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Production of fuel briquette from solid waste biomass using natural resin as a binder

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Abstract

Background: This research aimed to evaluate the use of natural resin as a binder for the production of fuel briquette from solid waste biomass.

Methods: Proximate analyses were made for fuel briquette prepared from solid waste biomass using natural resin as a binder in comparison with using starch as a binder.

Results: The results for density, percent content of moisture, percent content of volatile matter, percent content of ash, percent content of fixed carbon, and the caloric value of solid waste biomass obtained were 158.23 kg/m^3, 18.25%, 65.99%, 4.78%, 10.98%, and 18.65 MJ/kg, respectively. Besides natural resin binder-used fuel briquette was characterized for its density, percent content of porosity weight index, percent content of shatter resistance, percent content of moisture content, percent content of volatile matter, percent content of ash content, percent content of fixed carbon content, and caloric values as 751.05 kg/m^3, 13%, 40%, 4%, 12%, 1%, 30%, and 27.05 MJ/kg, respectively. In the same way, the starch binder-used fuel briquette was characterized for its density, percent content of porosity, weight index, percent content of shatter resistance, percent content of moisture content, percent content of volatile matter, percent content of ash, percent content of fixed carbon, and caloric values as 760 kg/m^3, 10%, 42%, 4%, 11%, 2%, 31%, and 28.09 MJ/kg, respectively.

Conclusion: According to the results of the study, it can be concluded that all characterized properties using natural resin as a binder indicate almost comparative properties in comparison with the use of starch as a binder.

Keywords: Solid waste, Environmental pollution, Carbon cycle

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Introduction

One of the major problems in the Ethiopian countryside is that solid waste from homes, industry, and various factories is dumped into Open Land or into the Open Landfill. Most of the waste generated is not properly collected and disposed of (1). This solid waste biomass produced contains harmful components that can pollute the environment by producing various toxic parts (2). It is common to dump on open lands, waterways, drains due to poor solid waste management in the largest cities like Addis Ababa, Jimma, Bahir Dar, Hawaasa, Mek'ele, Adama, and Dire Dawa (3). Waste is simply dumped into environmentally sensitive areas, poses pollution, and threats public health (4). Solid waste biomass has the potential to serve as an alternative renewable, CO_2-neutral raw material for energy production (5). There is a shortage of energy and it is necessary to procure other alternative energy sources that are different from the conventional ones. According to the Jimma City Council, 53%, 31%, and 17% of the city's waste are biodegradable, disposable, and recyclable (6).

When converting solid waste biomass, it is necessary to consider the type of binder. Binders are intended to improve the bond strength and quality of the fuel briquettes produced. Common types of binders used by various scientists for briquettes were starch, molasses, paper, and sawdust. Therefore, this study is a novel idea focused on replacing expensive starch binders with locally available natural resin binders. Since natural resins may bind materials based on previous studies, they may be used instead of starch and other binders in briquette applications.

The overall goal of this study was to convert Zima City's solid waste biomass into briquette fuel to improve environmental protection and energy recovery using local natural resins as binders. This study brings energy recovery by controlling the amount of solid waste biomass and providing briquette fuel.

Materials and Methods

Equipment and chemicals used

The equipment used in this study was a carbonizer for the carbonization process, a grinder for grinding, sunlight and an oven for drying charcoal briquettes, a mixer for homogenizing the binder, and carbonization, and evenly distributing the ground charcoal. Sieving was done for size distribution and a molding machine for molding charcoal briquettes. A calorimeter was used for characterizing charcoal briquettes. The chemicals used in this study were natural binders (resins) for binding, water to mix the binders, and solid waste biomass as a raw material.

