PRODUCTION AND CHARACTERIZATION OF BIRQUETTES FROM BANANA BUNCH AND PEEL WASTES FOR HOUSEHOLD ENERGY SOURCES, THE CASE OF ADDIS ABABA, ETHIOPIA.

M.Sc THESIS

ABRHAM ABNEH TERREFE



WONDOGENET COLLAGE OF FORESTRY AND NATURAL RESOURCES,

HAWASSA UNIVERSITY, ETHIOPIA.

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BY

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DEPARTMENT OF ENVIRONMENTAL SCIENCE, WONDOGENET COLLAGE OF FORESTRY AND NATURAL RESOURCES, GRADUATE STUDIES HAWASSA UNIVERSITY, ETHIOPIA.

IN PARTIAL FULFILMENT OF THE REQUIRMENTS FOR THE DEGREE OF MASTER OF SCIENCE IN RENEWABLE ENERGY UTILIZATION AND MANAGEMENT

(RENEWABLE ENERGY UTILIZATION AND MANAGEMENT)

MAJOR ADVISOR: SOLOMON T/MARIAM (PhD)

JUNE, 2019

APPROVAL SHEET-1

This is to certify that the thesis entitled with ***"Production and Characterization of Briquettes from Banana Bunch and Peel Wastes for Household Energy Sources, the case of Addis Ababa, Ethiopia"*** prepared by Abrham Abneh Terrefe Id No. MSc/ Reum/R001/10 in partial fulfillment of the requirements for the degree of Master of Science in Renewable Energy Utilization and Management that compiles with the regulations and accepted standards of the university with respect to the thesis quality and original work.

Major Advisor: Solomon T/Mariam (PhD) _______________ ___________

Name Signature Date

Co-Advisor: Zerihun Demrew (PhD) ________________ ___________

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APPROVAL SHEET-2

We the undersigned, members of board of examiners of the final open defense by Abrham Abneh Terrefe have been read and evaluated his thesis entitled with ***"Production and Characterization of Briquettes from Banana Bunch and Peel Wastes for Household Energy Sources the case of Addis Ababa, Ethiopia"*** has been examined and hence this is to certify that the thesis has been accepted in partial fulfillment of the requirements for the degree of Master of Science in Renewable Energy Utilization and Management.

Chairperson:____________________________ _______________ ___________

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Major Advisor: Solomon T/Mariam (PhD) _______________ ___________

Name Signature Date

Internal Examiner:________________________ ____________ ___________

Name Signature Date

External Examiner: _____________________ _______________ ___________

Name Signature Date

SGS approval: __________________________ ________________ ___________

Name Signature Date

DECLARATION

I under signed declare that this thesis entitled as ***"Production and Characterization of Briquettes from Banana Bunch and Peel Wastes for Household Energy Sources the case of Addis Ababa, Ethiopia"*** is my original work and has not been submitted to any other university for the award of any academic degree or diploma and all materials used as a source for this thesis has been cited and acknowledged.

Declared by:

Abrham Abneh:	_______________	___________
Name of student	Signature	Date

DEDICATION

This thesis is dedicated to my beloved brother Mr. Ayalew Walle for his courage and sincere support.

ACKNOWLEDGMENTS

Above all, I would like to thank the almighty God, for all what he has done to me to reach this stage of thesis work.

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Last but not least, I would like to express my great thanks to my family and to all my friends.

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List of acronyms and abbreviation

AC	Ash content
ASTM	American Standard Test Methods
EJ	Exajoules
EPA	Environmental Protection Authority
FAO	Food and agriculture organization of the united nation
FCC	Fixed carbon content
FVW	Fruit and vegetables wastes
GHG	Green House Gas
IEA	International Energy Association
INIBAP	International Network for the Improvement of Banana and Plantain
kg	Kilogram
kJ	Kilojoules
LPG	Liquefied Petroleum Gas
m	Meter
MC	Moisture content
%	Percent

TJ	Tera Joules
UNDP	United Nations Development Programme
VM	Volatile Matter
WGCF-NR	Wondo Genet Collage of Forestry and Natural Resource

Operational Terminology

Banana (musa spp) is a musaceae family and perennial monocotyledons usually grown in tropics with altitude 20^{o} above and below the equator where rain fall and temperature vary seasonally (Pua, 2007).

Briquette is made by compressing and molding of organic matter that suited with briquette stove in its size and shape (Okoko *et al.*, 2017).

Banana Bunch is the same stem that flowering parts and fruits collectively growing (Nelson *et al.*, 2006).

Charcoal is a solid residue of wood due to carbonization and

Firewood is direct use of wood for cooking without any conversion (Okoko *et al.*, 2017).

Production and characterization of briquettes from banana bunch and banana peel waste for household energy sources, the case of Addis Ababa, Ethiopia.

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Hawassa University WGCF-NR, May, 2019

ABSTRACT

There is a large amount of Banana bunch and Banana peel wastes that distribute throughout the city of Addis Ababa and simply dump and pollute the environment. This study aimed to produce and characterize briquettes from wastes of banana bunch and banana peel as well as determining fuel wood substitution by estimating energy potential of the briquettes. Samples of banana wastes were collected randomly from purposely selected area. After air drying, the samples of banana bunch and peel were carbonized inside a metal kiln. Then, the carbonized powder was mixed together with 15% of clay soil as a binder. Briquette with 12 holes called beehive briquettes was produced using beehive coal machine. A proximate analysis was carried out using ASTM Procedure. The results of briquettes produced from banana bunch, banana peel and mixture of banana bunch and banana peel have calorific value 11,547.63, 24,073.13 and 17,879.36 KJ/kg respectively. Based on those Calorific values yearly mean average energy potentials of banana bunch, banana peel and mixture of banana bunch and banana peel briquettes were 1.94 to 2.14TJ, 32.26 to 35.61TJ and 13.49 to 14.89 TJ respectively. These energy potentials can substitute a total of 1,548.73 to 1,708.9 ton of charcoal or 9,292.02 to 10,252.76 tons of fuel wood could be save from being deforestation per year. As a result a total of 1,703.61 to 1, 879.79 ton of CO_2 emission avoided from the atmosphere. It can be concluded that the briquettes produced from banana wastes can be used as a source of house hold energy and reduced CO_2 emission by reducing deforestation. Economic analysis and feasibility of briquettes of banana wastes should be studied in further.

Keywords: *Banana Bunch, Banana Peel, Energy Potential, Fuel Wood*

1. INTRODUCTION

1.1. Background

The world primary energy consumption increased to 13.5 billion tons of oil equivalent that is about 565EJ (exajoules) in year 2017. Due to that reason, renewable energy is becoming a suitable alternative for a large energy demand and environmental conditions (Pradhan, Mahajani and Arora, 2018).

Now days, 2.8 billion without access clean cooking conditions and one third of the world's population (2.5 billion people) depend on traditional solid biomass to cooking purpose and high growth of population in developing countries particularly sub-Saharan Africa in which the people depend on biomass for cooking and due to that traditional solid biomass for cooking they associated with health risks (IEA, 2017) but charcoal briquette that produced from agricultural wastes are economical, environmentally friendly, healthy (smokeless) and reduced deforestation. Therefore, production of briquette charcoal using agricultural wastes is another alternative to avoid pollution and health problem in addition to energy source (Bogale, 2009) that is why now a days the green house gasses (GHG) emissions, fossil fuel prices, geopolitical instability, and preference of consumers are the growing issues over the environmental impact and driving factors for the development and use of biomass as a source of renewable energy (Bajwa *et al.*, 2018). Biomass is a natural resource that is a backbone of energy sources in developing countries like Ethiopia and sub-Saharan countries. Adverse contribution of fossil fuels to global warming pushes the world community to shift to biomass energy which is relatively environmentally clean. Beside using biofuel as energy source the second main purpose is tackling global warming and reducing greenhouse gas (Gabisa and Gheewala, 2018).

Africa's 94% of rural population and 73% of urban population primary energy sources is based wood fuels (Okoko *et al.*, 2017).

Ethiopian 91% of the total primary energy consumption derived from biomass. Biomass energy is the main energy source used for all economic sectors in Ethiopia, and above 98% the rural household use firewood, crops residues/leaves and cows dung for cooking (Tucho *et al*., 2014).

Addis Ababa city generate solid waste with rate of 0.4kg/head/day from almost 4 million people and generates 23.1 tones of fruit and vegetable wastes (FVWs) daily. Wastes of fruit and vegetable in Addis Ababa dumped in open field that hold huge energy potential with a quantity of wastes from fruit that avoided in the city is very huge near to 164.51 tons/day that affect the environment adversely and cause public health problem because of open dumping disposal, therefore suitable waste management system is required like waste reduction, reuse and recycle that actually reduce solid waste accumulation (Dagnew *et al*, 2013).Due to that reason the main goal of this research to conduct in Addis Ababa is to reuse the solid waste from banana bunch and Banana peel by converting the waste to energy in form of charcoal briquetting that reduce direct use of wood for three stone open fire that in turn reduce deforestation and indoor air pollution.

1.2. Statement of the problem

There is a large amount of wastes of Banana bunch and Banana peel distribute throughout the city that simply dump and pollute the environment. There is a big problem in solid waste management or these wastes were not converted to usable energy sources in Addis Ababa (Tesema, 2010). Rural and poor urban household use traditional stove that is three stone open fire with less conversion efficiency of 10% (Tucho *et al*., 2014). Wood was used to provide the requirements for cooking up to now, but because of current deforestation, households have changed to agricultural residues as an energy source and if more efficient techniques are used such as briquetting and biogas can attain huge biomass saving of up to 60% (Tucho and Nonhebel, 2015).In Addis Ababa 75% of household energy need are traditional fuels (fuel wood, charcoal and dung) and the rest 25% is kerosene, LPG and electricity (Sanbata *et al.*, 2014).Therefore, production of briquette charcoal using agricultural wastes another alternative to avoid pollution and health problem in addition to energy source (Bogale, 2009). Hence by producing briquettes from banana bunch and banana peel wastes for clean household energy source and mitigate GHG by reducing deforestation.

1.3. Objective

1.3.1. General objective

The general objective of this research is to produce and characterize briquettes from wastes of banana bunch and banana peel as well as determining fuel wood substitution by estimating energy potential of the briquettes.

1.3.2. Specific objectives

- To estimate efficiency of wastes of banana bunch and banana peel carbonization.
- To characterize wastes of banana bunch and banana peel briquettes through proximate analysis.
- To determine the supply potential of banana and wastes that is produced from banana bunch and banana peel in Addis Ababa.
- To determine the energy potential and fuel wood substitution of produced briquettes by estimating calorific value of banana bunch and banana peel.

1.4. Research questions

- What is the carbonization efficiency of wastes of banana bunch and banana peel?
- How characterize the produced briquettes from wastes of banana?
- What is the supply potential of banana and wastes that produced from banana bunch and banana peel in Addis Ababa?
- What is the energy potential and wood fuel substitution of briquettes that produced from banana bunch, banana peel and their mixture?

1.5. Significance of the study

Converting these wastes to energy in the form of briquetting is an important issue that reduces deforestation that cut down for fire wood and briquettes have no smoke during burning that tackle environmental pollution and health problem. Production of briquettes from these banana wastes can create job opportunity and can generate individual or enterprise income.

1.6. Scope and limitation of the study

The study was conducted in Addis Ababa and its limitation was that in the city many agricultural products produced and many wastes distributed in the city, but the study was dealt only with wastes of banana bunch and banana peel and not includes Small wastes of banana leaves that cover the banana for safety purpose on trucks during banana transport.

2. LITRATUR REVIEW

2.1. Botanical description of banana

Bananas scientific name that preferred is musa species and musaceae (banana family).Dessert banana, plantain, cooking banana (English) are its common names. Its size is large 2-9 m in height that arises from rhizomes (“corms”) and which is perennial, monocotyledonous herb. Its bunch is the same stem that flowering parts and fruit collectively growing and hand is an individual cluster of fruits and these fruits are variable and which are elongate _cylindrical, straight to strongly curved, 3-40cm long and 2-8cm in diameter and Varieties of the cultivated banana is seedless. The false stem that contains leaves and their fused petiole bases is pseudo stem that supports a canopy consisting of 6-20 (or more) leaves and banana have many fibrous roots almost from 200 to 500 in numbers (Nelson *et al*, 2006)**.**

2.2. Banana production and its importance

Globally banana is a major food crop that is grown and consumed in more than 100 countries of tropics and subtropics and which is fourth important food crop next to rice ,wheat and maize (INIBAP, 2000) and Wastes of Banana used as a best business idea in different countries such as India, Nepal and Philippines (Mohiuddin *et al.*, 2014).

Banana is the second major fruit that produced after citrus in Ethiopia which produced throughout the country if there is enough rainfall or irrigation, but at present south and south-western Ethiopia are the major suppliers of banana to major cities like Addis Ababa from ArbaMinch, MizanTeferi, and Tepi. From these suppliers Addis Ababa merchants and consumer prefer Arba Minch banana because of high dry matter, long shelf life, good taste, and sign of excellence and due to its deep yellow color. Licensed merchants bring banana in large amount to Addis Ababa and merchants sell banana to those have ripening rooms, then ripen banana sell to retailers in bunch and finally retailers finish the process of ripening until to develop yellow color (Gebre-Mariam, 1999) and the type of banana that consumed are dessert type that are under production since early 1970s although both cooking and dessert types released through research in Ethiopia (Alemu and Dagnew, 2008). Banana bunch and peel wastes also can be used as a renewable energy sources with more eco-friendly for sustainable development (Sumrit and Vijitr, 2017).

2.3. Briquetting of biomass

Fuel wood and charcoal production from wood by cutting trees is the major reasons for deforestation that cause environmental degradation in the form of land and water resources degradation and lose of biodiversity (Demel, 2014).Briquette charcoal and wood charcoal produced from biomass but there is a difference in their charcoal making processing.

