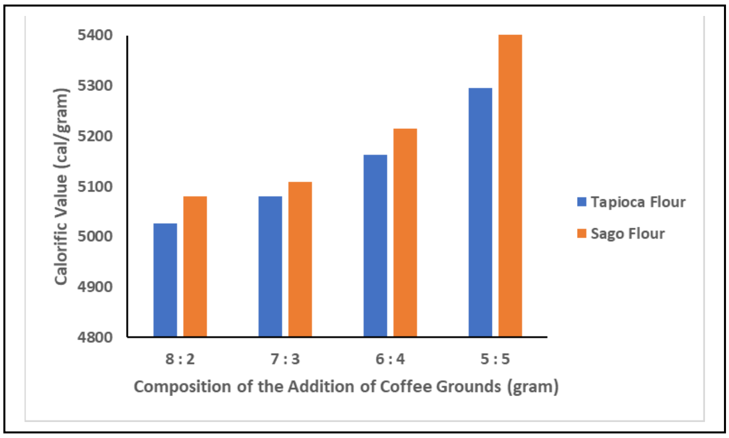

Fig. 1. Calorific Value of Briquettes at Variation of Composition of Coffee Grounds Addition.

According to Figure 1, briquettes with tapioca starch adhesives have the lowest calorific value (5027.61 Cal/gram). Briquettes with a mixture of sago starch adhesives have the highest calorific value (5404.27 Cal/gram). The addition of coffee grounds composition can affect the calorific value of the briquette; the greater the ratio of coffee grounds added, the greater the calorific value obtained; however, if the composition of coffee grounds is too dominant, it will decrease the calorific value of the briquette; therefore, the composition of biomass with coffee grounds must be comparable to obtain the maximum calorific value [25]. The eight briquette samples all met the standard calorific value of SNI 01-6235-2000 for the quality of wood charcoal briquettes with a calorific value of at least 5000 Cal/gram. Therefore, using sago flour adhesives produced the best briquette quality, indicated by a higher calorific value for both carbon sources (corn cobs and coffee grounds) than tapioca flour adhesives.

3.2. The effect of coffee grounds addition on briquette moisture content

Moisture content impacts the quality of charcoal briquettes; the lower the moisture content, the greater the calorific value and combustion power. Charcoal has a tremendous capacity for absorbing moisture from the air. The charcoal's surface area and pore size, as well as the amount of bound carbon in the briquette, influence its capacity to absorb water. In addition, charcoal particles' mesh size influences the briquette's water content, as the spaces or porosity between particle sizes can be filled with water. [23]. The greater the moisture content, the greater the smoke is produced during combustion [26].

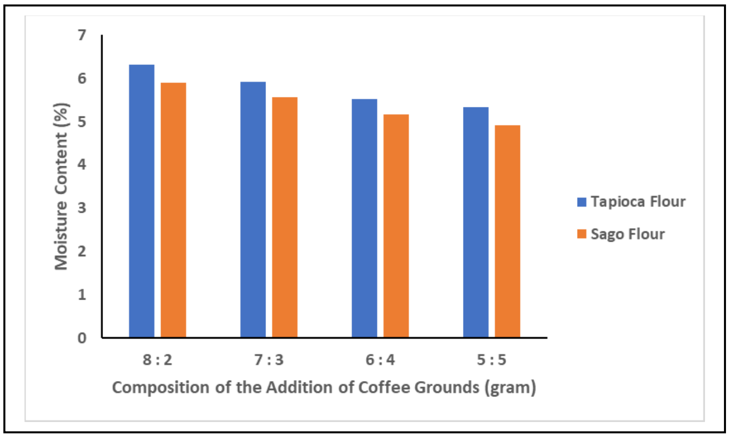

Fig. 2. Moisture Content in Variation of Coffee Grounds Addition Composition.

The briquettes with the lowest moisture content contain a mixture of sago starch adhesives with a moisture content of 4.92 %. In contrast, the briquettes with the maximum moisture content contain a mixture of tapioca starch adhesives with a moisture content of 6.32 %. Because coffee grounds can absorb the water content of briquette, the water content decreases as the proportion of coffee grounds increases. The high moisture content of the adhesive material is also affected by the ratio of amylose and amylopectin, which involves the solubility and degree of starch gelatinization. The higher the amylopectin content, the stickier and more likely the starch will be to absorb water [21]. All eight samples conform to the maximum 8% water content specification of SNI 01-6235-2000 for the quality of wood charcoal briquettes. The quantity of moisture present will influence the heating value produced. The excessive moisture content will result in a decrease in calorific value [27].