Characterizing solid waste biomass

Proximity analysis is a waste characterization to determine density, % moisture, % ash, and % volatiles. The density of solid waste samples was investigated by weighing empty cylindrical containers of known capacity and carefully filling the urban solid waste samples (7,8). This is shown in Eq. (1).

$$\rho BMSW = \frac{MBMSW}{Vcon} \quad (1)$$

Where $\rho BMSW$ is the density of BMSW (g/cm^3), *MBMSW* is the mass of BMSW (g), and *Vcon* is the quantity of the container (cm^3). Moisture content material is determined by weighing a component of the sample and drying it in an oven at 105°C for 3 hours (9,10). Moisture content material can be obtained using Eq. (2).

$$MC\ (\%) = C/D * 100 \quad (2)$$

Where *MC* is moisture content material, *D* is the mass of the sample before drying in (g), and *C* is the change in weight of the sample before and after drying in the oven. The composition of volatile matter (VM) of solid waste biomass was calculated by placing the check within the heater at a temperature of 550°C till the equal weight becomes recorded and weighed after to get the volatile matter percent (9). The percent content material of volatile matters was computed using Eq. (3).

$$VM\ (\%) = \left(\frac{w_3 - w_2}{w_2}\right)*100 \quad (3)$$

Where *VM* (%) represents the proportion of volatile substances in the degradable solid waste, W_2 represents the kiln-dried sample weight (g) of the degradable solid waste, and W_3 represents the kiln-dried decomposable solid waste. To determine the percentage of ash, a sample of decomposable solid waste was placed in the oven until the same weight was recorded (11,12). The oven-dried sample was then placed in an oven at 900°C and held there for approximately 30 minutes.

$$AC\ (\%) = \left(\frac{w_2}{w_1}\right)*100 \quad (4)$$

Where W_1 represents the initial weight of the oven-dried sample (g), W_2 represents ash weight (g), and *AC* (%) represents ash content percentage. Fixed carbon indicates the proportion of char that remains after the volatilization phase. The percentage of the fixed carbon content of briquettes was calculated as per (13) by subtracting the sum of PVM and PAC from 100. The same process was followed until the completion of the samples using Eq. (5).

$$PFC = 100\ (PMC + PVM + PAC) \quad (5)$$

where *FC* represents the percentage of fixed carbon, *MC* represents the percentage of water content, *VM* represents the percentage of volatile substances, and *AC* represents the percentage of ash. The calorific value indicates the amount of energy of the fuel. According to various scholars, the properties of biomass fuels depend on their chemical composition and moisture content. The most beneficial part of a fuel is its calorific value or calorific value (14,15).

$$Qc = (WT\text{-}e^1\text{-}e^2e^3)/m \quad (6)$$

Where *Qc* represents the heat of combustion (gross), *T* represents temperature rise (observed), *E* represents equal electricity of the calorimeter being used, e^1 represents heat generated by burning the nitrogen part of the air trapped in the bomb to shape nitric acid, e^2 represents heat produced by the formation of sulfuric acid from the response of sulfur dioxide, water, and oxygen, e^3 represents heat produced by the cotton thread, and heating cord where *m* represents the mass of the sample. The gross caloric fee has investigated the usage of the subsequent Eq. (7). In this equation, PMC, PVC, and PAC correlation is used to calculate the caloric heating value.

$$GCV\ (MJ/kg) = 37{:}777 - 0.647M - 0.387A - 0.089VM \quad R^{2=}\ 0.97 \quad (7)$$

Where *GCV* represents gross caloric value, *m* represents the content of moisture, *A* represents the content of ash, *VM* represents the content material of volatile matter, and *R* represents the coefficient of determination. Sorted waste contains many substances like meals waste, chat leaf and stalk, and other degradable waste which incorporate a high amount of moisture; then, to minimize the moisture content of solid waste, it was once placed in sunlight until dried. The size-reduced degradable stable waste was then introduced to carbonization for similar processing. After drying the degradable municipal waste, the carbonization procedure was performed using the furnace. The degradable solid waste was left to carbonize for three hours at 250°C. The dried raw materials were ground into smaller particles and screened using a sieve. The sieved pulverized charcoal was weighed and prepared.

Binder preparation

Starch was used as the standard binding material to achieve the proposed goals. The binder material was used to reinforce the fuel briquettes. The starch binder was prepared by dissolving 150 g of the resin in 100 mL of cold water to form a paste, and boiling 500 mL of water. The resin binder was prepared in the same manner by dissolving 150 g of resin in 100 mL of cold water to form a paste, and boiling 500 mL of water. The resulting paste was gradually mixed with boiling water and gently stirred until a smooth, homogeneous resin solution was observed.

Characterization of charcoal briquette

The properties like density, porosity index, crush resistance, the content of volatile matter, the content of ruins, the content of the fixed carbon, and gross calorific were determined. The characterization was accomplished based on Eqs. (8) to (16).

