PRODUCTION OF COFFEE HUSK BRIQUETTE AND ITS CHARACTERIZATION AS A SOURCE OF HOUSEHOLED ENERGY, A CASE OF DILLA TOWN, SNNPR OF ETHIOPIA

By

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MSC THESIS SUBMITTED TO

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APPROVAL SHEET - I

This is to certify that the thesis entitled “Production of Coffee Husk Briquetteandits Characterization to be used as a source of household Energy’’ submitted in partial fulfillment of the requirements for the degree of Master of Science with specialization in Renewable Energy Utilization and Management of the Graduate Program of the Department of Environmental science, Wondo Genet College of Forestry and Natural Resources, and is a record of original research carried out by BelaynehAlemuMekonen Id. No. MSc/REUM/R004/09, under my supervision, and no part of the thesis has been submitted for educational institutions for achieving any academic awards.

The assistance and help received during the course of this investigation have been duly acknowledged. Therefore, I recommend that it be accepted as fulfilling the thesis requirements.

ZerihunDemrew (PhD)__________________________ _____________

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APPROVAL SHEET - II

We, the undersigned, members of the board of examiners of the final open defense by BelaynehAlemuMekonen have read and evaluated his thesis entitled ‘‘Production of Coffee Husk Briquetteandits Characterization to be used as a source of household Energy’’, and examined the candidate. This is therefore 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 at Hawassa University, Wondo Genet college of Forestry and Natural Resources.

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Final approval and acceptance of the thesis is contingent upon the submission of the final copy of the thesis to the CGS through the DGC of the candidate’s department.

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STATEMENT OF AUTHOR

I, BelaynehAlemuMekonen, hereby declare to the school of graduate studies, Hawassa University that this thesis is my original work and all sources of materials used are duly acknowledged. This work had not been submitted to any other educational institutions for achieving any academic awards.

BelaynehAlemuMekonen____________________ ____________________

Full Name Signature Date

DEDICATION

This work is dedicated to my family.

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LIST OF ACRONYMS:

AC:	Ash Content
AEDPD	Alternate Energy Development and Promotion Directorate
ANOVA	Analysis of Variance
ASTM:	American Society for Testing and Materials
BD	Bulk Density
CH(s):	Coffee Husk(s)
CSA:	Central Statistical Agency
CV:	Calorific Value
ECRGE:	Ethiopian's Climate Resilient Green Economy
FAO	Food and Agriculture Organization
FC:	Fixed Carbon
GDP:	Gross Domestic Product
GHG:	Greenhouse Gasses
IM	Improved Micro Organism
IRENA:	International Renewable Energy Agency
MC:	Moisture Content
MOFEP	Ministry of Forest and Environment Protection
MOWIE	Ministry of Water, Irrigation and Energy
OCFCU	Oromia Coffee Farmers' Cooperative Union
SD	Standard Deviation
SNNR:	Southern Nation and Nationality Region
SPSS	Statistical Package for Social Science
UNDP:	United Nations Development Program
VM:	Volatile Matter

LIST OF SYMBOLS:

Cal/g	Calorie per gram
cm	Centimeter
g	Gram
Kg	Kilo gram
MJ	Mega joule
MJ/kg	Mega joule per kilogram
mm	Millimeter
T	Tone

Production of Coffee Husk Briquette and its Characterization as a Sources of Household Energy, A case of Dilla Town, SNNPR of Ethiopia

ABSTRACT

Most of the population of Ethiopia, like that of other Sub-Saharan African countries, depends on traditional biomass for cooking and baking food. Most rural people in the country have no access to electricity and the price of fossil fuel is increasing in alarming rate. On the other hand there are large amounts of coffee husks in coffee growing areas which are left unused. In most cases, they are either left in the fields or burning in open air and this causes severe environmental problems. A comprehensive study was carried out in Dilla town, a representative coffee growing area of the country, to assess the potential of coffee husks for production of briquettes to be used as a source of household energy. The amount of coffee husk produced in the town was assessed and briquettes were prepared with different carbonized coffee husk with different particle size using clay soil as a binder. The briquettes were characterized following ASTM procedure. The result showed that an average of 57,700.96 tone coffee husk is produced in the town every year. The coffee husk in the town is mostly used as fertilizer and traditional source of fuel. There was no proper way of coffee waste management to controlling environmental pollution. The extent of simple dumping of coffee husk were 83.4%, 90% and 80% in chichu, Sisota and Gola kebeles, respectively The minimum average LHV of the produced briquettes from coffee husk (dry process) as a factor of different particle size and charcoal to clay soil binder ratio was 17.7MJ/kg. The mean average value for fixed carbon content(FCC) and calorific value of the briquettes (particle size 1mm, 3.35mm, 5.60mm, and charcoal to binder ratio of 3:1, 4:1 and 5:1) were: 55.95±0.99 % and18.1±0.4 (MJ/kg); 48.17±3.24 % and 17.7±0.1 (MJ/kg);48.07±4.18% and 17.47±0.65(MJ/kg) and 47.85±3.27& 17.12%±0.26(MJ/kg); 49.92±3.05% &17.27 ±0.37(MJ/kg) and 52.76±1.53 &18.54±0.45(MJ/kg) respectively. The result showed that the calorific value of the raw material was lower than the briquettes produced in all the cases. Briquettes produced from higher charcoal to binder ratio was having the highest calorific value while briquettes produced from higher particle size observed to have the lowest calorific value. In general, coffee husk found to have better physicochemical properties as compared to other agricultural residues, especially in calorific value. Therefore, the use of coffee husk for briquette making to be used as a source fuel has to be considered in coffee growing areas. Further studies should be conducted regarding the effect of different varieties of coffee species and conditional/ environmental impact on the calorific value/ heat energy of briquettes produced from coffee husks.

***Key words**: biomass, briquette,briquetting,charcoal, coffee husk,fuel quality,*

1. INTRODUCTION

1.1. Background of the study

Access to affordable energy services is essential to human activities, development and economic growth (UNDP, 2004).However currently the dominant sources of energy in the world are fossil fuels that include coal, oil and natural gas, which result emission of greenhouse gases that are the main causes of increasing global warming, In addition such resources are limited and are not renewable. And an increasing in demand of heat and power for cooking, construction, manufacturing, communications, transportation, lighting and other utility have led to the great consumption and depilation of these energy sources and subsequently price increments over the years. This high demand is a good indication in the growth and development of economies especially in the developing countries (Okure, *et al*., 2006). And also accessing locally available and affordable energy services is an essential determining factor to human activities, development and economic growth (Mussatto, *et al*., 2011).

The energy sector of Ethiopia, like other developing countries of sub-Saharan Africa, is dominated by traditional biomass energy. 94% of the national energy consumption is based on biomass resources. Modern energy, which is mainly based on petroleum products and electricity from hydroelectric power, and infrastructure for energy supply is only available in urban areas. Majority of the population live in rural areas and have little access to modern energy. The country has got considerable potential of renewable energy resources including hydropower which is the major source of electricity, solar, wind, geothermal and biomass which may be exploited to ensure sustainable energy supply (Melis, 2006).

The non-renewable nature of fossil fuels and global warming are the reasons for growing interests for biomass utilization as a source of heat and power production. Renewable energy sources that use indigenous resources have considerable potential to provide sustainable solution to this situation. Especially, modern distributed forms of biomass seem particularly promising for their potential to provide rural areas with clean forms of energy (UNDP, 2000).However the major factor that limits the utilization of biomass for heat and power production is its low bulk density and heterogeneity. As a result of these problems, preparation of Briquettes from biomass is needed to increases its bulk density and offers several other benefits, such as a homogeneous shape and structure to the final products (Stelte, *et al*., 2012).

Biomass is locally available source energy that has huge potential to reduce greenhouse gas emissions resulting from the excessive use of petrol fuels. However the direct use of biomass as sources of energy is very difficult to handle, transport, store and utilize, due to factors include high moisture content, irregular shape and sizes, and low bulk density. But Briquetting of this biomass can produce dense products with uniform shape and sizes that can be more easily handled using existing handling and storage equipment and thereby reduce cost associated with transportation, handling, and storage. Agricultural bio waste is one of the sources of biomass which is mostly under- utilized worldwide. Currently, there is rapid increase in volume and types of waste agricultural biomass produced due to intensive agricultural activities in the wake of population growth and improved living standards. Ethiopia, with human population of more than 85 million, agriculture is the dominant activity and source of GDP for the country. According to ECRGE, Ethiopia's climate-resilient green economy strategic document (2011), among other, the country's ambition to build green economy focuses on increased greenhouse gas (GHG) sequestration and development of renewable and clean power generation.Ethiopia, as origin of coffee Arabica, huge amount of coffee and bio products such as residues of coffee husk and pulp are produced every year. However these products have been improperly utilized and managed or are simply left to decompose or burned (Seboka, 2009) or accumulated in the environment including water bodies (Hadis and Devi, 2008). So far these result facilitating pollution of air and water (Beyene,*et al.*, 2012).

Previous studies suggest that, the use of coffee husk as energy sources is an alternative option to diminish these problems (Kebede,*et al.*, 2010). In addition, the conversion of coffee husks in to briquette will increase the capacity of carbon sequestration through reducing the deforestation rate and also provides renewable, clean and sustainable energy as substitute for fuel wood and charcoal (Merete *et al*., 2014). If the resource is utilized properly, it has potential to aspire the country's longer-term vision of reaching middle-income status by 2025.

Coffee husk is obtained as a waste from coffee processing facilities. There are three coffee processing methods, namely: wet, semi-dry and dry processes. The husk constitutes the crumbly parchment skin for wet-processed coffee, the parchment skin and dried mucilage for semi-dry-processed coffee, and the entire dry leathery fruit covering for the dry-processed coffee (Wikipedia, 2010). This indicates that the husk yield and particle size is considerably bigger for dry process than the other two methods. Ethiopia exports 80-85% sun-dried (natural) coffee and 15-20% wet processed coffee (Sustainable Tree Crops Program (STCP), 2017). Hence, it can be seen that huge amount of this resource is available in the country. Thus, studying its properties and looking for a means to utilize it properly is important.

1.2. Statements of the Problem

Limited access to modern energy technology is a problem especially in rural areas of the country. The differing work and social roles of men and women are culturally established and vary from place to place. In many areas women are responsible for gathering fuels and use them for cooking, heating and boiling; in the process women are usually exposed to health hazards (Kaygusuz, 2011).

The potential of accessing the biomass resource is too huge on international scale, and the capacity to utilize locally available residue streams which may provide affordable cost, offers attractive near-term opportunities for biomass use. In the longer term, the development of sustainable, dedicated biomass energy plantations may further expand the resource base and help reduce the costs of energy produced from biomass. (Perlack, 2005),Since in Ethiopia more than 80 % of the population depends on agricultural activities Excesses accumulation of agricultural by products (bio waste), increasingly becomes a source of environmental pollutants. However if this potential resource properly managed, it can contribute to full fill the energy need of the community. Among these agricultural wastes coffee husks are the most common and which are burned directly in domestic stoves, but which are with considerable smoke and is unsuitable for cooking due to less durability (length of burning time) and its lightness in density. Coffee grows in most of Oromia and SSNP regions including Gedeo zone, Even though there exist huge potential of these coffee by-products (coffee husks) in Dilla, still no attentions is given to manage and convert it in to sources of energy. In Dilla women and children are devoting their effort and their time for the purpose of collecting fuel wood from far area for their energy sources while coffee husk is locally available on the nearby home gardens of farmlands which they can easily access with affordable costs.

Properties of solid biomass vary considerably with climate, geographical location, and many other factors. Understanding the behavior and properties of biomass feed stock for fuel application is important for proper and economic handling and storage as well as selecting appropriate technology and optimal design of the energy conversion systems to be used. Suitable system to bind energy from dry coffee husks is thermo-chemical conversion. Therefore, a thorough study of physical and thermo-chemical characteristics and identifying suitable conversion technologies are vital for effective and efficient utilization of the resources.

Enough research attentions are not given to studying about the characteristics, socioeconomic benefits and environmental impacts of coffee husk wastes (Esquivel and Jiménez, 2012).Due to lack of this scientifically supported information on the assessments of coffee husks, management practices, contribution a s household energy source, its role in natural resource degradation and the likes, the resource is still underutilization. Therefore, the study is motivated to explore the fuel characteristics of coffee husk and analyse the potential of coffee husk to be utilized as alternative household energy source in Dilla town of Gedio zone using available conversion technologies.

1.3. Objectives

1.3.1. General objective

The overall objective of the present study was to assess the potential sources of coffee husks and its use in Dilla town of Gedeo zone, conversion the husks in to fuel briquettes and perform its physical, combustion and proximate analysis.

1.3.2. Specific objectives

1. To assess the accessibility and potential of coffee husk within the study area
2. To assess the current application and management practice of the coffee husk waste in the study area.

3. To evaluate fuel quality of the briquettes produced through proximate analysis and combustion tests.
4. To explore the effect of particle size and charcoal to clay soil binder ratio difference on the physical proximate analysis and heating value of the produced briquette.

