Journal of Chemical, Environmental and Biological Engineering
2023; 7(1): 1-23
http://www.sciencepublishinggroup.com/j/jcebe
doi: 10.11648/j.jcebe.20230701.11
ISSN: 2640-2645 (Print); ISSN: 2640-267X (Online)

Briquette Potential of Municipal Solid Waste and Agro-Waste as Clean Energy Source and Waste Management: The Case of Boditi Area, Ethiopia

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To cite this article:
Eminet Eyasu Gebeyehu, Ashenafi Abebe, Takele Teshome. Briquette Potential of Municipal Solid Waste and Agro-Waste as Clean Energy Source and Waste Management: The Case of Boditi Area, Ethiopia. *Journal of Chemical, Environmental and Biological Engineering.* Vol. 7, No. 1, 2026, pp.1-23. doi: 10.11648/j.jcebe.20230701.11

Received: May 6, 2023; **Accepted**: June 12, 2023; **Published**: June 27, 2023

Abstract: In this paper we have studied from every day more than 209 tons of waste containing more than 40% of organic material is Generated in the city of boditi. Municipal solid waste (MSW) commonly known as trash or garbage in the United States and rubbish in Britain, is a waste type consisting of Everyday items that are discarded by the public. “Garbage" can also refer specifically to food waste, a sina garbage disposal; the two are sometimes collected separately. The paper covers that the objectives of the study were to produce fuel briquette from municipal solid waste and agro waste which generated from boditi area as well as to evaluate the fuel quality of the briquettes, estimate their potential through determination of other biomass briquettes. The avocado’s and mangos leaves residue were carbonized in oxygen scare environment separately by using carbonizing kiln at alternative energy development and promotion directorate. Then the carbonized resources were crushed to fine particles and mixed with a binder and transformed to briquettes by using beehive briquette machine. Triplicate samples were taking for laboratory analysis and carried out by Wolaita Sodo University for testing and materials procedure. We found that the fuel briquette produced from Avocados and Mangos leaves residue could be used as an alternative source of energy reduce and improve waste management.

Keywords: Biomass, Briquettes, Garbage, Municipal Solid Waste, Waste Management

1. Introduction

1.1. Background and Justification

Energy is avital input for development and an essential in gredient for the survival of man kind. Two of the major energy issues to day are that of energy security and environmental implication of Fossil fuel consumption. Municipal solid waste management is another huge challenge. In Developing countries like Ethiopia, the issues of energy security and municipal solid waste Management are more prominent. Ethiopia relies mainly on traditional sources (90%) of energy While the imported petroleum products, hydroelectricity and renewable and other forms of energy Meet small portion of the total energy demand of the country. All the petroleum products consumed In Ethiopia are imported from abroad. There is no denying that are source poor country like Ethiopia, is bound to face as evere energy crisis in the near future because of its over dependence on imported. On the other hand, the issue of municipal solid waste (MSW) management is receiving major Environmental concerns world wide. In Ethiopia, this problem is more acute especially in the Industrial and urban area sdue to the lack of resources, infrastructures, effective solid waste Management alternatives (techniques), trained man power and research back up for solid waste transformation into commercial products. While the volume of waste ending up in land fill is ever increasing, the space available for dumping is limited and decreasing. Recent study shows plastic and paper comprise large amount of the municipal solid waste in Ethiopia. Plastic waste, mainly polyethylene bags, in the MSW has high energy content, as much as kerosene. Such ahigh energy content material, which is all imported using the valuable foreign currency, should not be dumped in the landfill. It should be recycled and then used for heat recovery (Heejoon2006). Briquetting technology is one of the simple technologies practiced for making biomass-based fuels including wastes like milled paper, plastic and other combustible wastes.

The municipal waste of Boditi city can be best recovered/re used by transformation in to solid waste fuel briquettes either in the form Of Refuse Derived Fuel (RDF), acompressed form of waste paper, plastics, charcoal residues, Wood chips, agro-wastes and other combustible materials. In this light, waste-to-energy conversion Would be an economical and ecofriendly way for addressing both the issues of waste management and energy shortage, both at the same time.

1.2. Statement of the Problem

Waste management methods need to be explored in the city of Boditi, since the main waste Disposal system the land fill of Municipality, is expected to reach its maximum capacity. Several Studies have been conducted for improving waste management in the city of Wolaita zone.

However, these studies were focused on treating all combustible municipal solid waste and agro - waste of MSW at a large scale and none of them are focusing on how waste-to-energy Conversion strategies. Studies concerning the treatment of Briquette from municipal solid waste have not been conducted yet in the Wolaita zone of the Boditi area. It is necessary to make a Deeper study and explore the potential for producing Briquette to obtain energy treating MSW of Wolaita zone of Boditi town. This Thesis aims at covering this point.

This study is important since it will help to find an option for reducing the waste end to land fill and also to improve the conditions of the city of Boditi. The implementation of Briquette energy could lead the city towards sustainable development by reducing the dependence on fossil fuels, Reducing GHG emissions, and providing a better environment for the inhabitants. Moreover, Treating organic waste by producing Briquette energy can generate energy and services, creating New income for the city and helping to reduce social and environmental problems [7]. This study Basically focused on produce Briquette energy technology by treating Municipal solid waste and Agro wastes in order to solve problems of society through social, Environmental, and Economically. After production of Briquette under the right conditions, Briquette energy yields several benefits to end-users.

1.3. Objectives

1.3.1. General Objective

The main objective of this study will be to evaluate the fuel briquette potential of municipal solid Wastes and agro-wastes as clean energy source and waste management strategy from Boditi area of Wolaita zone, Ethiopia.

1.3.2. Specific Objectives

1. To produce fuel briquette from municipal solid wastes and agro-wastes.
2. To determine the physic-chemical properties of produced briquette.
3. To evaluate its fuel quality through proximate analysis and combustion test.
4. To compare fuel briquette made from municipal solid wastes and agro-wastes with other biomasses briquette.

1.4. Scope and Limitation of the Study

This study is limited only production and characterization of fuel briquette produced from Avocados and Mangos leaves residue which does not considered its economic analysis. In addition to this, it does not attempt the production of briquettes from other wastes that are scattered in the study area and it focus only on Agro wastes. On the other hand, the role of changing Avocados and Mangos leaves residue to fuel briquette location is not exclusively bounded to the target study area, its benefit and beneficiary community may extend beyond the study area.

2. Literature Review

2.1. Municipal Solid Waste (MSW)

Municipal solid waste (MSW), commonly known as trash or garbage in the United States and rubbish in Britain is a waste type consisting of everyday items that are discarded by the public "Garbage" can also refer specifically to food waste, as in a garbage disposal; the two are sometimes collected separately. In the European Union, the semantic definition is' mixed municipal waste,' given waste code 2003 01 in the European Waste Catalog. Although the waste may originate from a number of sources that has nothing to do with a municipality, the traditional role of municipalities in collecting and managing these kinds of waste have produced the particular etymology 'municipal'.

2.1.1. Composition

The composition of municipal solid waste varies greatly from municipality to municipality, Akolkar, A. B. (2016) and it changes significantly with time. In municipalities which have a well-developed waste recycling system, the wastes team mainly consists of intractable wastes such as plastic film and non- recyclable packaging materials. At the start of the 20th century, the majority of domestic waste (53%) in the UK consisted of coal ash from open fires Archived 2010-08-13. In developed areas without significant.

Recycling activity it predominantly includes food wastes, market wastes, yard wastes, plastic containers and product packaging materials, and other miscellaneous solid wastes from residential, commercial, institutional, and industrial sources U. S. EPA. Most definitions of municipal solid waste do not include industrial wastes, agricultural wastes, medical waste, radioactive waste or sewage sludge.

Waste collection is performed by the municipality with in a given area. The term residual waste relates to waste left from house hold sources containing materials that have not been separated out or sent for processing Archived 2007-09-27. Waste can be classified in several ways, but the following list represents a typical classification:

1. Biodegradable waste: food and kitchen waste, green waste, paper (most can be recycled, although some difficult to compost plant material may be excluded)
2. Recyclable materials: paper, cardboard, glass, bottles, jars, tin cans, aluminum cans, aluminum foil, metals, certain plastics, textiles, clothing, tires, batteries, etc.
3. Inert waste: construction and demolition waste, dirt, rocks, debris
4. Electrical and electronic waste (WEEE) - electrical appliances, light bulbs, washing machines, TVs, computers, screens, mobile phones, alarm clocks, watches, etc.
5. Composite wastes: waste clothing, Tetra Pack food and drink cartons, waste plastics such as toys and plastic garden furniture
6. Hazardous waste including most paints, chemicals, tires, batteries, light bulbs, electrical appliances, fluorescent lamps, aerosol spray cans, and fertilizers
7. Toxic waste including pesticides, herbicides, and fungicides
8. Biomedical waste expired pharmaceutical drugs, etc. For example, typical municipal solid waste in China is composed of 55.9% food residue, 8.5% paper, 11.2% plastics, 3.2% textiles, 2.9% woodwaste, 0.8% rubber, and18.4% non-combustibles.

2.1.2. Components of Solid Management

The municipal solid waste industry has four components: recycling, composting, disposal, and waste-to-energy viaincineration. There is no single approach that can be applied to the management of all waste streams, there fore the Environmental Protection Agency, a U. S. federal government agency, developed a hierarchy ranking strategy for municipal solid waste. The waste management hierarchy is made up of four levels ordered from most preferred to least preferred methods based on their environmental sound ness: Source reduction and reuse; recycling or composting; energy recovery; treatment and disposal.

The functional element of collection includes not only the gathering of solid waste and recyclablematerials, but also the transport of these materials, afterr collection, to the location where the collection vehicle is emptied. This location may be a materials processing facility, a transfer station or a landfill disposal site.

Waste handling and separation involves activities associated with waste management until the Waste is placed in storage containers for colleaction. Handled also encompasses the movement of Loaded containers to the point of collection. Separating different types of waste components is an important step in the handling and storage of solid waste at the source of collection. Segregation and processing and transformation of solid wastes.

The types of means and facilities that are now used for their covey of waste materials that have been separated at the source include curb side ('kerby side' in the UK) collection, drop-off and buy-back centers. This parathion and processing of wastes that have been separated at the source and the separation of coming led wastes usually occur at a materials recovery facility, transfer stations, combustion facilities and treatment plants.

This element involves two main steps. First, the waste is transferred from a smaller collection Vehicle to larger transport equipment. The waste is then transported, usually over long distances, to a processing or disposal site.

Today, the disposal of wastes by land filling or land spreading is the ultimate fate of all solid wastes, whether they are residential wastes collected and transported directly to a landfill site, residual materials from materials recovery facilities (MRFs), residue from the combustion of solid waste, compost, or other substances from various solid waste processing facilities. A modern sanitary land fill is not a dump; it is an engineered facility used for disposing of solid wastes on land without creating nuisances or hazards to public health or safety, such as the problems of insects and the contamination of ground water.

In the recent years environmental organizations, such as Freegle or Free cycle Network, have been Gaining popularity for their online reuse networks. These networks provide a worldwide online Registry of unwanted items that would otherwise be thrown away, for individuals and nonprofits to reuse or recycle. Therefore, this free Internet-based service reduces land fill pollution and promotes the gift economy.

Landfills are created by land dumping. Land dumping methods vary, most commonly it involves the mass dumping of waste in to a designated area, usually a hole or side hill. After the waste is dumped, it is then compacted by large machines. When the dumping cell is full, it is then “sealed" with a plastics heat and covered in several feet of dirt. This is the primary method of dumping in the United States because of the low cost and abundance of unused land in North America. Landfills are regulated in the US by the Environmental Protection Agency, which enforces Standards provided in the Resource Conservation Recovery Act, such as requiring liner sand Ground water monitoring. This is because landfills spouse the threat of pollution and can contaminate ground water. The signs of pollution are effectively masked by disposal companies and it is often hard to see any evidence. Usually landfills are surrounded by large walls or fence shedding the mounds of debris. Large amounts of chemical odor laminating agent are sprayed in the air surrounding landfills to hide the evidence of the rotting waste inside the plant.