Density

$$\rho br = \frac{Mbr}{Vbr} \quad (8)$$

Where *ρbr* shows the density of charcoal briquette (g/cm^3), *Mbr* shows the weight of charcoal briquettes (g), and *Vbr* represents briquettes volume (cm^3).

$$V_{br} = \pi R^2 H \quad (9)$$

Where, *Vbr* shows briquettes volume (cm^3), *R* represents briquette ranges (cm), *H* represents the length of the briquette (cm), and π represents numerical constant i.e. 3.14.

Porosity index

$$PI\ (\%) = \frac{(Ww\text{-}Ws)}{Ws} * 100 \quad (10)$$

Where *PI* shows porosity index, *Ws* represents dry sample mass of briquette (g), and *Ww* represents wet sample weight of the charcoal briquette subsequently immersed in water (g). According to different philosophers' perspectives, each briquette sample bear is allowed for the test to drop from a crest of 2 m onto actual five times. The endurance (%) can be raised from the ratio of the final bulk of the briquette leftover after five drops to the primary mass of the briquette.

$$WL\ (\%) = \frac{w_1\text{-}w_2}{w_1} * 100 \quad (11)$$

$$SR\ (\%) = 100\text{-}WL \quad (12)$$

Where *WL* suggests the weight misfortune (%), *W1* suggests the briquette bulk earlier than rupture (g), *W2* suggests the briquette bulk following in role or time fracture (g), and *SR* suggests the amount of rupture substance (%). According to previous studies (16,17), the moisture content of briquettes can be calculated using cautious attention of any of the samples and drying it stylishly in an oven at 1050°C for three hours.

Moisture content

$$MC\ (\%) = \frac{B}{A} * 100 \quad (13)$$

Where *MC* refers to the dampness content, *A* is the mass of the pattern earlier than drying, and g and *B* is the load adjustments of the pattern earlier than drying stylish the kitchen stove. According to previous studies (18,19), extraordinary substances display few of the biomass introduced as unstable something which are now no longer liquid or solid. The kitchen stove-fired process occurs by heating mechanism at a temperature of 550°C for 10 minutes of the contact time.

Volatile matter

$$VM\ (\%) = \frac{w_2 - w_3}{w_2} * 100 \quad (14)$$

Where *VM* (%) indicates the part of changeable components, W_2 indicates the majority of the kitchen stove-tired pattern (g), and W_3 represents the majority of the kitchen stove-tired pattern following in function or time heating elegant the kitchen stove (g) (18).

Fixed carbon

$$FC\ (\%) = 100(PMC+PAC+PVM) \quad (15)$$

Where *FC* (%) shows established carbon allotment, *PAC* shows percentage of ruins content, and *PVM* shows percentage of explosive matter. The caloric profit is calculated by an oxygen bomb caloric meter (20). The gross caloric profit is calculated using moisture content, changeable content, and ruins content by Eq. (16).

$$GCV = 37.777\text{-}0.647MC\text{-}0.387AC\text{-}0.089VMR^2 = 0.97 \quad (16)$$

Where *PM* is moisture content, *AC* is content, *VM* is volatile matter, and *R* is coefficient of determination.

Results

The characteristics of the solid waste biomass and charcoal briquettes produced from solid waste biomass were investigated. The heat value of municipal solid waste biomass for its density, moisture content, volatiles, ash content, and fixed carbon content and calorific value was determined. The physical and burning properties of the charcoal briquettes were tested for its density, porosity index, fracture strength, percent moisture content of the material, percent volatiles, percent material ash, and percent fixed carbon content and heat generation. The laboratory test results for each binder, i. e., starch and natural resin used products, are shown in Figures 1a and 1b, respectively.

Proximate analysis

Using equation 1, the density of degradable solid waste was determined to be 158.23 kg/m^3 (Table 1). This means that the low energy density of MSW makes it very difficult to store for long periods of time. The water content of BMSW was determined by weighing a 31.4 g sample and drying it in an oven at 105°C for 3 hours or until the sample mass was constant at 5.7 g. The moisture content of the solid waste was obtained as 18.25% using equation 3, as shown in Table 1. This indicates that MSW has a high moisture content and needs to be further dried before carbonization. It is necessary to reduce the water content of this MSW and produce charcoal briquettes. The volatile content was calculated to be 65.99% using equation 3, as reported in Table 1. It was recorded for 10 minutes at a temperature of 550°C.