Table 2.1: Briquette charcoal and wood charcoal making process comparison

Briquette charcoal	Wood charcoal
No need of digging	Digging
Mobile any where	Not mobile
Not fire hazardous	Fire sometimes
Safe in health factor	Not safe
Smokeless	Smoke
Faster heat release and greater heat value	Less heat value
Low production cost than wood charcoal price to purchase at local market	High production coast
Reduce impact of deforestation	Enhance deforestation
Burn for long time (2-3hr)	It can burn for short time(1-2 hr)

Source:(Bogale, 2009)

Biomass briquettes are a solid fuel form that used as source of energy and produced by compacting biomass residues in to solid blocks that can substitute fossil fuels charcoal and natural firewood for uses cooking and industrial heating process. If briquettes made from harvested biomass in sustainable way that can have the potential to be a source of a renewable energy and biomass controls the domestic energy market in east Africa and due to wood resources scarcity and the price of charcoal increases briquetting technology is a best alternative (Ferguson, 2012).

2.3.1. Briquetting of Agricultural wastes in Ethiopia

The main opportunity to adopt briquette technology in Ethiopia is the high availability of biomass resources such as wood, agro-industrial residues and municipal waste (Tekle, 2017). From the total energy consumption of Ethiopia 94% represents the biomass and from which 77% is wood fuel and 17% agricultural residues, dung and charcoal. The overall dependency of the majority of population on wood fuel and charcoal leads to deforestation that causes soil fertility reduction (Temesgen and Yonas zeslase, 2017).

Table 2.2: Ethiopia total energy consumption in 1998.

Energy type	Percentage (%)
Biomass	94
Petroleum	5
Electricity	1
Total	100

Source: (Temesgen and Yonas zeslase, 2017).

During harvesting crops only 30% to 40% contribute grain, fruits coffee, pods and tubers from the total biomass. Which means 60% to 70% of the total agricultural biomass is waste biomass from annually produced crops in Ethiopia. A little part of it used as fodder for cattle, but the remaining just wasted (Bogale, 2009) and the adoption and promotion of briquette technology has diversified environmental, Social and economic benefits such as : briquettes have uniform size and quality and fit with stove and burner, since it is smokeless avoid health problem or reduce indoor air pollution, which is easy to handle ,transport and store and reduce sanitation and disposal problem, reduce GHG emission, has long burning time and can create employment and source of income (Tekle, 2017)**.**

Agricultural wastes of Banana leaves briquettes have a potential to use as biomass fuel for energy generation. By increasing the compaction of wastes is increasing the energy density and reducing the problems associated with their disposal in the environment (Oliveira *et al.*, 2014).

2.3.2. Process to make a briquette

The process to produce a briquette will includes carbonization, feed stocks preparation, mixing with binder, compaction or production of briquette and drying.

Carbonization is a process of avoiding of volatile compounds and moisture that leaving a fuel with a higher proportion of carbon is carbonization or partial paralysis. In which the conversion process is controlled that reduce harmful emission.

Table 2.3: Carbonization methods comparison

Methods of carbonization	Yield %	Duration	Capital investment	Labour intensity	Cost US$
Earth pit kilns	10-15	Days	Low	High	0
Brick and steel kilns	25-30	Hours	Medium/high	Medium	50-200
Large scale plants or retorts	30-40	Continuously	High	Low	3000-5000

Source: (Ferguson, 2012)

Feedstock preparation in which first the feedstock must be in a powder form before compacting in to briquette and small particle forms like sawdust and rice husks not need powdering but others like bagasse,straw and large charcoal fines need powdering which can be crushed ,chopped manually or using mechanized then keep the consistency of powder by sieving.

Mixing with Binding in which the process of sticking together compacted materials. Without the addition of extra binding agents biomass materials can be bind with high temperature and pressure. Additional binding agents need in locally made briquette that activates the binding process commonly known binders include: cassava flour, molasses, wheat flour, fine clay and red soil.

Drying (before carbonization and after briquette production) for east African briquette producers drying is critical process. Noncarbonized briquettes of feedstock require 13% of moisture content of drying before going to the briquette machine and 10% of moisture content drying is preferred before carbonization for effective process. To dry the briquettes fully after its production with sun it takes 3-4 days.

Compaction (production of briquettes by compaction) for this processes a number of machines and techniques have been developed in worldwide to produce briquettes in different scales. The common types of briquetting machines include:

Piston extruders: These are large machines relatively in which a heavy piston that pressurized biomass material through a tempered die and which used to produce non-carbonized briquettes.

Screw extruders: Extrude briquettes in a die which uses a screw action and powered by electric motor.

Roller presses: To make charcoal briquettes roller press is the most common and which used by the largest east African producers of carbonized briquettes. Low capital manual techniques used for carbonized and non-carbonized feedstock in developing countries of briquettes production in rural societies where no industrial technologies accessibility (Ferguson, 2012).

2.3.3. Common binder agents in briquette production

Raw materials like charcoal without plasticity and charcoal dust cannot hold in to shape without adding a binding agent and the common binding agents include:

Starch produced from maize, cassava, wheat, sweet potatoes and rice powder which is used in small scale projects and that has good results of briquettes by contributing calorific value with percentage in the mixture from 4-8% and not increased ash content but expensive .

Clay soils which are cheap and suitable for briquettes production but the percentage not more than 15% in the mixture since it increased ash content and not contribute to calorific value.

Gum Arabic or **Acacia Gum** which used in semi-industrial applications with percentage of less than 10% in the mixture and contribute calorific value and not increased ash content in the briquette that produced which has medium to high cost.

Molasses produced from sugarcane which is used in semi-industrial applications with percentage of 20% in the mixture and contribute calorific value but increased ash content in the briquette that produced and has medium to high cost (BTG Biomass Technology Group BV, 2013).

3. MATERIALS AND METHODS

3.1. Description of the study area

This study were conducted in Addis Ababa which is the capital city of Ethiopia and currently includes 10 sub cities and 116 woredas with 6 inlets and outlets to other regions of Ethiopia namely: Gojjam Ber, Dessie Ber, Kality old Ber, Kality new (Tuludimtu) Ber, Jimma Ber and Wolega Ber and the city is located between 9.03^0 N latitude and between 38.74^0 E longitude. The city has an area of 530.14km^2 and it has cool to warm climate that influenced by the altitude and that show the temperature difference from 10^0C up to 22^0C depending on the elevation and wind pattern. It has 2,326 meters to 3,000 meters altitude ranges above sea level (Alem *et al.*, 2010).

Addis Ababa has a total population of 3,434,000 from these population 1,625,000 represent males and1,809,000 females (CSA, 2013).

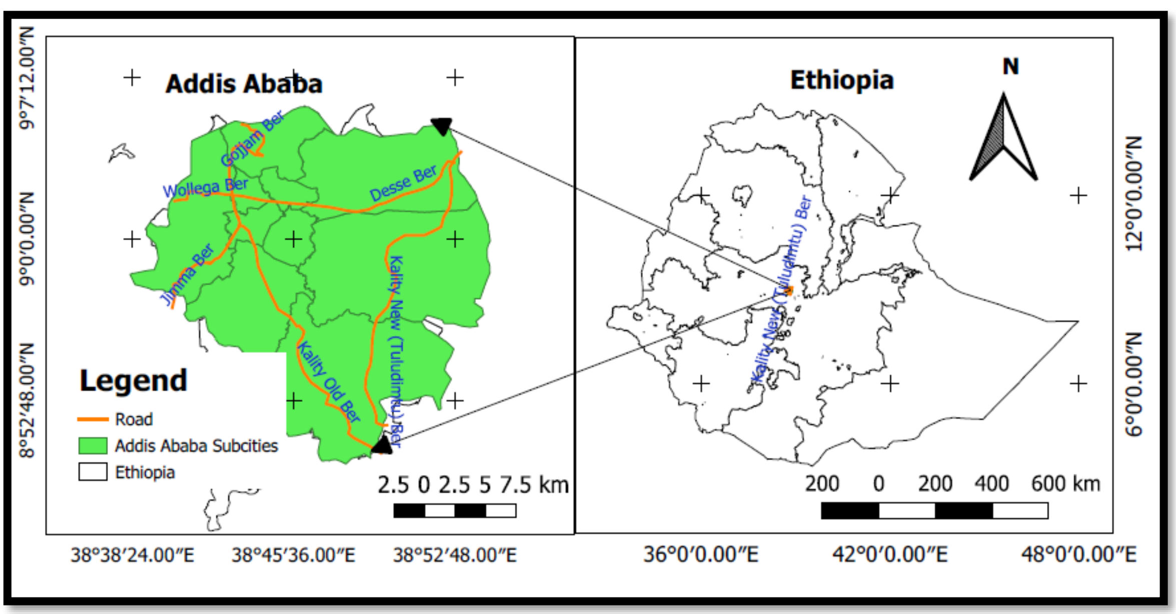

Figure 3.1: Map of the study Area

3.2. Sample material collection and experimental testing

3.2.1. Materials and equipments

The materials that used in this study were wastes of banana bunch and banana peel, water and clay soil. The equipments that used in the laboratory were oxygen bomb calorimeter, electrical furnace, oven, meter, crucibles, stopwatch, digital balance, beehive briquette mold press machine, and stoves.

3.2.2. Conceptual framework of the study

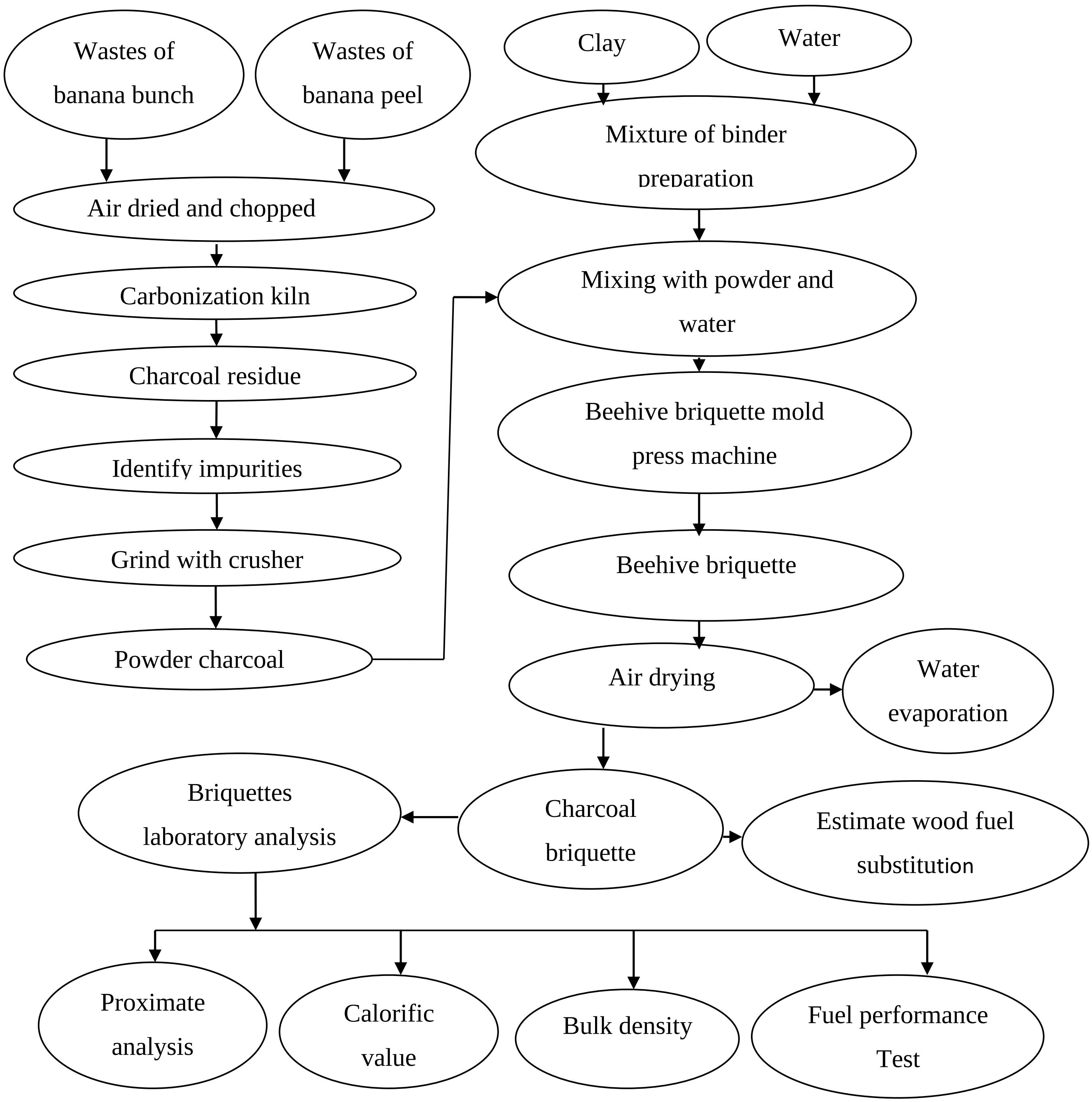

Figure 3 2: Conceptual frame work of the study.

Adopted from (United Nations Development Programme, 2009)

3.3. Carbonization process

The samples were collected randomly from Addis Ababa City Arada Subcity Atikilt Terra from banana distributer, retailer and juice houses. This subcity is selected purposely for the sampling because Atikilt Terra found in this subcity where high exchange of fruits and vegetables including banana in the city of Addis Ababa due to that reason a lot of banana distributer, retailers and juice houses found in the sub city. The banana bunch and banana peel samples were taken to Ministry of water, Irrigation and Energy Work shop and Laboratory compound and the banana bunch chopped in to small pieces to fit the carbonization kiln and for equal distribution of heat during sun drying and carbonization.

