Original Scientific Paper/Originalni naučni rad UDC/UDK: 620.952:662.8
Paper Submitted/Rad primljen: 10.12.2024.
Paper Accepted/Rad prihvaćen: 10.01.2025.
DOI: 10.5937/SJEM2501011W

Proizvodnja briketa od otpadne biomase putem veziva od otpadne biomase

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Apstrakt: U mnogim delovima zemalja u razvoju, korišćenje drveta, kao izvora energije, postaje oskudan resurs. S obzirom na ovo, neophodan je razvoj zamenskog goriva za drveni ugalj. Zgušnjavanje otpadne biomase u brikete od biomase, može da obezbedi alternativno čvrsto gorivo za domaćinstvo, posebno u ruralnim oblastima Etiopije. Ova studija ima za cilj da ispita fizičko-hemijske osobine i kalorijske vrednosti briketa, proizvedenih od otpada biomase drvenog uglja od pirinčane ljuske, koristeći skrob ekstrahovan iz otpadnih plodova jezgra avokada i jezgra manga. Otpadna pirinčana ljuska, sakupljena je iz ruralnih područja severozapadnog Tigraja, dok su otpadni plodovi jezgra manga i zrna avokada, sakupljeni iz grada Mekele. Pirinčana ljuska je karbonizovana u zatvorenoj peći za sagorevanje, a zatim zdrobljena do veličine oko 1 mm u prečniku, da bi se formirao fini prah drvenog uglja. Sitni ugalj je pomešan sa vezivnim sredstvom za skrob, ekstrahovan iz zrna manga i avokada, da bi se formirao potreban briket. Količina skroba, ekstrahovanog iz jezgra avokada je bila 25%, a odnos skroba, ekstrahovanog iz jezgre manga je bio 18%. Grejna vrednost briketa, proizvedenih samo od pirinčanog drvenog uglja u prahu, bila je manja od briketa, formiranih kombinacijom uglja u prahu pirinčane ljuske sa vezivnim sredstvom za skrob, ekstrahovano iz jezgra manga i plodova zrna avokada.

Ključne reči: otpadna biomasa, ekstrakcija skroba, pirinčana ljuska, izvor energije, formiranje briketa

Production of Briquette from Biomass wastes via biomass waste binders

Abstract: In many parts of developing countries, using wood as a source of energy is becoming a scarce resource. Given this, the development of a substitute fuel for wood charcoal is necessary. Densifying waste biomass into biomass briquettes can provide an alternative household solid fuel, especially in rural areas of Ethiopia. This study seeks to investigate the physicochemical properties and calorific values of briquettes produced from biomass wastes of rice husk charcoal using starch extracted from waste fruits of avocado kernel and mango kernel. Waste rice husk was collected from rural areas of North West Tigray whereas the waste fruits of mango kernel and avocado kernel were collected from Mekelle city. The rice husk was carbonized in a closed burning furnace and then crushed to around 1 mm in diameter size to form charcoal fine powder. The charcoal fine was mixed with starch binders extracted from the mango and avocado kernels to form the required briquette. The amount of starch ratio extracted from the avocado kernel was 25 % and the starch ratio extracted from the mango kernel was 18%. The heating value of briquettes produced from rice husk charcoal powder alone was less than briquettes formed by combinations of rice husk powder charcoal with starch binders extracted from mango kernel and avocado kernel fruits.

Keywords: biomass waste, starch extraction, rice husk, energy source, briquette formation

1. Introduction

Briquette is a block of compressed materials suitable for burning. Briquettes can be made from low-cost materials such as old newspapers, and agricultural residues wastes. Briquettes can be used as fuel instead of charcoal and firewood (Kumar, Kumar et al. 2015).

Biomass densification, which is also known as briquetting of solid wastes and agricultural residues has been practiced for many years in several countries. Briquette is a type of clean coal that can help to prevent flooding and serve as a global warming countermeasure by conserving forestry resources through the provision of a stable supply of briquettes as a substitute for charcoal and firewood (Espinoza-Tellez, Montes et al. 2020). As fuel, charcoal briquettes have a higher heating value than wood or plain charcoal. They are almost smokeless when burning and give off intense and steady heat (Erol, Haykiri-Acma et al. 2010). They can be used in the smelting of iron ore since it is compact and dense.Aside from their use as fuel, charcoal briquettes can be converted to other industrial products. In the chemical industry, they are used in the manufacture of carbon disulfide, carbon electrodes, carbon tetrachloride, carbon carbide, sodium cyanide and activated charcoal for purifying air or water.