The highest costs of volatiles indicate that decomposable municipal solid waste can easily ignite. Compared to the volatile components of briquettes, it is very expensive. This is due to decomposed or unbonded municipal solid waste. The content material of ash was calculated by dividing the weight of ash by the weight of the dry sample using equation 4 and obtained to be 4.78% at a temperature of 900°C as indicated in Table 1. In the clean municipal solid waste, particles are not bonded to each other and this allows the adequate flow of oxygen within the inner part of the waste. However, within the charcoal briquettes, particles are bonded strongly due to adding resin, which makes high ash content. Using equation 5, the fixed carbon content of biomass was calculated as 10.98%. The

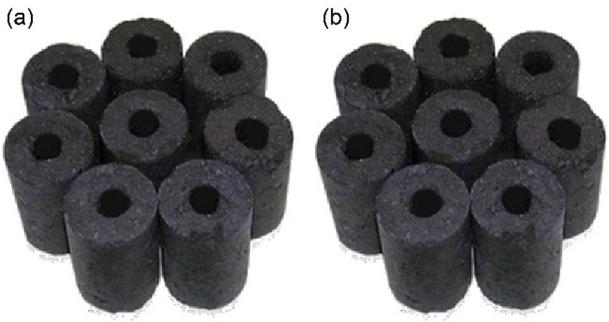

Figure 1. Fuel briquette produced from a) starch used as a binder and b) natural resin used as a binder

Table 1. Properties of solid waste biomass

Properties	Numerical value
Density	158.23 kg/m^3
Moisture content	18.25%
Volatile matter	65.99%
Ash content	4.78%
Fixed carbon	10.98%
Caloric value	18.65 kJ/kg

common constant carbon content material of biomass is fallen in the range of 9.78% to 24.16%, which is within the literature values. Using equation 6, the calorific value of the DMSW was calculated to be 18.65 kJ/kg as reported in Table 1.

As mentioned above, solid waste biomass was characterized by its water content, ash content, fixed carbon content, and volatile content. Figure 2 shows a summary of the properties of solid waste biomass.

Characterization of charcoal briquette prepared from starch binder

The density of charcoal briquettes made from starch was obtained at 760.00 kg/m^3 using equations 7 and 8 (Table 2 and Figure 3). This cost indicates that charcoal briquettes purchased from degradable solid waste using starch as a binder have a higher density than the comparative density of charcoal and the density of tube bagasse charcoal. The diameter of the mold or cylinder has a positive effect on the density of charcoal briquettes. Porosity is characterized as the number of voids contained in a portion of the material and, in some cases, as a part of the volume of voids in the entire volume. Briquettes with a high porosity index have low water resistance. The porosity of starch-hardened charcoal briquettes was calculated to be 10% using equation 10 (Table 2 and Figure 3).

The high cost of the acquired porosity index is currently between 0% and 1%, and the water resistance is low. If the charcoal briquettes have a better porosity list, they will absorb more water and decompose easily. The fracture strength was calculated to be 42% using equations 10 and 11 (Table 2 and Figure 3). This resulting chip resistance price indicates excessive chip resistance. This shows that high density briquettes have higher fracture strength than low density briquettes when dropped from a height of 2 meters to the ground. This increases the density of the charcoal briquettes and increases the probability of losing some. Higher fracture strength means lower weight loss and lower stress management. After that, the briquettes delivered at our factory have a magnificent toughness. The water content of charcoal briquettes using starch as a binder was calculated to be 4% using equation 1 (Table 2 and Figure 3). This price is between 4% and 10% as reported by Onukak et al (21), which is acceptable. The unstable percentage of starch charcoal

Table 2. Summary of the properties of natural resin and starch binder charcoal briquette