Figure 3.3: Banana bunch sample that is prepared for carbonization process
a) Wet banana bunch sample b) Wet banana bunch sample preparation c) Dry banana bunch sample

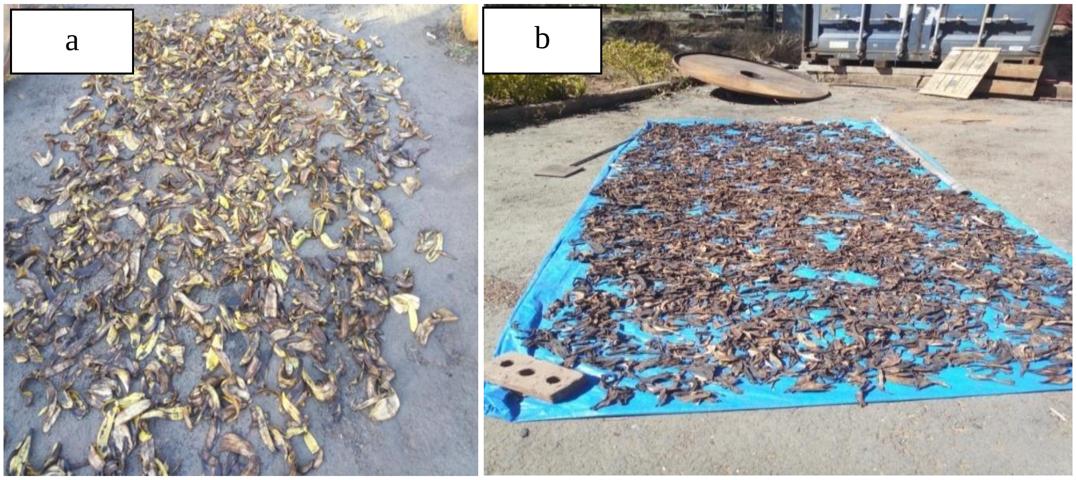

Figure 3.4: Banana peel sample that prepared for carbonization process

a) Wet banana peel sample b) Dry banana peel

The wet collected banana bunch and banana peel samples were 685.89 kg and 323.38 kg and after sun drying with moisture content of 0.6% and 2.53% the sample became 51kg and 48 kg respectively. A metal kiln were used which operates manually and has a capacity to hold 15 kg of sun dried banana bunch and banana peel wastes separately for one cycle. Then the sun dried samples were filled in to the metal kiln and fired through the opening and by following attentively the fire through the drum kiln side openings closed each of them when fire seen in the opening to protect air that may change the sample to ash so the burning process will be slow in the absence air or proper controlling of air and the fire will be spreads to the biomass through the holes (Sugumaran.p *et al,* 2010) and all side openings closed in this way and when the smoke become thinner and thinner and become light blue the main opening covered with mud around its cover and the top smoke opening covered with metal. Then finally after cooling of the drum kiln opened in the morning and charcoal and ash separated and measured their weight and the drum kiln carbonization conversion efficiency.

Figure 3.5: During carbonization process

a).Input sample to kiln preparation b) Carbonization in the kiln c) Output after carbonization

3.3.1. Mass conversion efficiency

The conversion efficiency of mass of banana bunch and banana peel in carbonization were estimated as the ratio of output mass after carbonization and input mass before carbonization according to (Nitin *et al*, 2014).

Mass conversion efficiency% = output mass after carbonization (kg) / Input mass before carbonization (kg) (3.1)

3.4. Briquette production process

Briquetting is the way of changing from low bulk density to high bulk density with energy concentrated briquettes. Preparation of briquettes involves a cost effective binders that used in the process (Sugumaran.p *et al*, 2010) and the binders were with 15% clay content using clay binder greater than 15% makes more ash in the briquette that reduce the quality of fuel briquette (Gebresas *et al.*, 2015) and clay soils which are cheap and suitable for briquettes production but the percentage not more than 15% in the mixture since it increased ash content and not contribute to calorific value (BTG Biomass Technology Group BV, 2013) and briquettes were produced from wastes of banana bunch ,banana peel and mixture of 50% banana bunch and 50% banana peel using carbonized and crushed powder with 15% clay soil binder ratio in this study.

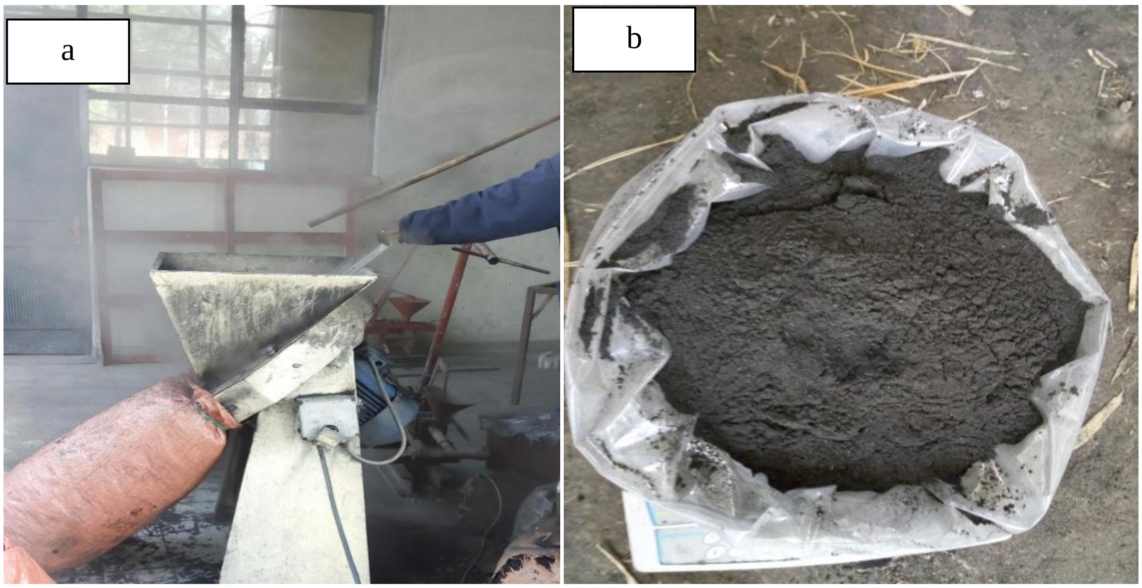

Figure 3.6: Carbonized powder preparation for briquette production

a) Grinding carbonized banana waste with machine b) Carbonized powder

Figure 3.7: Briquette production

a).Beehive coal machine b) Produced sample briquette

3.5. Briquettes characterization

3.5.1. Proximate analysis

According to (ASTM D5142-02a, 2003) standard test methods for proximate analysis samples of banana wastes and briquettes were analyzed .Each proximate terms defined and calculated as follows:

3.5.1.1. Determination of moisture content

The moisture content of briquettes of banana bunch and banana peel were determined by heating in the drying oven that of weighed 1gm sample in crucibles without the covers at 105°C for 1hr.The moisture content in percentage from the sample analysis were calculated as follows:

$$MC\% = [(W-B)/W] \times 100 \tag{3.2}$$

Where:

MC%=Moisture content in percentage

W = Weight of specimen used, g and

B = Weight of specimen after drying in moisture test in g

3.5.1.2. Determination of volatile matter

The volatile mater of banana bunch and banana peel briquettes were determined by placing the crucibles in the furnace that heated to 950 °C and hold for 7 min at this temperature. The volatile matter contents were calculated from the sample analysis in percentage as follows:

$$VM\% = [(B-C)/W] \times 100 \tag{3.3}$$

Where:

$VM\%$ = Volatile matter in percentage

C =Weight of specimen after heating in volatile matter test in g.

3.5.1.3. Determination of ash content

The ash content of briquettes of banana bunch and banana peel were determined using the residual specimens in crucibles heated without cover in a furnace at 750 °C for 2h,then crucibles removed from the furnace ,cool in a desiccators to minimize moisture absorption and weigh the crucibles as soon as possible. The calculation of ash contents in a briquettes sample analyzed as follows:

$$AC\% = [(F-G)/W] \times 100 \qquad (3.4)$$

Where:

$AC\%$ = Ash content in percentage

F = Weight of crucible and ash residue in g and

G = Weight of empty crucible in g

3.5.1.4. Determination of fixed carbon content

Fixed carbon content of banana bunch and banana peel were calculated as the difference of between 100% and the sum of moisture content, volatile matter content and the ash content in percentage.

$$FCC\% = 100\% - (MC\% + VM\% + AC\%) \qquad (3.5)$$

Where:

FCC% = Fixed carbon content in percentage.

MC% = Moisture content in percentage.

VM% = Volatile matter content in percentage.

AC% = Ash content in percentage

3.5.2. Calorific value

Calorific value of banana bunch and banana peel briquettes specimens were analyzed by an adiabatic oxygen bomb calorimeter parr 6200. Then the samples of briquettes were milled with 1g and placed in capsule within adiabatic oxygen bomb calorie meter where the sample was combusted and gross calorific value recorded in calories per gram equivalents according to (ASTM D5865-12, 2016).

3.5.3. Banana bunch, banana peel and their mixture briquettes physical property

3.5.3.1. Bulk density

Bulk density of banana bunch, banana peel and their mixture briquettes were calculated as the ratio of the mass of the briquette and volume of the briquettes (Jain *et al.*, 2014).

The bulk density was calculated as follows:

Bulk density =Mass of briquette/Volume of briquettes (3.6)

Mass of briquettes that was produced in kg

Volume of briquettes (V) $= (\Pi /4) \times D^2 \times H$ (3.6.1)

Where:

Π=3.14

D = Diameter of a briquette

H =Height a briquette

3.5.4. Briquettes performance Test

3.5.4.1. Water boiling test

The produced briquettes of banana bunch and banana peel were tested with 0.5L, 1L and 2L (Liters) of water were boiled and through the combustion of briquettes its durability or rate of burning ,spark, smokes were analyzed practically (Sintayehu *et al.*, 2017).

3.5.4.2. Burning rate of briquettes

Rate of burning of a briquette were evaluated from a sample briquette combusted completely per a given period of time that recorded and calculated as follows(Jain *et al.*, 2014).

Rate of burning = Mass of briquette / Total time taken in combustion (3.7)

3.5.5. Total emission test

Briquettes that produced were tested its emission in MOWIE alternative energy development and promotion directorate laboratory and workshop where gaseous emission or concentration of O_2, CO, CO_2, NO, NO_X were analyzed by placing Testo 3320-LL model gas analyzer prope at 750mm from the boiler's flue gas outlet (Kažimírová and Opáth, 2016).

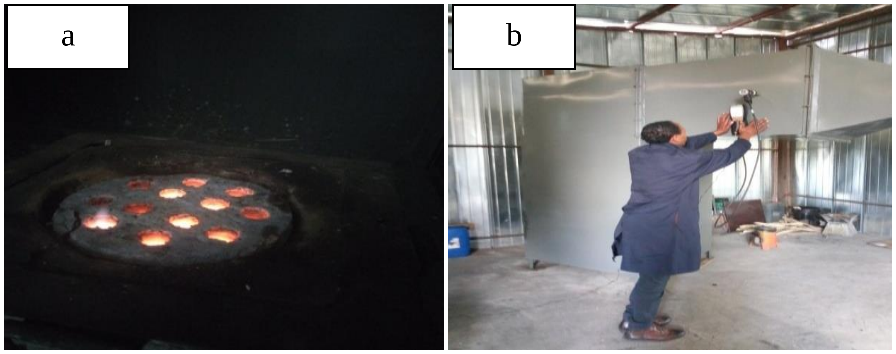

Figure 3.8: Total emission test of the produced briquettes
a) Briquette during burning b) Emission test during burning of briquette

3.6. Potential of wastes of Banana bunch and banana peel and fuel wood substitution

3.6.1. Potential of wastes of banana bunch and banana peel

The potential of banana were estimated using the data that collected from the number of trucks (ISUZU and FSR) that loads banana and enters to Addis Ababa through six inlets at the check points such as Gojjam Ber, Dessie Ber, Kallity old Ber, Kallity new (Tuludimtu) Ber , Jimma Ber and Wollega Ber two times for seven days per week which adopted from (Alem *et al.*, 2010) that uses 7days per week for supply data recording one time, but in this study two time data for two weeks were used for two different month to increase data quality that means data were taken at the inlet check point for one week of 7 consquetive days with minimum supply of banana at October end the beginning of November and one week for 7 consquetive days with maximum supply at January first since the price is minimum at January and slightly increase from August to October according to (Alemu and Dagnew, 2008) then the average value were taken to estimate the banana supply potential that enters to Addis Ababa by taking the difference between total trucks that load banana and enters to Addis Ababa and total trucks that load banana and out from Addis Ababa.

Banana bunch waste were estimated by taking 50kg of banana with bunch from which average banana bunch waste estimated by triplicate measurement then yearly total banana bunch waste were estimated according to total banana potential that estimated based on one ISUZU load on average from 5 to 5.5 tone and one FSR 8 to 9 tone of banana (Woldu *et al.*, 2015) and banana peel waste potential were estimated as: first the difference between the total banana potential and banana bunch waste potential were un-ripe banana and from these un-ripe banana ripe banana were estimated by taking one kilogram of un-ripe banana then measured after ripe and banana peel waste that generated were estimated using a triplicate measurement and based on that yearly banana peel waste were estimated.

Figure 3.9: Banana waste and its measurement to estimate the potential

a) Banana supply at “Atikilt Terra” Addis Ababa b) Banana bunch waste at “Atikilt Terra” Addis Ababa   c) Banana waste measurement

3.6.2. Energy potential of wastes of banana bunch and banana peel

Energy potential of wastes of banana bunch and banana peel were estimated from the calorific value that were analyzed in the laboratory and from wastes of banana bunch and banana peel potential .The annual energy potential were estimated from the annual potential of wastes of banana bunch and banana peel by considering how much energy produced from its calorific value per 1kg.

3.6.3. Fuel wood substitution

Fuel wood substitution was estimated based on the calorific value of the briquettes by estimating the energy value per one kilogram sample based on:1 KJ/kg =0.2389 cal/gm (FAO, 1985).Then based on the total kilogram per year for each briquettes total energy potential were estimated and the charcoal substituted by that total energy potential were estimated based on:1 kg charcoal =30,800KJ energy produced (FAO, 1999) and The fuel wood substitution estimated based on:1 ton of charcoal = 6 m^3 fuel wood substituted (FAO, 1999).

Finally the amount of CO_2 that were reduced due to that fuel wood substitution was estimated according to:1ton of charcoal = 1.1 ton of CO_2 emission avoided (Girard, 2002).

3.7. Data Analysis

Data were collected, recorded from laboratory analysis in MOWIE Alternative energy Development and promotion Energy Laboratory and workshop center, Geological survey of Ethiopia and the banana potential at the six inlets of Addis Ababa and the waste potential measurement at fruit and vegetable trading business unit (Etfruit). In data analysis triplicate test were used and finally data were processed and analyzed using descriptive statistics and Microsoft excel.

4. RESULTS AND DISCUSSIONS

4.1. Carbonization efficiency

The conversion efficiency of the carbonization of air dried banana bunch and banana peel to charcoal is 37.73% and 37.82% at moisture content of 0.6% and 2.53% respectively as shown in (Table 4.1).