The Quality of briquette is highly dependent on the source of materials used to make and the operational technologies (Ahiduzzaman and Islam 2016). Briquettes are environmentally friendly renewable sources of energy. It has cleaner and lower emissions of carbon dioxide (CO_2) and other environmental pollutants than charcoal when burning. The other important aspect is it helps solid waste management by converting into fuel sources. Briquettes produced from biomass wastes are fairly good substitute for coal, lignite, and firewood. It can offer numerous advantages; Briquettes are cheaper than coal, oil or lignite, there is no sulfur in briquettes**,** there is no fly ash when burning briquettes**,** briquettes are clean to handle & can be packed in bags for ease of handling & storage. Newspaper, woodchips, rice husks, coffee husks, coir pith, jute sticks, bagasse, groundnut shells, mustard stalks, cotton stalks, sawdust are some of the waste resource use to make briquettes (Sanchez, Aspe et al. 2022). Production of fuel briquettes involves the collection and compaction of a combination of combustible waste materials that are not directly usable because of their low density and processing them into a solid fuel product of any convenient shape that can be burned like wood or charcoal.

Briquetting of biomass improves the handling characteristics of the materials during transportation as well as the storing process. This technology can help in expanding the use of biomass in energy production, since densification improves the volumetric calorific value of a fuel, reduces the cost of transport and can help in improving the fuel situation in rural areas (Vivek, Rochak et al. 2019). Briquetting is one of several agglomeration techniques which are broadly characterized as densification technologies. Agglomeration of residues was done to make them denser for their use in energy production. A briquette made from rice husk is a desirable fuel because it produces a hot, long-lasting and virtually smokeless fire. Successful briquette operations and formations are found mostly in developed countries. However, briquetting operations are not successful in developing countries like Ethiopia and other African countries (Shahapur, Desai et al. 2017). This is mostly due to the high cost of production, lack of awareness of its sustainability, availability of market and poor packaging and distribution systems for the product.

Although the importance of biomass briquettes as substitute fuel for wood, coal and lignite is well recognized, the numerous failures of briquetting machines in almost all developing countries have inhibited their extensive exploitation. Briquetting technology is yet a challenging in many developing countries because of the technical constraints involved and the lack of knowledge to adapt the technology to suit local conditions (Islam, Hossain et al. 2014). Overcoming operational problems and ensuring the quality of the raw material used are crucial factors in determining commercial success for this sector.

Mangoes and avocadoes are among the common fruits commonly consumed by many people in Ethiopia inraw form as well as in juice form. During theprocessing and raw consumption of the seeds, products like the kernel and cover parts are simply disposed of into the environment as garbage. In Ethiopia, rice husks are disposed as a waste without utilizing or dried and burnt which gives very little energy and results into air pollution (Chukwuneke, Umeji et al. 2020). However, the declining fuel wood and charcoal sources and rising prices of electricity, kerosene and LPG cooking gas call for seeking alternative energy sources for both domestic and industrial use (Medashe and Abolarin 2012).

The objective of the study was to investigate the calorific values (heating values) of briquettes formed from biomass wastes and analysis ofbinder performancefor briquette formations by extracting from biomass wastes. In addition to that the purpose of the study was to analyze, the effect of binder to carbonized charcoal ratios on quality of briquettes,and the effect of binder composition on the calorific values based on the waste material used.

2. Materials And Methods

2.1 Study Area

Mekelle is the capital city of Tigray regional state of the federal democratic republic of Ethiopia. According to the Geological Survey of Ethiopia, it is located around 783 kilometers north of the capital city of Ethiopia (Addis Ababa). Administratively, Mekelle is considered as a special Zone, which is divided into seven sub-cities. Mekelle is the economic, cultural, and political hub of northern Ethiopia.According to (Macro 2006) national census report Mekelle City has a total population of 215,914 of which104,925 are male and 110,989 are female. It is found at a coordinate of 39^{o}28' E and 13^{o}29'N at an average altitude of about 2,254 meters above sea level.

2.2 Collection and Preparation of Samples

Raw materials necessary for the production of Bio-Briquette were collected from Mekelle city and rural areas near Mekelle city.Rice husk was collected from farmers around Mekelle city; the wastes of mango kernel and avocado kernel were collected from juice houses within Mekelle city. Metal, plastic and fiber containers have been usedfor handling, sorting and storage of solid waste materials. Plastic containers were used for holding up the components that have substantial moisture content (for example, food waste), to avoid absorption of moisture. The moisture content of rice husk was reduced with open-air sun drying for one day. After drying in the open air, the size was reduced to less than 1 mm by using an electrical jaw crusher. After ground to powder form size analysis of the powder was conductedusing a sieve machine to find uniformity and required size of the powder. It is very important to make a uniform size to bind charcoal fine powder easily with binders.