Properties	Starch Binder	Natural Resin Binder
	Value obtained	Value obtained
Density	760 kg/m³	751.05 kg/m³
Porosity index	10-23.05%	13-29.45%
Shatter resistance	42-94.32%	40-93.65%
Moisture content	4-8.56%	4-9.57%
Volatile matter	11-24.20%	12-28.4%
Ash content	2-3.12%	1-3.11%
Fixed carbon percentage	31-69.95%	30-69.5%
Caloric value	28.09 MJ/kg	27.05 MJ/kg

briquettes was calculated to be 11% using equation 13 (Table 2 and Figure 3). These values of volatile substances received in our plants are in the range of 10% to 30% according to the study of Mašek et al (22). Ash content was previously calculated to be 2% using equation 14 as shown in Table 2 and Figure 3. High-quality charcoal briquettes have an ash content in the range of 2% to 4%. If the ash contains all other impurities, it will not burn. According to the results of some studies (23,24), the more ash in the fuel, the higher the amount of dirt emitted. This potential result indicates low ash content and high quality.

The solid carbon charge of starch charcoal briquettes was calculated to be 31% using equation 15 as shown in Table 2 and Figure 3. In contrast to the study of Van Wesenbeeck et al (25), this cost of materials with constant carbon content ranges from approximately 30% to 45%. At some point, the carbonization method used by us was used because constant carbon materials are involved in the carbonization process. Fixed carbon is positively correlated with carbon monoxide, and high levels of fixed carbon in charcoal briquettes resulted in high levels of carbon monoxide and long cooking times due to their excessive heat release (26,27). Using equation 16, the caloric value of charcoal briquettes was calculated to be 28.09 MJ/kg (Table 2). This calorific value of charcoal briquettes supplied from biodegradable civil waste using starch is higher than the calorific value of 8.27 MJ/kg of charcoal and higher than the calorific value of 23.4 MJ/kg of charcoal briquettes. High calorie values reflect the high values of charcoal briquettes (28). The viable factors that affect charcoal briquette include particle size, the diameter of the mold, binder, or resin content. The binder or resins content material influences the high quality of charcoal briquettes using their amount. In this study, 25% of resin content was used to produce charcoal briquette which is equal to the well-known binder (starch) used. According to the study of Wasfy and Awny (29), the charcoal briquettes with high quality was found at resin content from 25% to 30%.

The particle size of this learning resource is 4 mm. According to this particle size, charcoal briquettes are characterized by their water content, density, volatile components, ash content, constant carbon content, and calorific value. Therefore, according to the study of Wu et al (30), charcoal briquettes with these best properties were obtained with a particle size less than 4 mm. The two prominent diameters of the cylinder may also indicate the new characteristics of the briquettes. This shows the relationship between the nature of charcoal and the diameter of its shape. However, at solid diameters, the shape or cylinder has a high porosity index weight and