Table 4.1: Carbonization efficiency**.**

Sample to be carbonized	Input(kg)	Output (kg)	carbonization Conversion efficiency
Air dried raw banana bunch sample	15	5.66±0.05	37.73±0.03
Air dried raw banana peel sample	15	5.67±0.03	37.82±0.18

Data were means ±SD

In this study, the carbonization efficiency is relatively good comparing with a typical yield of metal kiln at 15% moisture content is 30% and the charcoal yield influenced moisture content, type of kiln, type of biomass, climatic conditions oxygen supply and pressure (United Nations Development Programme, 2009).

4.2. Proximate analysis, calorific value and physical properties of banana waste sample

4.2.1. Proximate analysis and gross calorific value of un-carbonized air dried banana bunch and banana peel.

Air dried banana bunch and banana peel could have 0.6% and 2.53% moisture content, 61.65% and 65.48% volatile matter, 10.19% and 17.68% fixed carbon content, 27.57% and 14.31% ash content and 2975.20 cal/gm and 3891.99 cal/gm calorific value respectively and air dried raw banana peel has higher calorific value comparing with air dried raw banana bunch waste sample as shown in (Table 4.2).

Table 4.2: Proximate analysis and gross calorific value of un-carbonized air dried banana bunch and banana peel.

Sample type	Proximate analysis (%)				Calorific value(cal/gm)
	MC (%)	VM (%)	FC (%)	AC (%)	CV(cal/gm)
Air dried raw banana bunch sample	0.60±0.05	61.65±1.52	10.19±0.85	27.57±0.33	2975.20±133.99
Air dried raw banana peel sample	2.53±0.16	65.48±1.33	17.68±1.39	14.31±0.57	3891.99±191.27

Data were mean value ±SD

4.2.2 Proximate analysis and gross calorific value of carbonized banana bunch and banana peel sample

Carbonized banana bunch and banana peel powder could have 0.92% and 0.60% moisture content, 27.60% and 25.62% volatile matter, 16.08% and 42.14% fixed carbon content, 55.40% and 31.65% ash content and 2327.06 cal/gm and 4684.56 cal/gm calorific value, respectively as shown in (Table 4.3) and carbonized banana peel powder could have lower ash content and high fixed carbon that leads to higher calorific value than carbonized banana bunch relatively.

Table 4.3: Proximate analysis and gross calorific value of carbonized banana bunch banana peel sample

Sample type	Proximate analysis (%)				Calorific value(cal/gm)
	MC (%)	VM (%)	FC (%)	AC (%)	CV(cal/gm)
Carbonized banana bunch sample	0.92 ±0.17	27.60 ±0.82	16.08 ±0.77	55.40 ±0.22	2327.06 ±135.21
Carbonized banana Peel sample	0.60 ±0.13	25.62 ±1.11	42.14 ±1.06	31.65 ±0.85	4684.56 ±126.44

Data were mean value ±SD

4.2.3 Proximate analysis and physical properties of briquettes produced from carbonized banana bunch, banana peel and mixture of banana bunch and peel waste sample

Briquettes were produced from carbonized banana bunch, banana peel and mixture of banana bunch and banana peel powder and 15% clay soil powder used as a binder and which could have 5.17%, 0.31% and 0.60% moisture content, 28.65%, 25.81% and 26.48% volatile matter ,19.10%,48.82% and 33.99% fixed carbon,47.08%,25.06% and 38.93% ash content , 2758.73 cal/gm ,5751.07 cal/gm and 4271.38 cal/gm calorific value and 0.74 gm/cm^3,0.47 gm/cm^3 and 0.53 gm/cm^3 bulk density of the produced briquette respectively as shown in (Table 4.4) and the banana peel briquette would have lower moisture content, lower ash content and higher fixed carbon that leads to higher calorific value than banana bunch and the mixture briquette relatively.

Table 4.4: Proximate analysis and physical properties of sample briquette

Sample briquette type	Proximate analysis (%)				Calorific value	Physical property
	MC (%)	VM (%)	FC (%)	AC (%)	CV(cal/gm)	BD(gm/cm^3)
Banana bunch Briquette	5.17 ±0.57	28.65 ±0.90	19.10 ±1.81	47.08 ±1.71	2758.73 ±95.83	0.74 ±0.03
Banana peel Briquette	0.31 ±0.08	25.81 ±1.62	48.82 ±1.89	25.06 ±1.65	5751.07 ±95.56	0.47 ±0.04
Banana bunch and banana peel Mixture briquette	0.60 ±0.12	26.48 ±1.31	33.99 ±1.07	38.93 ±1.22	4271.38 ±74.55	0.53 ±0.01

Data were mean value ±SD

4.2.4. Moisture content

Air dried raw banana bunch sample and air dried raw banana peel would have 0.6% and 2.53% moisture content respectively and carbonized banana bunch powder and banana peel powder would have 0.92% and 0.60% moisture content respectively and carbonized banana bunch briquette, banana peel briquette and mixture of banana bunch and banana peel briquette would have 5.17%, 0.31% and 0.60% moisture content respectively and carbonized banana bunch briquette has largest and banana peel briquette has lowest moisture content as shown in (Figure 4.1).

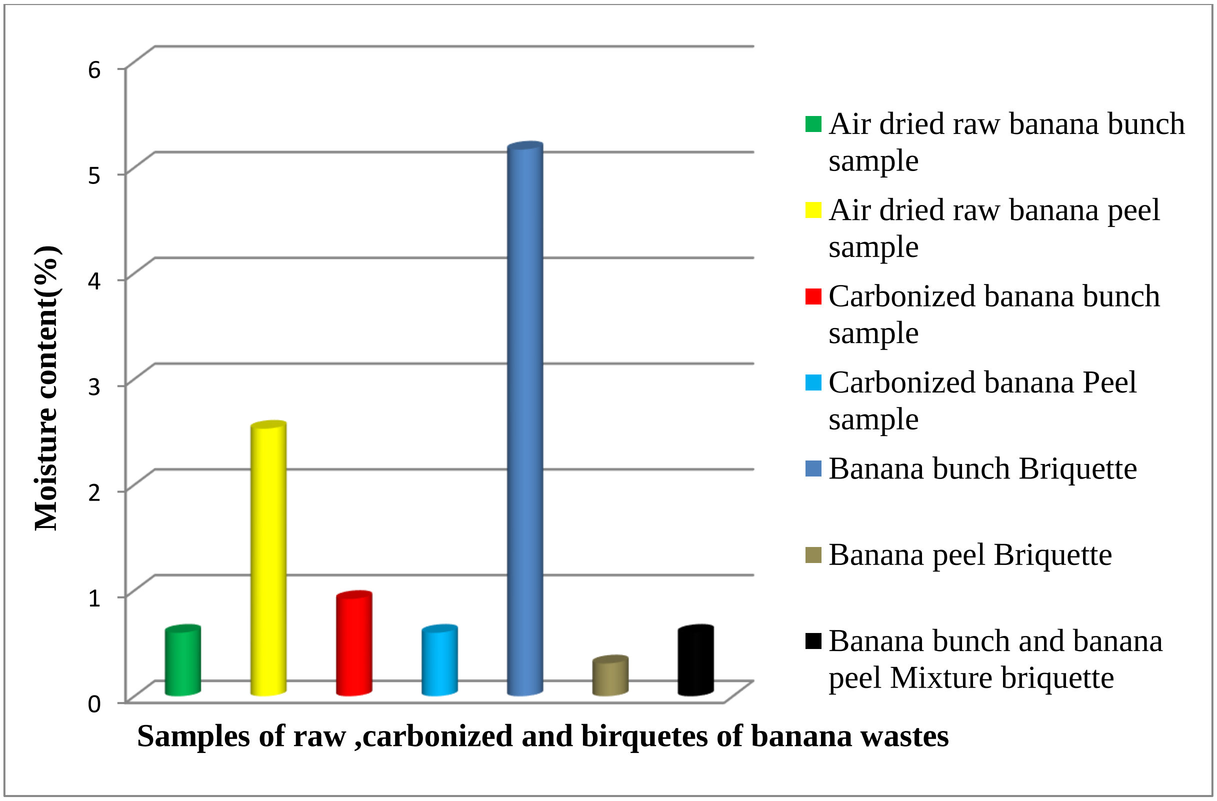

Figure 4.1: Moisture content of Samples of raw, carbonized and briquettes of banana wastes

The maximum moisture content for good quality charcoal should have 10% (FAO, 1987). The moisture content of briquettes from banana wastes in this study ranges from 0.31% to 5.17% as shown in (Figure 4.2) which full fill this criteria and from the produced banana waste briquettes banana peel briquette had the lowest moisture content of 0.31% and the highest calorific value of 5751.7cal/gm as shown in (Table 4.4) which agrees to that lower moisture content results for higher calorific value (FAO, 1985) .

The produced briquettes of banana bunch, banana peel and mixture of banana bunch and banana peel of this study have lower moisture content comparing to banana leave briquette (Oliveira *et al.*, 2014) ,Teppi coffee husk and pulp briquettes (Merete *et al.*, 2014) and saw dust briquette, bagase, sawdust, carbofirewood and eucalyptus fire wood (Eduardo *et al.*, 2014) .

4.2.5. Volatile matter

Air dried raw banana bunch and banana peel would have 61.65% and 65.48% volatile matter, respectively and carbonized banana bunch powder and banana peel powder would have 27.60% and 25.62% volatile matter respectively and carbonized banana bunch briquette, banana peel briquette and mixture of banana bunch and banana peel briquette would have 28.65%, 25.81% and 26.48% volatile matter respectively as shown in (Figure 4.3).

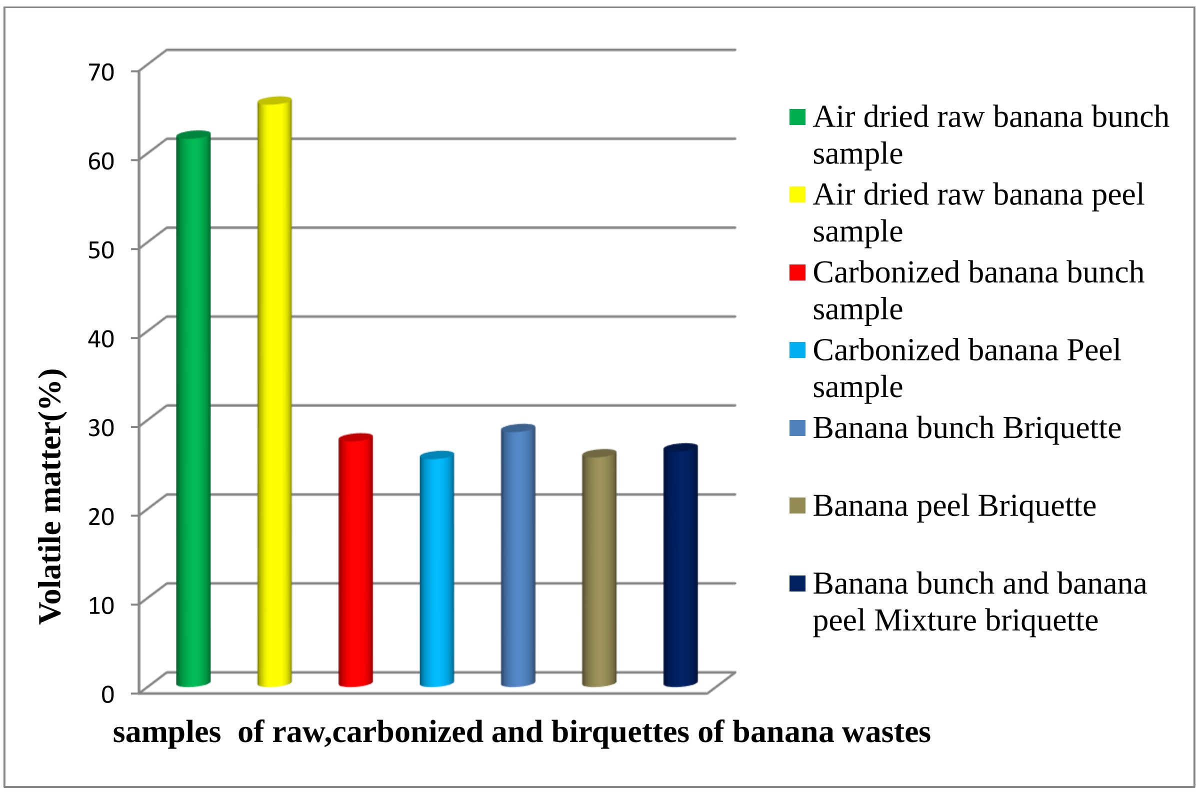

Figure 4.2: Volatile matter of Samples of raw, carbonized and briquettes of banana wastes

Air dried raw banana bunch and air dried raw banana peel had highest volatile matter of 61.65% and 65.48 % since not carbonized and not in line with described range that volatile matter of charcoal vary from maximum 40% to a minimum of 5% or less than 5% (FAO,

1985) but the carbonized banana bunch and carbonized banana peel as well as the banana waste briquettes of carbonized banana bunch, banana peel and the mixture of banana bunch and banana peel lies in the range of 25.62% to 28.65% of volatile matter as shown above in (Figure 4.4) that fulfill good marketable charcoal has a net volatile matter of 30% (FAO, 1985).

The produced briquettes of banana bunch and banana peel have greater volatile matter comparing to banana bunch and banana peel briquette of (Sumrit and Vijitr, 2017) and Teppi coffee husk and pulp briquettes (Merete *et al.*, 2014) to some extent but have lower volatile matter comparing to banana leave briquette (Oliveira *et al.*, 2014) and saw dust briquette, bagase, sawdust, carbofirewood and eucalyptus fire wood (Eduardo *et al.*, 2014) as shown in (Table 4.5).

4.2.6. Fixed carbon

Air dried raw banana bunch and banana peel would have 10.19% and 17.68% fixed carbon, respectively and carbonized banana bunch powder and banana peel powder would have 16.08% and 42.14% fixed carbon respectively and briquettes of banana bunch, banana peel and mixture of banana bunch and banana peel would have 19.10%, 48.82% and 33.99% fixed carbon, respectively and banana peel briquette would have the largest fixed carbon content as shown in (Figure 4.3).