Charcoal particles can absorb moisture from the surrounding air, increasing the initial low humidity level when adhering and drying charcoal into briquettes. In addition, adding adhesives raises the water content, so adhesives capture the water in the charcoal particulates with a high binding capacity [19]. Additionally, the inclusion of adhesives affects the moisture content due to the hygroscopic properties of adhesives derived from starchy materials [28]. The greater the value of water absorption in the air, the greater the volume expansion of briquettes, which leads to the expansion of briquette particulates [29].

3.3. The effect of coffee grounds addition on the ash content of briquettes

The ash content of a test specimen is a measurement of the material and various inorganic materials present. Ashes are the byproduct of heating solid biomaterials at a constant weight. High ash content can decrease the calorific value of charcoal briquettes; therefore, briquettes with a high ash content are of lower quality [30]. Ash in briquettes contains metal minerals that cannot vaporize and are flammable, so the high ash content of this briquette can result in pore formation [31].

The graph reveals that briquettes with sago adhesive have the lowest ash content at 2.22 %, while those with a mix of tapioca starch adhesives have the most excellent ash content at 2.86%. As the proportion of coffee grounds increases, the concentration of particles decreases. The primary component of ash is silica mineral, which harms the thermal value produced, resulting in lower-quality briquettes [26]. The SNI 01-6235-2000 standard for wood charcoal briquettes specifies a maximum ash content of 8%, met by all eight briquettes.

In general, the ash content of biomass consists of carbohydrate salts, sulfates, phosphates, potassium, calcium, and magnesium silicates. Approximately 67.41% of the ash in corncob charcoal consists of silica [32]; therefore, the incorporation of coffee grounds will result in the formation of calcium silicate hydrate (CSH) compounds [33], where the formation of these compounds can increase the calorific value of burned briquettes [34].

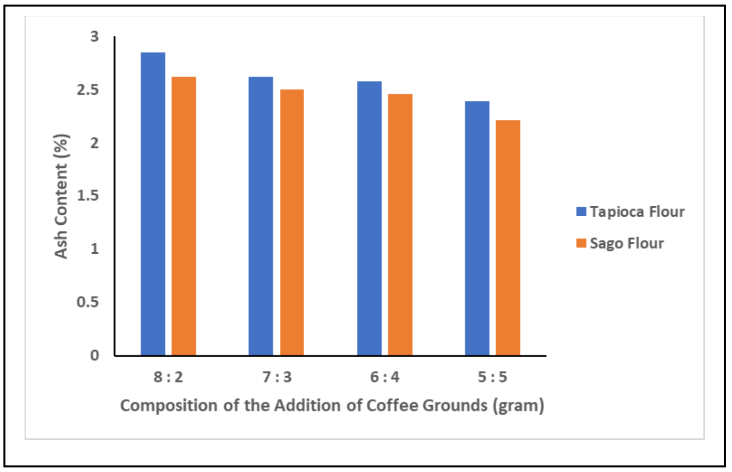

Fig. 3. Ash content in a variation of the composition of coffee grounds addition.

4. Conclusion

Based on an analysis of corncob briquettes containing coffee grounds, it has been determined that the composition of coffee grounds increased the calorific value. The results of the study of briquettes from a variation of the composition of mixture and coffee grounds (80:20; 70:30; 60:40; 50:50%) with variation adhesive (Sago and tapioca starch) conform to SNI 01-6235-2000. Briquettes of the highest quality are produced from maize cobs and coffee grounds in a 50%:50% ratio. Sago starch performs as an adhesive in the production of briquettes that consist of a 50% corn cob and 50% coffee ground composition, resulting in the best product characterized by the lowest ash content (2.22%), the lowest moisture content (4.92%), and the highest calorific value of 5027.61 Cal/gram, in comparison with the addition of tapioca adhesive.

Notation

For calorific value calculation:
ΔT = Difference in final temperature - initial temperature
W = 2690,39 Cal/°C
CVT = 21 Cal (yarn calorific value))
CVW = 9,32 Cal (heating value of wire)
M = mass of burnt sample (gram)

For calculation of moisture content:
$m1$ = empty cup weight (gram)
$m2$ = weight of empty cup + sample (gram)
$m3$ = weight of empty cup + sample after drying (gram)

For calculation of ash content:
$m1$ = empty cup weight (gram)
$m2$ = weight of empty cup + sample (gram)
$m3$ = weight of empty cup + ash (gram)

Acknowledgment

The author would like to thank Salsabila Angelica Jasmine and Aziza Inda Rama Dani for completing this research in the Basic Chemistry Laboratory of the Department of Chemical Engineering, POLINEMA.

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