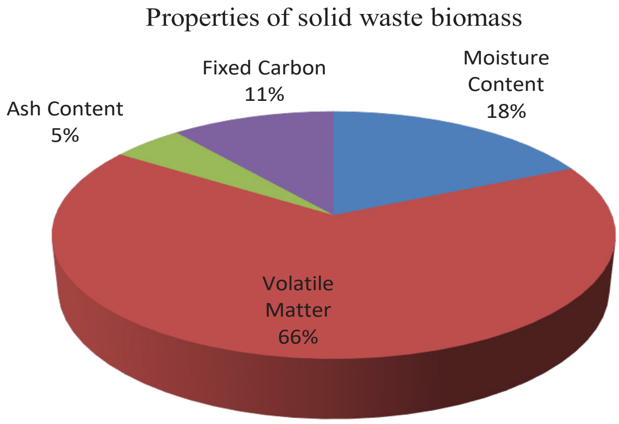

Figure 2. Properties of solid waste biomass

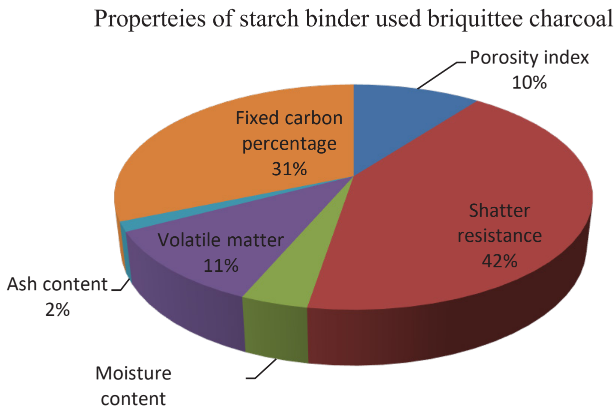

Figure 3. Properties of starch binding charcoal briquette

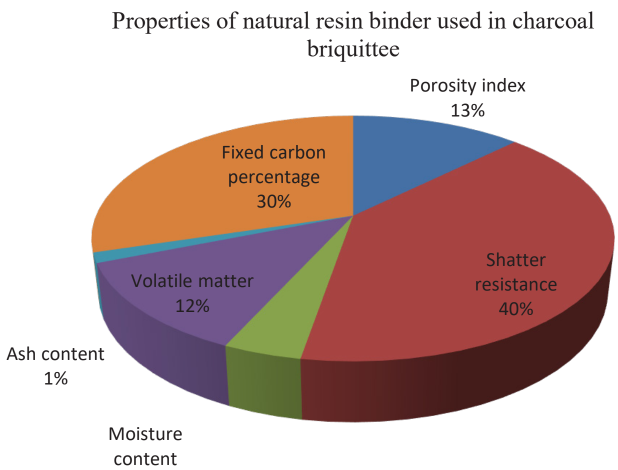

Figure 4. Properties of natural resin bonded charcoal briquette

high fracture toughness. Real charcoal is made from resin that is used as a binder.

Solid waste biomass was characterized by its water content, ash content, bound carbon content, porosity index, crushing strength, and volatile content. Figures 3 and 4 show a summary of the properties of solid waste biomass for both resin and starch binders.

Characterization of charcoal briquette prepared from natural resin binder

The density of charcoal briquettes made from resin is 751.05 kg/m^3 obtained using equations 7 and 8 (Table 2 and Figure 4). This value indicates that charcoal briquettes made from solid waste are denser than the densities of charcoal and sugar cane bagasse. The diameter of the mold or cylinder has a beneficial effect on the density of the charcoal briquettes. Porosity is characterized by the degree of voids in the texture and can be a part of the range of voids throughout the volume. Their diameter ranges from 0 to 1 mm. Briquettes contribute to a higher porosity index with lower water resistance. The porosity index for resin binding charcoal briquette was calculated to be 13% using equation 10 (Table 2 and Figure 4). The above-mentioned value of the porosity index obtained to be between 0 and 1%, indicating low water resistance. Subsequently, if charcoal briquettes have the next porosity list, it retains extra water and will be deteriorated effortlessly. The Shatter resistance was calculated to be 40% using equations 10 and 11 (Table 2 and Figure 4). This value indicates high shatter resistance. This reflects the fact that when they are dropped from top to bottom from 2 meters, charcoal briquettes with high reaction force density have greater breaking strength than high-density charcoal briquettes. There are many ways to lose the denser charcoal briquettes and their phases. Higher breaking strength means lower weight loss and reduced stress tolerance. This shows that charcoal briquettes produced by using a resin binder shows good durability. The binder moisture content was calculated using equation 13. Accordingly, the water content of the charcoal briquette using the resin is presented in Table 2 which is 4%. This value is in the range of 4% to 10% according to the study of Kivumbi et al (31), which is acceptable. The resin-dependent charcoal briquettes are calculated to be 12% using equation 13 as shown in Table 2 and Figure 4. These unstable counts obtained in our factories range from 10% to 30%. According to the study of Xie et al (32), ash-rich charcoal briquettes tend to burn poorly, resulting in high smoke. It will occur and cause a harmful gas leak. Ash content was pre-calculated to be 1% using equation 14 (Table 2 and Figure 4). The ash content of excellent quality briquettes is 24%. If the ash contains other impurities, it will not burn. Low-ash fuels are better suited for heat utilization than high-ash fuels. According to some studies (23,33), the more ash in the fuel, the more dust is usually emitted. The fixed carbon value of resin charcoal briquettes was calculated to be 30% using equation 15 (Table 2 and Figure 4). The cost of this fixed carbon content is almost high, about 30% to 45%, which is inconsistent with the results of the study of Blessing et al (34). The constant carbon content of the entire carbonization process used in this study is further related to the carbonization process. Fixed carbon is positively correlated with carbon monoxide, and the excess constant carbon contained in charcoal briquettes resulted in high carbon monoxide levels and long cooking times due to its excessive heat release (35). Using equation 16, the calorie value of charcoal briquettes was calculated to be 27.05 MJ/kg (Table 2). This calorific value of charcoal briquettes obtained from biodegradable civil waste using tar is greater than the calorific value of charcoal (8.27 MJ/kg), and the calorific value of charcoal briquettes made from bagasse (23.4 MJ/kg), which is higher than the calorific value reported by Serna-Jiménez et al (36). The high calorific value indicates that the quality of the charcoal briquette is very high.