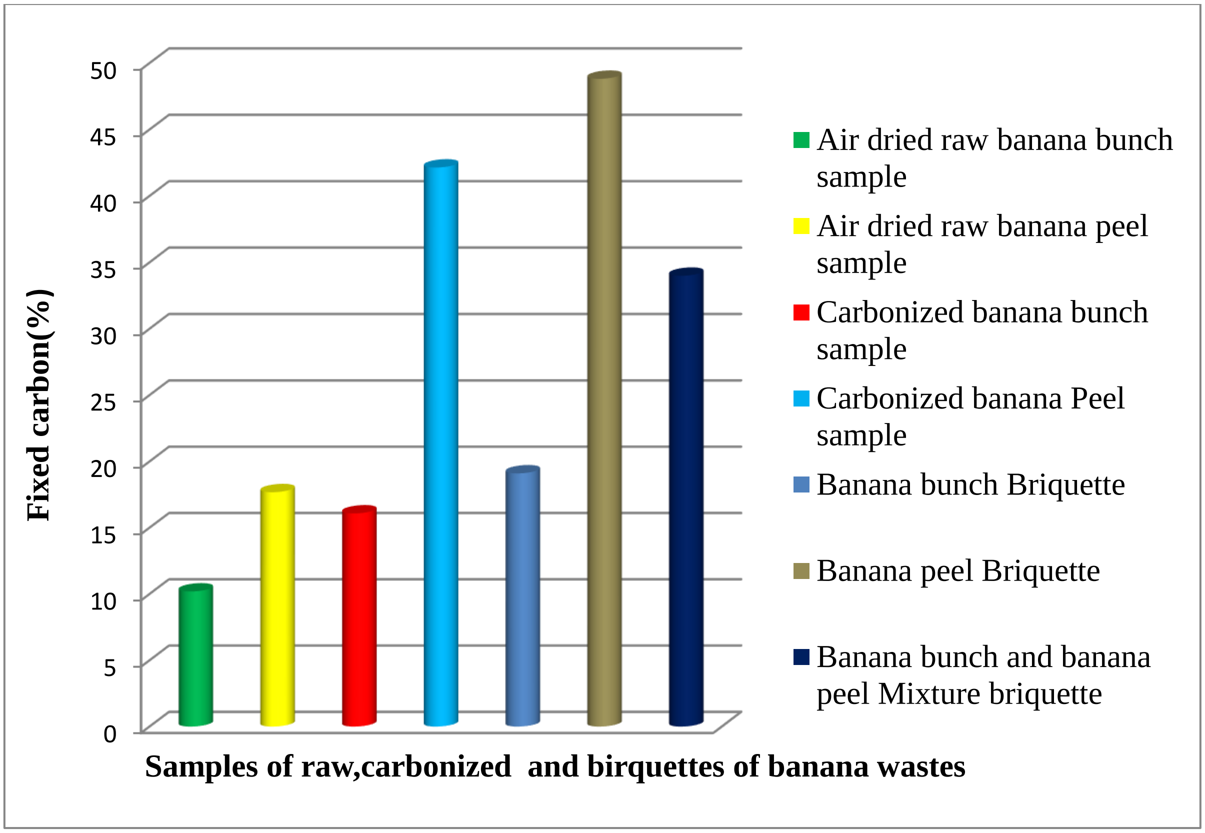

Figure 4.3: Fixed carbon of Samples of raw, carbonized and briquettes of banana wastes

The fixed carbon of charcoal vary from 50% to 95% (FAO, 1985) according to this from the produced banana waste briquettes banana peel briquette had 48.82% almost near to those ranges but the rests banana sample fixed carbon content below the ranges that described by FAO and also with this high fixed carbon content banana peel briquette had highest calorific value from the rests of banana samples as shown in (Figure 4.5) this in line with the high fixed carbon content result in high calorific value (FAO, 1985).

Banana bunch briquettes of this study banana bunch have lower fixed carbon content comparing to banana bunch briquette of (Sumrit and Vijitr, 2017) but the banana peel briquettes of the present study would have greater fixed carbon content comparing to banana bunch and banana peel briquettes of (Sumrit and Vijitr, 2017) and also briquettes of banana bunch, banana peel and mixture of banana bunch and banana peel of the present study have greater fixed carbon content comparing to banana leave briquette (Oliveira *et al.*, 2014) and saw dust briquette, bagase, sawdust, carbofirewood and eucalyptus fire wood (Eduardo *et al.*, 2014) and lower fixed carbon content comparing to Teppi coffee husk briquettes (Merete *et al.*, 2014) and charcoal (Eduardo *et al.*, 2014) as shown in (Table 4.5).

4.2.7. Ash content

Air dried raw banana bunch and banana peel would have 27.57%and 14.31% ash content respectively and carbonized banana bunch powder and banana peel powder would have 55.40% and 31.65% ash content respectively and carbonized banana bunch briquette, banana peel briquette and mixture of banana bunch and banana peel briquette would have 47.08%, 25.06% and 38.93% ash content respectively as shown in (Figure 4.4).

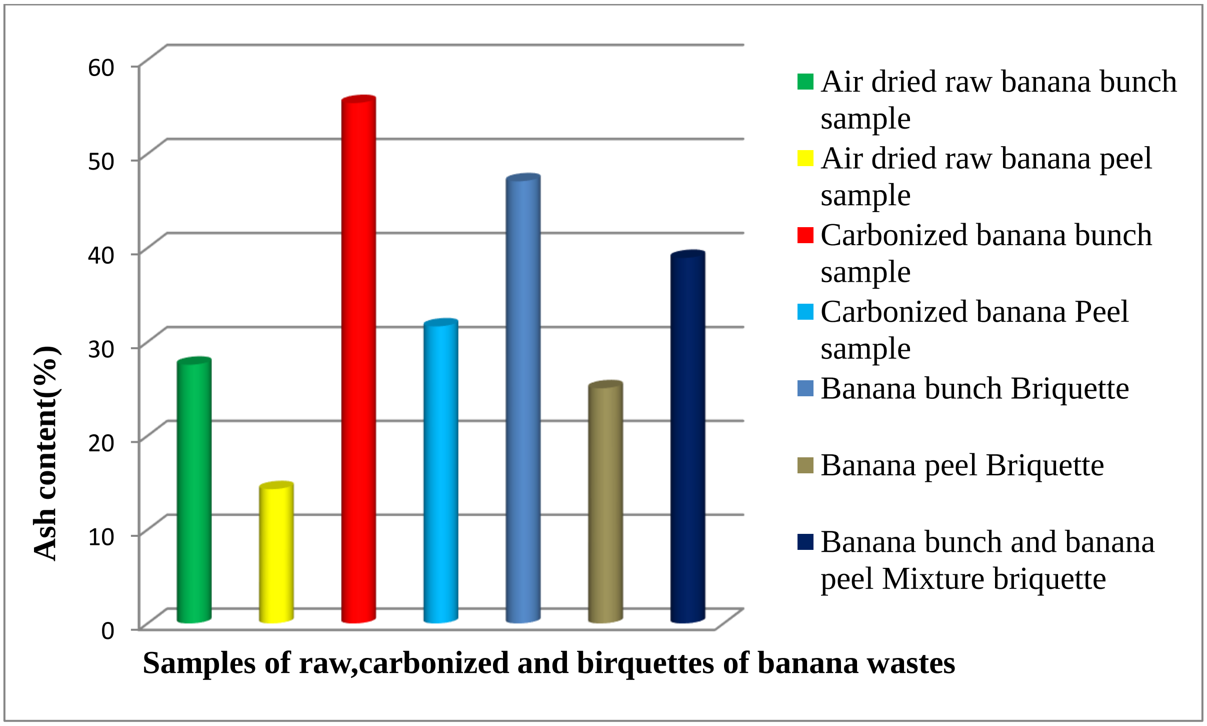

Figure 4.4: Ash content of Samples of raw, carbonized and briquettes of banana wastes

Air dried raw banana peel sample and banana peel briquette would have the lowest ash content relatively as shown in (Fig 4.4).

Usually ash content of good quality charcoal vary from 3% to 4% (FAO, 1987) but the ash content of banana wastes had greater value than the criteria described by FAO as shown above (Fig 4.4) that might be due to the binder of clay soil and the briquettes made from the banana wastes which also not like hard wood species since for different wood species ash content of charcoal vary from 0.5% to 5% or more (FAO, 1985).The produced briquettes of banana bunch and banana peel have greater ash content comparing to banana leave briquette (Oliveira *et al.*, 2014) ,Teppi coffee husk and pulp briquettes (Merete *et al.*, 2014) and charcoal saw dust briquette, bagase, sawdust, carbofirewood and eucalyptus fire wood (Eduardo *et al.*, 2014) but banana peel briquettes have lower ash content comparing to banana peel briquettes of (Sumrit and Vijitr, 2017) as shown in (Table 4.5).

4.2.8. Calorific value

Air dried raw banana bunch and banana peel would have 2975.20 cal /gm and 3891.99 cal /gm calorific value respectively and carbonized banana bunch powder and banana peel powder would have 2327.06 cal /gm and 4684.56 cal/gm calorific value respectively and briquettes of banana bunch, banana peel briquette and mixture of banana bunch and banana peel would have 2758.73 cal/gm, 5751.07 cal/gm and 4271.38 cal/gm calorific value respectively as shown in (Figure 4.5).

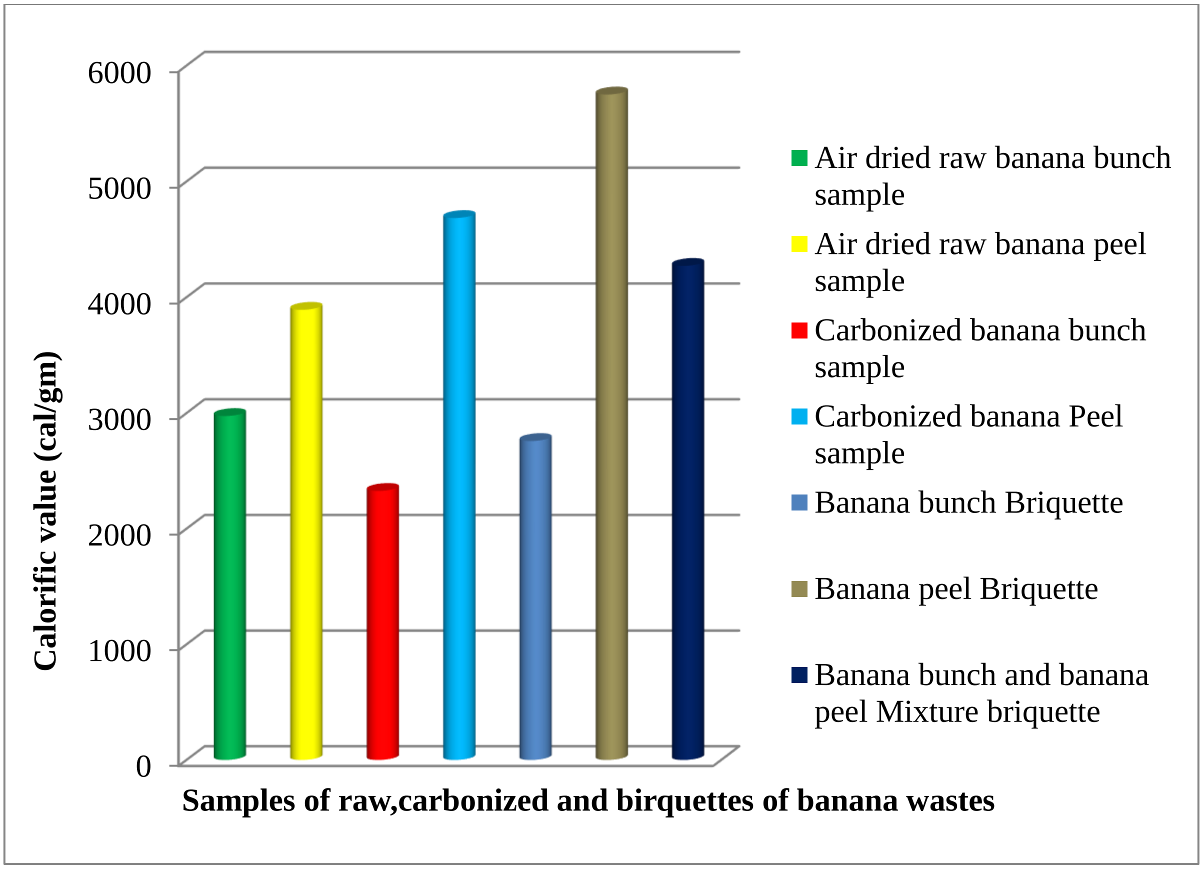

Figure 4.5: Calorific value of samples of raw, carbonized and briquettes of banana wastes

High calorific value is the result of high fixed carbon content (FAO, 1985) according to this criteria the banana peel briquette had highest calorific value with highest fixed carbon from the different banana samples as shown in (Fig 4.5) and (Fig 4.3) respectively in present study. Briquettes of banana bunch in present study have the lowest calorific value comparing to banana bunch briquettes of (Sumrit and Vijitr, 2017), banana leave briquette (Oliveira *et al.*, 2014), Teppi coffee husk and pulp briquettes (Merete *et al.*, 2014) and charcoal saw dust briquette, bagase, sawdust, carbofirewood and eucalyptus fire wood (Eduardo *et al.*, 2014) but briquettes of banana peel in present study would have the greatest calorific value comparing to banana peel briquettes of (Sumrit and Vijitr, 2017), banana leave briquette (Oliveira *et al.*, 2014), Teppi coffee husk and pulp briquettes (Merete *et al.*, 2014) and saw dust briquette, bagase, sawdust, carbofirewood and eucalyptus fire wood (Eduardo *et al.*, 2014) as shown in (Table 4.5).

4.2.9. Bulk density

Briquettes of banana bunch, banana peel briquette and mixture of banana bunch and banana peel would have 0.74gm/cm^3,0.47gm/cm^3 and 0.53gm/cm^3 bulk density respectively as shown in (Figure 4.6).