Municipal solid waste can be used to generate energy. Several technologies have been developed that makes the processing of MSW for energy generation cleaner and more economical than ever before, including land fill gas capture, combustion, pyrolysis, gasification, and plasma arc *gasification*. While older waste incineration plants emitted a lot of pollutants, recent regulatory changes and new technologies have significantly reduced this concern. United States Environmental Protection Agency (EPA) regulations in the research [11-14] under the Clean Air Act have succeeded in reducing emissions of dioxins from waste-to-energy facilities by more than 99 percent below 1990 levels, while mercury emissions have been reduced by over 90 percent. The EPA noted these improvements in 2003, citing waste-to-energy as a power source" with less environmental impact than almost any other source of electricity".

2.2. Major Biomass Briquetting Processes

2.2.1. Drying

Drying is a critical process in briquette manufacturing and is often the limiting process for the Producers in east Africa. According to the study carried out by these authors [1-6]"Non-carbonized biomass requires the feedstock to be dried to a moisture content of around 13% before entering the carbonizing kiln to increase the efficiency of carbonization, and after carbonization it needs drying in order to evaporate the water that was added to cool down the carbonizing kiln." [1]

In addition, it is needed to dry out the newly produced biomass briquettes which were produced wet. East African countries such as Ethiopia use sunlight to dry biomass briquettes due to the presence of high natural radiation from the sun. The briquettes are put over polypropylene, polyethylene, or related materials and laid under sunlight. Depending on the amount of radiation on the day, briquettes are completely dried within 3-4 days [1-2].

2.2.2. Carbonization

Carbonization (or partial pyrolysis) drives off volatile compounds and moisture leaving fuel with a higher proportion of carbon remaining (char). This is the same process that creates charcoal from Wood and is preferred particularly in urban environments for its superior burning characteristics and smokeless use. Carbonization is carried out with oxygen limited environment to bring pure carbon with less quantity of dangerous emission when compared with burning raw biomass. Even if the need to carbonize wood depends on the application, most of the developing countries use traditional techniques of charcoal making having up to 10% conversion efficiency. Nevertheless, there have been technologies in place for small scale pure carbon production, with the efficiencies up to 30% [1].

2.2.3. Binding

Binding is the process of "sticking together" the compacted material. If subjected to sufficiently high temperature and pressure, biomass materials can bind without extra agents for binding. High temperature can melt a naturally occurring substance called lignin and under pressure this can act as glue (Alula Gebresas 2015). If high temperatures cannot be achieved (as is the case with most locally made briquette machines), additional binding agents such as cassava flour, molasses, wheat flour, fine clay, and red soil need to be added to enhance or activate the binding process.

2.2.4. Compaction

In all over the world a number of machines sand techniques have been developed for briquetting Charcoal on variable production scale. The local manufacturing sector in Uganda, for instance, has emerged in providing low-capital solutions to small scale briquetting technology while larger scale machineries are imported from India. Among the many briquetting machines, Piston extruders, the relatively large machines, in which a weighty piston forces biomass material through atapereddie, are used to briquette charcoal. "Another type of briquetting machine that uses a screw action to Extrude briquette through a die is screw extruder son which biomass is fed in to the machine from A hopper in to the rotating screw" [1]. A number of low-capital manual Technologies have been industrialized both for carbonized and non-carbonized raw materials and Distributed in the developing countries to promote the production of biomass briquettes among rural societies that lacked access to built-up technology.

2.3. Biomass Briquetting and Its Implication for Sustainable Energy

The briquetting of the biomass, especially the foliage which is normally left to waste or burnt in Open fires, has the potential to fill the energy gap and ensure energy sustenance in rural Communities located close to the infested water bodies [6].

Briquettes are Compact materials produced in the process of densification of loose biomass material such as wood Charcoal dust, sawdust, crop residues and another solid biomass waste. According to the international SO17225STANDARD, solid biofuels, fuel specifications and classes, a briquette Is a"densified biofuel made with or without additives, having a cubic, prismatic or cylindrical shape, with a25mm diameter, produced from woody biomass compression or crushed herb. "The densification/briquetting process is the physical transformation of loose raw organic materials into high density fuel briquettes through a compacting process which increases the calorific value and combustion efficiency of the product [9-10]. In the briquetting process, biomass residues will turn in to uniform and solid fuel as briquettes which will enhance its properties with more added values. This biomass briquette has the characteristic of higher density and energy content besides having less moisture content compared to the raw materials [7].

2.3.1. Biomass Briquetting Technologies

Biomass briquetting denotes a set of technologies for the transformation of biomass residues into an appropriate energy. The technology is also known as briquetting or agglomeration. Depending On the types of equipment used, it could be categorized in to five main types:-Piston press densification, Screw press densification, Roll press densification, Pelletizing and Low pressure or manual presses [8-11].

Two types of piston press, which are die and punch technology and hydraulic press have been devised. In the die and punch technology, biomass is punched in to a die by a interchanging gram with a very high pressure there by compressing the mass to obtain a compressed product. The typical size of the biomass briquette produced using this machine is 60mm, diameter. The power required by a machine of capacity 700kg/houris25kW. Compacting the biomass comes first in the vertical direction and then again in the horizontal direction in the hydraulic press process. The standard briquette weight is 5kg and its dimension share: 450mmx160mmx80mm. A raw material with moisture content up to 22% is acceptable by this technology. The process of oil Hydraulics allows a speed of 7cycles/ minute against 270 cycles/minute for the die and punch process. The low process minimizes the wear rate of the parts. The moves approximately270 times per minute in this operation.

The compaction ratio of screw presses ranges from2.5: 1 to 6: 1 or even more. In this process, the Biomass is extruded continuously by one or more screws through taper die which is heated externally to reduce the friction. Here also, due to the application of high pressures, the temperature Rises fluidizing the lignin present in the biomass which acts as a binder. The external surface of the Biomass briquettes attained using this method is carbonized and has a hole in the center which helps better burning having standard size of the briquette is 60 mm diameter [9].

Roller presses are also one of the commonly used charcoal briquetting machines. Ina briquetting Roller press, the feedstock falls in between two rollers, rotating in opposite directions and is Compacted In to pillow-shaped briquettes Wet charcoal is fed to the hopper, which falls in to the Indentation and is compressed on turning the rollers. Then the briquettes with draw from the Machine as a single lump in pillow shape. The level of densification obtained by a roller press is relatively low related to a piston or screw extruder and so it is well-matched to biomass briquetting Of wet powders containing binder to aid binding. Thus, production capacity of a roller press Machine cans reach1.5 tons per hour which is very high. Roller presses are used by most of the largest east African producers of carbonized briquettes. This type of machine is used for briquetting carbonized biomass to produce charcoal briquettes.

Pelletizing is closely related to briquetting except that it uses smaller dies (approximately 30mm) So that the smaller products are called pellets. The pelletizer has a number of dies arranged as holes Bored on a thick steel dis coring and the material is forced in to the dies by means of two or three rollers. The two main types of pellet presses are: flat/disk and ring types. Other types of pelletizing machines include the Punch press and the Cog-Wheel pelletizer. Pelletizers produce cylindrical briquettes between 5mm and 30mm in diameter and of variable length. They have good mechanical strength and combustion characteristics.

Pellets are suitable as a fuel for industrial applications where automatic feeding is required. Pelletizers can produce up to 1000 kg of pellets per hour but initially require high capital investment and have high energy input requirements.

There are different types of manual presses used for briquetting biomass feed stocks. Manual clay Brick making presses are a good example. They are used both for raw biomass feedstock or charcoal. The main advantages of low-pressure briquetting are low capital costs, low operating costs and low levels of skill required to operate the technology. Manual press technologies are appropriate for briquetting green plant waste such as coir or bagasse (sugar-cane residue). The wet material is shaped under low pressure in simple block presses or extrusion presses. The obtained biomass briquette produced by this approach has a greater density than the original biomass but still requires drying before it can be used. The dried briquette has little mechanical strength and crumbles easily. The use of a binder is imperative. Beehive briquettes are cubic in shape (13 cm in diameter and 8cm long), can be produced about 2000-2500 briquettes per hour and each briquette have a number of holes (usually12 longitudinal holes of 13mm diameter). A single Bee hive char-briquette will weigh about 400 to 500grams after drying. Such briquettes due to their size are suitable for where heating for relatively longer hours is required. Beehive briquettes also require a specially made beehive briquette-burning stove and are suitable for activities that require continuous heat for relatively longer hours than is demanded from common charcoal stoves.

Burning qualities of beehive briquettes or honey comb briquettes are excellent as they burn from The inside out through small holes so the energy release is gradual and uniform, ultimately giving a blue flame.

2.3.2. Briquetting Experience in Ethiopia

This technology was introduced in 1980s. The first briquetting plant in stalled in Ethiopia was low Pressure piston machine in stalled by private individuals. The raw-material is primarily seen dust (60%) and the rest40% were coffee husk and cotton-seed husk. The briquettes are sold mainly to middle-class hotels in Addis Ababa which have installed wood-burning stoves of some sophistication (FAO, 2013). The other significant effort on the briquetting technology in Ethiopia was the cooperation agreement signed by the Ethiopian government with the World Bank to implement the energy I project in 1985 in Della. However, the plant was not installed and remained idle for more than 20 years. The plant was installed and begun operation on September, 2012, with a capacity of producing 120 quintals of briquette (12 tones) in one work shift. The project has a capacity of manufacturing 1.5 tons of material per hour, and they early capacity ranges from 1, 800 to 5,400 tones. “The briquettes are distributed in Della and its surroundings, as well as in deforestation prone zones and fuels carce are as like Arsi-Negelle in the Central Rift Valley” (Horn of Africa Regional Environment Centre and Network).

Currently encouraging efforts are being made to promote biomass briquetting in Ethiopia by Different governmental institutions and local NGO. The principal government institutions working To promote the technology are Addis Ababa city Environmental Protection Authority (EPA), Ministry of environment, forest and climate change (MEFCC), Horn of Africa Regional Environment Centre and Network (HoARECN) and Alternative Energy Development and Promotion Directorate (AEDPD), with in the Ministry of Water, I*rrigation* and Electricity.

Nowadays, Addis Ababa EPA is working to promote biomass briquetting from solid biomass Wastes through awareness creation on the uses and benefits of technology, waste handling and turning waste to energy (briquettes), organizing job less groups and women and providing training and demonstrations on briquetting process. Briquette is considered as alternative source of clean energy supply in areas where traditional biomass is the primary source of energy. Availability of raw materials, market opportunity, technological capacity and applicable policy and strategies are the basic requirements for the biomass briquetting technology. The abundance of the rapidly growing Avocados and Mangos Plant presents both environmental challenges and opportunities. It is envisaged that Avocados and Mangos plant this a potential biomass material for the production of briquettes because of its high growth yield and availability in large amounts throughout the year [5].

3. Materials and Methods

3.1. Description of the Study Area

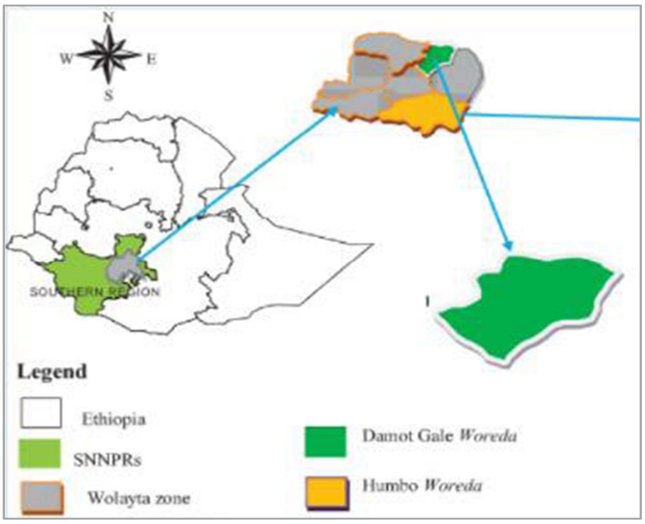


Figure 1. *Description of the study area.*

The study will be conducted in Wolaita Zone, Damot Gale woreda which is one of administrative Woreda of Wolaita zone in southern nation, nationalities and peoples of region (SNNPR). Wolaita Zone is found at south enteral Ethiopia between 6.4N0-6.9N0 latitude and 37.4E0-37.8E0 longitude, which is located 390kms south of Addis Ababa, the capital city of the country and160 kms from Hawassa, the capital of the regional state. The total population of the zone is estimated to be 1.528,000. Wolaita zone is one of the most densely populated zone, which is sub divided in to 22 administrative district. Damot gale is located at 320kms away from Addis Ababa 140km from Hawassa. Damot gale is boarded on the south west by Sodo zuria, on the North West by Boloso sore and Damot pulassa on the north by the Hadiya zone, on the east by Diguna fango and On the south east by Damot weyde. The administrative center of Damot gale is boditi. Most of the Inhabitants practice agriculture based economy; particularly inset and maize are the main products. Based on data obtained from energy sector of the zone out of 436 kebele, only 200 kebele get electricity infrastructure, relatively only 25-35% of the populations gets the services.