1.4. Research Questions

1. How is the potential of coffee husk in the study area?

2. What are the physical and chemical properties of coffee husks?

3. What methods/ procedures and experimental design can be applied or practiced for the production of briquettes?

4. What will be the characteristics of the produced briquettes?

5. How are the effect of varying particle size and ratio of binders with charcoal on the physical, proximate analysis and heating value of briquettes

1.5. Significances of the Study

This study is believed to help stakeholders to understand the potential sources of coffee husks, management practices undertaken by community, production of briquettes from coffee husks, activities on determination of the physical, combustion and proximate analysis of briquettes and its contributions as a source of sustainable household energy for both rural and urban people in the study area and to provide a baseline information for further scientific studies. The output of the study can also be used by planners, energy sector, further researchers, environmentalists, policy makers, and in the study area in particular, to make coffee husks play a great role on promoting as alternative sources of household energy and environmental sustainability through increasing the benefit of the rural and urban communities. As a very useful and environment friendly source of energy, coffee husk briquettes can reduce the burden on our forests by reduce biodiversity and wild life habitat degradation. Our world is facing shortage of natural oil and associated environment calamities, this study will give a direction towards a better future for the next generations.

1.6. Scope of the Study

This research study seeks to only focus on assessing the energy potential of coffee husk in dilla town and its characterization as a factor of different particle size and charcoal to clay soil binder ratios. The scope of this piece of work is also limited based on the literature availability and within a specific time frame of its execution.

The scope of this work pertaining to limited literature availability, accuracy of the information and the time frame of executing this research cannot serve as an impediment in conducting this research to meet the objectives.

1.7. Limitation of the Research

Although many studies are studied about the consumption of biomass as sources of energy, however it becomes difficult for accessing enough literatures regarding to the effect of particle size and charcoal to clay soil binder ratio difference for the purpose of comparison. Financial support and shortage of time for collecting sufficient data and for further studies and analysis were also the other problem which was faced during the study.

2. LITRITURE REVEW

2.1. Concepts of Biomass Energy

World population growth results an increase in energy demand, together with growing global consciousness about the scarcity of the earth's natural resources, has turned the attention of researchers into alternative renewable energy sources. Traditional energy sources are characterized as exhaustible and some of them, especially fossil fuels, have substantial impacts on the natural environment and are the main offender of climate change. As a global solution, renewable energies play a key and unique role in eliminating these problems, since they are obtained from natural, regenerative sources that do not deplete; and they also cause minimal to no environmental problems, such as climate change, radioactive waste, acid rain and air pollution. Sources of renewable energy that have reached full commercial maturity are: solar, wind, tides and waves, rivers, geothermal energy, organic waste and energy stored biomass (Okure, *et al,* 2006).Biomass can be synthesised through photosynthesis by using CO_2 and H_2O as raw materials with solar energy, which is used for double purposes sources of renewable energy and greenhouse gas mitigation (Battersby, *et al*, 1999),Whereas biomass energy obtained by converting organic energy into fuels can be used for transportation, heat and/or electric power generation. World bio energy supply has gradually increased over recent years. In 2010, the total estimated bio energy supply was over 50 EJ, corresponding to about ten per cent of the total world primary energy supply (Saygin, *et al,* 2014). A large majority of biomass consumption takes place in residential and commercial premises (such as cooking and heating Fuel).

2.2. Definition of Terms

Biomass: refers to the biological material derived from living, or recently living organisms. In the context of biomass for energy, the term is often used to mean plant based material, but can also apply to both animal and vegetable derived material. Biomass is the building block or 'feedstock' for many other fuels.

Briquette: is a compressed block of coal dust or other combustible biomass material such as charcoal, sawdust, wood chips, peat, or paper used for fuel and kindling to start a fire. The term comes from the French language and is related to brick.

Briquetting: is the process of converting low bulk density biomass into high density and energy concentrated fuel briquettes. Briquetting creates additional raw material resources from fine materials, primarily fuels and ores, the use of which would otherwise be inefficient or difficult; it also makes it possible to use waste products, such as dust, slags, and metal chips. In all cases, the usefulness of briquetting is judged by economic factors.

Coffee husks: Coffee husks are the waste products which are produced when coffee beans are harvested and dried. Coffee husks were used as fertilizers in most coffee rowing area

Measurement: is the collection of quantitative or numerical data that describes the property of an object or event. A measurement is made by comparing a quantity with a standard unit. Since this comparison cannot be perfect, measurements inherently include error, which is how much a measured value deviates from the true value.

Production: is a process of integrating two or more materials inputs and immaterial inputs in order to make something for consumption (the output). It is the act of creating output, a good or service which has value and contributes to the utility of individuals (Moroney, 1967).

Drying: the mass transfer process which consisting of the removal of water or another solvent by evaporation from a solid, semi-solid or liquid. This process is often used as a final production step before selling or packaging products. To be considered "dried", the final product must be solid, in the form of a continuous sheet (e.g., paper), long pieces (e.g., wood), particles (e.g., cereal grains or corn flakes) or powder (e.g., sand, salt, washing powder, milk powder

2.3. Coffee processing methods, coffee husk yield and types

Coffee is one of the most important crops used as stimulant throughout the world. An estimated 3.5 billion cups of coffee are used worldwide every day. It is grown in over 70 countries and amounts to over 16 billion pounds of beans every year .That is a lot of beans and when they are only used once and thrown away, it also contributes to a huge amount of waste (Bhutta, *et al*, 2013).

Coffee production possesses series of stages: Planting, Harvesting the cherries, processing the cherries, drying the beans and tasting the coffee. Coffee seeds are generally planted in beds in nurseries with shed and can be done during the wet season; as a result the soil exists as moist while the roots become firmly established Depending on the variety, it takes approximately 3 to 4 years for the newly planted coffee trees to bear fruit. Typically coffee has one major harvest season per year. In different areas with the available local resources, coffee is processed by one of three different methods known as dry, wet and semi-dry processing; even all methods aim at avoiding the fruit flesh of coffee cherry, they do it in different mechanism (Blinová, *et al*. and Duarte, G., *et al*., 2010). If the beans have been processed by the wet method, the pulped and husk should be allowed to dry. Fomented beans must now be dried to approximately 11 % moisture to properly prepare them for storage. The beans then can be roasted and ground in to powder for further processing or can be export as raw beans. The produced coffee is repeatedly tested for quality and taste.

Coffee processing states the consecutive activities involved in converting the ripe red coffee cherries in to a drinkable cup of coffee, the activities include picking the red cherries from the trees, processing and milling, roasting the green beans, grinding and brewing. Three coffee processing methods are there based on the number of stages and the mechanism used to extract clean green beans from red coffee cherries. These are wet processing, dry processing and semi-dry processing (Wikipedia, 2010).

There are two major categories of coffee trees grown in the world, Arabica and Robusta. Arabica is considered to be a higher quality bean, prized for its complex aroma and flavor. Robusta is a higher caffeine bean and, while sometimes described as bitter, it is often blended with Arabica to bring flavor and caffeine balance (Promar Consulting, 2011). Robusta trees account for about 30% of the world coffee harvest and the rest is Arabica (Coffee Fair, 2011). Among the three processing methods, wet processing and dry processing are the two widely used methods. Robusta is primarily dry processed. For Arabica, wet processed Arabica is known as Mild Arabica‖ and dry processed as “Hard”Arabica (Promar Consulting, 2011). Most of Ethiopian coffee is dry processed and a small remaining proportion is wet processed. The steps involved in the three coffee processing methods, the coffee husk yield and types are illustrated here giving more emphasis on the two widely used methods.

2.3.1. Wet Processing Method

Coffee processed by this method is known as wet processed or washed coffee. In this method, the coffee cherries are sorted by immersion in water. Bad or unripe fruits will float and the good ripe ones will sink. The skin of the cherry and some of the pulp is removed by pressing the fruit by machine in water through a screen. After this, some remaining pulp and mucilage is removed from the bean either by the classic ferment and wash method or by a newer procedure variably called machine assisted wet processing, aqua pulping. What is left then after is the bean surrounded by two additional layers, the silver skin and the parchment and this is called wet parchment coffee.

The wet parchment coffee must be dried to the moisture content of about 11.5% to obtain stable dry parchment coffee (Sustainable Tree Crops Program (STCP), 2007). This may be done naturally in the sun on raised drying tables or using a machine or partially in sun and partially using a machine. The dry parchment coffee is then sorted and taken to hullers to remove the remaining crumbly parchment skin using a hulling machine. Coffee occasionally is sold and shipped in parchment. The husk obtained from this process is the crumbly parchment skin removed from the green beans by hulling and constitutes about 15% of the entire coffee cherries (20% the dry parchment coffee) (Coffee and Conversion, 2007). It is called coffee parchment.

2.3.2. Dry Processing Method

This is the oldest method of processing coffee. The coffee processed by this method is familiarly known as unwashed or natural coffee. In this method, the entire coffee cherries after harvest are first cleaned, sorted and placed in the sun to dry on large concrete or brick patios or matting raised to waist height on trestles. Natural coffee takes 3-4 weeks or even more in cloudy or damp weather before it dries to the required moisture content of 11.5%. As the cherries dry, they are racked or turned by hand to ensure even drying and prevent mildew (Wikipedia, 2010). On large plantations, machine drying is sometimes used to speed up the process after the coffee has been pre-dried in the sun for a few days. After drying, the entire leathery skin of the cherry is removed in one step by a hulling machine.

The husk obtained from this process is the entire leathery skin of the coffee cherry and constitutes about 40% of the entire dry coffee cherries (Coffee and Conversion, 2007). This is the type which is commonly referred to as coffee husk in energy literatures

2.3.3. Semi-dry Processing Method

This is a hybrid process used in Indonesia and Brazil. It is not used in Ethiopia. In this process, farmers remove the outer skin from the cherries mechanically using locally built pulping machines. The coffee beans still coated with mucilage, are then stored for up to a day. Following this waiting period, the mucilage is washed off and the parchment coffee is partially dried in sun before sale at 30-35% moisture content. Finally, the remaining mucilage and parchment skin is hulled at 30-35% moisture content using a machine. The husk obtained from this process is the dried mucilage and the parchment skin. Husk yield is more than that of wet process but considerably less than that of the dry process (Wikipedia, 2010).

2.4. Consumption of CoffeeHuskWaste Products

According to the mechanism used for coffee processing, different by-products are taken:

- Pre-roasting coffee by-products
- dry processing: coffee cherry husks,
- half-dry and wet processing: coffee pulp
- Post-roasting coffee by-products: coffee silver skin, spent coffee grounds **(**Cruz, 20**1**4).

2.4.1. Coffee Husk

Coffee husks are the major by-product derived from the dry method, where the coffee cherry husk is composed of the dried skin, pulp and parchment (Cruz, R., 2014). There are many uses of the coffee by product utilization, like used as manufacturing of fuel pellets or briquettes, as raw material for biogas and alcohol production, absorbent to remove heavy metals and dyes from aqueous solutions, biodiesel production or fertilizer, and as well as a biomaterial in the pharmaceutical industry. Finding alternatives for the use of these residues is of great importance, which is due to their toxic character, which can be harmful if disposed into the environment (Blinova, *et al.*, 2010).

2.4.2. Coffee Husk Resource Availability

2.4.2.1. World Scenario

The two types of coffee trees, Arabica and Robusta, prefer different cultivation environment. Arabica is mostly produced in high lands and Robusta in low lands. In general, Robusta trees are hardier and more tolerant of pests, allowing higher yield under harsher conditions than Arabica. This has led to Robusta being a cheaper, and some say easier, bean to produce (Promar Consulting, 2011). From humble origins in Africa, coffee cultivation wandered both east and west, eventually forming the so called ―Coffee Belt (fig. 1), the tropical area roughly bounded by the tropic of Cancer and the tropic of Capricorn (Coffee Fair, 2011).

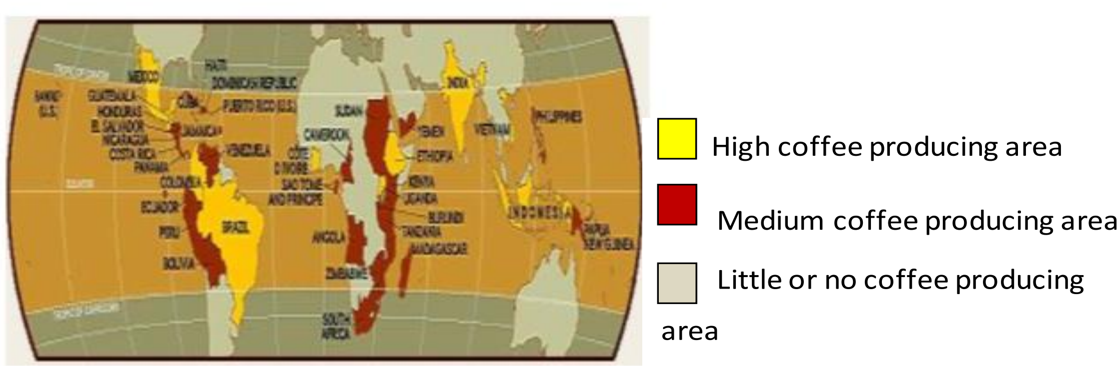

Fig.1: The Coffee Belt

(Source: Coffee Fair)

The major coffee producing regions today are Latin America and Southeast Asia, followed by Sub-Saharan Africa and Central America (fig. 2). Africa, the origin of coffee, lags the production increase in South America and Asia, producing 801,000 MT only which accounts just about 11% of the current world production. Its share has been slowly, yet continuously shrinking, from 17% in 1995 to 13.6% in 2007, and to nearly 11% today (Promar Consulting, 2011). Below, the share for each of the main production regions is indicated.