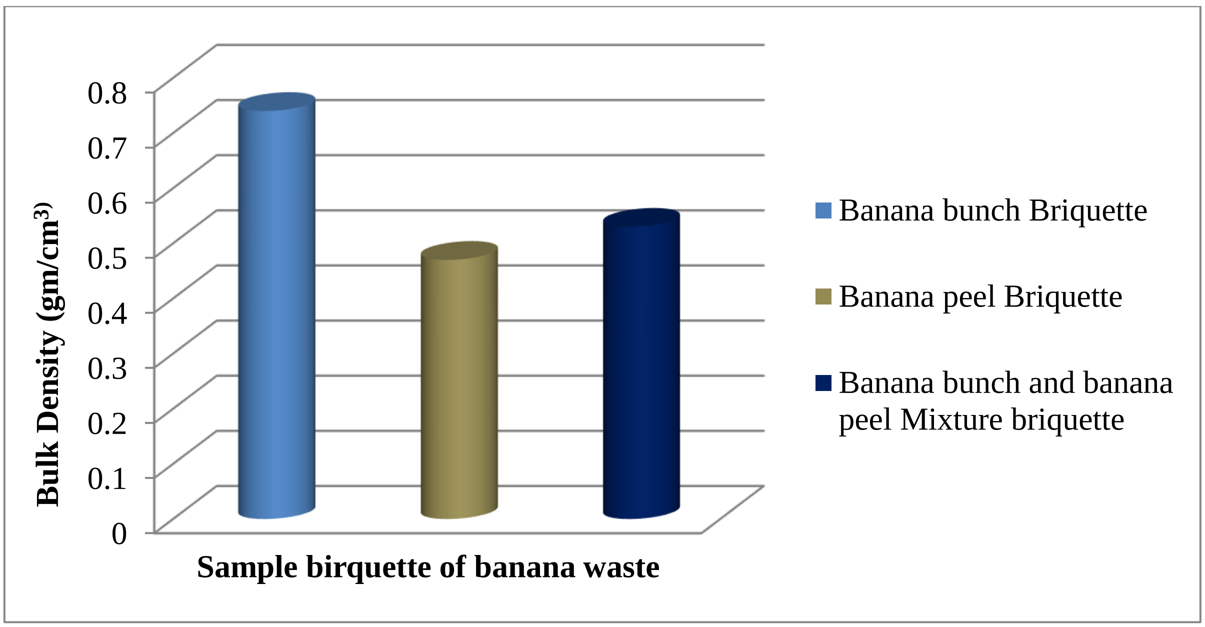

Figure 4.6: Bulk density of Sample briquettes of banana

Briquettes of banana bunch and banana peel of this study have lower bulk density comparing to banana leave briquettes of (Oliveira *et al.*, 2014) sawdust briquette and carbofirewood (Eduardo *et al.*, 2014) but higher bulk density comparing to Teppi coffee pulp briquettes (Merete *et al.*, 2014) and bagase, sawdust (Eduardo *et al.*, 2014) as shown in (Table 4.5).

Table 4.5: Comparison of this study proximate analysis and physical properties of sample briquette with other study

Measurement	Briquettes from Banana waste (Present study)			(Sumrit and Vijitr, 2017).		(Oliveira *et al.*, 2014)	(Merete *et al.*, 2014)	
	Banana bunch briquette	Banana peel briquette	Mixture of banana bunch and banana peel	Banana bunch briquette	Banana peel briquette	Banana leave briquette	Teppi coffee husk	Teppi coffee pulp
MC (%)	5.17 ±0.57	0.31 ±0.08	0.60 ±0.12	-	-	7.17 ±0.31	6.18 ±0.25	11.33 ±2.21
VM (%)	28.65 ±0.90	25.81 ±1.62	26.48 ±1.31	24.83	24.06	75.30 ±0.85	22.32 ±2.83	24.12 ±1.55
FC (%)	19.10 ±1.81	48.82 ±1.89	33.99 ±1.07	37.14	34.80	14.00 ±1.52	58.95 ±2.80	42.4 ±1.42
AC (%)	47.08 ±1.71	25.06 ±1.65	38.93 ±1.22	38.03	41.14	10.70 ±1.03	12.54 ±0.47	22.14 ±1.03
Average calorific value(cal/gm)	2758.73 ±95.83	5751.07 ±95.56	4271.38 ±74.55	5,434.09	5,115.51	4,228.53 ±47.78	5,041.1 ±168.60	4037.6 ±219.39
BD(gm/cm^3	0.74 ±0.03	0.47 ±0.04	0.53 ±0.01	-	-	0.99 ±0.05	0.65 ±0.07	0.44 ±0.03

Measurement	Briquettes from Banana waste (Present study)			(Eduardo *et al*., 2014)					
	Banana bunch briquette	Banana peel briquette	Mixture of banana bunch and banana peel	Charcoal	Sawdust briquette	Bagasse	Sawdust	Carob firewood	Eucalyptus Firewood
MC (%)	5.17 ±0.57	0.31 ±0.08	0.60 ±0.12	4.76	10.00	67.1	15.8	17.4	18.7
VM (%)	28.65 ±0.90	25.81 ±1.62	26.48 ±1.31	24.96	83.41	86.00	82.89	82.28	89.31
FC (%)	19.10 ±1.81	48.82 ±1.89	33.99 ±1.07	73.51	15.29	12.06	16.32	16.8	10.48
AC (%)	47.08 ±1.71	25.06 ±1.65	38.93 ±1.22	1.53	1.3	1.94	1.39	0.92	0.21
Average calorific value(cal/gm)	2758.73 ±95.83	5751.07 ±95.56	4271.38 ±74.55	7,358.12	4,730.22	4,132.97	4,515.21	4,610.77	4,658.55
BD(gm/cm^3)	0.74 ±0.03	0.47 ±0.04	0.53 ±0.01	0.68	0.89	0.169	0.22	0.82	0.63

4.3. Briquette combustion test

4.3.1 Water boiling Test

Briquettes of banana bunch, banana peel and mixture of banana bunch and banana peel would have taken an average time to boil 0.5 litter water 22 min, 16 min, and 17min and to boil 1 litter water 25min, 20min and20 min and to boil 2litter water 34 min, 29 min and 30 min respectively and average time taken to turn ash were 2hr and 5 min, 2hr and15min and 2hr and 10 min with calorific value 2758.73cal/gm,5751.07cal/gm and 4271.38cal/gm respectively using Mirchaye-stove. Briquettes of banana peel would have taken lowest time to boil water with highest calorific value comparing to the rest banana briquette relatively (Table 4.6).

Table 4.6: Water boiling tests of briquettes banana waste and Comparison to other related study

Measurement	Briquettes from Banana waste (Present study)			Briquette from lantana camara weed species (Sintayehu *et al.*, 2017).			
	Banana bunch briquette	Banana peel briquette	Mixture of banana bunch and banana peel	Branch briquette	Leave briquette	Stem briquette	Root briquette
Average time to boil 0.5L(min)	22 ±0.81	16 ±1.25	17 ±1.24	6 ±0.75	7 ±0.85	4 ±1.05	3 ±0.97
Average time to boil 1L(min)	25 ±0.82	20 ±1.24	21 ±1.25	13 ±2.08	15±1.75	10 ±2.75	9 ±1.5
Average time to boil 2 L (min)	34 ±2.9	29 ±1.25	30 ±1.30	20 ±1.25	23 ±2	17 ±0.95	15 ±2.05

Measurement	Briquettes from Banana waste (Present study)			Briquette from lantana camara weed species (Sintayehu *et al.*, 2017).			
	Banana bunch briquette	Banana peel briquette	Mixture of banana bunch and banana peel	Branch briquette	Leave briquette	Stem briquette	Root briquette
Average time to turn to ash in (hr&min)	2:05 ±4.08	2:15 ±4.10	2:10 ±4.08	3:31 ±0.16	2:58 ±0.37	4:17 ±0.34	4:23 ±0.08
Average calorific value(cal/gm)	2758.73 ±95.83	5751.07 ±95.56	4271.38 ±74.55	5135.36 ±150.29	3690.68 ±182.0	6479.59 ±1004.51	6525.54 ±250.03

Beehive briquettes produced from banana wastes and their combustion test done by Mirchaye-stove by boiling water and during boiling no spark and smoke formation but which have taken higher time to boil 0.5L, 1L and 2 Liters of water and lesser time taken to change to turn to ash comparing to briquettes of lantana camara weed species (Sintayehu *et al.*, 2017) as shown above (Table 4.6).

4.3.2. Burning rate of briquettes

Briquettes of banana bunch, banana peel and mixture of banana bunch and banana peel would have an average burning rate of 5.37gm/min,3.14 gm/min and 3.68 gm/min respectively with calorific value 2758.73cal/gm,5751.07cal/gm and 4271.38cal/gm respectively as shown in (Table 4.7).

Briquettes of banana peel would have lowest burning rate that show it burns slowly and give more service for an average highest time for 2hr and 15 min as shown in (Table 4.6) with highest calorific value comparing to the rest banana briquette relatively.

Table 4.7: Banana waste briquettes burning rate and Comparison to other related study

Measurement	**Briquettes from Banana waste (This study)**			(Mitchell *et al.*, 2014)		
	Banana bunch briquette	**Banana peel briquette**	**Mixture of banana bunch and banana peel**	**Polish coal**	**Local cut wood**	**Reed briquette**
Burning rate (gm/min)	5.37 ±0.08	3.14 ±0.13	3.68 ±0.03	13.16	41.33	22.50
Average calorific value(cal/gm)	2758.73 ±95.83	5751.07 ±95.56	4271.38 ±74.55	8,046.63	4,138.94	4,178.36

Briquettes of banana bunch , banana peel and the mixture of the two would have lower burning rate comparing to polish coal, local cut wood and reed briquette (Mitchell *et al.*, 2014) as shown above (Table 4.7) that show that the banana briquette burning slowly and can burn for longer time.

4.3.3 Total emission Test

Briquettes of banana bunch and banana peel have a total CO_2 emission of 0.25% and 0.28% respectively and banana bunch briquettes have a total CO emission of 2457ppm and 1913 ppm respectively in this study and according (Sumrit and Vijitr, 2017) total CO emission of 1568 ppm and 3463 ppm from briquettes of banana bunch and banana peel respectively. Banana bunch briquette higher total CO emission and banana peel briquette lower total CO emission in this study comparing to (Sumrit and Vijitr, 2017).

Table 4.8: Total emission Test

Comparison To other Study		**Emission Component**				
		CO_2 (%)	**CO (ppm)**	**O_2 (%)**	**NO (ppm)**	**NO_X (ppm)**
Sample briquettes of this study	Banana bunch briquette	0.25	2457	20.16	3	3
	Banana peel briquette	0.28	1913	20.18	2	2
(Sumrit and Vijitr, 2017).	Banana bunch briquette	-	3463	-	-	-
	Banana peel briquette	-	1568	-	-	-
(Mechanical Engineering Division (MED), 2013)	Preferable Standard range	0-20 with resolution of 10 ppm	0-1000 with resolution of 1 ppm	0-25 with resolution of 100 ppm	-	-

The CO emission from briquettes of banana bunch and banana peel show some variation from the recommended range of Indian standard for portable solid biomass cook stove (Mechanical Engineering Division (MED), 2013) as shown above (Table 4.8) but gas mixtures of atmosphere with low concentration of CO in the range up to 4,947 ppm (0.5%) do not present any toxic threat to consumers according to international standard for the determination of toxicity gases as cited by (Sumrit and Vijitr, 2017).

4.4. The supply Potential of banana and banana wastes

Banana supplied throughout the years where farmers harvest at least once per two month on average. But the price is minimum at January and slightly increase from August to October based on farmers banana supply (Alemu and Dagnew, 2008).According to this the minimum and maximum banana supply potential data were collected for 7 days from each October end and January first in two round by counting the number of trucks that loads banana and enters to Addis Ababa through the inlets of Jimma Ber, Kality new (Tuludimtu) Ber ,Kality old Ber, Wolega Ber,Gojjam Ber and Dessie Ber.

4.4.1. The number of banana loading trucks through the entries of Addis Ababa

Table 4.9: The first round banana load trucks that enter to Addis Ababa

Name of entries ("Ber")	FSR/day		ISUZU/day	
	Enter to Addis Ababa	Out From Addis Ababa	Enter to Addis Ababa	Out From Addis Ababa
Jimma Ber	1	-	15	-
Kality New Ber (Tulu Dimitu entry)	1	-	13	-
Kality Old Ber	-	-	2	-
Wollega Ber	-	-	-	3
Gojjam Ber	-	-	2	3
Dessie Ber	-	-	-	4
Total	2	-	32	10
Total trucks that load banana and enters and remain in Addis Ababa	2		22	

Table 4.10: The second round banana load trucks that enter to Addis Ababa:

Name of entries ("Ber")	FSR/day		ISUZU/day	
	Enter to Addis Ababa	Out From Addis Ababa	Enter to Addis Ababa	Out From Addis Ababa
Jimma Ber	2	-	25	-
Kality New Ber (Tulu Dimitu entry)	2	-	23	-
Kality Old Ber	-	-	2	-
Wollega Ber	-	-	-	4
Gojjam Ber	-	-	2	6
Dessie Ber	-	-	-	8
Total	4	-	52	18
Total trucks that load banana and enters and remain in Addis Ababa	4		34	

Table 4.11: Average Number of banana load trucks that enter and remain in Addis Ababa:

Type of truck that Enter s and remain in Addis Ababa	Total trucks that load banana and enters and remain in Addis Ababa			
	1st round average number of trucks per day	2nd round average number of trucks per day	Average number of trucks from the two round data record per day	Average number of trucks from the two round data recorded per year
FSR	2	4	3	1,095
ISUZU	22	34	28	10,220

4.4.2. The banana bunch waste potential

Table 4.12: Banana bunch waste measurement

Trial	Amount of banana with bunch measured (kg)	Amount of banana bunch waste generated (kg)
TBB1	50	4.33
TBB2	50	4.72
TBB3	50	3.96
Mean ±SD	50	4.34±0.31

From 50 kg of banana 4.34 kg of banana bunch waste generated averagely by using a triplicate measurement then by using the potential of banana that loaded by ISUZU and FSR with number of 10,220 and 1,095 per year respectively (Table 4.11) and one ISUZU load on average from 5 to 5.5 tons and one FSR 8 to 9 ton of banana (Woldu *et al.*, 2015). Based on these 51,100 to 56,210 tons and 8,760 to 9,855 tons of banana loaded with ISUZU and FSR per year respectively and from that banana potential wastes of banana bunch from 4,435.48 to 4,879.03 tons and 760.37 to 855.41tons were generated per year respectively according to the banana bunch waste measurement as shown in (Table 4.12).