Figure 2. *Study area of biomass.*

3.2. Sampling

In this study, the biomasses *of* municipal solid wastes and agro-waste will be collected from Boditi area, in Wolaita administrative zone, Ethiopia. The municipal solid wastes and agro-waste raw materials will be manually collected and chopped to the appropriate size in order to fit carbonizing kiln. The raw materials will be sun-dried for a week to remove moisture and make it easy for handling, transportation and storage. My sample size selection based on both municipal and agro waste likes that the risued of mango's and Avocado's Leaves.

3.2.1. Mango Plant (Mangiferia Indica) Leaves

Mangiferia Indica, commonly known as Mango, is a species of flowering plant in the family Anacardiaceous. It is a large fruit tree, capable of growing to a height of 30 meters (100 feet).

Figure 3. *Sample size of mangos leaves residue.*

Figure 4. *Sample size of Avocados leaves residue.*

It is a bright green fruit with a large pit and dark leathery skin. They're also known as alligator pears or butter fruit. Avocados are favorite avocado (per sea Americana), also called alligator pear, tree of the family lauraceous and its edible fruit. Avocados are Native to the Western Hemisphere from Mexico south to the Andean regions and are widely grown in warm climates.

3.2.2. Material

Avokados leaves residue, Mangos leaves residue, paper and water materials used for this work.

3.2.3. Equipment

Drum charring units, oven, Electrical Furnance (more than heat 30-3000^{0}C), Hood, Testo 330 Emission Analyzer, calipers, Analytical balance (sensitive to 0.0001g), sieves, cutter and Beehive Briquette machine press mold, Digital Balance (0.5g – 16Kg), stop watch, crucibles, crucible Tongs, Matter, Desiccators, stove (Merchayae – stove), Metal pots and oxygen Bomb calorimeter (parr 6200) were the equipment's used to characterize Avokados and Mangos leaves residue fuel briquette.

3.3. Carbonization Process

Before the carbonization process Begun, first weight the sun – dried Avocados and Mangos leaves residue to know the conversion efficiency of Avocados and Mangos leaves residue which had sun – dried mass of 7Kg and 5Kg respectively. The carbonization of Avocados and Mangos leaves residue was carried out using the drum kiln which made in MOWIE Work shop which accommodates 7Kg and 5Kg of air dried Avocados leaves and Mangos leaves residue separately for one cycle. Drum kiln was selected because it is suitable for small amount of burning, easily fabricated from a local material and low cost (sanger et al., 2011). The sun – dried Avocados and Mangos leaves residue was compactly full in to the inner drum through the opening at the top and fire for 25 minutes to 1hr of Avocados leaves residue and 30 minutes to 1hr of Mangos leaves residue. This is below of carbonizing time of the sun – dried Avocado's and Mangos Leaves residue was compactly full in to the inner drum through the opening at the top and fire for 45 minutes to 1hr according to the research [14]. The smoke color would be continuously observed to estimate the selected raw material.

Figure 5. *Carbonization process.*

Figure 6. *Briquette production is the moisture of the sun dried sample.*

The color of smoke the blue and the light blue indicates the burning materials was changed in to carbonized materials or not. If the raw material was changed in to carbonized material primarily blue smoke was changed in to light blue and then it became purer. At this time to block the air entrance, the bottom part of the drum was covered by mud and consequently, the top side was covered by the metal cover (Emmanuel et al., 2014). Finally, the kiln needs stay until cool down after carbonization and separate the carbonized material and the ash then; their weight was note as stated by the author [4]. And the conversion efficiency of Avocados and Mangos leaves residues in to carbonized material was computed [13], as follows.

$$\text{Carbonization efficiency of Avokados Leaves residue (\%)} = \frac{\text{Weight of carbonized Avokados leaves}}{\text{Weight of raw Avokados leaves}} \times 100\%$$

$$\text{Carbonization efficiency of Mangos Leaves residue (\%)} = \frac{\text{Weight of carbonized Avokados leaves}}{\text{Weight of raw Avokados leaves}} \times 100\%$$

3.4. Cooling of Carbonized Sample

After carbonization of sample, finally the kiln needs stay until cool down for 2hr and after cooling of the kiln separate the carbonized Avocados and Mangos leaves sample and the Ash then the weight of carbonized sample was measured.

Figure 7. *After carbonization cooling process.*

3.5. Carbonized Yields

The conversion efficiency of raw feedstock (un carbonized Avocados and Mangos leaves residue in to carbonized materials) from 5Kg of air dry Mangos leaves net Average carbonized residue amounts 1.5Kg and on the other hand from 7kg of air dry Avocados leaves the net average carbonized residue amounts 1Kg.

The typical yield of a metal kiln at 15% moisture sample content is about 30% (Seboka, 2009). Hence, the carbonization yield in this study was small difference from the above idea. this is could be due to the moisture difference and type of kiln used in this study which is Philippine model carbonization efficiency can be affected with several aspects such as the moisture contents of the input sample, type of the kiln (The number of holes in the kiln that control the amount of air for the appropriate carbonization), cooling personal skill, weather condition. One of the major factors that affect the quantity and quality of fuel charcoal or fuel briquette production is the moisture of the sun dried sample (Abebe et al., 2017).

Generally, the solid carbonaceous char yield varies from 24.87 to 32.49% by weight for different pyrolysis condition (Belay and Gabbiye, 2015). Therefore, the result of the carbonization yield in line with the above criteria.

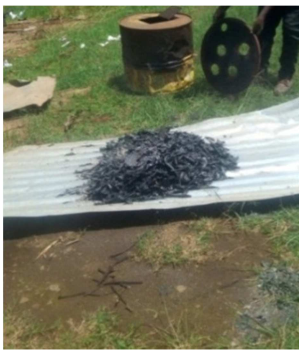


Figure 8. *Carbonized Mangos and Avocados leaves sample.*

3.6. Binding Preparation and Mixing of Avocados & Mangos Leaves Residue

Figure 9. *Carbonization yield in line with the above criteria.*

Paper was selected as a binder because its availability, non-expensive and alternative use and the importance the paper was to act us a binder and it was added in same amounts to the sample 20% (i, e 1: 5 ratio).

This binder was used to increase the bonding between the carbonized Avocados and Mangos leaves residues. It also increases the heating time and strength of the output. Mixing of carbonized Avocados and Mangos leaves residue powder with paper, it was done manually after carbonizing Avocados and Mangos leaves residue was changed to a powder using crusher; while mixing.

3.7. Briquetting Procedure

The collected municipal solid wastes and agro-waste will be chopped and sun-dried for a week. After completely dried, it will be carbonized in metal barrel-kiln for 3-6 hours and it will be taken Out of barrel-kiln and cooled. In this study, the process of carbonization will be carried out in Oxygen limited condition in barrel kiln with long chimney; which used to control the proper air for Carbonization process. Then closed with screw when dehydration completed just when cloudy Smoke become closely to blue or black so as limited oxygen environment was created and the Chimney was also covered by clay mud for charcoal production and cooled in controlled manner. After being cooled and sorted, the carbonized municipal solid wastes and agro-waste will be Ground using a milling machine (hammer mill) and sieved with a mesh size of 3mm to obtain particles in the size range from 1 to 3 mm. The other raw materials like cartons, cow dung or saw dust will be used as a binder.

For instance, cow dung will be dried and crushed manually and sieved using a sieve with them ash size of 3mm To obtain particles in the size range from1 to 3mm. Dried and pulverized cow dung will be used As binder and co-mixture to improve compactness, strength and calorific value of the biomass briquette. The carbonized will be ground using electrical metal hammer mill (grinder) and mixed manually with dry and crushed cow dung until a uniformly blended mixture will be obtained.

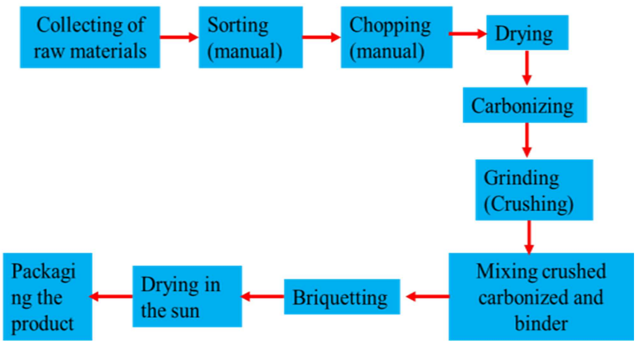


Figure 10. *Flowchart showing the steps for the production of biomass briquettes.*

Blends of municipal solid wastes and agro-waste-cow dung will be prepared at the ratios of 100: 0, 90: 10, 80: 20, 70: 30, 60: 40, and 50: 50 on a weight percent basis respectively. The materials will Be mixed in to soupy slurry using hot water. A fixed quantity of the slurry will be put inside the Briquetting machine (hand press molder) and cylindrical beehive briquettes with different holes Will be produced and dried for three weeks (Figure below). The dried biomass briquettes will be used to carry out proximate analysis and combustion test in order to determine its biofuel potential for cooking and heating purpose. Used to carry out proximate analysis and combustion test in order to determine its biofuel potential for cooking and heating purpose.

Figure 11. *Briquette preparing process.*

3.8. Experimental Design and Activities

Each laboratory test will be replicated 3times. The experimental activities for the identification of Physical and chemical characteristics of the important parameters in producing good quality.

Briquettes will be carefully carried out in the Wolaita Sodo University laboratories and workshop of alternative energy development and technology promotion directorate at Ministry of Water, Irrigation and Electricity and Addis Ababa University, Ethiopia.

3.9. Proximate Analysis

3.9.1. Moisture Content (MC)

The moisture content of the ground material before and after compaction will be determined Involving the use of oven drying methods. The initial weight of the sample will be determined (W) and placed in an ovens et at 105ºC for 3hours. The samples will be removed and cooled in a desiccator, reweighed (W) and calculated as:

$$\mathrm{MC} = \frac{W_1 - W_2}{\mathrm{w}}$$

3.9.2. Volatile Matter (VMC)

The volatile matter will be determined in triplicate by weighing 2g of each sample in a crucible, Then covered with laid and placing it in a muffle furnace set at a temperature of 550°C for 10 minutes and then weighed after cooling in a desiccator (ASTM, 2003).

$$VM = \frac{W_2 - W_3}{W_1} \times 100\%$$

Where B is the weight of the oven-dried sample and C is the weight of the sample after 10 min in the furnace at 550°C.

3.9.3. Ash Content (AC)

The ash content will be determined in triplicate by weighing 5g of the sample in to a crucible, then Placed in a muffle furnace and heated at 750°C for 4hours. Then the crucibles will be taken out from the furnace and put in to the desiccator to cool. After cooling the weight will be used to determine the ash content (AOAC, 1999).

$$AC = \frac{W_3 - W_4}{W_1} \times 100\%$$

Where D is the weight of ash and B is the weight of the oven-dried sample.

3.9.4. Fixed Carbon Content

"The percentage fixed carbon will be computed by subtracting the sum of percentage moisture [13].