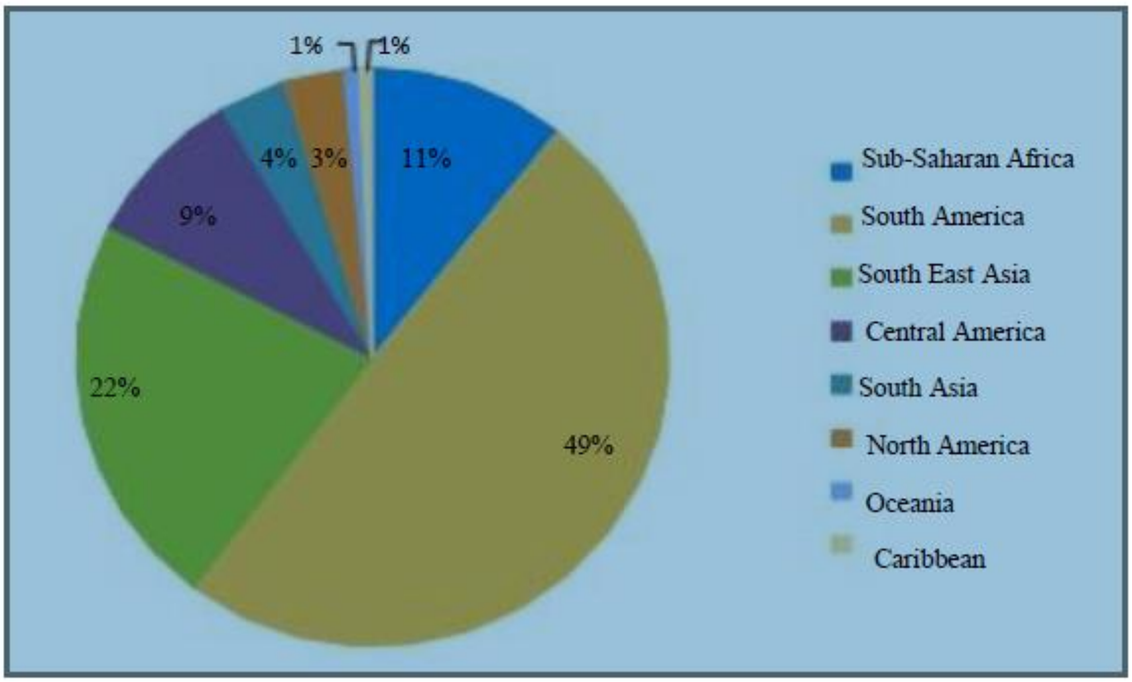

Fig.2: Global Coffee Production by Region, 2010/2011

(Source: Promar Consulting, 2011)

World coffee production is dominated by Brazil (fig. 3). Although production is biennial, it remains the always world leader whether it is an on or off year. Vietnam has also expanded its industry since it began producing recently in 1994, becoming a major coffee powerhouse. Six of the top ten producer countries are from Latin America, with Ethiopia the only African producer (Although Uganda is nearly even with 10th place Peru) (Promar Consulting, 2011).

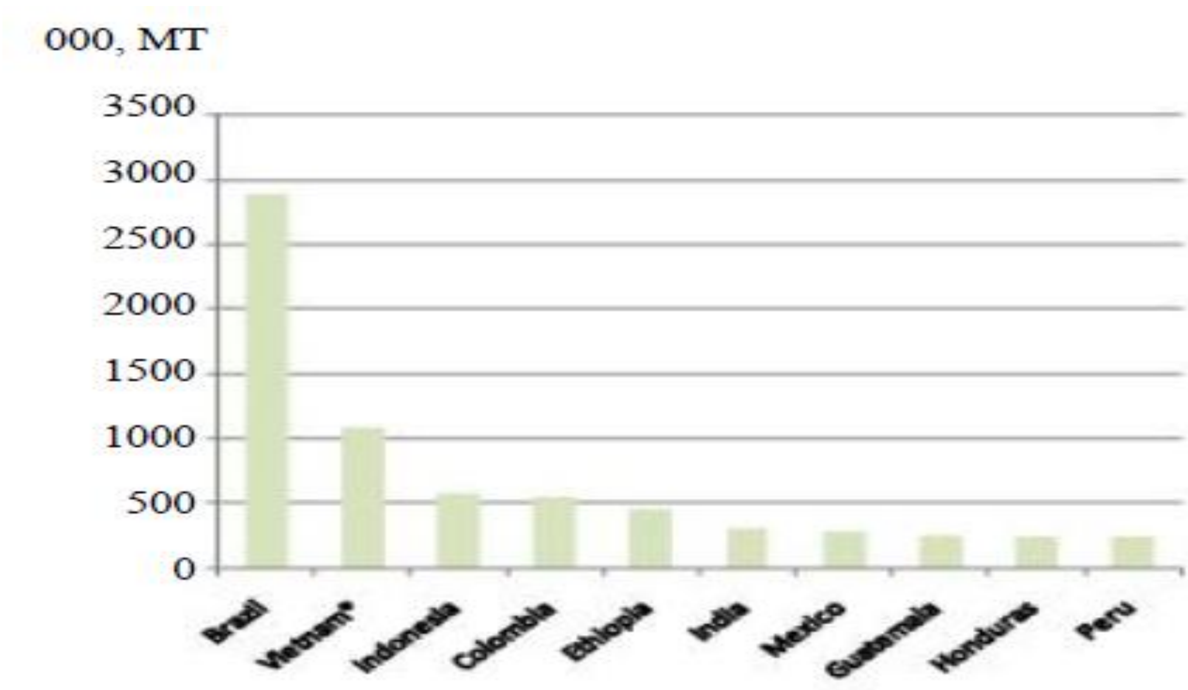

Fig.3: Coffee Production Volumes for the Top 10 Global Coffee Producers, 2010

(*Source: PromarConsultin, 2011)*

More than 80 countries including Ethiopia, cultivate coffee, which is exported as the raw, roasted or soluble product to more than 165 countries worldwide. More than 121 countries export and /or re-export coffee. More than 50 developing countries, 25 of them in Africa, depend on coffee as an export, with 17 countries earning 25 per cent of their foreign exchange from coffee (Sustainable Tree Crops Program (STCP), 2007). It is the 2nd most traded commodity in the world after crude oil (Promar Consulting, 2011).

The top exporting countries are a similar list as the top producers, with the notable exception of Ethiopia which has a strong and ancient coffee drinking culture and consumes about 50% of the coffee it produces. Brazil and other developing countries are also increasing domestic consumption. The top coffee consuming countries are USA, Brazil, Germany, Japan and France.

However, per capita coffee consumption is the highest in Scandinavian countries. Recently emerging countries like Brazil, Indonesia, Vietnam and Russia are expanding their coffee consumption. The vast majority of coffee production takes place in developing countries while the bulk of consumption is in developed countries. This creates a stark dichotomy between coffee producing countries and coffee importing countries.In general, world coffee production is increasing due to increased demand and its intricate trade features. The total production of green beans has increased from 81 million bags (4.8 million MT) in 1980/81 to 120 million bags (7.2 million MT) in 2,009/10 (Promar Consulting, 2011). The global coffee husk resource can be estimated from coffee production volumes. As pointed out in earlier sections, it accounts at least for 20% of dry parchment coffee for wet processing and at least for 40% of the total dry coffee cherries for dry process. This is similar as to say wet process yields at least as much as 25% of the green beans and dry process yields at least as much as 67% of green beans. Thus, taking average between the two values, coffee husk yield may be fairly estimated to be nearly as much as 50% of the green bean production. According to this calculation, the total global green coffee bean production of 7.2 million MT is equivalent to 3.6 million MT of coffee husk out of which 0.81 million MT (equivalent to 0.405 million MT of coffee husk) is in Africa.

2.4.2.2. The Scenario of Ethiopia

Ethiopia, the birth country of coffee, is the 5th largest producer and 9th largest exporter of coffee in the world. It is the top producer as well as exporter in African continent. Uganda, Cot D'Ivoire and Tanzania follow in respective order to dominate African production (Promar Consulting, 2011).Ethiopia produces only Arabica coffee (fig.4). Coffee Arabica plays an important role in Ethiopian economy as well as politics and social life. According to the Ethiopian trade statistics, coffee today is not only Ethiopia's top export crop but it is the top export product in value overall. It brings valuable foreign currency to the revenue poor government and due to this it has been referred to as Ethiopia's ''Black Gold''. The high genetic diversity of native Ethiopian coffee is of great national and international value because of the potential to develop new breeds of coffee with particular strengths from unique flavors to higher disease tolerance, higher yields or low caffeine. Unlike other coffee producing countries, Ethiopia is also a coffee consuming country with a long tradition of coffee preparation. In Ethiopia, coffee ceremony is a traditional way of welcoming guests. Over 50% of the produced coffee is consumed domestically, more than any coffee producing country including Brazil.

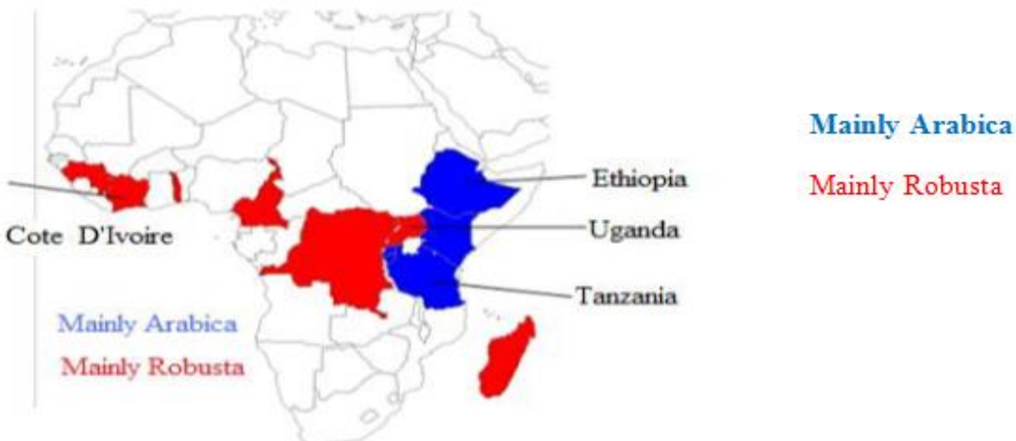

Fig.4: Major African Coffee Producers(*Source: Promar Consulting.2011)*

The vast majority of Ethiopian coffee is grown within the areas in two big regions: Oromia and Southern Nations, Nationalities and People's (SNNP) Regional State (fig. 5) These areas are centered in the southwest and southern part of the country(Figure 5), 73% of the total production is in Oromia, 26% is in SNNP and only 1% in Amhara.

Total coffee production for the country has been increasing fairly steadily over the past decade. Statistics reported to ICO by Ethiopia shows a pick production year in 2007 of 273,000

MT. The volume of coffee production in Ethiopia is estimated through yearly Ministry of Agriculture and Rural Development sampling surveys and can be somewhat inexact especially since a large amount of the coffee produced is consumed directly on the farm (Promar Consulting, 2011).

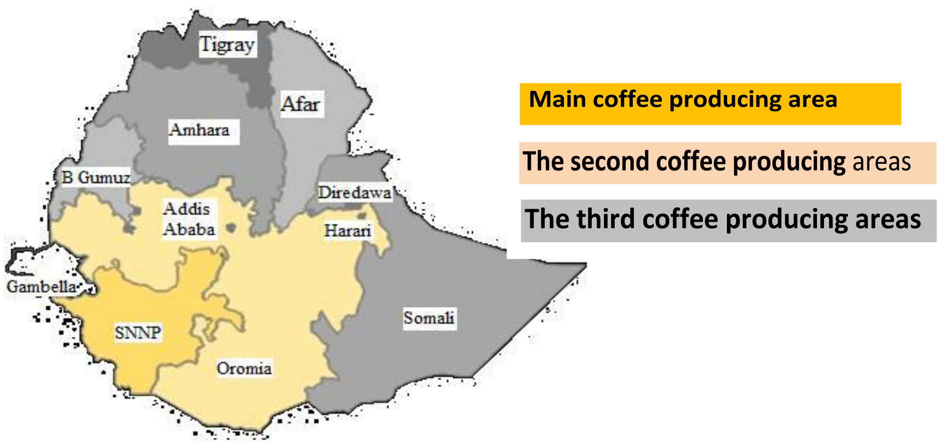

Fig.5: Main coffee growing regions of Ethiopia

(*Source: Promar Consulting, 2011)*

2.5. Fundamental Aspects of Briquetting

Biomass briquetting is the combination or integration of biomass material (coffee husks) as a result of applying pressure. Briquettes are distinguished from pellets by their size. Pellets typically have a length of 5 to 30mm, compared to briquettes which can range from 30mm to 200mm in diameter and from 50mm to 400mm in length (Olorunnisola, 2004).Briquetting is the set of burnable materials which are not functional as such because of their low density, and converting them into a solid fuel product of any convenient shape that can be burned like wood or charcoal. Briquettes are more prefer than the previous or original organic wastes materials due to, easier to package and store, cheaper to transport, more convenient to use, and their burning characteristics (Katimbo, *et al*., 2014).The process of briquetting provides the following advantages: The net calorific value per unit volume is increased, Easier for handling, Lower transportation cost Uniformity of the fuel produced in size and quality, Disposal of residue is facilitated, and Environmental friendly fuels. Briquetting can also be considering as a waste control measure of Agricultural by-products. However, according to the material used, briquetting gives fuel source as a pre-emptive measure to many ecological struggles. During the process, fine material is packed into regular shape and size which does not separate during transportation, storage or burning. The briquetting of biomass is one mechanism of protecting climate change and ensure sustainable development since it reduces reliance on fossil fuel, use waste products, as well as it reduces pollution which may have resulted in case of discarding (Emerhi,2011). There are mechanisms that have been available to answer the difficulty of how to set the large volume of wastes from agriculture and agro-processing industries in to some functional purpose. And these Briquettes are produced from materials which are less in cost or easy gain, like, from partially decomposed plant waste or agro processing wastes, to be an alternate fuel to charcoal, firewood or coal, and may cost less. Based on inputs used to produce the briquettes, they may burn cleaner than coal.