2.3 Binder Extraction from Biomass Wastes

The extraction procedure of binders from the mango kernel and avocado kernel is described in Figure 1. Following the principles stated by (Syahariza, Li et al. 2010) first, the dirty particles were removed from the kernels of both mango and avocadoand then peeled out the outer covers before cutting for further process since this part doesn't have any starch content. It is stated in Figure 2a, how the kernels were manually peeled using by hand. Then based to processes explained by (Li, Tian et al. 2022) kernels were soaked by a bowl containing water as stated in Figure 2b. Soaking with water was important for kernels to be moister and could be easily milled by the cutter mill. The kernel is milled using a cutter mixer at a rotation of 1500 rpm for one minute as explained by (Syahariza, Li et al. 2010). The crushed kernel has been collected and made ready for extraction by using water and sieve cloth. After the extraction process, the fruitwater separation was done. Finally, the starch and fruit water are separated by using decantation, next to decantation drying using open sun was conducted. The dried binder for mango kernel was packed in plastic back temporally until for further use as shown in Figure 3c**.** By the same process for avocado binder, it was packed in plastic back temporally until for further use as shown in Figure 3d.

Figure 1: Flow sheet for extraction of starch from mango kernel

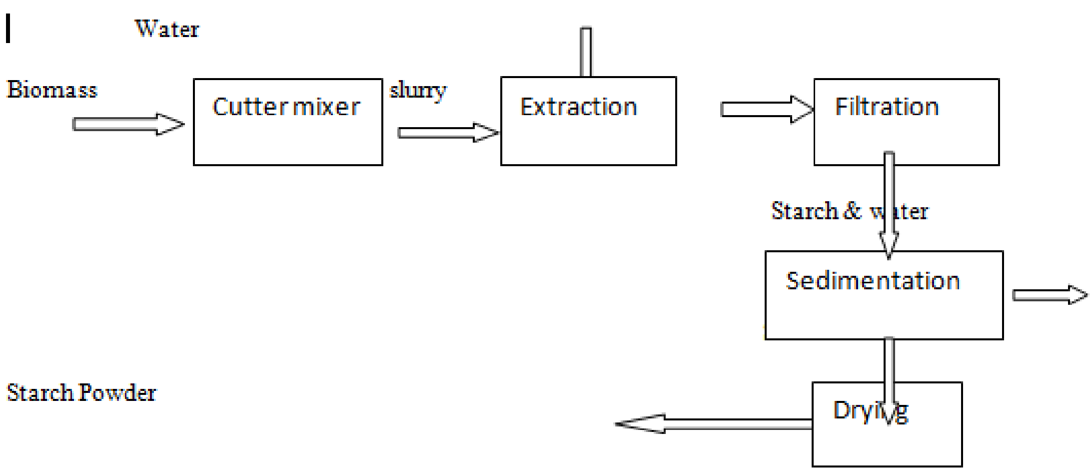

Figure 2: a. Manual Washing and Peeling of the kernels, b. Soaking Process of the kernels

Figure 3: c. Dried and packed AvocadoStarch, d. Dried and packed Mango Starch (powder)

2.4 Preparation of Rice Husk Fine Charcoal

Collected rice husk from the rural areas was first partially burned in an environment where fresh air was controlled. The process is known as charring or carbonization (Onukak, Mohammed-Dabo et al. 2017). The advantage of carbonization is for getting smokeless when the briquette is formed which is considered as key for household users. For carbonization of the rice husk, it was burned in a closed furnace for three days in the absence of oxygen (O_2) (Nuriana and Anisa 2014). After the rice husk was carbonized, the materials were then compacted using a press machine. Then the size was reduced with a crusher to get fine and uniform charcoal.

2.5 Briquette Formation

The charcoal finesprepared from rice husk weremixed with gelatinized starch binders extracted from the mango and avocado kernels. An appropriate mixing using double-shaft mixer was done. A proper mixing was very mandatory and critical to obtain mechanically strong and high-quality product (Sengar, Mohod et al. 2012). Following procedures stated by (Zhang, Sun et al. 2018), after thorough mixing of charcoal fines and the binders, mixtures were fed into the molds where pressure is applied to make the particles compact. The size and shape of the briquettes were shaped with the molds.