Fixed carbon = 100% - (PMC + PVM + PAC

3.10. Combustion Test and Bulk Density Determination

3.10.1. Calorific Value Determination

For the determination of the calorific value the higher heating value (HHV) will be measured by an automatic bomb calorimeter by weighing 0.5g of the sample into an ignition cup, then wrapped with a fuse wire and sealed inside the bomb. The bomb will be then filled with 30 atmospheres of oxygen, and then placed in astatic jacket filled with 2liters of water. After combustion will be taken place in about 6minutes, the calorific value will be read out on the screen of the calorimeter in Cal/g.

$$\mathrm{GCV} = \frac{M_1 + M_2 C_W * T_{1-T_2}}{M_S}$$

M= heat capacity of calorimeter obtained from standard experiment, kJ/ °C

M= Mass of water in copper calorimeter (kg),

T=Initial temperature of water (°C),

T= Final temperature of water (oC),

M= Mass of fuel sample taken (kg)

C=specific heat capacity of water (kJ/kg°C)
The tests will be done in 3 replicates.

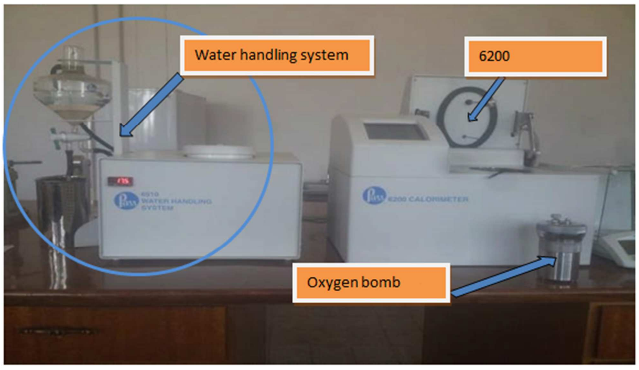


Figure 12. *Adiabatic oxygen bomb calorimeter per 6200.*

3.10.2. Burning Rate Determination

Burning rate determines the rate at which a certain mass of fuel is combusted in air. Fuel burning Rate will be determined according to (International Association for Energy Economics. 2009). Briquette sample of known weight will placed on wire gauze (briquette stove) and the burner ignited. This will be positioned on top of amass balance and rate at which the briquette will be burning was monitored at every 5minutes throughout the combustion process using stopwatch until the briquette will be completely burnt and constant weight will be obtained. The weight loss at specific time will be computed from this expression:

$$\mathrm{BR} = \frac{W1 - W2}{T}$$

Where, BR = Burning rate, g/min
W= Initial weight of fuel prior to cooking (g)
W= Final weight of fuel after cooking (g)
T = Total burning time (min)

3.10.3. Ignition Time

A single briquette will be placed alone in the center of briquette stove resting on three supporting fire-retardant bricks, allowing the free flow fair around the briquette. The dried briquettes will be placed directly on the fired electrical stove and ignition of the briquettes started. Caution will be taken to avoid flame spread in the transverse directions. The electrical stove will be left in until the briquette will be well ignited and has entered into its steady state burn phase.

3.10.4. Bulk Density

High density products are desirable in terms of transportation, storage and handling. Bulk density (ρ bulk) is the density of amaterial when packed or stacked in bulk; it depends on the solid density, geometry, size, surface properties, and the method of measurement. It will be determined 3weeks after removal from the press and dried. The weights of briquettes will be determined on the balance in the laboratory. Then,

1. The volumes of briquettes will be determined by a simple calculation based on the direct measurement of length, width and thickness of the briquettes.
2. The volume of the briquette will be determined by placing the known weight of the

Biomass briquette in the known volume of the flask.

$$\text{Density} = \frac{M}{V}$$

M = Mass
V = Volume

3.10.5 Data Analysis

The Physical and chemical characteristics of the data will be analyzed by using statistical and Mathematical tools mainly Matlab, Microsoft excel, IBM SPSS Statistics 20and Origin 2021 software. Theproximate Analysis will be carried out to determine the moisture content, volatilematter, ash content and fixed Carbon content. The analyses of calorific value, bulk density, ignition time, burning rate and water Boiling test of the produced biomass briquettes will be also accomplished by applying the above mentioned soft wares.

4. Discussions

4.1. Results and Discussion

In this study, biomass briquettes produced from the mixture of Mango's leaves and Avocado's Leaves with paper as binder and their fuel properties were determined. The produced biomass Briquettes had cubic shape having average value of length 7cm, width 7cm and heights equals to 7cm. So that the combustion characteristic was enhanced by increasing the exposed surface area. Proximate analysis was also carried out to determine moisture, ash, volatile matter and fixed carbon and combustion test on dry basis of biomass briquettes were done as indicated below.

4.1.1. Average Amount of Avocado's and Mango's Leaves Potential from Damot Gale Areas

According to the information provided by peoples who live in the Damot Gale woreda, the mango's and Avocado's plants are native to the region and therefore more than 2012 total volume of Avocado's leaves and 2016 total volume of Mango's leaves supplied per month.

Generally Damot Gale was estimated to 22,747.97Kg of Avocado's leaves and 32,497.109 Kg of Mango's leaves of monthly yields from Damot Gale region.

However, not all Mango's and Avocados leaves residue generated is Available. Some part used as compost for fertilizer and while some part is disposed as part of the solid waste removed from the area.

4.1.2. Amount of Briquette Produced from the Average Amount of Avocados and Mangos Leaves

The result indicated that from 10Kg total samples of wet mangos leaves residues, 5Kg air dried mangos leaves residues and from 15Kg total samples of wet Avocados leaves residues, 7Kg air dried Avocados leaves residues were found.

I.e. From 100% of wet Mangos leaves residue 50% of air dried Mangos leaves residue and from 100% of wet Avocados leaves residue 46.6% of air dried Avocados leaves residues.

On the other hand from 5Kg air dried un carbonized mangos leaves residue 1.5Kg carbonized Mangos leaves residue yields briquette potential of 3543.72g and from 7Kg air dried un carbonized Avocados leaves residues 1Kg carbonized Avocados leaves residue yields 2065.5g of briquette potential.

In addition to this, the mixture of 1.5Kg of carbonized Mangos leaves and 1Kg carbonized Avocados leaves with specified measured binder (1: 5 ratios) had 3543.72g of mangos leaves briquette and 2065.5g of Avocados leaves briquette.

Table 1. *Sample of mangos leaves residue.*

Sample selection	Amount of sample in Kilogram (Kg)
Wet mangos leaves	10Kg
Air dried mangos leaves	5Kg
Carbonized mangos leaves	1.5Kg
Briquette produced from carbonized Mangos leaves with binders	3.54kg

Table 2. *Amount of substances in units.*

Statistics		sample selection	Amount of sample in kilogram
	Valid	4	4
	Missing	0	0

Table 3. *Percent analysis of mangos leaves sample.*

Sample selection		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	air dried mangos leaves	1	25.0	25.0	25.0
	from carbonized mangos Leaves with binder briquette produced	1	25.0	25.0	50.0
	carbonized mangos leaves	1	25.0	25.0	75.0
	wet mangos leaves	1	25.0	25.0	100.0
	Total	4	100.0	100.0	

Table 4. *Frequency analysis of mangos leaves sample.*

Amount of sample selection					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	1.50	1	25.0	25.0	25.0
	3.54	1	25.0	25.0	50.0
	5.00	1	25.0	25.0	75.0
	10.00	1	25.0	25.0	100.0
	Total	4	100.0	100.0	

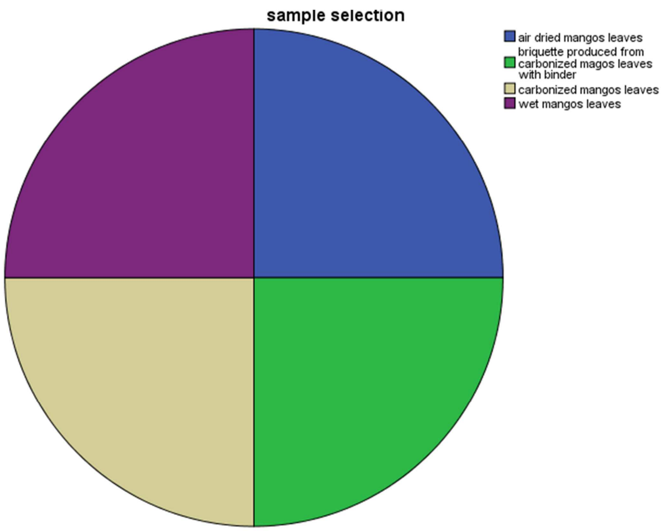


Figure 13. *Pai chart of mangos leaves sample.*

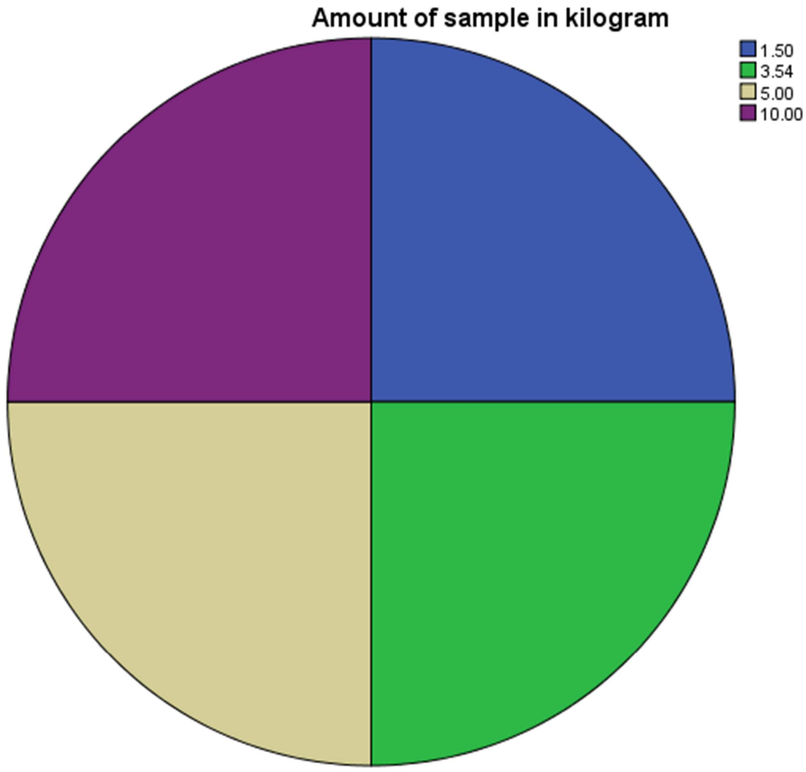


Figure 1. *Pai chart of amounts of mangos sample in kilogram.*

Table 5. *Sample of Avocados leaves residue.*

Sample selection	Amount of sample in Kilogram (Kg)
Wet Avocados leaves	15Kg
Air dried Avocados leaves	7Kg
Carbonized Avocados leaves	1Kg
Briquette produced from carbonized Avocados leaves with binders	2.06Kg

Table 6. *In units analysis of Avocados leaves sample.*

Statistics		Sample selection	Amount of sample in kilogram
N	Valid	4	4
	Missing	0	0

Table 7. *Percent analysis of Avocados leaves sample.*

Sample selection		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Air dried Avocados leaves	1	25.0	25.0	25.0
	Briquette produced from carbonized Avocados leaves with binders	1	25.0	25.0	50.0
	Carbonized Avocados leaves	1	25.0	25.0	75.0
	Wet Avocados leaves	1	25.0	25.0	100.0
	Total	4	100.0	100.0	

Table 8. *Frequency analysis of Avocados leaves residue.*

Amount of sample in units					
		Frequency	Per cent	Valid Per cent	Cumulative Per cent
Valid	15Kg	1	25.0	25.0	25.0
	2.06	1	25.0	25.0	50.0
	7.00	1	25.0	25.0	75.0
	15.00	1	25.0	25.0	100.0
	Total	4	100.0	100.0	