4.4.3. The banana peel waste potential

Table 4.13: Banana peel waste measurement

Trial	Amount of un-ripe banana measured (kg)	Amount of ripen banana (kg)	Amount of banana peel waste generated from ripen banana (kg)
TBP1	1	0.91	0.37
TBP2	1	0.96	0.40
TBP3	1	0.90	0.36
Mean ±SD	1	0.92 ±0.03	0.38 ±0.02

One kilogram of un-ripe banana would get 0.92kg of ripen banana and this ripen banana 0.38kg banana peel would be generated as waste (Table 4.13) and one ISUZU load on average from 5 to 5.5 ton and one FSR 8 to 9 ton of banana (Woldu *et al.*, 2015). According to this the total banana potential were estimated as, 51,100 to 56,210 ton and 8,760 to 9,855 tons of banana that loaded with ISUZU and FSR respectively and from these banana potential 4,435.48 to 4,879.03 tons and 760.37 to 855.41tons of banana bunch waste were generated per year respectively the rest were un-ripe banana that was the difference between the total banana potential and banana bunch waste which were 46,664.52 to 51, 33.972 tons and 7,999.63 to 8,999.58 tons of un-ripe banana respectively and from these un-ripe banana 42,931.36 to 47,224.49 tons and 7,359.66 to 8,279.61 tons of ripen banana would be estimated respectively and from these ripen banana 17,732.52 to 19,505.77 tons and 3,039.86 to 3,419.84 tons of banana peel wastes were generated per year respectively.

4.4.3. Total banana potential

The banana potential were estimated based on the number of trucks (ISUZU and FSR) using the six entries of Addis Ababa as shown above (Table 4.9,4.10 and 4.11) and full load banana ISUZU and FSR in which one ISUZU loads 5 to 5.5 tons of banana and one FSR loads 8 to 9 tons of banana (Woldu *et al.*, 2015). According to that the amount of total banana potential and the banana wastes of banana bunch and banana peel potential were estimated as shown below (Table 4.14).

Table 4.14: Potential of banana in Addis Ababa (ton/year)

Potential type of banana	**Type of truck that load banana and estimated potential**		**Total potential of banana in Addis Ababa (ton/year)**
	Load of ISUZU (ton/year)	**Load of FSR (ton/year)**	
Banana with bunch	51,100 to 56,210	8,760 to 9,855	59,860 to 66,065
Wet Banana bunch waste	4,435.48 to 4,879.03	760.37 to 855.41	5,195.85 to5,734.44
Wet Banana peel waste	17,732.52 to19,505.77	3,039.86 to 3,419.84	20,772.38 to 22,925.61
Air dry banana bunch waste	329.80 to 362.78	56.54 to 63.60	386.34 to 426.38
Air dry banana peel waste	2,632.08 to 2,895.28	451.21 to 507.61	3,083.29 to 3,402.89
Carbonized banana bunch	124.45 to 136.89	21.33 to 24.00	145.78 to 160.89
Carbonized banana peel	994.93 to 1,094.42	170.56 to 191.88	1,165.49 to 1,286.30
Briquettes produced from carbonized banana bunch with 15% clay soil binder	143.14 to157.45	24.54 to 27.60	167.68 to 185.05
Briquettes produced from carbonized banana peel with 15% clay soil binder	1,144.08 to 1,258.48	196.13 to 220.64	1,340.21 to 1,479.12
Briquettes produced from mixture of 50% carbonized banana bunch and50% carbonized banana peel with 15% clay soil binder	644.16 to 708.86	110.43 to 124.23	754.59 to 833.09

4.5. The energy potential of banana briquettes and its wood charcoal or fuel wood substitution

The produced briquettes of banana waste can substitute wood charcoal that produced by cut down tree which estimated based on 1 kg of charcoal produce 30,800 KJ energy (FAO, 1999) ,based on this the banana bunch briquette had 11,547.63 KJ/kg calorific value and a total potential of 167,680 to 185,050 kg and that can produce a total energy of 1,936,220,800 to 2,136,925,076 KJ that substitute 62.86 to 69.38 ton of wood charcoal and in turn can substitute 377.16 to 416.28m^3 fuel wood and 69.15 to 76.32 ton of CO_2 emission avoided from the atmosphere due to the produced banana bunch briquettes as shown in (Table 4.15) and the banana peel briquette had 24,073.13KJ/kg calorific value and a total potential of 1,340,210 to 1,479,120 kg and that can produce a total energy of 32,262,887,790 to 35,607,204,040 KJ that substitute 1,047.56 to 1,156.08 ton of wood charcoal and in turn can substitute 6,285.00 to 6,936.48m^3 fuel wood as a result 1,152.32 to 1,271.69 ton of CO_2 emission avoided from the atmosphere due to the produced banana peel briquettes (Table 4.15) and mixture of banana bunch and banana peel briquette had 17,879.36KJ/kg calorific value and a total potential of 754.59 to 833.09 ton and that can produce a total energy of 13,491,586,260 to14,895,116,020 KJ that substitute 438.31 to 483.44 ton of wood charcoal and in turn can substitute 2,629.86 to 2900 m^3 fuel wood as shown in (Table 4.15) that estimated based on 1 tone of charcoal produced from 6m^3 of fuel wood (FAO, 1999) as a result 482.14 to 531.78 to 531.78 ton of CO_2 emission avoided from the atmosphere due to the produced banana peel briquettes which estimated according to 1ton of charcoal equivalent to 1.1 tons of CO_2 emission reduction (Girard, 2002).

Table 4.15: The energy potential of banana briquettes and its wood charcoal and fuel wood substitution

Briquette type	Calorific value (KJ/kg)	Energy potential (KJ/year)	Wood charcoal substitution (ton/year)	Fuel wood substitution (m^3/year)	Co2 emission reduction (ton/year)
Banana bunch briquette	11,547.63	1,936,220,800 to 2,136,925,076	62.86 to 69.38	377.16 to 416.28	69.15 to 76.32
Banana peel briquette	24,073.13	32,262,887,790 to 35,607,204,040	1,047.56 to 1,156.08	6,285.00 to 6,936.48	1,152.32 to 1,271.69
Mixture of banana bunch and banana peel briquette	17,879.36	13,491,586,260 to 14,895,116,020	438.31 to 483.44	2,629.86 to 2,900	482.14 to 531.78

5. CONCULUSIONS AND RECOMMENDATIONS

5.1. Conclusions

This study showed that the produced briquettes from banana wastes can be used as a source of energy for households and produced three types of briquettes such as banana bunch, banana peel and mixture of banana bunch and banana peel briquettes and their mean average value of fixed carbon (FC) and calorific value (CV) were 19.10% and 2,758.73 cal/gm, 48.82% and 5751.07cal/gm and 33.99% and 4,271.38 cal/gm respectively. But banana peel briquette would have the highest fixed carbon content and highest calorific value comparing to the rest two banana waste briquettes and would have a competitive value compared to the common charcoal that studied by Eduardo both would have high calorific value of 5,751.07cal/gm and 7,358.12cal/gm respectively, high fixed carbon content of 48.82% and 73.51% respectively, low volatile matter of 25.81% and 24.96% respectively, low ash content of 25.06% and 1.5% respectively and low moisture content of 0.31% and 4.76% respectively. The produced banana waste briquettes of banana peel could be substituted 1,047.56 to1, 156.08 tons of charcoal or 6,285 to 6,936.48 tons of fuel wood could be replaced as a result 1,152.32 to 1,271.69 tons of CO_2 could be avoided from the atmosphere.

Briquettes of banana wastes reduce deforestation that cut down for charcoal production and fire wood purpose and also provide clean energy source for the households. Since the briquettes made from the wastes of banana that makes the environment clean in addition to energy source as well as creates job opportunity.

5.2. Recommendations

Economic analysis and feasibility studies on briquettes of banana wastes should be under taken for a wide research.

The government should give incentive who invests waste to energy like briquette production from banana wastes, since there is low attention and low awareness about the multi-directional uses of banana waste.

Stakeholders should participate and assist who involves in briquetting technologies.

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APPENDICES

Appendix 1: Sample preparation of banana waste for carbonization

Fig 1a Banana bunch waste sample

Fig 1b Banana peel waste sample

Appendix 2 Air dry banana sample carbonization

Fig 2a.During carbonization

Fig 2b. After carbonization

Appendix3. Briquette making

Fig 3a. Carbonized powder and clay soil binder preparation

Fig 3b. Briquette production

Appendix 4. Briquette combustion test

Fig 4a. Water boiling test with briquettes

Fig 4b. Emission test with briquettes

Appendix 5. List of tables for raw data in laboratory analysis and banana waste potential determination

Table 1. Carbonization Efficiency.

Sample to be carbonized	**Trials**	**Input (kg)**	**Output (kg)**	**carbonization Conversion efficiency**
Air dried raw banana bunch sample	TAdBB-S1	15	5.72	38.13
	TAdBB-S2	15	5.61	37.40
	TAdBB-S3	15	5.65	37.66
Mean ±SD		15	5.66±0.05	37.73±0.03
Air dried raw banana peel sample	TAdBP-S1	15	5.64	37.60
	TAdBP-S2	15	5.67	37.80
	TAdBP-S3	15	5.71	38.06
Mean ±SD		15	5.67±0.03	37.82±0.18

Where: TAdBB-S=Trial of Air dried Banana Bunch Sample

TAdBP-S=Trial of Air dried Banana Peel Sample

Table 2:- Proximate analysis and calorific value

Sample type	**Trials**	**Proximate analysis (%)**				**Calorific value**
		MC (%)	**VM (%)**	**FC (%)**	**AC (%)**	**CV(cal/gm)**
Air dried raw banana bunch sample	TAdBB-S1	0.56	62.75	8.88	27.81	3162.52
	TAdBB-S2	0.67	59.50	12.71	27.12	2856.76
	TAdBB-S3	0.57	62.70	8.95	27.78	2906.32
Mean ±SD		0.60 ±0.05	61.65 ±1.52	10.19 ±0.85	27.57 ±0.33	2975.20 ±133.99

Sample type	**Trials**	**Proximate analysis (%)**				**Calorific value**
		MC (%)	**VM (%)**	**FC (%)**	**AC (%)**	**CV(cal/gm)**
Air dried raw banana peel sample	TAdBP-S1	2.74	67.37	15.01	14.88	3975.32
	TAdBP-S2	2.33	64.55	19.59	13.53	3627.45
	TAdBP-S3	2.52	64.52	18.44	14.52	4073.2
Mean ±SD		2.53 ±0.16	65.48 ±1.33	17.68 ±1.39	14.31 ±0.57	3891.99 ±191.27
Carbonized banana bunch sample	TBB-Pwd1	0.99	28.73	14.61	55.67	2517.33
	TBB-Pwd1	0.68	26.81	17.38	55.13	2215.44
	TBB-Pwd1	1.09	27.26	16.25	55.40	2248.41
Mean ±SD		0.92 ±0.17	27.60 ±0.82	16.08 ±0.77	55.40 ±0.22	2327.06 ±135.21
Carbonized banana Peel sample	TBP-Pwd1	0.79	26.78	39.57	32.86	4725.31
	TBP-Pwd1	0.51	24.12	44.34	31.03	4513.40
	TBP-Pwd1	0.50	25.96	42.48	31.06	4814.97
Mean ±SD		0.60 ±0.13	25.62 ±1.11	42.14 ±1.06	31.65 ±0.85	4684.56 ±126.44

Where: TBB-Pwd= Trial of banana bunch carbonized powder

TBP-Pwd= Trial of banana peel carbonized powder

Table 3:- Proximate analysis and calorific value of sample briquette

Sample briquette type	Trials	Proximate analysis (%)				Calorific value
		MC (%)	VM (%)	FC (%)	AC (%)	CV (cal/gm)
Banana bunch Briquette	TBB-BR1	5.92	29.73	14.98	49.37	2878.42
	TBB-BR2	4.53	27.51	22.68	45.28	2643.83
	TBB-BR3	5.06	28.71	19.64	46.59	2753.94
	Mean ±SD	5.17 ±0.57	28.65 ±0.90	19.10 ±1.81	47.08 ±1.71	2758.73 ±95.83
Banana peel briquette	TBP-BR1	0.43	27.32	47.26	24.99	5725.36
	TBP-BR2	0.27	23.57	53.09	23.07	5878.83
	TBP-BR3	0.23	26.54	46.11	27.12	5649.02
	Mean ±SD	0.31 ±0.08	25.81 ±1.62	48.82 ±1.89	25.06 ±1.65	5751.07 ±95.56
Banana bunch and banana peel Mixture briquette	TBB+BP-BR1	0.48	27.82	34.47	37.23	4184.15
	TBB +BP-BR2	0.76	24.71	34.50	40.03	4263.72
	TBB +BP-BR3	0.56	26.91	33.00	39.53	4366.27
	Mean ±SD	0.60 ±0.12	26.48 ±1.31	33.99 ±1.07	38.93 ±1.22	4271.38 ±74.55

Where**:** TBB-BR= Trial of Banana Bunch Briquette

TBP-BR= Trial of Banana Peel Briquette

TBB+BP-BR= Trial of Banana Bunch and Banana Peel mixture Briquette

Table 4: - Bulk density

Sample briquette	Trials	Bulk density (gm/cm^3)
Banana bunch Briquette	TBB-BR1	0.77
	TBB-BR2	0.71
	TBB-BR3	0.74
Mean ±SD		0.74±0.03
Banana peel Briquette	TBP-BR1	0.42
	TBP-BR2	0.50
	TBP-BR3	0.49
Mean ±SD		0.47±0.04
Banana bunch and banana peel Mixture briquette	TBB+BP-BR1	0.51
	TBB +BP-BR2	0.53
	TBB +BP-BR3	0.54
Mean ±SD		0.53±0.01