Generally, converting “offhand” materials into energy source is an attractive due to its sustainable process. Briquettes can be used as an option to fuel-wood as the command for the latter. The problem of managements and disposal of agricultural and municipal waste (i.e. sawdust, rice and coffee husk, office and household waste, etc.) is posing confront to the public as these wastes constitute a pain to the environment. Also, more than two billion people globally use biomass for cooking food. Emissions from burning biomass are one of the fourth leading causes of death and disease in the world’s poorest countries (Bhattacharya,*et al., 2002*).

2.6. Technologies for Coffee Husk Industrial Energy Application

For many households, switching away from traditional biomass is not feasible in the short term. Therefore, improving the way biomass is supplied and used for cooking is an important way of reducing its harmful effects. This can be achieved by transforming the biomass into more energy dense and less polluting forms like charcoal and briquettes, and/or through provision of improved cook stoves and sufficient ventilation (IEA, 2007).The utilization of agricultural residues in general and coffee husk in particular for domestic (household) energy application mainly for cooking has not yet been well succeeded. There are two main mechanisms under research. These are, burning them directly as a collection of individual particles and converting them into briquettes. Currently, the best method of burning coffee husks is as a collection of individual particles. When burnt this way, they combust very quickly and ignite at relatively low temperature. They are very light and so have a tendency to be blown away in the combustion process. These properties however, are not particularly ideal for cooking. It is wasteful to use them this way. Nevertheless, researches are underway to come up with gasifier cook stoves to utilize them more efficiently. Another alternative is to press them into briquettes. Some improved stoves are developed to use these briquettes efficiently. However, one of the biggest disadvantages is that, pure coffee husk briquettes are very brittle and so not suitable for long distance transportation. Nevertheless, further research could show that coffee husks help ignition when pressed with additional substances (MadeGood, 2010).

2.7. Briquetting Technologies

Biomass densification represents a set of technologies for the conversion of biomass residues into a convenient fuel. The technology is also known as briquetting or agglomeration. Depending on the types of equipment used, it could be categorized into five main types: Piston press densification, Screw press densification, Roll press densification, Briquetting, Low pressure or manual presses (Onuegbu, et *al*., 2012). Densification of biomass is done with the purpose of improving the handling, transportation and storage characteristics of the material as well as increasing volumetric calorific value to use the material as fuel (Grover P.D. 1996).

2.8. Characteristics of Briquettes

The characteristics of briquettes are determined through the application of proximate analysis which is a standardized procedure of analysis to accomplish and quantify some main characteristics of briquettes (Olorunnisola, 2004).

2.8.1. Moisture Content

The moisture content can be determined through considering a small pre-weighed sample and oven drying it at 105^{o}c. then the difference in weight can be used to determine the sample's percentage moisture content. Moisture content can also presented either on a wet basis, or as the moisture content as received, (this is the biomass' moisture content as a percentage of the total as received mass), or on a dry basis, which is the moisture content as a percentage of the dry mass9. Moisture content is an essential value which highly affects the burning properties of the biomass (Yang,*et al.,* 2005)

2.8.2. Ash Content

Ash is the unburnable parts of biomass, where the maximum in the fuel's ash content, which is the lower in its calorific value (Shao,*et al.*,2012). And which can obtained from both mineral matter bound in the carbon structure of the biomass during its combustion (Ragland *et al*., 1991), and in the form of particles from dirt and clay introduced into the fuel during harvest, transport and processing (the entrained ash) (Shao,*et al*.,2012).

The ash content can be calculated through heating a dry sample of biomass in an open crucible in a furnace at 750oC. Regarding to the type of biomass, the ash content can vary between 0.8% for groundnut shells (Jekayinfa and Omisakin, 2005).During the burning processes of biomass that slogging, fouling, and increase the rate of corrosion of metal as a result of the existence of ashes (Shao *et al.*, 2012).

2.8.3. Caloric Value

The caloric value (or energy/ heating value) is the amount of heat developed when a unit weight of fuel is completely burnt and the combustion products are cooled to 298K and it is the standard measure of the energy content of a fuel (Appleton,*et al.*, 2005).The calorific value of a given fuel relates to the amount of oxygen that is essential for complete burning, that is for each gram of oxygen burnt, 14,022 joules of energy are out. As a result, fuels that containing carbon with a maximum degree of oxidation will have a lower calorific value, since less oxygen is required for their complete oxidation. In other word, when fuels contain compounds like, hydrocarbons that have a lower degree of oxidation, which causes to raise the calorific value of the biomass (Jenkins,*et al*,. 1998).

2.8.4. Bulk Density

Density of biomass can vary , from around 100 kgm^{-3} for light dry straw, to over 2000 kgm^{-3} for highly compressed biomass fuels .The maximum the density of the fuel, the greater the energy density., this then influences the ratio of energy input per unit volume into a cook stove's burning hallow (Shao, *et al*.,2012). The fuel briquette's density will then influence its bulk thermal properties: the thermal conductivity will be reduced as the density is decreased (increased fuel porosity), but the lower the density, the less heat is required for a specific volume of fuel to reach the ignition temperature. As a result the ignition time, and the rate of thermal decomposition will be affected. The denser the material the thinner the pyrolysis reaction zone, which reduces the time that the reacting gases are in this reaction zone. This produces the interesting result of an increase in the concentrations of the gases CO, CH_4 and H2 leaving the fuel surface for denser fuels. If valid for large biomass particles, it would be of interest in understanding the emissions performance of cook stoves in relation to the fuel (Yang, *et al.*, 2005). Density might also affects the residence time of the gases within the char matrix of compressed biomass material; materials compressed to a higher density will tend to have a lower porosity, and the density of the final char, after revitalization, might also have a lower porosity. This would increase the residence time of volatile gases in the porous char, leading to secondary reactions becoming more important (Zaror and Pyle, 1982).

2.9. Common Binders used in Biomass Briquettes

Binders are substances which can be organic or inorganic, natural or synthetic, that can stick two or more things together. The two common types are combustible and non-combustible binders. Combustible binders can support combustion and burning processes. Examples are starch, petroleum residues, molasses, cottonseed oil etc. Whereas Non-combustible binders are binders that cannot support combustion examples are clay, cement, limestone, etc. Starches have proved very satisfactory as binders. Binders improve the binding characteristics of the biomass and produce a more durable product. Binders also help reduce wear in production equipment and increase abrasion resistance the fuel (Bhattacharya *et al.,* 2002). Table 1 shows the most common binders used in briquette making.

Table 1: Classification of the most important binders

Classification of binders	
Organic binders	**Inorganic binders**
molasses	Clay
Coal tar	Cement
bitumen	Lime
starch	Sulfite liquor

The binder plays an important role in the final quality of the briquettes. Each binder has a steady effect on: Briquette solidity (important in case of transportation), Sensitivity to moistness (important in case of long storing), Mineral matter content, Market price (Raju *et al*., 2017).

3. MATERIALS AND METHODS

3.1. Description of the Study Area

3.1.1. Location

The study was conducted in Dilla town which is found at the north tip of Gedeo zone political administration and bounded by Sidama zone from its north part, the eastern edge of the rift valley, 365kmfrom Addis Ababa and 96km from Hawassa of SNNP Regional State (fig. 6). It possessed a long history of becoming a center of political administration for various regimes and currently serving as a capital of Gedeo zone administration. It is situated at a center or midpoint from Addis Ababa to Moyale. These possessions had yielded and strengthen an opportunity to become market center just distributor for the whole surrounding numerous towns, villages and rural areas. And it is located at 1600 meters above sea level and practices whole year humid type temperature.

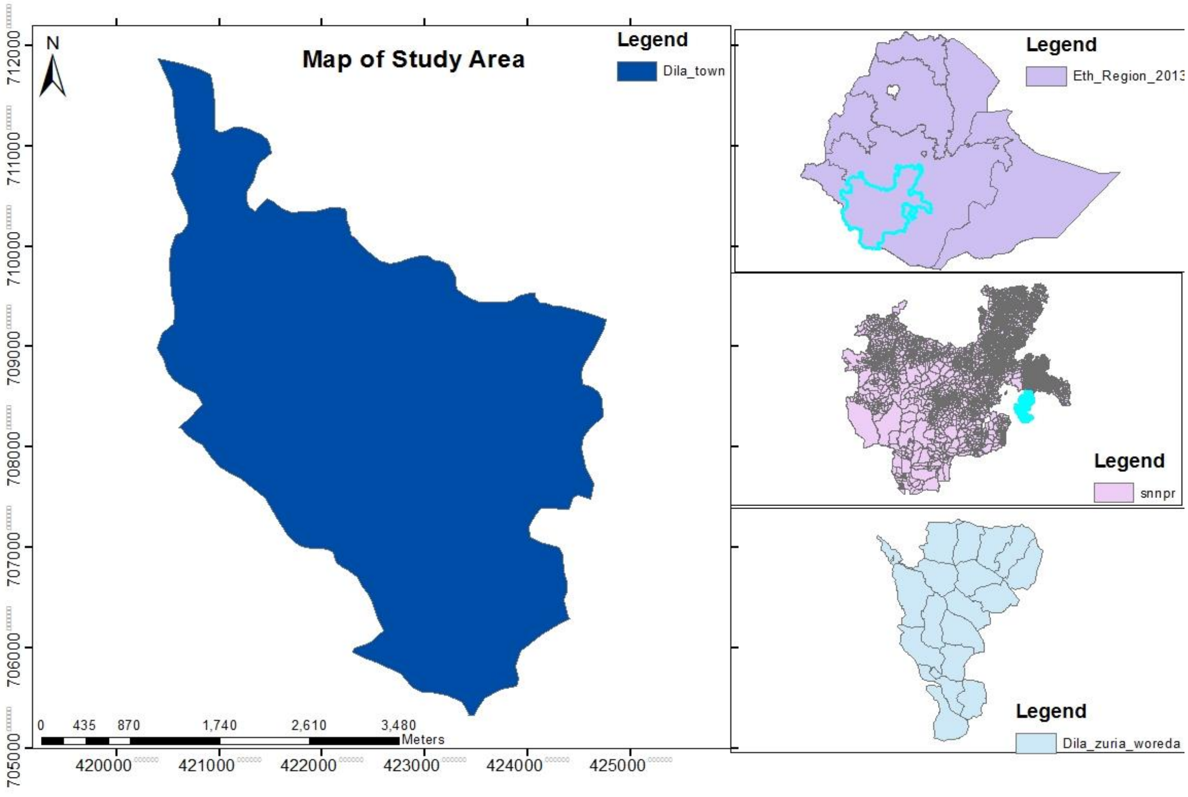

Fig.6: Location Map of dilla town

3.1.2. Population

According to the 2007 Central Statistical Agency (CSA), this town has an estimated total population of 59,150, of whom 31,068 are men and 28,082 are women; With an estimated area of 1123.47hectare land, The majority of the inhabitants were practiced Ethiopian Orthodox Christianity, with 41.65% of the population reporting that belief, 39.2% were Protestants, 15.93% were Muslim, and 2.68% were Catholic. The dominant activities in the town are commercial activities followed by government work and small scale industries such as flour mills and coffee processing industries. The fact that commercial activities are very dominant in the town is because of the location of the town. The town is found along the main road from Addis Ababa to Moyale, which is the main passage of goods from Kenya.

3.2. Materials and Equipment Required

3.2.1. Materials

Coffee husks, water and clay soil were used in the present investigation.

3.2.2. Equipment Used

Oven, electrical furnace, analytical balance, sieves (1mm, 3.35mm and 5.6mm), mixer, homemade briquetting press , digital balance, stop watch, crucibles, meter, desiccators, and oxygen bomb calorimeter (Parr 6200) were the equipment used to characterize both coffee husks raw material and the produced briquettes.

3.3. Methods Used

3.3.1. Selection of study area

The study was carried out at Dilla town and dillazuriakebels of Gedeo Zone. Selection of the study were mainly guided by the objectives of the study and existence of high potential sources of coffee production within the selected area, the impact of environmental pollution as result of huge accumulation of coffee by-products as bio waste, existence of individual coffee product processers and the data were collected from the selected coffee production processers.

3.4. Sampling Technique

3.4.1. Household Survey

Dillazuria district was selected purposively as sources of inputs for those of coffee processors in the dilla town. Farmers in this district did not carry and transport their allcoffee products to that of coffee processors rather they were separating the clean coffee bean with that of coffee husk by traditional means. The practice were suitable to study the current applications and ways of coffee husk management

3.4.2. Collection of Coffee Husk

The coffee husk used in the present study was collected from dilla town within the coffee possessor plants and taken to the laboratory of ministry of water, irrigation and electricity laboratory at Addis Ababa for briquette preparation and physicochemical analysis.