After a thorough mixing of charcoal fines and the binders, mixture was fed into molds where pressure was applied to make the particles compact (Ferronato, Mendoza et al. 2022). The size and shape of the briquettes were determined based on the molds. Then briquettes were dried with sunlight in the open air before it was packed to make them strong.

The binder mixing combination proportions used were; avocado starch with rice husk charcoal fine and mango starch with rice husk charcoal. Considering different reviews (Drobikova, Vallova et al. 2018, Obi, Pecenka et al. 2022) different proportional ratios were used by weighing the charcoal fines of rice husk with corresponding binders using a digital weighing scale. The mixture of charcoal fine and binder proportions used to produce the briquettes with desired qualities is summarized in Table 1.

Table 1: Ratio of the Rice husk charcoal fine: avocado/mango kernel powder

S/N^{O}	Ratio of Rice husk: avocado/mango kernel powder
1	100:00
2	90:15
3	75:20
5	75:25

2.6 Proximate Properties of the Formed Briquettes

Moisture content: Using the standard method of (García, Pizarro et al. 2013), the moisture content (MC) of the biomass waste has been determined by heating a known weight of waste in drying equipment. The moisture content of the sample was extracted by laboratory dry oven, without damaging the components of the samples. Samples were dried to constant mass in an oven dryer at 105 ± 5°C and reweighted after moisture was removed.

Density: The density of the briquette was calculated from the ratio of the mass to the volume of the briquette by referring to principles stated in (Jittabut 2015). Mass was obtained by weighing the briquette on the digital weighing scale. The volumes of the briquettes were determined considering the formula of a cylinder by direct measurement of the diameter and height of the briquettes while subtracting the holes of the briquettes (Karunanithy, Wang et al. 2012). To quantity the value it is based on equation 1 statedbelow.

$$\rho = \frac{M}{V} \quad (1)$$

Where; ρ =density (kg/m^3); M=mass (kg); V=volume (m^3) =π (D^2 –nd$^{2)}$* H/4, (where D is diameter of the briquette, H= is height of the briquette d is diameter of the hole and n = is number of holes in a briquette)

Calorific value:The gross calorific value of the produced bio briquettes was determined with the guidance of (Özyuğuran and Yaman 2017). The equipment used to determine the calorific value wasthe oxygen bomb calorimeter. Approximately 2 g of developed briquette fractionwas burnt in the bomb calorimeter until complete combustion was obtained. The difference between themaximum and minimum temperatures obtained was used to compute the gross calorific values of the biomass materials as shown in equation 2.

$$Q = \frac{(Cwater + Ccal)\,(T2 - T1)}{Wf} \quad (2)$$

Where; Q = Calorific value ofthe material (KJ/kg); W_f = Weight of the biomass material (kg); C_{cal} = Heat capacity of the bomb calorimeter (kJ/kg ^{o}C); T_2 –T_1 = Rise in temperature (^{o}C); C_{water}= Heat capacity of water (kJ/kg^{o}C)

Ash content: The ash content of the formed briquette was estimated bythe principles stated(Parikh, Channiwala et al. 2007).Insertingthe briquette in a muffle furnace for ignition set at 550 ^{o}C for some duration of time until the briquette is completely converted to ash and will be calculated as follows:

$$\text{Ash Content (\%)} = \frac{Weight\ of\ Ash}{Initial\ weight} * 100 \quad (3)$$

3. Results and Discussion

3.1 Starch content of the binders

Amountby mass weight for each wasted avocado kernel and mango kernel was prepared. The process of extracting the starch from the raw fruits wasexplained in section 2.3. After extraction, the separation of the extracted starch from water and other impurities was done. Finally, the starch and water were separated by using decantation and drying was conducted using open air using sun light. The amount of starch extracted from each raw kernel is depicted in Table 2. The percentage of extracted starch from the raw kernels can be determinedusing the formula explained in Equation 4.