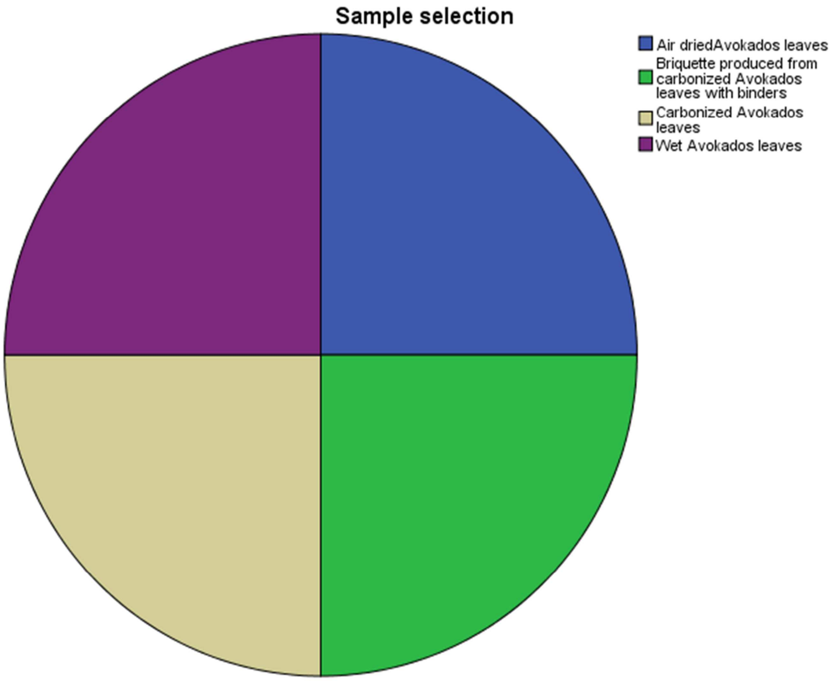


Figure 15. *Pai chart of Avocados leaves sample.*

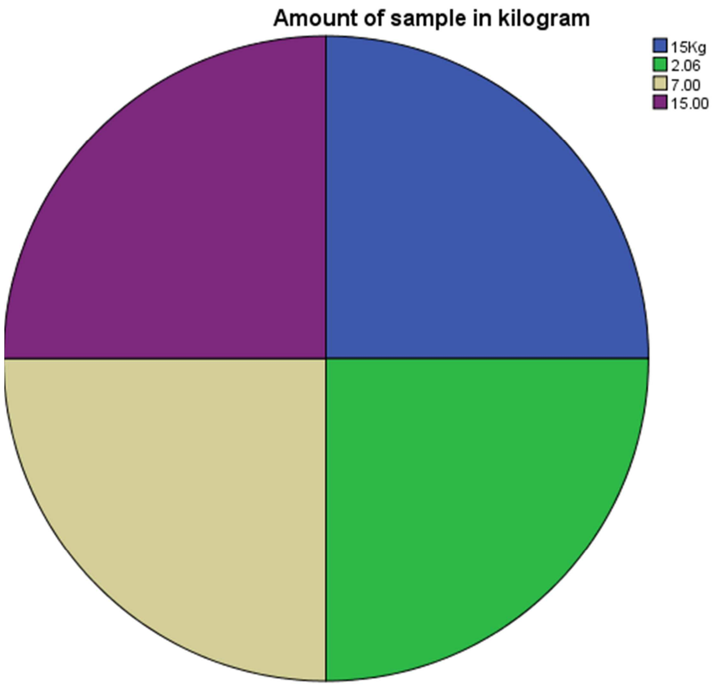


Figure 16. *Pai chart of amounts of Avocados leaves sample in kilogram.*

4.2. Proximate Analysis and Physical Property

4.2.1. Proximate Analysis and Gross Calorific Value of Raw Mangos and Avocados Leaves Residue

Table 10 showed the results of the testing of the proximate analysis and Gross calorific value of the raw Avocados and Mangos leaves residue. On Average the Avocados leaves residue had a MC of 15.35%, a Vm of 26.18%, an Ac of 13.09%, a Fc of 45.38% and a Gcv of 15,851.23KJ/Kg And Mangos leaves residue had Mc, Vm, Ac, Fc and Gcv of 13.27%, 19.91%, 13.34%, 53.48% and 17,204.36 KJ/Kg respectively. Determination of Avocados leaves briquette of Mc Vm Ac and Fc.

Table 9. *Avocados leaves briquette.*

Statistics of Avocados leaves briquette		
Determination of Avocados leaves briquette of MC, VM, AC, FC		
N	Valid	4
	Missing	0
	Mean	2.5000
	Std. Deviation	1.29099

Table 10. *Determination of Avocados leaves of MC, VM, AC, FC.*

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	15.35	1	25.0	25.0	25.0
	26.18	1	25.0	25.0	50.0
	13.09	1	25.0	25.0	75.0
	45.38	1	25.0	25.0	100.0
Total		4	100.0	100.0	

Table 11. *Determination of Mangos leaves briquette of Mc Vm Ac and Fc.*

Statistics of Avocados leaves briquette		
Determination Of Mangos leaves briquette of MC, VM, AC, FC		
N	Valid	4
	Missing	0
	Mean	2.5000
	Std. Deviation	1.29099

Table 12. *Determination of mangos leaves Of MC, VM, AC, FC.*

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	13.27	1	25.0	25.0	25.0
	19.91	1	25.0	25.0	50.0
	13.34	1	25.0	25.0	75.0
	53.48	1	25.0	25.0	100.0
	Total	4	100.0	100.0	

4.2.2. Proximate Analysis and Physical Properties of Fuel Briquettes

The result of the testing of the proximate analysis and physical properties of the briquettes made from Avocados leaves. Briquette made from carbonized Avocados leaves residue a Mc of 15.35%, a Vm of 26.18%, a Ac of 13.09%, a Fc of 45.38%, a BD of 0.81 g/cm3 and a Gcv of 15,851.23 KJ/Kg and Briquette produced from carbonized Mangos Leaves residue had a Mc of 13.27%, a Vm of 19.91%, an Ac of 13.34%, a Fc of 53.48%, a BD of 0.86g/cm3and a Gcv of 17,204.36 KJ/Kg respectively.

The moisture content of raw carbonized Avocados and Mangos leaves residue were 15.35% and 13.27% respectively. The moisture content of Briquette produced from carbonized Avocados and Mangos leaves residue were greater than that moisture content of Briquette produced from nut shell which were 5 to 6 % (Sanger et al., 2011) and all the produced briquette were greater than rice husk, caw dung and corncob briquettes which were 12.67%, 7.33% and 13.47%, respectively [7]. The result full fill the quality specification of charcoal which restricts between 5 to 15 % moisture content and to smooth heat transfer, moisture content should be as low as possible [2]. Moisture content is one of the key parameters that regulate briquette quality. A lower moisture content of briquettes indicates a higher calorific value [3]. Also this study showed that the Avocados leaves briquette and Mangos leaves briquette moisture content were 15.35% and 13.27% respectively indicates it was higher from the others and that could be had a lower calorific value compared with others produced briquettes in this study.

Table 13. *Compering moisture conten of produced briquette with other biomass briquette.*

No	Briquette potential	moisture content
1	Avocados leaves	15.35% (my result)
2	Mangos Leaves	13.27% (my result)
3	Nut shell	6% (Sanger et al., 2011)
4	Rice husk	12.67% (Oladeji., 2010)
5	Caw dung	7.33% (Oladeji., 2010)
6	Corncob	13.47% (Oladeji., 20100

Statistics		Briquette potential	Moisture content
N	Valid	46	7
	Missing	0	39

Table 14. *Cumulative Percent.*

Briquette potential		Frequency	Percent	Valid Percent	Cumulative Percent
Valid		40	87.0	87.0	87.0
	Avocados leaves	1	2.2	2.2	89.1
	Caw dung	1	2.2	2.2	91.3
	Corncob	1	2.2	2.2	93.5
	Mangos leaves	1	2.2	2.2	95.7
	Nut shell	1	2.2	2.2	97.8
	Rice husk	1	2.2	2.2	100.0
	Total	46	100.0	100.0	

Table 15. *Proximate Analyses of moisture content.*

Moisture content		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	6.00	1	2.2	14.3	14.3
	7.33	1	2.2	14.3	28.6
	12.67	1	2.2	14.3	42.9
	13.27	1	2.2	14.3	57.1
	13.47	1	2.2	14.3	71.4

Moisture content		Frequency	Percent	Valid Percent	Cumulative Percent
	15.00	1	2.2	14.3	85.7
	15.35	1	2.2	14.3	100.0
	Total	7	15.2	100.0	
Missing	System	39	84.8		
	Total	46	100.0		