3.5. Sample Determination for Household Survey

Among 17 kebeles in the study area, threekebeles were selected purposively based on their huge potential of coffee production. Thirty households were also selected from each of the three kebeles and the data collected based on the information obtained from these household

3.6. Sources of Data

Data for the present study were collected from both primary and secondary sources. The data from both sources were important for estimating the potential of coffee husks to be used as alternative household energy sources and for evaluating the physical and chemical characteristics of briquettes produced. The experimental frame work of the study is shown in fig. 7.

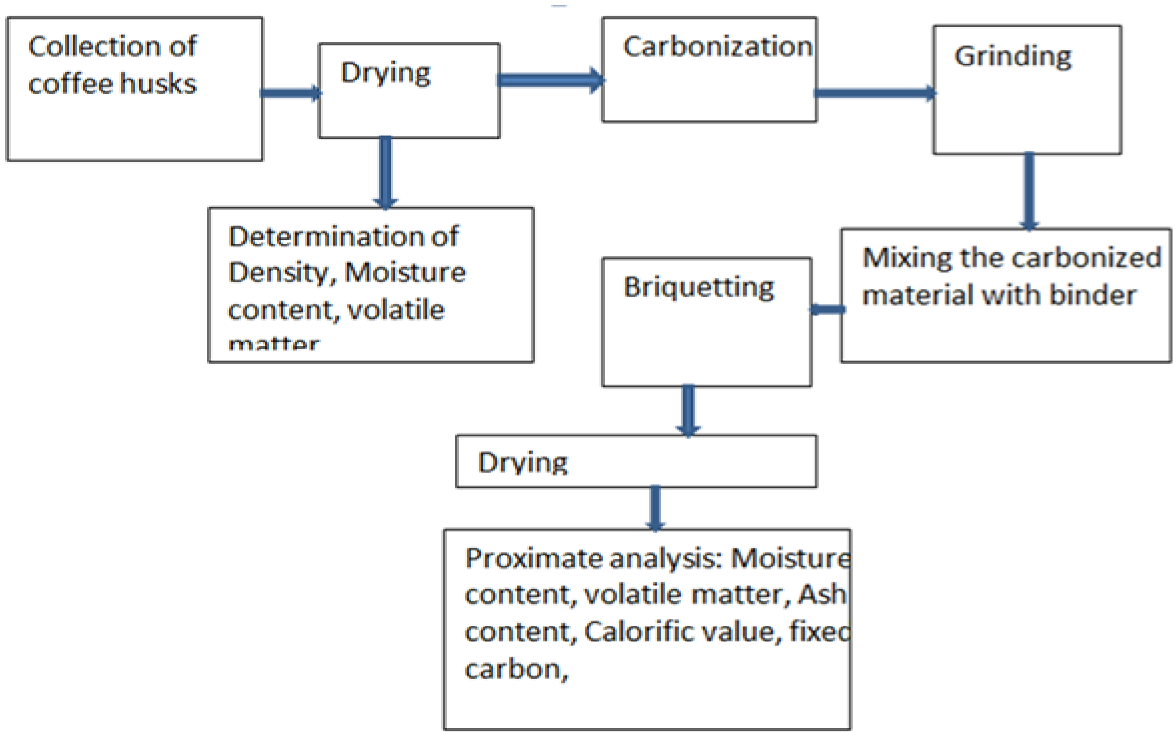

Fig.7 experimental frame work of the study

3.6.1. Primary Sources of Data

Primary data were collected through key informative interviews, questionnaire, and survey of individual households or farmers, coffee producers and from laboratory experiment

3.6.2. Secondary Sources of Data

Secondary data were collected through referring different documents, books, referring recorded data from the town's agricultural office.

3.7. Methods of Coffee Husk Collection

Coffee husk samples were collected from coffee processing plants located at Dilla town, Gedeo zone of the Southern Nations Nationalities People Regional State. The collected samples were transported to the Chemical Analysis Laboratory of the Ministry of Water, Irrigation and

Electricity laboratory workshop at Addis Ababa. The coffee husk was allowed to dry with sunlight to have appropriate moisture content. Following that, the characteristics of the sample were determined.

3.8. Characterization of Raw Coffee Husk

Coffee husks raw material were characterized in terms of moisture content volatile matter ,ash content and heating value. The percentage of moisture content of the husk was determined by weighing a specific amount of sample husk before and after oven drying at105^{0}C (ASTM, 1983).The change in weight of the sample is taken as the percentage moisture content of the husk using the following relation.

$$MC\ (\%) = B/A * 100$$

Where MC is moisture content, A is the mass of sample (g) before drying and B is the change in weight of sample before and after drying in oven.

On the other hand percentage of volatile matter content of the coffee husks was evaluated by taking the husk after the moisture removed and keeping it in a furnace at a temperature of 950^{o}c for 7 minutes (ASTM, 1983). The husk sample husk then weighted after cooling in desiccators to obtain the change in weight, the percentage volatile matter then computed by using the equation:

$$VM\ (\%) = (W3/W2)*100$$

Where, VM (%) = percentage volatile matter of coffee husk, W2 =oven dried sample weight of coffee husk, and W3 =change in weight of oven dried coffee husk before and after transferred to muffle furnace.

The ash content of the coffee husks were also determined by placing a sample in an oven until a constant weight was obtained. The oven dried sample was then transferred in to the furnace set at a temperature of 750^oC for 6 hours (ASTM, 1983). Then after, the crucible and its contents were transferred to desiccators and then reweighed to obtain the weight of ash. Then the percentage ash content was calculated as the ratio of weight of ash to that of weight of dry sample as follows:

$$AC (\%) = (W2/W1) *100$$

Where, W1 = Initial weight of oven dried sample (g), W2 = weight of ash (g) and AC (%) = percentage ash content.

The other parameter was the percentage of fixed carbon content of the raw coffee husk. It was computed by subtracting the sum of volatile matter (VM), ash content (AC), and MC (moisture content) from 100(ASTM, 1983).

$$FC (\%) = 100 - [MC\% + VM\% + AC\%]$$

3.9. Carbonization Processes of Coffee Husk

After the coffee husk dried, 91.8 kg of sample in three trials (30kg, 30.8kg and 31kg) was carbonized in an oxygen scarce using coffee husk cherry as explained by (woldemedine, et al., 2014).And the conversion efficiency of the coffee husk was calculated as:

Carbonization efficiency of coffee husk = (weight of carbonized husk/weight of raw coffee husk)*100 (Pari,*et al*., 2004)

Here carbonization processes is important during the production of fuel briquettes for; the removal of volatile matters and for transformation of coffee husks in to carbonized material.

3.10. Briquette Production

The carbonized materials were grounded in to fine particles and separated by using sieve of different size (1mm, 3.35mm and 5.6mm).These particle sizes were selected because of limitation of sieves of other sizes in the laboratory.The carbonized materials (charcoal) of different particle size then mixed with a soil binder in the ratio of3:1(charcoal : soil) for studying the effect of particle size on the physical, combustion and proximate analysis of produced briquettes. Here clay soil was used as a binder material as it was easily available around. Then the mixtures were converted in to briquettes by using a briquette extruder machine. This was done by pouring the mixture into the briquette extruder machine (Merete *et al*, 2014).Here a total of 38briquettes, taking particle size as a factor (15from particle size of 5.60mm, 12 from particle size 3.35mm and 11 from particle size 1mm) were made. The variation in the number of briquettes occurred as a result of compaction capacity of the charcoal with different particle size in the formation of briquettes. In the second phase briquettes were produced by considering charcoal (carbonized materials) to binder ratio as a factor. The carbonized materials were grounded in to fine particles and mixed with a binder in the 3:1, 4:1 and 5:1 ratios. A total of 47 briquettes were produced with different carbonized husk and binder ratio (12 from 3:1, 16 from 4:1 and 19: from 5:1).The briquettes were placed on a suitable material for drying under the sun and then three briquettes were taken from each individual treatment for further analysis.

3.11. Proximate Analysis of the Briquettes

Three samples of the dried briquettes from all treatments were used for determination of moisture content (MC), volatile matter (VM), ash content (AC), and fixed carbon content (FC).

3.11.1. Moisture Content

The moisture content (%) of the briquette was determined by drying the sample of briquette in oven at 105^{o}C for 2 hours (ASTM, 1983). The moisture content of the sample then computed on weight basis according to the following equation:

MC (%) = ((Weight of sample (g) – Oven dried Weight of sample (g))/ Weight ofsample (g)) × 100

3.11.2. Volatile Matter Content

The volatile matter of the briquette was determined by heating an oven-dried sample in absence of oxygen at 950^{o}C for six minutes (ASTM, 1983). The volatile matter was then computed as the difference between the initial weight and final weight of the sample to the ratio of weight of the briquette sample as follows.

VM (%) = ((Weight of sample dried at 105 ℃ (g) – Weight of sample (g) at 950 ℃)/ Weight of sample dried at 105 ℃ (g) × 100.

3.11.3. Ash Content

Ash content of the briquette was determined by heating the briquette sample in a crucible at 750^{o}C for three hours in an oven. The ash content was then calculated as the proportion of the weight of the ash in the briquette to the weight of briquette sample as follows(ASTM, 1983):

AC (%) = ((Weight of sample at 950 ℃(g) - Weight of sample at 750 ℃ (g))/(Weight of briquette sample at 750^{0}C (g)) × 100

3.11.4. Fixed Carbon Content

The percentage of fixed carbon content of the briquette was computed by subtracting the sum of volatile matter (VM), ash content (AC), and MC (moisture content) from 100 (ASTM, 1983).

$$FC\ (\%) = 100 - [MC\% + VM\% + AC\%]$$

3.12. Physical and Combustion Characteristics of Coffee Husk Briquette

3.12.1. Bulk Density

Since the produced briquette was cylindrical in shape The bulk density was determined by calculating the volume from the its height and radius, the BDwascomputed by using the formula as follows (Rabiera, et al. 2006)

$$BD = m/v = M/\pi r^2 h.\ V = \pi r^2 h$$

Where:

BD bulk density

mmass of the produced briquette

V volume of the produced briquette

πconstant value 3.14

r radius of produced briquette

h height of produced briquette

Then, Bulk Density = (mass of briquette) / (volume of briquette)

3.12.2. Calorific Value

The gross calorific values of coffee husks briquettes were determined using a standard Oxygen Bomb calorimeter (Parr 6200). The bomb was fired up by depressing the ignite switch to burn the sample in an excess of oxygen. A predetermined mass of each sample was burnt in the bomb calorimeter until complete combustion was obtained, and then the 6200 calorimeter was automatically made all of the calculations necessary to produce a gross heat of combustion for the sample

3.13. Data Analysis

The gathereddata were recorded, processed and analyzed using Microsoft excels and SPSS software. Descriptive statistics and graph were used to compare means and standard deviation (SD) of the result of analysis. All the analysis evaluates were done in triplicate (n=3).

4. RESULTS AND DISCUSSION

4.1. Socioeconomic Characteristics of the Households

The socioeconomic situations of the household determine the current application and waste management systems of coffee husks. The socio-economic features of the sample households in the study area were presented under (table 2). The numbers of men respondents were higher (90.1 %) than women respondents. Larger proportions of the respondents (70 %) were with the age class of 51-65years.With regard to education level, majority of the respondents (57 %) were attended 1-10 grade while the others were either can only reading and writing or attended preparatory and higher level education. About 56.7 % of households had family size within the range of 6 to 9 persons. Agriculture was the major occupations for about 92% the households.

Table**2:** Households' socioeconomic characteristic of respondent in the study site, Ethiopia (n=90)

Socioeconomic characteristics	Category	Frequency	Percent (%)
Sex	Male	82	90.1
	female	8	8.9
Marital status	Married	82	90.1
	Widowed	8	8.9
Age	36-50	27	30
	51-65	63	70
Family size	2-5	39	43.3
	6-9	51	56.7
Education	Illiterate	15	16.7
	(1-10 grade)	63	70
	above grade10	12	13.3
Occupation	Agriculture	83	92.2
	Agriculture and other	7	7.8

4.2. Annual Coffee Husk Production Potential of the Study Area

The average annual clean coffee beans production of the zone found to be about 31069.76T which is 35% from the total coffee production in the area. The rest, which is about 57700.8T (65%) were coffee husk waste (table 3). Sixty percent of the coffee produced in the study area processed by wet processing. The remaining coffee (40%) processed under natural condition (sun-dried). The yield of clean coffee beans from sun-drying was 54-60% of the entire dry coffee cherries. On the other hand, the yield ofclean coffee beans from wet process was 78-80% of the dry parchment coffee (Agriculture and Rural Development Bureau of the Zone, 2010). This indicates that the zone produces about 24545.11T washed coffee and about 6524.65T sun-dried coffee which is equivalent to about 32889T of parchment and 24811T of coffee husk (dry process). The respective annual production of clean coffee beans and coffee husks are shown in table 3 bellow.

Table 3: Annual coffee production with respect to coffee husk from the year 2006 to 2010 E.C

No	Year E.C	Clean Coffee beans (T)	Coffee husk(T)
1	2006	10265.1	19063.8
2	2007	10,099.5	18,756.2
3	2008	11,8087.4	21,9305.1
4	2009	12,365.2	22,963.9
5	2010	4531.6	8415.8
Total		155348.8	288504.8

Source Dillazuria town agriculture and rural development office, 2018

4.3. Specific Locations where the Coffee Husk is Available

Generally, the coffee husk, whether it is parchment or coffee husk (dry process), is found at the coffee hullers. Dry processed (natural) coffee is almost entirely hulled in the coffee producing areas. The hullers are concentrated at the main central towns of coffee producing area. On the other hand, the washed coffee is de-pulped, washed and dried in coffee producing areas and the dry parchment coffee is exclusively transported to the capital, Addis Ababa. There are about 24 coffee processors in which almost all this dry parchment coffee husk is produced in the town.