Table 5. Water Boiling Test

Sample briquette	Trials	Average time to boil 0.5L(min)	Average time to boil 1L(min)	Average time to boil 2 L (min)	Average time to turn to ash in (hr&min)	Average calorific value (cal/gm)
Banana bunch briquette	TBB-BR1	21	24	30	2:05	2878.42
	TBB-BR2	23	26	35	2:00	2643.83
	TBB-BR3	22	25	37	2:10	2753.94
Mean ±SD		22 ±0.81	25 ±0.82	34 ±2.9	2:05 ±4.08	2758.73 ±95.83
Banana peel briquette	TBP-BR1	14	18	28	2:15	5725.36
	TBP-BR2	16	20	31	2:10	5878.83
	TBP-BR3	17	21	29	2:20	5649.02

Sample briquette	Trials	Average time to boil 0.5L(min)	Average time to boil 1L(min)	Average time to boil 2 L (min)	Average time to turn to ash in (hr&min)	Average calorific value (cal/gm)
	Mean ±SD	16 ±1.25	20 ±1.24	29 ±1.25	2:15 ±4.10	5751.07 ±95.56
Banana bunch and banana peel Mixture briquette	TBB+BP-BR1	15	19	29	2:05	4184.15
	TBB +BP-BR2	17	21	30	2:15	4263.72
	TBB +BP-BR3	18	22	32	2:10	4366.27
	Mean ±SD	17 ±1.24	21 ±1.25	30 ±1.30	2:10 ±4.08	4271.38 ±74.55

Table 6:- Burning Rate of Briquettes

Sample briquette	Trials	Average burning rate of briquettes(gm/min)	Average calorific value (cal/gm)
Banana bunch briquette	TBB-BR1	5.36	2878.42
	TBB-BR2	5.38	2643.83
	TBB-BR3	5.37	2753.94
	Mean ±SD	5.37±0.08	2758.73±95.83
Banana peel briquette	TBP-BR1	3.21	5725.36
	TBP-BR2	2.95	5878.83
	TBP-BR3	3.26	5649.02
	Mean ±SD	3.14±0.13	5751.07±95.56
Banana bunch and banana peel Mixture briquette	TBB+BP-BR1	3.72	4184.15
	TBB +BP-BR2	3.69	4263.72
	TBB +BP-BR3	3.65	4366.27
	Mean ±SD	3.68±0.03	4271.38±74.55

Table 7. Number of ISUZU/FSR that entered to Addis Ababa or Out from Addis Ababa

Table 7a.First round number of ISUZU/FSR that entered to Addis Ababa or Out from Addis Ababa

(From October 30 /2011 to November 6/2011 EC for 7 consquetive days).

Name of entries ("Ber")	Truck Type	Enter/Out	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7	Mean per day
Jimma ber	ISUZU	Enter to Addis Ababa	12	14	13	15	16	15	14	15±1.51
		Out from Addis Ababa	-	-	-	-	-	-	-	-
	FSR	Enter to Addis Ababa	-	1	-	1	1	1	1	1±0.53
		Out from Addis Ababa	-	-	-	-	-	-	-	-
Kality Ber New (Tulu Dimtu) Ber	ISUZU	Enter to Addis Ababa	13	12	11	13	14	14	13	13±1.00
		Out from Addis Ababa	-	-	-	-	-	-	-	-
	FSR	Enter to Addis Ababa	-	-	1	-	1	1	1	1±0.65
		Out from Addis Ababa	-	-	-	-	-	-	-	-
Kality old Ber	ISUZU	Enter to Addis Ababa	1	1	2	1	2	2	1	2±0.75
		Out from Addis Ababa	-	-	-	-	-	-	-	-
	FSR	Enter to Addis Ababa	-	-	-	-	-	-	-	-
		Out from Addis Ababa	-	-	-	-	-	-	-	-
Wollega Ber	ISUZU	Enter to Addis Ababa	-	-	-	-	-	-	-	-
		Out from Addis Ababa	2	3	2	2	3	3	2	3±0.75

Name of entries ("Ber")	Truck Type	Enter/Out	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7	Mean per day
	FSR	Enter to Addis Ababa	-	-	-	-	-	-	-	-
		Out from Addis Ababa	-	-	-	-	-	-	-	-
Gojjam Ber	ISUZU	Enter to Addis Ababa	-	1	1	2	2	2	1	2±1.00
		Out from Addis Ababa	2	3	2	3	4	4	3	3±0.75
	FSR	Enter to Addis Ababa	-	-	-	-	-	-	-	-
		Out from Addis Ababa	-	-	-	-	-	-	-	-
Dessie Ber	ISUZU	Enter to Addis Ababa	-	-	-	-	-	-	-	-
		Out from Addis Ababa	3	4	3	5	4	5	4	4±0.75
	FSR	Enter to Addis Ababa	-	-	-	-	-	-	-	
		Out from Addis Ababa	-	-	-	-	-	-	-	

Table 7b. Second round number of ISUZU/FSR that entered to Addis Ababa or Out from Addis Ababa

(From January 1 - 7, 2011 E.C for 7 consquetive days).

Name of entries ("Ber")	Truck Type	Enter/Out	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7	Mean per day
Jimma Ber	ISUZU	Enter to Addis Ababa	19	22	23	27	28	25	26	25±1.96
		Out from Addis Ababa	-	-	-	-	-	-	-	-
	FSR	Enter to Addis Ababa	-	1	1	-	2	2	2	2±1.19
		Out from Addis Ababa	-	-	-	-	-	-	-	-
Kality Ber New (Tulu Dimtu) Ber	ISUZU	Enter to Addis Ababa	18	21	23	25	27	24	22	23±2.69
		Out from Addis Ababa	-	-	-	-	-	-	-	-
	FSR	Enter to Addis Ababa	1	1	1	2	1	2	2	2±0.75
		Out from Addis Ababa	-	-	-	-	-	-	-	-
Kality old Ber	ISUZU	Enter to Addis Ababa	2	1	2	3	3	2	1	2±0.75
		Out from Addis Ababa	-	-	-	-	-	-	-	-
	FSR	Enter to Addis Ababa	-	-	-	-	-	-	-	-
		Out from Addis Ababa	-	-	-	-	-	-	-	-
Wollega Ber	ISUZU	Enter to Addis Ababa	-	-	-	-	-	-	-	-
		Out from Addis Ababa	2	4	5	4	4	5	3	4±1.00
	FSR	Enter to Addis Ababa	-	-	-	-	-	-	-	-

Name of entries ("Ber")	Truck Type	Enter/Out	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7	Mean per day
		Out from Addis Ababa	-	-	-	-	-	-	-	-
Gojjam Ber	ISUZU	Enter to Addis Ababa	2	1	1	3	2	3	1	2±0.84
		Out from Addis Ababa	4	6	7	7	5	7	6	6±1.07
	FSR	Enter to Addis Ababa	-	-	-	-	-	-	-	-
		Out from Addis Ababa	-	-	-	-	-	-	-	-
Dessie Ber	ISUZU	Enter to Addis Ababa	-	-	-	-	-	-	-	-
		Out from Addis Ababa	6	5	7	9	8	9	7	8±1.55
	FSR	Enter to Addis Ababa	-	-	-	-	-	-	-	-
		Out from Addis Ababa	-	-	-	-	-	-	-	-

ANNEXES

Annex1. Letter that support banana potential estimation at the entry of Addis Ababa

የኢ.ፌ.ዲ.ሪ ፌደራል ፖሊስ ኮሚሽን
ወን/መከ/ዘርፍ ቀጥ/ሀግ/ማስ/ዳይሬክቶሬት
የቀጠና 4 ዲቪዥን

ቁጥር 2090/[illegible]

ቀን 19 ህዳር 2011

ለሀዋሳ ዩኒቨርሲቲ

ወንዶ ገነት ደንና ተፈጥሮ ሀብት ኮሌጅ

<u>አ/አበባ</u>

ተማሪ አብርሀም አብነህ በወንዶ ገነት ደንና ተፈጥሮ ሀብት ኮሌጅ በመደበኛ መርሀ ግብር በ renewable Energy Utilization and management ሁለተኛ ዲግሪ ትምህርቱን በመከታተል ላይ የሚገኝና በአሁኑ ሰዓት የመመረቂያ ፅሁፍን ለመስራት ያመች ዘንድ በተቋማችን አስፈላጊውን ትብብር እንዲደረግለት በተጠየቀው መሰረት በተቋማችን በሚጠበቅ ጀዌ ኬላ ላይ በአካል በመገኘት በኬላው ላይ ወደ አዲስ አበባ የሚገባ የሙዝ መጠን በማወቅ ለመመረቂያ ፅሁፉ ግብዓት ሊሆን የሚችል ስራ ያከናወነ መሆኑን እንገልፃለን ፡፡

ከሠላምታ ጋር!!

ዋቅጋሪ ተመስገን
Wakgari Temesgen
ኮማንደር
Commander
በፀ/ህ/ማስ/ዳይ/የቀጠ/4/ዲቪዥን ኃላ.

<u>ግልባጭ</u>

- ለቀጠና 4 ዲቪዥን ፅ/ቤት

<u>አ/አበባ</u>

Annex2. Letter of summarized (average) experimental result.

	GEOLOGICAL SURVEY OF ETHIOPIA	Doc.Number: GSE/F 5.10-2	Version No: 1
	GEOCHEMICAL LABORATORY DIRECTORATE		Page 1 of 1
Document Title:	Hydrocarbon Laboratory Analysis Report	Effective date:	May, 2017

Issue Date: - 28/03/2019

Customer Name: -**Abrham Abneh**

Request No: - GLD/175/19

Report No: - GLD/TR/134/19

Sample type: - coal

Sample Preparation : - 60 Mesh

Date Submitted: - 21/03/2019

Number of Sample: -Seven (7)

Elements to be determined:- (Moisture, Volatile matter, Fixed carbon and Ash), & Calorie .

Method of analysis: Proximate Analysis and Adiabatic Calorie Metter .

Collectors' Code	Moisture %	Volatile Matter %	Fixed carbon %	Ash %	Calorific Value Cal/gm.
BB-BR	5.17	28.65	19.10	47.08	2758.73
BP-BR	0.31	25.81	48.82	25.06	5751.07
BB+BP-BR	0.60	26.48	33.99	38.93	4271.38
AdBB-S	0.60	61.65	10.19	27.57	2975.20
AdBP-S	2.53	65.48	17.68	14.31	3891.99
CBB-Pwd	0.92	27.60	16.08	55.40	2327.06
CBP-Pwd	0.60	25.62	42.14	31.65	4684.56

Note: - This result represent only for the sample submitted to the laboratory.

Analysts	Approved By	Quality Control
Haimanot Bayeh		
Shashe Haile	Alemnesh Abate	Negash Worku

Annex3. Letter of certification for banana waste measurement to estimate total banana waste potential that enter in Addis Ababa.

በኢትዮጵያ የንግድ ሥራዎች ኮርፖሬሽን
Ethiopian Trading Businesses Corporation
የአትክልትና ፍራፍሬ ንግድ ሥራ ዘርፍ
Fruit and Vegetable Trading Business Unit

ኢትፍሩት
Etfruit
Fruit and Vegetable Trading Business Unit

ፖ.ሣ.ቁ 2374

ስልክ ቁ. / Tel. 0114 -163665, 0114 - 160338, 0114 - 164288, 0114 - 163620, 0114 - 160292

ፋክስ / Fax 251- 0114 -163631

E-mail-etfruit@etfruit.et

አዲስ አበባ
ኢትዮጵያ
Addis Ababa
ETHIOPIA

የምርት ዓይነት

- ብርቱካን
- መንደሪን
- ሀብሀብ
- ሎሚ
- ፓፓዬ
- ሙዝ
- ግሬፕ ፍሩት
- ማንጎ
- ዘይቱን
- ቲማቲም
- ፎሶሊያ
- ቀይ ሽንኩርት
- ድንች
- ጥቅል ጎመን
- ቀይስር
- ስኳር ድንች
- የቲማቲም ድልህ
- የብርቱካን ማርማላድ
- የቲማቲም ጭማቂ
- የዘይቱን ወለላ
- የአትክልት ዘሮች

Product

- Orange
- Mandarin
- Water Melon
- Lemon
- Papaya
- Banana
- Grape Fruit
- Mango
- Guava
- Tomato
- Green Beans
- Onion
- Potato
- Head Cabbage
- Beet Root
- Sweet Potato
- Tomato Paste
- Orange Marmalade
- Tomato Juice
- Guava Nectar
- Vegetable Seeds

ቁጥር / Ref.No. ህሥ112/15-10

ቀን / Date 13 ግንቦት 2011

ለሀዋሳ ዩኒቨርሲቲ
ወንዶገነት የደንና ተፈጥሮ ሀብት ኮሌጅ
ሀዋሳ

አቶ አብርሃም አብነህ በሀዋሳ ዩኒቨርሲቲ በወንዶገነት የደንና ተፈጥሮሀብት ኮሌጅ በ"Renewable energy utilization and management" የሁለተኛ ዲግሪ የመመረቂያ ጽሁፋቸውን ለማዘጋጀት ይረዳቸው ዘንድ ለዘርፋችን ከዩኒቨርሲቲው በተፃፈው የሥራ ትብብር ደብዳቤ መሠረት አዲስ አበባ ከሚገባው ሙዝ የሚገኘውን የሙዝ ተረፈ ምርት (Banana bunch and banana peel waste) ለማወቅ በአትክልትና ፍራፍሬ ንግድ ሥራ ዘርፍ መስሪያ ቤት ተገኝተው ልኬት ያደረጉ መሆናቸውን በአክብሮት እንገልፃለን።

ከሠላምታ ጋር

ግልባጭ/
- ለሀብት አመራር መምሪያ
- ለሽያጭና ስርጭት መመሪያ
  አ.ፍ.ን.ሥ.ዘ.

Exporter and Distributor of Fresh Fruits, Vegetables, and Processed Horticultural Products

BIOGRAPHICAL SKETCH

The M.Sc candidate was born on January 14/1988 G.C in Amhara region East Gojjam Zone Debremarkos, Ethiopia. He attended his elementary school from Nigus T/Haymanot and Dibza Preparatory School in D/Markos. Then he certified with BSc degree of Electrical Engineering (Power Engineering) from Addis Ababa University institute of Technology in, 2016 G.C, and then he served in Addis Ababa Environmental Protection Authority as energy officer. Finally, he joined Hawasa University Wondo Genet College of Forestry and Natural Resources to for M.Sc program in Renewable Energy Utilization and Management in 2017 GC.