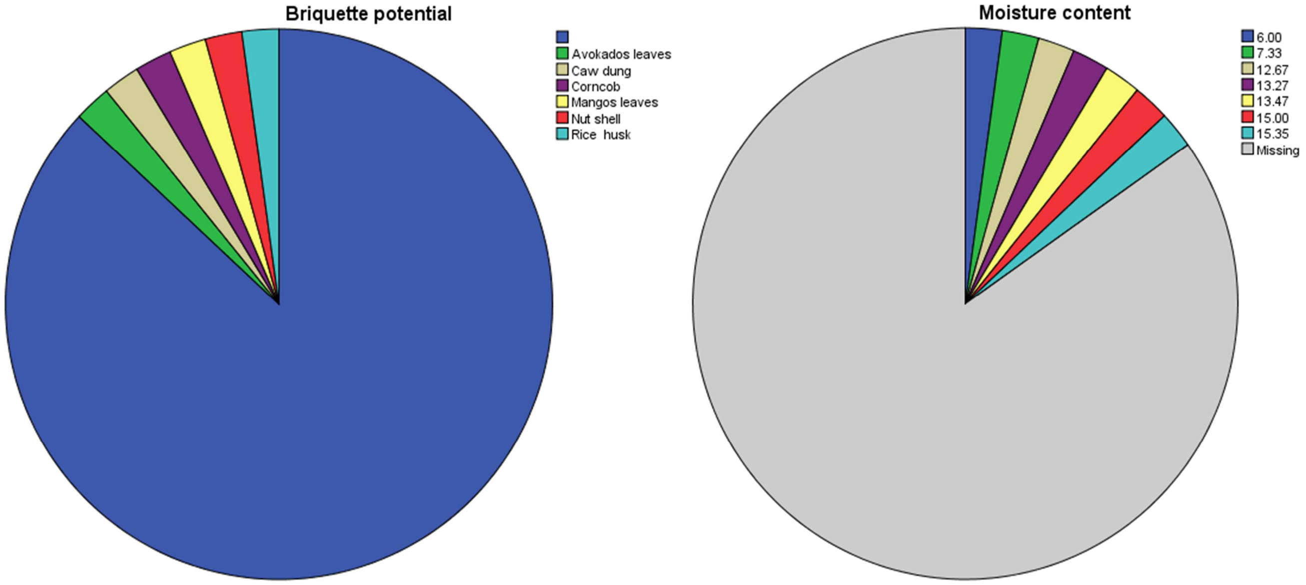


Figure 17. *Pai chart of moisture content of briquette biomass.*

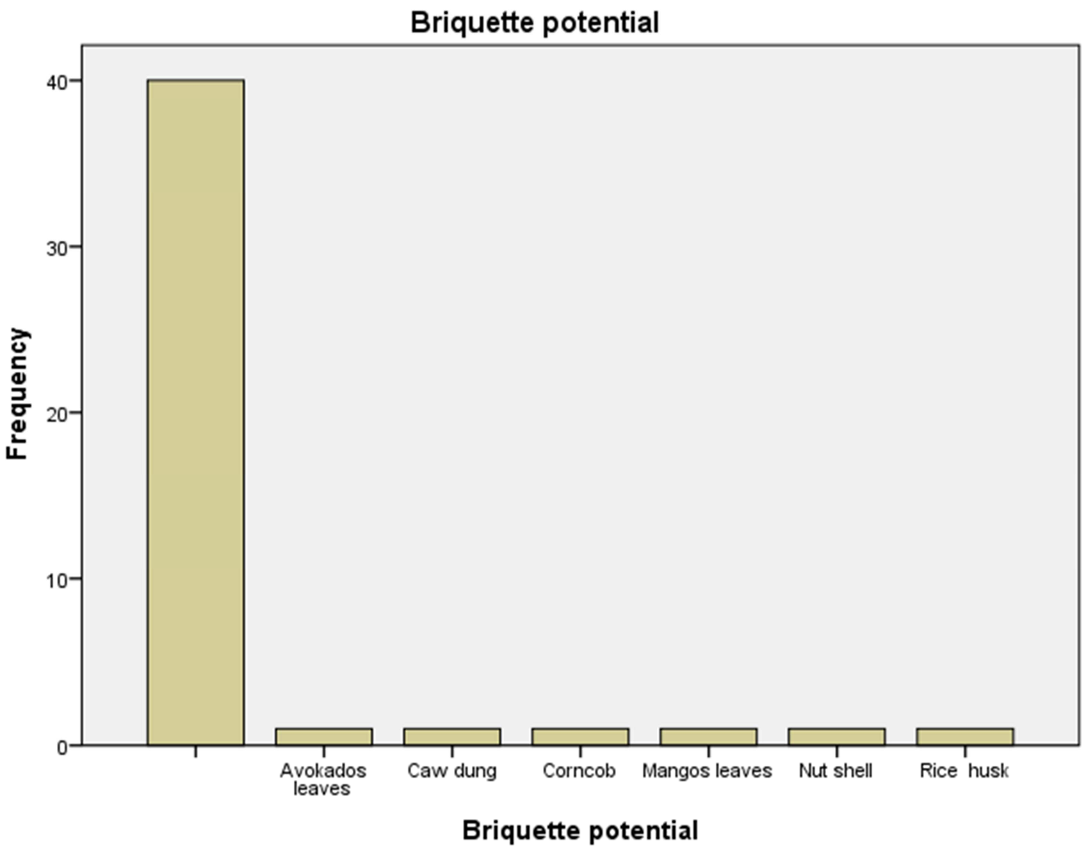


Figure 18. *Bar chart of frequency of briquette biomass.*

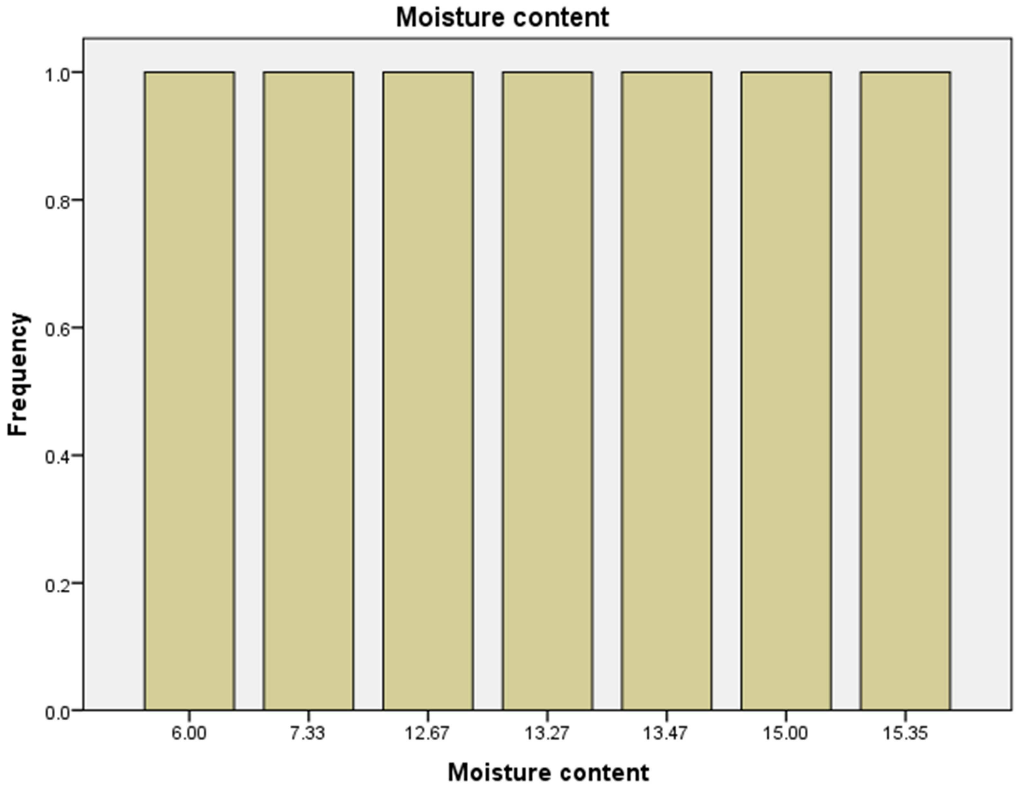


Figure 19. *Bar chart of frequency of moisture content.*

Volatile matter of raw Avocados leaves and mangos leaves residue were 26.18% and 19.91% respectively. From the result, volatile matter of raw carbonized Avocados leaves greater than that of carbonized mangos leaves residue.

The volatile matter is the constituents of hydrogen, carbon, and oxygen present in the biomass that heated turn to vapor, generally a mixture of long and short chain hydrocarbons. It influences the thermal behavior of sold fuels, but the structure and bonding behavior also influence it.

The weight of the dry biomass normally contains volatile content in the range 70 to 86% koppejan and van Loo, (2012). This characteristic makes the biomass a more volatile fuel giving a much faster combustion rate during the depolarization phase than other fuels like coal and briquette with high volatile content, have a tendency to complete combustion which leads to insignificant amount of smoke and release of toxic gas (koppajan and van Loo, 2012).

The result of raw material used in this study also in line with the above idea. Good marketable charcoal has net volatile matter content of about 30%. But the volatile matter of charcoal can fluctuate from maximum 40% or it may lower up to 5% or less than 5% [7].

Good quality charcoal should have volatile matter between 20 to 25% [8]. But the briquette produced from carbonized mangos and avocados leaves residue are not in line with the described criteria.

There might be the mangos and avocados leaves residue was not properly carbonized because of this the carbonized Avocados and Mangos leaves briquettes have higher volatile matter that is not in line with the described criteria by (FAO, 1985) and (FAO, 1987). The higher the volatile contents indicates the quicker will be the ignition but with the smoke [8]. This showed that the briquette produced from carbonized Avocados leaves had the characteristics of faster ignition and more smoke than briquette produced from carbonized Mangos leaves residue.

From the result, carbonized Avocados leaves residue has more indoor air pollution than briquette produced from carbonized Mangos leaves residue in this study.

Table 16. *Volatile Matter of produced Briquette.*

NO	Briquette potential	Volatile Matter (%)
1	Avocados leaves	26.18%(my result)
2	Mangos Leaves	19.91%(my result)

Statistics		Briquette potential	volatile mater
N	Valid	2	2
	Missing	0	0

Table 17. *Briquette potential.*

Briquette potential		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Avokados leaves	1	50.0	50.0	50.0
	Mangos leaves	1	50.0	50.0	100.0
	Total	2	100.0	100.0	

Table 18. *Frequency table of Volatile matter of produced briquette.*

Volatile cumulative percentage					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	19.91	1	50.0	50.0	50.0
	26.18	1	50.0	50.0	100.0
	Total	2	100.0	100.0	

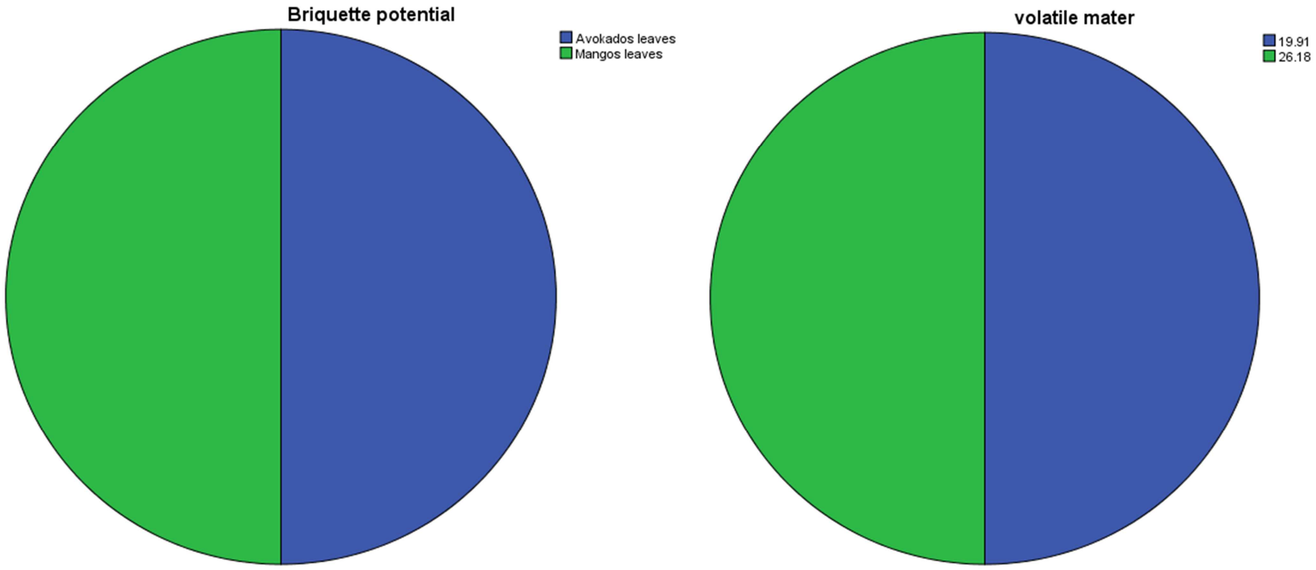


Figure 20. *Pai chart of Volatile matter of produced briquette.*

The briquette produced from carbonized Avocados and Mangos leave residue had ash content of 13.09% and 13.34% respectively.

The Ash is non – combustible inorganic residue remains after complete combustion. It indicates that the bulk mineral matter after oxygen, carbon, sulfur, and water has been driven off during combustion [13].

According to [7], the Ash content of charcoal fluctuated from 0.5 to 5% or more than 5% that based on the wood specie.

The good quality charcoal should have usually the ash content fluctuated from 3 to 4% (FAO, 1987). The ash content of the carbonized Avocados and Mangos leaves residue fails the good quality charcoal criteria by [7] this might be due to improper carbonization.

For better utilization of briquette, the lower ash contents preferable which increase the combustion efficiency [9].

The binder used to in this study, the paper also increases the ash contents of produced briquettes. The ash content of produced briquette from this study were lower than the ash content of the bio-briquette made from coffee husk and rice husks which was 0.60 and 15.63% respectively [9]. This difference could be caused because of the type of the binder used but the Avocados and Mangos leaves briquette had lower ash content than other briquettes produced in this study. In this finding the ash value is less than the briquette made from 50% [3] husk and 50% pressed cake which was 26.21% and the entire briquette produced in this study, had lower ash content than briquette produced from saw dust which was 28.13% [5].