4.4. Current use of Coffee Husk in the Study Area

Only a small portion of the coffee husk available in the study areas is used for limited purposes. The limited uses include: as a cooking fuel in traditional means (direct burning system) in urban areas and its surroundings (especially for injera baking); for mulching and organic manure (without pre-treatment) in coffee farms; and composting using natural process for fertilizer (table 4). Though the farmers use the husk for those limited purpose, the coffee husk has potential to be used for different purposes including as feedstock for biogas production. Such applications were not observed in the study area.Table4showed the response of respondents in respect of current uses of coffee husk at house hold level. Table 4 clearly showed that the household in the study area use coffee husks mainly as fertilizer and traditional source of fuel.

Table 4:Current uses of coffee husk at household level

Kebele	current application	frequency	Respondents (%)
Chichu	As fertilizer	12	40
	As fuel	9	30
	As animal feeding	6	20
	No purpose	3	10
	Total number of respondent	30	100
Sisato	As fertilizer	10	33.3
	As fuel	11	36.7
	As animal feeding	6	20
	No purpose	3	10
	Total number of respondent	30	100
Gola	As fertilizer	7	23.3
	As fuel	10	33.3
	As animal feeding	5	16.7
	No purpose	8	26.7
	Total number of respondent	30	100

On the other hand, coffee processers distribute the coffee husk to consumers. To some extent the processors themselves used as a fuel source and dump off the remaining husk (Table 5)

Table 5: Current uses of coffee husk at coffee processor level

Type of	Current application	frequency	Respondents (%)
Private	Distribute for consumers	5	50
	As fuel	2	20
	No purpose	3	30
	Total number of respondents	10	100
Share	Distribute for consumers	2	40
	As fuel	2	40
	No purpose	1	20
	Total number of respondents	5	100
Mahiberat	Distribute for consumers	2	40
	As fuel	1	20
	No purpose	2	40
	Total number of respondents	5	100

4.5. Coffee Husk Management Practice System

The current investigation revealed the existence of very poor coffee husks management systems in the study area which could play a significant impact on environmental pollution. Table 6 indicates that most of the coffee husks are managed by simple dumping off along the road sides.

Table 6:Current coffee husk wastes management practice at house hold level

Kebele	Coffee husk management system	frequency	Respondents (%)
Chichu	dumping	25	83.4
	Open burning	4	13.3
	Release to the river	1	3.3
	No way of Management practice system	-	-
	Total number of respondents	30	100
Sisato	dumping	27	90
	Open burning	3	10
	Release to the river	-	-
	No way of Management practice system	-	-
	Total number of respondents	30	100
Gola	dumping	24	80
	Open burning	4	13.3
	Release to the river		0
	No way of Management practice system	2	6.7
	Total number of respondent	30	100

The other coffee husk management systems were open burning and releasing to the river.It has been observed that there is higher similarity in the coffee husk management practice at household and coffee processors level (table 7). Almost thesame coffee husk waste management practice system were applied at coffee processors level in private, share and Mahiberatin which simply dumping way of coffee husk waste management practices is employed mainly.

Table 7: Current coffee husk wastes management practice at coffee processor level.

Type of company	Coffee husk management practice	frequency	Respondents (%)
Private	dumping	7	77.8
	Open burning	1	11.1
	Release to the river	1	11.1
	No way of Management practice system	-	-
	Total number of respondents	9	100
Share	dumping	5	100
	Open burning	-	
	Release to the river		
	No way of Management practice system	-	
	Total number of respondents	5	100
Mahiberate	dumping	5	100
	Open burning	-	-
	Release to the river	-	-
	No way of Management practice system		-
	Total number of respondents	5	100

4.6. Proximate Characterization of Raw Coffee Husk and Briquettes Produced

The proximate and combustion characteristics of the raw coffee husk were studied. Moisture content, volatile matter, ash content, fixed carbon and calorific value (gross heat value) of the husk to be used for briquette production were instigated. The qualities of coffee husk briquettes were evaluated by using operating factors, coffee husk charcoal to clay soil binder percentage (ratio) and average particle size of carbonized coffee husk. The physical and combustion properties of the coffee husk briquettes examined in this work were limited to density, percentage volatile matter, percentage ash content, fixed carbon percentage and gross calorific value.

4.6.1. Proximate Analysis of Coffee Husk Raw Material

Before introducing any type of biomass residues as sources of fuel, it is important to evaluate its physical and chemical properties. Hence characterization of the raw coffee husk to be used for briquette making in the present investigation was done in terms of moisture content, volatile matter, ash content and heat value. Table 8showed the different physicochemical characteristics of coffee husk raw material.

Table 8: characteristics of coffee husk raw material used for briquette making

treatment	No of trials	%MC	%VM	%AC	%FC	CV(MJ/Kg)
Coffee husk raw material	T1	11	30.56	5	53.44	16.91
	T2	9	28.77	8	54.23	16.86
	T3	11	33.82	6	49.18	16.69
	Mean ±SD	10.33±1.15	31.05±2.56	6.33±1.53	52.28±2.71	16.82± 0.14

The moisture content of the coffee husk generally ranges between 9-11%. The volatile matter of the coffee husk was in between 28.77-33.82%, while the ash content found to be from 5 - 8%. On the other hand the fixed carbon content and gross heat value of the husk used for briquette preparation were from 49.18 - 54.23% and 16.69 - 16.91MJ/Kg, respectively. In addition, the average proximate analysis of the raw coffee husk forMC, VM, AC, FC and CV were 10.33%, 31.05%, 6.33%, 52.28% and 16.82 MJ/Kg, respectively. The coffee husk in this study showed lower MC than leaves & vegetable (12.79%) and was comparable with wood waste (9.40%) and higher as compared to bones(3.58%), food waste (5.9%) % fruit waste (8.5%) as reported by Rominiyi,*et al.,* (2017). Similarly the VM of the coffee husk was lower than that of bones(67.2%) and higher as compared to food waste(9.49%), fruit waste(20.6%), wood waste (12.24%), leaves& vegetable(24.87%). The ash content was lower as compared to biomass wastes; bones(64.27%), leaves & vegetable(19.27%) & fruit waste(14.47%) and comparable with that of foodand woodwastes, 7.66 and 8.55, respectively. However, coffee husk in this study area have highest calorific value as compared to these all biomass wastes, bones(5.92MJ/Kg), wood waste(15.31MJ/Kg), leaves &vegetable(12.38MJ/Kg), food waste(16.02MJ/Kg) and fruit waste(13.97MJ/Kg)(Rominiyi, *et al.*, 2017).

4.6.2. Carbonization Efficiency of the Raw Coffee Husk

Carbonization efficiency indicates the amount of charcoal produced and determined in terms of percentage. The carbonization efficiency can be affected by factor like moisture content of the input, number of air hole in the kiln that regulate the amount of air for the proper carbonization and cooling, personal skill and experiences. The conversion efficiency of the coffee husk into carbonized material in this study was 33.07±2.7% (table 9). Since the annual average amount of coffee husk waste to be processed was around 57,700.96T which is 65% of the total coffee produced from 24 coffee processers, (14 private, 5 share and 5 mahiberat), 19,041.3T carbonized coffee husk can be obtained annually. If19, 041.3T is mixed with the binder in 3:1 it would be possible to produce about 23801.6T of briquettes every year in the study area.

Table 9: Carbonization efficiency of coffee husk

sample of feed stock	No of trials	Mass of raw husk (kg	Mass of carbonized material (kg	Conversion efficiency (%)
	T1	30	10.74	35.8
Coffee husk	T2	30.8	10.16	33
	T3	31	9.12	30.4
	Mean ± SD	30.6±0.53	10.01±0.82	33.07±2.7

Table 9 showed that the conversion efficiency of the coffee husk into carbonized material in the present study ranges from 33 to 35.8% that results about an average 33.07±2.7%, which is relatively higher than the conversion efficiency reported by Woldemedine, *etal*.(2014).

4.6.3. Evaluation of the Energy Potential of the Briquette Produced from Coffee Husk

Since the average of the calorific mean values of the briquettes produced from the study site was 17.7 MJ/kg or 4,227.57 cal/g(Table 14). If 19,041.3T were mixed with the specified proportion of the binder 3:1 it could possibly produce an average of 25,388.4T briquettes, which would have a calorific value of 1.07x1011cal/g as a total energy.

According to(FAO, 1999) One kg of fuel wood gives 13.8 MJ of energy, which is equal to 3,296.82 cal/g of energy and one cubic meter of fuel wood equals to 750 kg. Therefore, through production of briquettes, the study site could possibly substitute $4478*10^5$MJ energy obtained from $32.45*10^5m^3$ of firewood. Tropical high forest could provide 80 to 100 m3 of firewood per hectare (FAO, 1987). Based on this conversion, dilla town could save 32,450 to 40,562ha of forest from deforestation annually.

4.6.4. Physical, Combustion and Proximate Analysis of Coffee Husk Briquettes

4.6.4.1. The Effect of Particle Size on Physical, Fuel and Proximate Character of the Briquettes

It is generally accepted that raw material particle size influence the density of produced briquettes as the decrease in particle size increases the capacity of compacting or bindingthe charcoal each other. With constant ratio of feedstock to binding material, small particles give a higher density of single briquette. Three levels of average particle size of coffee husk charcoal (1mm, 3.35mm and 5.6 mm) were used. For each particle size, 33.33% (3:1 charcoal to binder) of clay soil was combined as a binder. Table 10 showed the effect of applying different particlesize of the charcoal on the proximate characterization of briquettes with a constant amount of binding material.

Table 10: Proximate analysis of produced briquettes, particle size as a factor

Particle size	No of trials	%MC	%VM	%AC	%FC
	T1	6.8	25.25	13.37	54.88
	T1	7.2	24.8	12.49	56.11
1mm	T3	7.1	25.03	12.32	56.85
	Mean± SD	7.03±0.21	25.026±0.22	12.72±0.56	55.95±0.99
	T1	7.1	27.65	13.46	51.79
	T2	7.1	32.15	13.57	47.18
3.35mm	T3	6.3	28.9	12.96	45.54
	Mean ±SD	6.8±0.46	29.56±2.32	13.33±0.32	48.17±3.24
	T1	6.5	30.35	14.01	48.84
5.60mm	T2	6.6	28.02	12.89	51.82
	T3	5.8	35.6	13.75	43.55
	Mean ±SD	6.3±0.43	31.32±3.88	13.55±0.58	48.07±4.18

The moisture content of briquettes for particle size 1mm ranges between 6.8-7.2% with an average value 7.03% while for particle size 3.35mm the moisture content were in between 6.3 to 7.1% with an average of6.8%, Generally when the particle size of the charcoal increased, the moisture content of the briquette showed to be decreased. It might be related with the compaction capacity i.e. when the particle size decreases the compaction capacity increase so that the moisture might not be easily released during drying. It is suggested that the moisture content need to be withinthe range of 10-15% (Grover and Mishra, 1996).Higher moisture content will pose problems in grinding and excessive energy is required for drying (Kaliyan and Morey, 2009; Ollet, et al. 1993).

Table 11: Analysis of variance (ANOVA) on proximate analysis of briquette made from different particle size of carbonized coffee husk (charcoal)

dependent variables	Treatment (particle size as a factor)	N	Mean± SD	SE
Moisture content	1mm	3	6.3±0.43a	0.120
	3.35mm	3	6.8±0.46a	0.2667
	5.6mm	3	7.03±0.21a	0.252
	total	9		0.156
Volatile mater	1mm	3	25.026±0.22a	4.519
	3.35mm	3	29.56±2.32a	1.341
	5.6mm	3	31.32±3.88b	0.129
	total	9		1.529
Ash content	1mm	3	12.72±0.56a	0.339
	3.35mm	3	13.33±0.32b	0.188
	5.6mm	3	13.55±0.58b	0.326
	total	9		0.191
Fixed carbon	1mm	3	55.95±0.99b	4.757
	3.35mm	3	48.17±3.24a	1.871
	5.6mm	3	48.07±4.18a	0.574
	total	9		1.875
Calorific value	1mm	3	18.1±0.4c	9.47
	3.35mm	3	17.7±0.1b	1.10
	5.6mm	3	17.47±0.65a	5.61
	total	9		3.919

There was no a significance difference in percent of moisture content , volatile mater content and ash content under three levels of particle size difference and there was a significance difference in percent of fixed carbon and in calorific value under the three levels of particle size differences under 95% confidence level.

In the current investigation, the average fixed carbon content of briquette made from particle size of 1mm was significantly higher than the mean fixed carbon content of briquette made from particle size of 3.35mm and 5.60mm, carbonized coffee husk, while the difference in Fixed carbon content from particle size of the latter two (3.35mm and 5.60mm) was not significantly different (table 11). The mean gross heat value (calorific value) was significantly different for briquette made from the different particle size. In comparison, the mean calorific value of the briquette with 1mm particle size was the highest and that of from 5.60mm was the lowest. The relation between particle size and gross heat value of the briquette made is presented in fig. 8.