Discussion

Strength of the product

According to the findings of various studies, charcoal briquettes obtained from solid waste have a higher calorific value than charcoal and charcoal briquettes made from molasses. The properties of the resin-bonded charcoal briquettes studied in this study were within the scope of various types of literature. Therefore, it is highly recommended to convert solid waste to charcoal briquettes using naturally available resins as binders rather than polluting the environment. In this study, 25% of the resin content was used to make the same charcoal briquettes as the standard binder (starch) used. As shown in Figure 4, comparative evaluation of the properties of charcoal organized using resin as a binder shows a product with near-best quality when starch is used as a binder. Comparing the quality of charcoal briquettes made of resin and starch bonds, there is not much difference. Factors that can affect charcoal briquettes include particle size, mold diameter, binder or resin content. The content of the binder or resin affects the quality of the charcoal briquettes depending on the amount.

Conclusion

In this study, the characteristics of degradable solid waste and the produced charcoal briquette using resin as a binder were determined for its proximate analysis. The characterization of raw material is very useful to decide which raw material is suitable for the manufacturing of charcoal briquette. Biodegradable municipal solid waste indicates the lowest density, excessive moisture content, high volatile matter, low constant carbon percentage, and low caloric value in contrast with a standard binder which is starch. It has high density, typical moisture content, high volatile content, typical ash content, and low content for fixed carbon as relative to other charcoal briquettes got from the different feedstock. The charcoal briquette produced in this study has the lowest caloric price compared to the caloric value of wood charcoal, charcoal briquette produced from agro waste and that produced from sugarcane bagasse, and it has the lowest caloric value as compared to charcoal briquette produced from wood residue. It was concluded that converting highly degradable waste into briquettes is an effective way to manage solid waste or reduce the problems caused by this waste. To reduce deforestation, it is necessary to promote the use of briquettes as an alternative energy source. In addition, using solid waste as charcoal can reduce the accumulation of waste in the environment. For environmental reasons, briquettes can be used to reduce the amount of wood and charcoal consumed by ordinary households. This task is intended to assist in the management of solid waste and can be used as a tool for managing the daily waste decisions made by the Jimma people in various activities. Comparing the results, using resin as a binder shows a beautiful product that is almost correct regarding the use of starch. Premium fuel briquettes suggest the use of resin as a binder and are comparable to starch-bound charcoal briquettes.

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Ethical issues
The authors certify that this manuscript is the original work of the authors and all data collected during the study are as presented in this manuscript, and no data from the study will be published separately.

Competing interests
The authors declare that there is no conflict of interests.

Authors' contributions
Conceptualization: Abreham Bekele Bayu, Surafel Mustefa Beyan , Temesgen Abeto Amibo, Dereje Tadesse.
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Formal Analysis: Abreham Bekele Bayu, Surafel Mustefa Beyan , Temesgen Abeto Amibo, Dereje Tadesse.
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Methodology: Abreham Bekele Bayu, Surafel Mustefa Beyan , Temesgen Abeto Amibo, Dereje Tadesse.
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Software: Abreham Bekele Bayu, Surafel Mustefa Beyan , Temesgen Abeto Amibo, Dereje Tadesse.
Supervision: Abreham Bekele Bayu, Surafel Mustefa Beyan , Temesgen Abeto Amibo, Dereje Tadesse.
Validation: Abreham Bekele Bayu, Surafel Mustefa Beyan , Temesgen Abeto Amibo, Dereje Tadesse.
Visualization: Abreham Bekele Bayu, Surafel Mustefa Beyan , Temesgen Abeto Amibo, Dereje Tadesse.
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Writing – review & editing: Abreham Bekele Bayu, Surafel Mustefa Beyan , Temesgen Abeto Amibo, Dereje Tadesse.

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