Table 19. *Compering Ash content of produced briquettes with other biomass briquette.*

No	Briquette potential	Ash content
1	Avocados leaves	13.09%(my result)
2	Mangos Leaves	13.34%(my result)
3	coffee husk	0.60%(S suryaningsih et al., 2017)
4	Rice husk	15.63%(S suryaningsih al., 2017)
5	Pressed cake	26.21%(Murali et al., 2015)
6	Saw dust	28.13%(Murali et al., 2015)

Statistics		Briquette potential	Ash content
N	Valid	6	6
	Missing	0	0

Briquette potential		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Avocados leaves	1	16.7	16.7	16.7
	Coffee husk	1	16.7	16.7	33.3

Briquette potential		Frequency	Percent	Valid Percent	Cumulative Percent
	Mangos leaves	1	16.7	16.7	50.0
	Pressed cake	1	16.7	16.7	66.7
	Rice husk	1	16.7	16.7	83.3
	Saw dust	1	16.7	16.7	100.0
	Total	6	100.0	100.0	

Table 20. *Frequency table of Ash content of briquette biomass.*

Ash content	Frequency	Percent	Valid Percent	Cumulative Percent	
	.60	1	16.7	16.7	16.7
	13.09	1	16.7	16.7	33.3
	13.34	1	16.7	16.7	50.0
Valid	15.63	1	16.7	16.7	66.7
	26.21	1	16.7	16.7	83.3
	28.13	1	16.7	16.7	100.0
	Total	6	100.0	100.0	

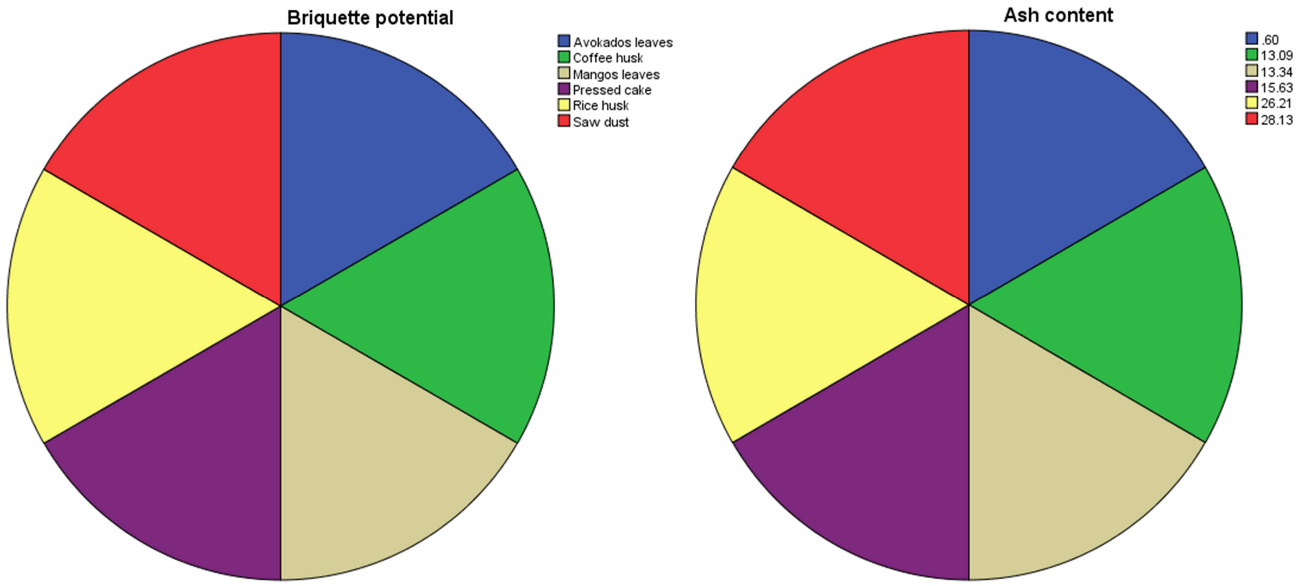


Figure 21. *Pai chart of Ash content of briquette biomass.*

Fixed carbon content of raw carbonized Avocados and Mangos leaves residue with paper binder (1: 5ratio) were 45.38% and 53.48% respectively.

According to [7], the fixed carbon of charcoal fluctuates nearly between 50% up to 95% thus the charcoal hold mostly of carbon and it also recommend that the charcoal produced from mixed tropical hard wood had fixed carbon fluctuated 68.6% and 69.8%.

The charcoal produced in this study fulfills the described criteria by [7], however the charcoal briquette produced from Mangos leaves residue fulfills the described criteria of (. But the charcoal briquette produced from Avocados leaves residue fail the described criteria by [7]. The higher the fuel's ash contains, the lower is its calorific value [8] and the high fixed carbon content gives the result of high calorific value [7].

From the above concept the fixed carbon content of the produced briquettes in this study had, lower, because of higher ash amount was found in to the produced briquettes this is also related to the paper used as a binder in this study.

The produced briquettes in this study are much less than the fixed carbon content of charcoal briquettes produced from Neem wood residue bonded with gum Arabic and Starch which was affixed carbon content of 84.38 and 84.31% respectively, [8] this might be the binder difference used to produce the fuel briquettes.

The Avocados and Mangos fuel briquette is greater than the fixed carbon content of the charcoal briquette produced from sesame stalk which was a fixed carbon content of 44.40% [3]. Briquette produced in this study also greater than the charcoal briquette produced from saw dust briquette which was affixed carbon content of 20.7% [5] and the whole produced briquette in this study, are greater than the fixed carbon content of briquette produced from wood which had the corresponding value of 1.6% stated by [9].

Table 21. *Compering fixed carbon content of produced briquette with other biomass briquette.*

No	Briquette potential	Fixed Carbon content
1	Avocados Leaves	45.38%(my result)
2	Mangos Leaves	53.48%(my result)
3	Hard wood	68.6%(Malatji et al., 2011)
4	Neem wood with gum Arabic	84.38%(Sotannde et al., 2015)
5	Neem wood with starch	84.31%%(Sotannde et al., 2015)
6	sesame stalk	44.4%(Gebresas et al., 2015)
7	Saw dust	20.7%(Akowuah et al., 2012)

Statistics		Briquette potential	Fixed carbon content
N	Valid		7
	Missing	0	0

Briquette potential		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Avocados leaves	1	14.3	14.3	14.3
	Hard wood	1	14.3	14.3	28.6
	Mangos leaves	1	14.3	14.3	42.9
	Neem wood with gum Arabic	1	14.3	14.3	57.1
	Neem wood with starch	1	14.3	14.3	71.4
	Saw dust	1	14.3	14.3	85.7
	Sesame stalk	1	14.3	14.3	100.0
	Total	7	100.0	100.0	

Table 22. *Frequency table of fixed carbon content of briquette biomass.*

Fixed carbon content		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	20.70	1	14.3	14.3	14.3
	44.40	1	14.3	14.3	28.6
	45.38	1	14.3	14.3	42.9
	53.48	1	14.3	14.3	57.1
	68.60	1	14.3	14.3	71.4
	84.31	1	14.3	14.3	85.7
	84.38	1	14.3	14.3	100.0
	Total	7	100.0	100.0	

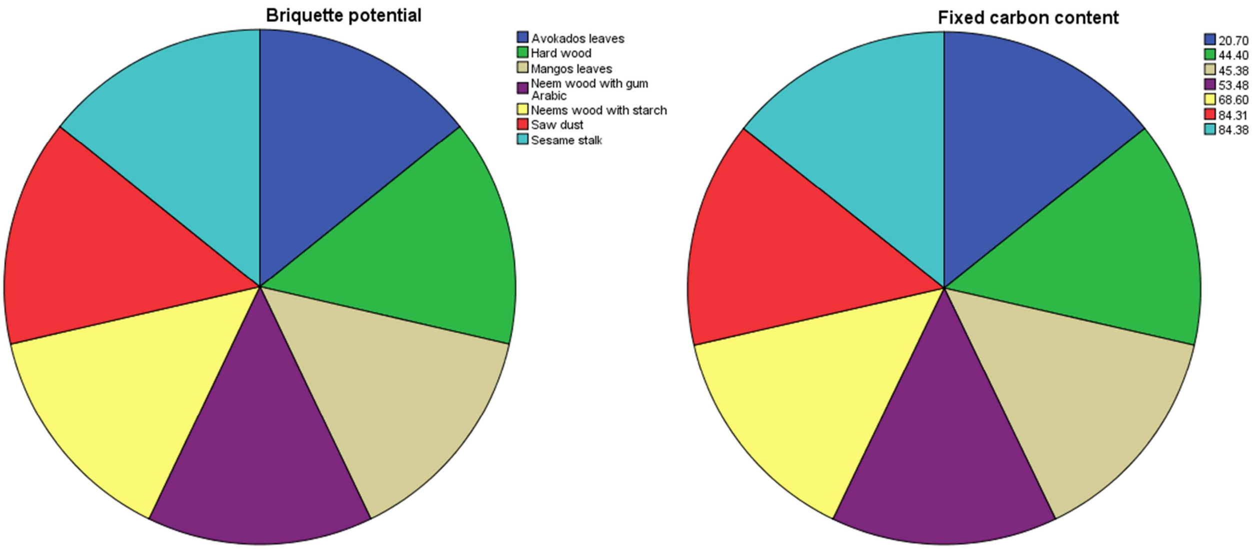


Figure 22. *Pai chart of fixed carbon content of briquette biomass.*

The bulk density of the produced briquettes in this study carbonized Avocados and Mangos leaves residue were 0.81g/cm3 and 0.86g/cm3 respectively. Bulk density is one of the most important parameter of briquettes, where the higher the density, the higher is the energy per volume ratio and its slow burning property.

Therefore, high density crops are required interims of transportation, handling, and storage. The density of bio-waste briquette depend on the density of the original bio-waste, the briquetting pressure and, to a certain extent, on the briquetting temperature, and time [4].

The bulk Density achieved from this study Were much higher than that of Eupatorium spp. With bulk density 0.33g/cm3 [3] and less than the charcoal briquette produced from saw dust which had bulk density of 0.89g/cm3 [4] and the charcoal briquette produced from banana leaves briquette which was in the range 0.99 to 1g/cm^3 [2].

The bulk density achieved from this study was higher than that of the charcoal briquette produced from coconut husks which had bulk density of 0.76g/cm^3 [7].

Table 23. *Compering Bulk density of produced briquettes with other biomass briquette.*

No	Briquette potential	Bulk density (g/cm3)
1	Avocados Leaves	0.81 (my result)
2	Mangos Leaves	0.86 (my result)
3	Saw dust	0.89 (S suryaningsih et al., 2017)
4	Banana Leaves	0.99 to 1 (Maia et al., 2014)
5	Coconut husk	0.76 (S suryaningsih et al., 2017)

Statistics		Briquette potential	Bulk density
N	Valid	5	5
	Missing	0	0

Briquette potential		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Avocados leaves	1	20.0	20.0	20.0
	Banana leaves	1	20.0	20.0	40.0
	Coconut hack	1	20.0	20.0	60.0
	Mangos leaves	1	20.0	20.0	80.0
	Saw dust	1	20.0	20.0	100.0
	Total	5	100.0	100.0	

Table 24. *Frequency table of bulk density of briquette biomass.*

Bulk density		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	.76	1	20.0	20.0	20.0
	.81	1	20.0	20.0	40.0
	.86	1	20.0	20.0	60.0
	.89	1	20.0	20.0	80.0
	.99	1	20.0	20.0	100.0
	Total	5	100.0	100.0	

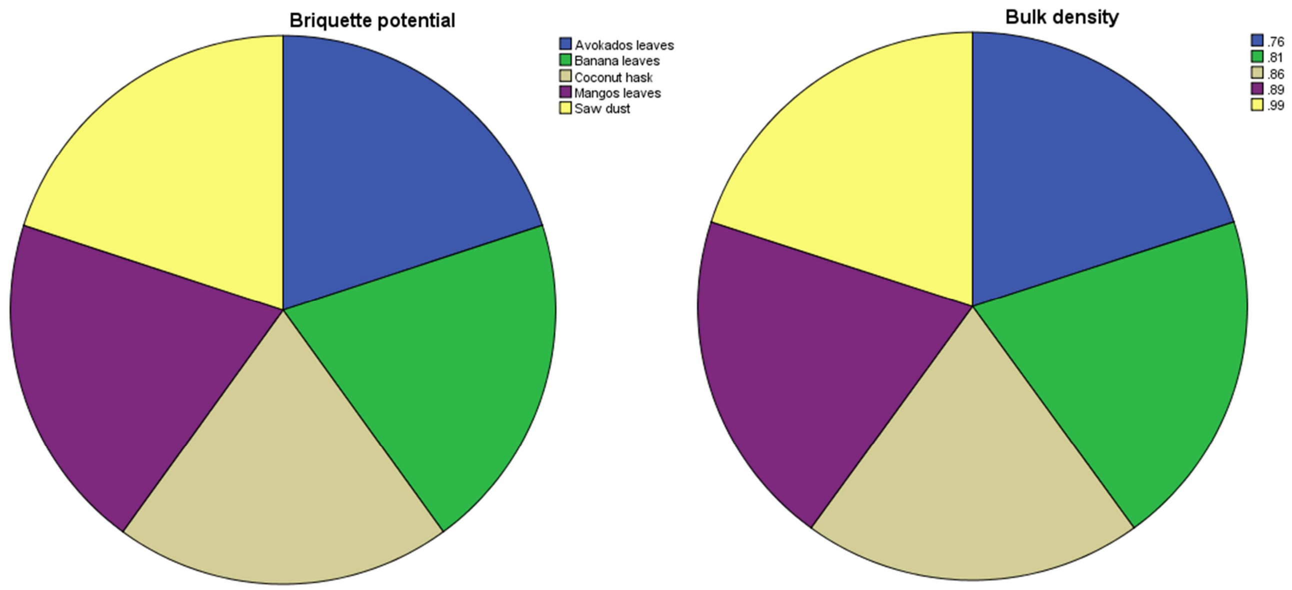


Figure 23. *Pai chart of bulk density of biomass briquette.*

The mean gross calorific value of raw Avocados leaves residue had lower gross calorific value of 15,851.23KJ/Kg than, the mean gross calorific value of raw Mangos leaves residue which had 17,204.36 KJ/Kg. However, significance differences of the gross calorific value were found between the produced briquettes. Calorific Value or heating value regulates the energy contents of a fuel. It is also the property of biomass fuel that can be influenced by its moisture content and chemical composition. In addition to this, it is the most important fuel property [6].