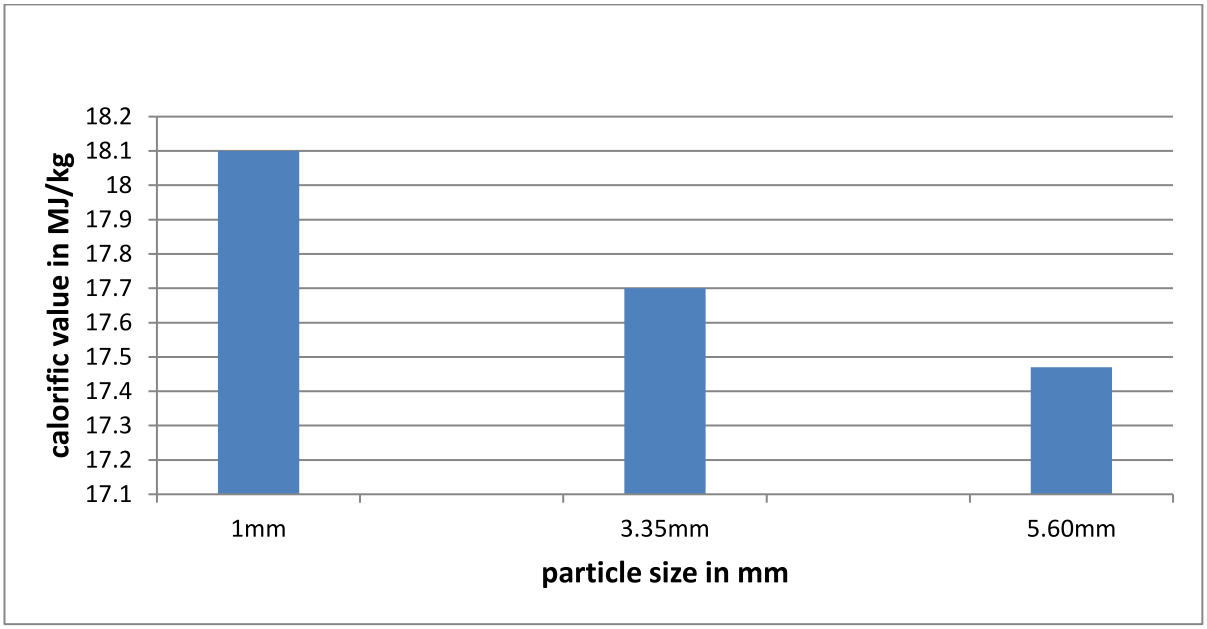

Fig.8 calorific value of briquette vs particle size of charcoal

The above figure showed that as the particle size in which the briquette is made increased, the gross heat value was decreased as a result of decreased bulk density.

4.6.4.2. Effect of Charcoal to Binder Ratio Difference on the Fuel Physical and Proximate Characteristics of Briquette

In the production of briquettes, binders are essential for increasing the strength, durability and weather resistant capacity of briquettes. Variation in efficiency between different agricultural waste and organic binders has been demonstrated by many researchers, however, enough reports were not found related to the effect of different charcoal to binder(clay soil) ratio on the fuel quality of briquettes.

The moisture content of the charcoal determines the physical properties of the briquettes.If the moisture content is low the briquette will have resistance to biodegradation and less vulnerable to the attack of biological agents' as well atmospheric changes, which mean increases its durability (Heya, et al., 2014). The quality specification of charcoal usually limits the moisture content between 5 to 15% (FAO, 1985; FAO, 1999) while the good quality of charcoal should have a maximum moisture content of 10%. On the other hand, there is some evidence concerned that charcoal with high moisture content, more than 10% tends to shatter when heated in the blast furnace (FAO, 1987). In this study the result from coffee husk charcoal (table 12) showed moisture contents of the briquettes as particle size and charcoal to clay soilbinder ratioas a factor ranged from 5.8% to 7.2% and 5.35% to 6.36% respectively, which matches within the desirable criteria set by (FAO, 1987).

Table 12: Proximate analysis of produced briquettes, sample to binder ratio as a factor

treatments	No of trials	Proximate analysis			
		%MC	%VM	%AC	%FC
Sample to binder ratio 5:1	1	5.68	26.09	15.65	52.58
	2	5.59	25.25	17.84	51.32
	3	5.35	23.85	16.43	54.37
	Mean ±SD	5.54±0.17	25.06±1.13	16.64±1.11	52.76±1.53
Sample to binder ratio 4:1	1	6.18	24.97	17.52	51.33
	2	6.33	29.63	17.95	46.09
	3	5.55	25.01	18.01	51.43
	Mean ±SD	6.02±0.41	26.54±2.68	17.81±0.27	49.62±3.05
Sample to binder ratio 3:1	1	5.99	25.42	18.74	49.85
	2	6.14	25.27	18.96	49.63
	3	6.36	30.54	19.02	44.08
	Mean SD	6.16±0.19	27.08±3.00	18.91±0.15	47.85±3.27

The volatile matter of the briquettes in this study(table 12) is lower than the volatile matter of briquette produced from Coconut pith briquette and Sawdust briquette which have the matching values of 71and 60 %, respectively (Murali, *et al.*,2015). The higher the volatile matter implies the faster will be the ignition but with high smoke (Sotannde, *et al.*, 2010). On the other hand, the ash content of the briquettes in the present investigation (table 12) is higher than the ash content of briquette produced from elephant grass and spear grass which have the values of 4.35 and 6.09 %, respectively (Onuegbu*et al*., 2012).The higher ash content in this study might be due to the binder type used. It is been observed that as the proportion of binder increased, the ash content of the briquette also increased. This might be associated with the non-compostable nature of the binder used.Generally, the lower the ash content the better will be the briquette for utilization, and the higher the ash content the higher will be the formation of dust and it affect the combustion efficiency. Briquettes with lower ratio of the clay soil will have high quality of fuel as compared to briquettes of high clay soil binder ratio (Akowuah, *et al.*, 2012).

The other factor assessed in the present study is the effect of charcoal to binder ration on fixed carbon content of the briquette.Fixed carbon contents of the briquette is the solid combustible residue that remains after the briquettes were heated and the volatile matter was removed. The fixed carbon content of the briquettes for this study (table 12) is much less than the fixed carbon content of the briquettes produced from sawdust (Sayakoummane and Ussawarujikulchai, 2009) and greater than briquettes produced from Hazelnut shell (Haykiri-Acma and Yaman, 2010).

Table 13: ANOVA analysis onmean heat value and proximate analysis (in MJ/Kg and % respectively) under three levels of charcoal to binder ratio difference

Table 13: ANOVA analysis on mean heat value and proximate analysis (in MJ/Kg and % respectively) under three levels of charcoal to binder ratio difference

Heat value and proximate analysis	Treatment (charcoal to clay soil binder ratio)	N	Mean± SD	SE
Moisture content	3:1 ratio	3	6.16±0.19a	0.43
	4:1 ratio	3	6.02±0.41a	0.46
	5:1 ratio	3	5.54±0.17a	0.2
Volatile mater	3:1 ratio	3	27.08±3.00a	0.22
	4:1 ratio	3	26.54±2.68a	2.32
	5:1 ratio	3	25.06±1.13a	3.88
Ash content	3:1 ratio	3	18.91±0.15b	0.56
	4:1 ratio	3	17.81±0.27b	0.32
	5:1 ratio	3	16.64±1.11a	0.58
Fixed carbon	3:1 ratio	3	47.85±3.27a	0.99
	4:1 ratio	3	49.62±3.05b	3.24
	5:1 ratio	3	52.76±1.53b	4.18
Calorific value	3:1 ratio	3	17.12±0.26a	0.4
	4:1 ratio	3	17.27±0.37b	0.1
	5:1 ratio	3	18.54±0.45c	0.65

Table 13 showed that there was no significance difference on percent of moisture content and volatile matter content, whereas there was significance difference in percent of ash content, fixed carbon content and gross calorific value under the three levels of coffee husk charcoal to clay soil binder ratio at 95% confidence interval. The mean value of ash content (%) in the two ratio (3:1 ratio and 4:1raio) was significantly lower than the mean value in the later ratio (5: 1). In addition, the difference in moisture content of briquettes from the first two ratio (3:1 and 4:1raio) was not significant, while significantly variations were observed gross heat value (calorific value) under each level of charcoal to binder ratio (table 13).

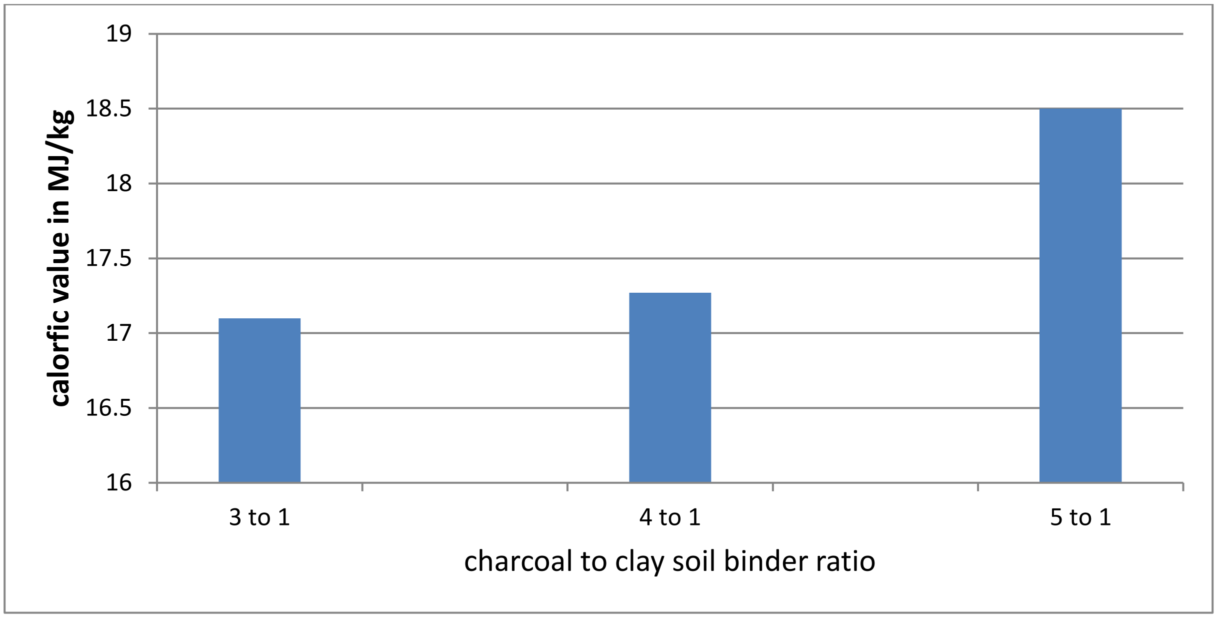

Fig.9: Calorific value vs charcoal to binder ratio

The figure above shows as the proportion of coffee husk charcoal over clay soil binder increases results an increase in gross heat value, this increasing graph was due to an increasing in the percent of ash content due to an increasing the amount of the binder clay that may be due to reduce the burning tendency of the briquette and as a result of increasing in the amount of fixed carbon content.

4.6.4.3. The Physical and Combustion Characteristics of the Produced Briquettes

In this study, the physical property and combustion character of the briquette produced were characterized in terms of bulk density(BD) and calorific value(CV), respectively.The calorific value of the coffee husk briquette from thus study ranges from 17.47±0.1 to 18.1±0.4MJ/kg and from 17.12±0.26 to 18.54± 0.45MJ/kg (table 14) as a factor of particle size difference and coffee husk charcoal to clay soil binder ratio difference respectively, which was higher than thereported calorific value of 4045 (SitiJamilatun, 2008,) and smaller than the calorific value 5132.98 reported by woldemedine,*et al. (*2014).

Table 14: Physical and combustion characteristics of produced briquette as particle size and charcoal to binder ratio a factor

treatments		Physical properties mean SD	
		BD density (g/cm3)	CV (MJ/kg)
Particle size as a factor	1mm	0.73±0.48	18.1±0.4
	3.35mm	0.69±0.02	17.7±0.1
	5.60mm	0.62±0.02	17.47±0.65
Charcoal to binder ratio as a factor	3:1 ratio	0.72±0.03	17.12±0.26
	4:1 ratio	0.60±0.01	17.27±0.37
	5:1 ratio	0.64±0.02	18.54± 0.45

4.7. Comparison of Coffee Husk Fuel Properties with those of Other Typical Local Biomass Resources

From literature survey, it is possible deduce that coffee husk has better thermo-chemical properties as compared to most other common agricultural residues. Nevertheless, some of the studies indicate that its moisture content is relatively higher (Tenagne, 1992);othervalues do not have much variation from those obtained from literature except that the moisture content is considerably lower in the present investigation. Solid biomass fuels commonly used in Ethiopia are firewood, charcoal and agricultural residues. Firewood and agricultural residues are used as substitutes of one another. The firewood most commonly used in urban and peri-urban areas is eucalyptus. Very little information is available in the country on studying thermo-chemical properties of these fuels. The average HHV and MC of coffee husk (form dry processes) in our experiment is compared with those of eucalyptus wood and some common agricultural residues obtained as shown in table 15.