Table 2: Amount of starch obtained in dry basis

Biomass used	Wet weight of bio mass used (gram)	Starch in dry weight (gram)
Mango kernel	1567.16	174.14
Avocado kernel	5447.3	274.01

$$\text{Starch ratio} = \frac{\text{weight of starch in dry basis}}{\text{dry weight of the biomass used}} *100\% \quad (4)$$

Starchratio for mango kernel= $\frac{174.14}{579.7}$*100%

Starch ratioof mango kernel= 30.04%

Starchratio of avocado kernel= $\frac{274}{1716}$ * 100%

=15.96%

3.2 Moisture content of binding powders

Analysis of samples for determining the moisture content is as shown in equation 5. The difference in mass before and after the drying process is used to calculate the total solids and the moisture content. After drying samples wereweighed again and MC was calculated using the equation below:

$$MC = \frac{w-d}{w} *100 \quad (5)$$

Where; w= initial weight of binding starch, d = weight of starch after drying

The result of the moisture content of the extracted powders of the mango kernel and avocado kernel is presented in Table 3

Table 3: Analysis of moisture content of samples

Samples used	Wet weight (gm)	Dry weight of sample (gm)	Percentage of Moisture content (MC %)
Mango kernel	35.04	12.96	63
Avocado kernel	86.16	27.15	68.5

3.3 Proximate Properties of Formed Briquette

Table 1 show that the moisture content of bio briquettes was found to be in the range of 4.42 to 8.14%. The lowest moisture content was found at 4.42 % for rice husk: mango starch binder (75:25). The maximum moisture content was found 8.14% for rice husk: mango starch (100:0). The moisture content of briquette fuels has been decreased when the content of the rice husk has increased.

Density: The physical properties of formed briquettes including the density, is as observed in Table 4. The maximum bulk density was found to be 545.7 kg/m^3. The maximum density value of the formed briquette was, with the proportion of rice husk: mango starch (75:25). The lowest bulk density was found to be 459.5Kg/m^{3}and this was at the proportion of rice husk: mango starch (100:00).

The density of briquette fuels is increasing with the increase of the binder proportions in both Mango and Avocado starches.

Table 4: Physical properties of formulated briquettes

Rice husk: Avocado kernel combinations	**Height*Diameter (cm*cm)**	**Diameter of holes (cm)**	**Weight (g)**	Volume (cm^3)	**Density (kg/m^3)**
100:00	7*12	1.5	306.8	667.64	459.5
85:15	7.5*12	1.5	332.5	715.33	464.8
80:20	6.5*12	1.5	290	619.95	467.5
75:25	6.8*12	1.5	309	648.5	476.5
Rice husk : Mango kernel combination					
100:00	6*10	1.3	200	407.32	491.4
85:15	5.8*10	1.3	205	393.74	520.3
80:20	5.3*10	1.3	192	359.8	533
75:25	5*10	1.3	185	339.43	545.7

Ash content: The ash content of the formed briquette was as depicted in **Table 5**. The result showed that the ash content of briquettes decreased with an increase in the percentage composition of binders. Hence binder composition has a great role in the ignition efficiency of briquettes.

Calorific value: Table5 below shows the proximate values of the briquette product including the calorific values. The calorific value of formed briquettewas found to be in the range of 12.9 to 15.3MJ/kg. The maximum calorific value was found 15.3 MJ/kg in the ratio of rice husk: mango kernel (75:25) combination.The lowest calorific value was found to be 12.9 MJ/kg in combinations of rice husk and Avocadokernel (100:0) ratio.The calorific value was decreased as the percentage composition of binding powder decreased. This may be due to the blending of biomass and the addition of valuable components which are combustible substances that contribute to the total heat value released (Sharma, Das et al. 2002).

Table 5: proximate properties of formedbriquettes

Rice husk: Avocado kernel combinations	**M.C (%)**	**Ash (%)**	**Calorific (KJ/Kg)**
100:00	11.1	20.3	12,924.00
85:15	11.4	19.4	13,326.00
80:20	11.9	18.9	14,725.00
75:25	12.3	17.8	15,002.00
Rice husk: Mango kernel combination			
100:00	11.8	19.1	13,520.00
85:15	12.2	18.6	14,237.00
80:20	12.5	17.5	15,102.00
75:25	12.7	17.2	15,321.00

4. Conclusion

Recycling biomass wastes into fuel briquettes contributes to solving societies' needs by generating income, providing a new and cheap alternative source of energy, avoiding excess waste disposal of solid waste to the environment. Renewable fuel briquettes are environmentally friendly alternative fuel sources replacing expensive and depleting fuel sources including firewood, coal, liquid propane gas and kerosene. The research output indicates that briquettes formed from rice husk binding with biomass wastes such as mango kernel and avocado kernel increased the quality of heating value. The calorific value of briquettes formed from rice husk alone is less than briquettes formed by combinations of rice husk powder with starch binders extracted from mango kernel and avocado kernel fruits.

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Acknowledgment

We want to express our deepest gratitude to Ethiopian Institute of Technology, Mekelle University for financial support with the grant No. of EiT-M/RB/17/2012.