The gross calorific Value raw carbonized Avocados leaves residue was less than that of carbonized Mangos leaves residue this could be because of the amount of binder added to sample. High percentage of volatile matter doesn't mean will decrease the burning capacity.

If its composition contains flammable gas, it will increases burning capacity by proportionately increases flame length, and helps in easer agnation of coal [13].

In addition to this during carbonization process the difference of the environmental conditions like the temperature difference also one factor influence the significantly different in gross calorific value [7]. The calorific value after carbonization was higher than fuel briquette which was used paper as binder [10].

In this study carbonized Mangos leaves briquettes had greater gross calorific value than charcoal briquette made from coffee pulp which was 16,905.62KJ/Kg but less than the gross calorific value of the charcoal briquettes made from coffee husk which was 21,106.08KJ/Kg [12].

Carbonized Avokados leaves briquettes had less gross calorific value of both charcoal Briquette made from coffee pulp which was 16,905.62KJ/Kg and charcoal briquettes made from coffee husk which was 21,106.08KJ/Kg [11].

All briquettes made from this study had greater calorific value than wood which was 13,803.12KJ/Kg [3].

Table 25. *Compering Gross Calorific value of produced briquette with other biomas briquette.*

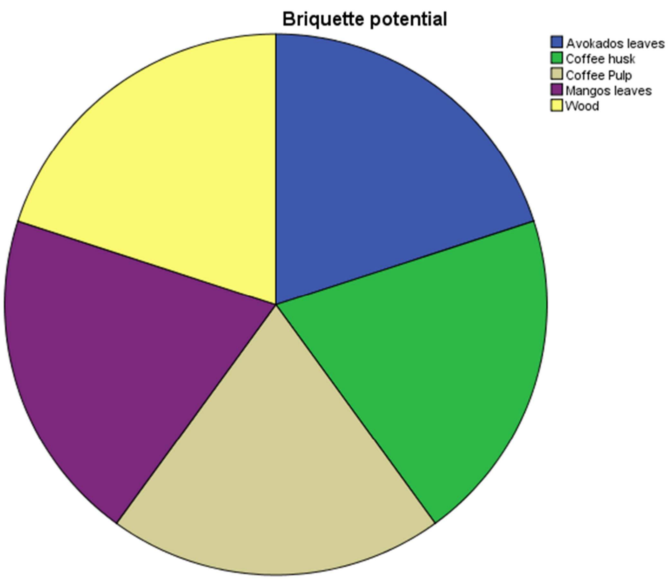
No	Briquette potential	Gross Calorific Value (KJ/Kg)
1	Avokados Leaves	15,851.23 (my result)
2	Mangos Leaves	17,204.36 (my result)
3	Coffee PULP	16,905.62 (Merete et al., 2014)
4	Coffee husk	21,106.08 (Merete et al., 2014)
5	Wood	13,803.12 (FAO, 1999)

Statistics		Briquette potential	Gross Calorific value
N	Valid	5	5
	Missing	0	0

Briquette potential		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Avokados leaves	1	20.0	20.0	20.0
	Coffee husk	1	20.0	20.0	40.0
	Coffee Pulp	1	20.0	20.0	60.0
	Mangos leaves	1	20.0	20.0	80.0
	Wood	1	20.0	20.0	100.0
	Total	5	100.0	100.0	

Table 26. *Frequency table of Gross Calorific value biomass briquetee.*

Gross calorific value		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	13803.12	1	20.0	20.0	20.0
	15851.23	1	20.0	20.0	40.0
	16905.62	1	20.0	20.0	60.0
	17204.36	1	20.0	20.0	80.0
	21106.08	1	20.0	20.0	100.0
	Total	5	100.0	100.0	



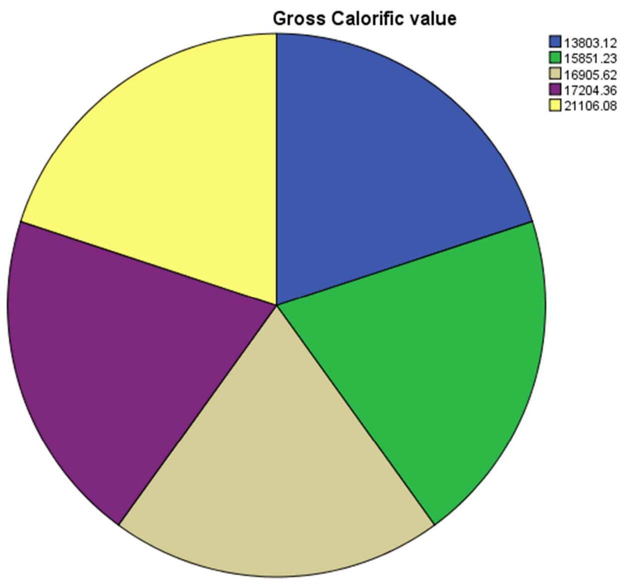


Figure 24. *Pai chart of Gross calorific value of biomass briquette.*

4.3. Fuel Performance Test

4.3.1. Combustion and Water Boiling Capacity Test

The test result showed that the carbonized Avocados and Mangos leaves briquettes are strong heat which got on average 23 min and 35 min to boil one litter of water at the first time respectively, and the fastest fuel briquette changing the water in to vapor was carbonized Avocados leaves which was one average 1hr and 11 min and carbonized mangos leaves fuel briquette was 1hr and 22 min and also fuel briquettes made from carbonized Avocado's and Mangos leaves had average time taken to turn to ash were 2hr and 48 min, 2hr and 14 min Respectively.

The result for fuel performance test of the produced fuel briquette made from carbonized Avocados leaves showed that there is no smoke (Smoke free) except at a startup, no spark formation, no soot production, no smell or odor but Mangos leaves residue have small amount of smoke and little small or odor until 10 min after startup.

Furthermore, the study indicated that the time taken to boil a given amount of water highly related to the calorific value (i.e. the higher calorific value the fastest to boil the water).

The carbonized fuel briquette made from Avocados leaves had almost similar qualities when compared with sesame stalk which was 20 min (Gebresas et al., 2015) and lower than the briquette made from lantana camera L. fuel briquette root, steam, branch and leaves with trunk fuel briquette which had 9, 10, 13 and 15 min to boil one litter of water [1].

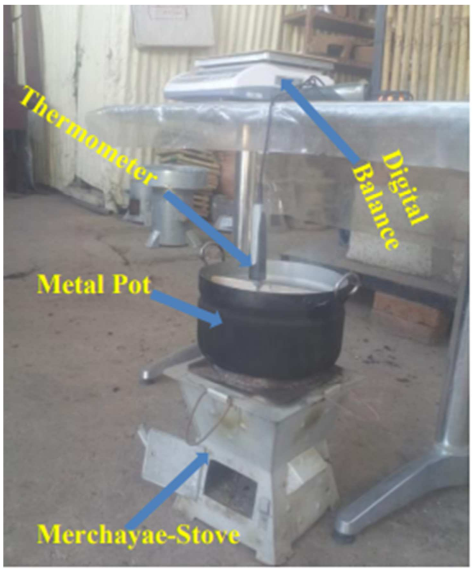


Figure 25. *Combustion and water boiling capacity test.*

4.3.2. Total Emission Test

The hardiness of the briquettes is related to the dust and co emission. The highest hardiness of the briquette results in lower dust and co emission and higher amounts of fixed carbon increase the probability of more complete oxidation and extensive combustion in addition to these briquettes having high amounts of fixed carbon have low dust and co emission [14].

Carbonized Avocados and Mangos leaves fuel briquettes had total co emissions of 728 (0.07%) ppm and 831 ppm (0.08%) respectively were 1% co=10,000ppm.

The carbonized Avocados and Mangos leaves fuel briquettes had lower co-emission than charcoal briquettes produced from banana peel and banana bunch which had total co-emission of 3463ppm (0.35%) and 1568ppm (0.16%) respectively, [12].

Gas mixture of atmosphere with allow concentration of co in the range up to 4,947ppm (0.5%) do not present any toxic threate to consumers according to international standard for the determination of toxicity of Gases as cited by [13].

Hence the produced fuel briquettes from Avocados and Mangos leaves do not cause any threat to consumers.

5. Conclusion and Recommendation

5.1. Conclusion

According to the findings of this study, Results of moisture, Volatile matter, Fixed carbon, Ash content, Calorific value, Bulk density, Burning rate, Burning time and Ignition time for biomass briquettes of Avocados and Mangos leaves were 15.35%, 26.18%, 13.09%, 45.38%, 0.81g/cm3, 15,851.23KJ/Kg, 23 min and 13.27%, 19.91%, 13.34%, 53.48%, 0.86g/cm3, 17,204.36KJ/Kg, 35 min respectively.

So, this study showed that biomass briquette produced from Avocados and Mangos leaves residue with paper as binder was found to be highest in terms of calorific value, fixed carbon content, bulk density and burning time as well as lowest in terms of ash content and burning rate. So as the binder composition (paper) increased calorific value, fixed carbon content, and bulk density also increased. Hence this composition ratio can be taken as optimum value for the production of biomass briquettes from the Avocado's and Mangos leaves.

So, utilization of Avocados and Mangos leaves as a source of biomass briquette delivers clean energy that reduce indoor air pollution, respiratory and infectious disease that occurred due to the release of smoke during cooking. Besides, biomass briquette can solve the rural and urban house hold energy shortage by supplying a clean renewable energy and also reduce forest degradation. The physical and chemical analysis of biomass briquette produced from Avocados and Mangos leaves residue were found a promising product that can generate income and create job opportunity to the local community micro enterprises. Moreover, this way of controlling and managing the infestation of Avocados and Mangos leaves has double benefits for the surrounding communities in that minimizing the environmental waste or solid waste and converting it in to wealth through biomass briquettes production. Therefore, based on this findings using municipal solid waste and Agro waste as feed stoke for clean energy source can be a best option for controlling solid waste infestation and also increase the surrounding communities, incomes by creating new job opportunities.

5.2. Recommendation

It is evident that the treat created by Avocados and Mangos leaves could be transformed to benefit the communities who previously re-laid on farming activities.

Therefore, I recommended that the community members should be trained on biomass briquette production from Avocados and Mangos leaves to increases their income and contribute towards controlling the waste infestation.

The production of briquettes from this study and its utilization could be advocated since its usage as solid biofuel, will alleviate the challenges caused by this solid waste. This will be perhaps the best method to control and make safe environment. This could also enhance: rural economic development, farm income, market diversification, reduction in agricultural surplus, international competitiveness, reduce negative environmental impact and creation of employment opportunities in the area of production and utilization.

If Avocados and Mangos leaves going to be used as biomass briquette on industrial scale, it is likely that there should be some kind of collaboration among governmental, industrial partners and local communities in order to utilize and control it sustainably.

To do this, the government should formulate and bring about policies and programs for the promotion of biomass briquetting from invasive species like Avocados and Mangos in order to control the municipal solid waste infestation and upgrade and promote renewable energy use in our country.

Additionally, Market development and protection should be given to fuel wood and fossil fuels where ever possible and also the government should establish a unit within MEFCC/MWIE to look after (scale-up) biomass briquetting technologies and promote biomass briquette production.

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