Table 15 :Comparison of coffee husk fuel properties with those of other commonly used local biomass fuels

No.	Fuel			%MC	HHV(MJ/kg)
1	Firewood			15.0	17.8
2	Wheat straw			10.0	17.6
3	Cotton stalk			12.0	16.8
4	Cane residue			12.0	17.5
*5	Coffee husk	Particle size as a factor	Particle size 1mm	7.03	18.1
			Particle size3.35mm	6.8	17.7
			Particle size 5.60mm	6.3	17.47
		Charcoal to clay soil binder ratio as factor	Charcoal to clay soil binder ratio 3:1	6.16	17.12
			Charcoal to clay soil binder ratio 4:1	6.02	17.27
			Charcoal to clay soil binder ratio 5:1	5.54	18.54

(Source: Tenagne, 1992; *This Study)

5. CONCLUSION AND RECOMMENDATION

5.1. Conclusion

Currently, limited uses were found for coffee husk in the coffee growing areas. Some of the uses included: cooking fuel in traditional stoves in urban and peri-urban areas, (especially for injera baking), for preparing hot beverage drink, for mulching and organic manure (without pre-treatment) in coffee farms and composting using natural process. cooking fuel for the households. Current fuel sources are: firewood, charcoal and kerosene for cooking and grid electricity and diesel gen-sets for power generation.

In the present study, the calorific value of the raw material was lower than the calorific value of briquettes produced in all cases (particle size and charcoal to clay soil binder ratio deference as factor),which can be due to the impact of carbonization resulting an increasing of carbon content even the use of clay soil as a binder material which increases the ash content of the produced briquette.Briquettes produced from the higher charcoal to binder ratio results the highest calorific value and briquettes produced from the higher particle size was having the lowest calorific value.from the experimental result the moisture content of the produced briquette is not significantly affected with the action of different particle size and charcoal to clay soil binder ratio, while the other fuel quality characteristics (volatile mater, ash content and fixed carbon content are significantly depend on these factors except in some case, while the gross heat (calorific) value is significantly depend on the on different particle size and charcoal to binder ratio. In general, experimental study showed that coffee husk has better thermo-chemical properties as compared to most other agricultural residues, especially in calorific value.

5.2. Recommendation

Based on the present study the following recommendations are forwarded.

- Wide research like ultimate analysis should be undertaken to evaluate the chemical composition of briquette produced from coffee husks.
- Economic analysis and feasibility of the overall production of coffee husk, Fuel briquetting, charcoal, the impact of coffee weed in human being, crop production and livestock product in Ethiopia has to be evaluated for effective utilization.
- Fuels for household cooking are very expensive in urban and peri-urban areas of Ethiopia.Coffee briquettes can be taken as alternative energy source in such places.
- This type of indigenous researches have to be promoted and the available resources have to be utilized to overcome household energy problems in the country
- Further studies should be conducted regarding the effect of different verities of coffee species and conditional/ environmental impact on the calorific value/ heat energy of briquettes produced from coffee husks.

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7. APPENDIXES

Appendix 1 poor management systems of the coffee husk wastes from the coffee husk processers

Appendix 2 preparation of the coffee husk charcoal for briquetting




Appendix 3drying stageof the produced briquettes

Appendix4Preparation for physical and chemical analysis of the produced briquette.

Appendix 5 proximate analysis of the produced briquettes (moisture content, volatile matter, ash content, fixed carbon)

Appendix 6calibration of calorimeter and measurement of calorific value

Appendix 7 physical and combustion characteristics of the produced briquettes as particle size and charcoal to clay soil binder ratio a factor

treatments		No of trials	BD density calculation				Calorific value MJ/kg
			Wt(g)	Height (cm)	Radius of briquette(cm)	Density(g/cm^3)	
Particle size as a factor	Particle size 1mm	1	758.6	9.3	5.95	0.73	18.5
		2	748.4	9.5	5.95	0.71	18.1
		3	775.8	9.4	5.95	0.74	17.7
		Mean±SD				0.73±0.48	18.1±0.4
	Particle size 3.35mm	1	732.6	9.3	5.95	0.71	17.6
		2	690.2	9.2	5.95	0.67	17.8
		3	696.9	9.1	5.95	0.69	17.7
		Mean±SD				0.69±0.02	17.7±0.1
	Particle size 5.6mm	1	654.1	9.1	5.95	0.64	18.1
		2	609.3	9	5.95	0.61	16.8
		3	625.7	9.05	5.95	0.62	17.5
		Mean±SD				0.62±0.02	17.47±0.65
Charcoal to binder ratio as a factor	Charcoal to binder ratio 3:1	1	745.4	9.7	5.95	0.69	16.9
		2	752.8	9.7	5.95	0.74	17.02
		3	730.2	9.6	5.95	0.72	17.4
		Mean±SD				0.72±0.03	17.12±0.26
	Charcoal to binder ratio 4:1	1	665.3		5.95	0.63	17.03
		2	696.9		5.95	0.66	17.08
		3	703.8		5.95	0.67	17.7
		Mean±SD				0.64±0.02	17.27±0.37
	Charcoal to binder ratio 5:1	1	603.4		5.95	0.59	18.04
		2	623.8		5.95	0.61	18.7
		3	613.4		5.95	0.62	18.9
		Mean±SD				0.60±0.01	18.54±0.45

Appendix 8 ANOVA Multiple Comparisons analysis result of proximate analysis and gross heat value of the produced briquettes as a factor of particle size.

Dependent Variable	(I) level by particle size	(J) level by particle size	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
moisture content	1mm	3.35mm	-.53333	.31505	.283	-1.5000	.4333
		5.6mm	-.73333	.31505	.127	-1.7000	.2333
	3.35mm	1mm	.53333	.31505	.283	-.4333	1.5000
		5.6mm	-.20000	.31505	.807	-1.1667	.7667
	5.6mm	1mm	.73333	.31505	.127	-.2333	1.7000
		3.35mm	.20000	.31505	.807	-.7667	1.1667
volatile matter content	1mm	3.35mm	-4.54000	2.13547	.164	-11.0922	2.0122
		5.6mm	-6.29667	2.13547	.058	-12.8489	.2556
	3.35mm	1mm	4.54000	2.13547	.164	-2.0122	11.0922
		5.6mm	-1.75667	2.13547	.704	-8.3089	4.7956
	5.6mm	1mm	6.29667	2.13547	.058	-.2556	12.8489
		3.35mm	1.75667	2.13547	.704	-4.7956	8.3089
ash content	1mm	3.35mm	-.60333	.41283	.372	-1.8700	.6633
		5.6mm	-.82333	.41283	.194	-2.0900	.4433
	3.35mm	1mm	.60333	.41283	.372	-.6633	1.8700
		5.6mm	-.22000	.41283	.859	-1.4867	1.0467
	5.6mm	1mm	.82333	.41283	.194	-.4433	2.0900
		3.35mm	.22000	.41283	.859	-1.0467	1.4867
fixed carbon content	1mm	3.35mm	7.77667	2.54007	.050	-.0170	15.5703
		5.6mm	7.87667*	2.54007	.048	.0830	15.6703
	3.35mm	1mm	-7.77667	2.54007	.050	-15.5703	.0170
		5.6mm	.10000	2.54007	.999	-7.6936	7.8936
	5.6mm	1mm	-7.87667*	2.54007	.048	-15.6703	-.0830
		3.35mm	-.10000	2.54007	.999	-7.8936	7.6936
calorific value	1mm	3.35mm	.40000	.36311	.547	-.7141	1.5141
		5.6mm	.63333	.36311	.265	-.4808	1.7475
	3.35mm	1mm	-.40000	.36311	.547	-1.5141	.7141
		5.6mm	.23333	.36311	.803	-.8808	1.3475
	5.6mm	1mm	-.63333	.36311	.265	-1.7475	.4808
		3.35mm	-.23333	.36311	.803	-1.3475	.8808

Dependent Variable	(I) level by particle size	(J) level by particle size	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
moisture content	1mm	3.35mm	-.53333	.31505	.283	-1.5000	.4333
		5.6mm	-.73333	.31505	.127	-1.7000	.2333
	3.35mm	1mm	.53333	.31505	.283	-.4333	1.5000
		5.6mm	-.20000	.31505	.807	-1.1667	.7667
	5.6mm	1mm	.73333	.31505	.127	-.2333	1.7000
		3.35mm	.20000	.31505	.807	-.7667	1.1667
volatile matter content	1mm	3.35mm	-4.54000	2.13547	.164	-11.0922	2.0122
		5.6mm	-6.29667	2.13547	.058	-12.8489	.2556
	3.35mm	1mm	4.54000	2.13547	.164	-2.0122	11.0922
		5.6mm	-1.75667	2.13547	.704	-8.3089	4.7956
	5.6mm	1mm	6.29667	2.13547	.058	-.2556	12.8489
		3.35mm	1.75667	2.13547	.704	-4.7956	8.3089
ash content	1mm	3.35mm	-.60333	.41283	.372	-1.8700	.6633
		5.6mm	-.82333	.41283	.194	-2.0900	.4433
	3.35mm	1mm	.60333	.41283	.372	-.6633	1.8700
		5.6mm	-.22000	.41283	.859	-1.4867	1.0467
	5.6mm	1mm	.82333	.41283	.194	-.4433	2.0900
		3.35mm	.22000	.41283	.859	-1.0467	1.4867
fixed carbon content	1mm	3.35mm	7.77667	2.54007	.050	-.0170	15.5703
		5.6mm	7.87667*	2.54007	.048	.0830	15.6703
	3.35mm	1mm	-7.77667	2.54007	.050	-15.5703	.0170
		5.6mm	.10000	2.54007	.999	-7.6936	7.8936
	5.6mm	1mm	-7.87667*	2.54007	.048	-15.6703	-.0830
		3.35mm	-.10000	2.54007	.999	-7.8936	7.6936
calorific value	1mm	3.35mm	.40000	.36311	.547	-.7141	1.5141
		5.6mm	.63333	.36311	.265	-.4808	1.7475
	3.35mm	1mm	-.40000	.36311	.547	-1.5141	.7141
		5.6mm	.23333	.36311	.803	-.8808	1.3475
	5.6mm	1mm	-.63333	.36311	.265	-1.7475	.4808
		3.35mm	-.23333	.36311	.803	-1.3475	.8808

*. The mean difference is significant at the 0.05 level.

Appendix 9 the Multiple Comparisons analysis in 95% Confidence Interval of the effect of charcoal to clay soil binder ratio on the proximate analysis and gross heat value.

Dependent Variable	(I) charcoal to binder ratio	(J) charcoal to binder ratio	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
moisture content	3:1 ratio	4:1 ratio	.14333	.22854	.811	-.5579	.8446
		5:1 ratio	.62333	.22854	.076	-.0779	1.3246
	4:1 ratio	3:1 ratio	-.14333	.22854	.811	-.8446	.5579
		5:1 ratio	.48000	.22854	.170	-.2212	1.1812
	5:1 ratio	3:1 ratio	-.62333	.22854	.076	-1.3246	.0779
		4:1 ratio	-.48000	.22854	.170	-1.1812	.2212
volatile mater content	3:1 ratio	4:1 ratio	.54000	1.96972	.960	-5.5036	6.5836
		5:1 ratio	2.01333	1.96972	.591	-4.0303	8.0570
	4:1 ratio	3:1 ratio	-.54000	1.96972	.960	-6.5836	5.5036
		5:1 ratio	1.47333	1.96972	.746	-4.5703	7.5170
	5:1 ratio	3:1 ratio	-2.01333	1.96972	.591	-8.0570	4.0303
		4:1 ratio	-1.47333	1.96972	.746	-7.5170	4.5703
ash content	3:1 ratio	4:1 ratio	1.08000	.54268	.195	-.5851	2.7451
		5:1 ratio	2.26667*	.54268	.014	.6016	3.9318
	4:1 ratio	3:1 ratio	-1.08000	.54268	.195	-2.7451	.5851
		5:1 ratio	1.18667	.54268	.152	-.4784	2.8518

	5:1 ratio	3:1 ratio	-2.26667*	.54268	.014	-3.9318	-.6016
		4:1 ratio	-1.18667	.54268	.152	-2.8518	.4784
fixed carbon content	3:1 ratio	4:1 ratio	-1.76333	2.22961	.722	-8.6044	5.0777
		5:1 ratio	-4.90333	2.22961	.150	-11.7444	1.9377
	4:1 ratio	3:1 ratio	1.76333	2.22961	.722	-5.0777	8.6044
		5:1 ratio	-3.14000	2.22961	.395	-9.9811	3.7011
	5:1 ratio	3:1 ratio	4.90333	2.22961	.150	-1.9377	11.7444
		4:1 ratio	3.14000	2.22961	.395	-3.7011	9.9811
calorific value	3:1 ratio	4:1 ratio	-.16333	.30183	.855	-1.0894	.7628
		5:1 ratio	-1.44000*	.30183	.007	-2.3661	-.5139
	4:1 ratio	3:1 ratio	.16333	.30183	.855	-.7628	1.0894
		5:1 ratio	-1.27667*	.30183	.013	-2.2028	-.3506
	5:1 ratio	3:1 ratio	1.44000*	.30183	.007	.5139	2.3661
		4:1 ratio	1.27667*	.30183	.013	.3506	2.2028

*. The mean difference is significant at the 0.05 level.

Appendix 10structured HH questioner

Household survey on current application and management system of coffee husk in dilla town, Ethiopia

Masters thesis Survey

BelaynehAlemu

Hawassa University Wondo Genet College Of Forestry and Natural Resources

1. General information

Household survey identification: ____

Interviewer: ____

Date of interview____

Checked by: ____

Date checked: ____

1.1) Respondent name____

1.2) Sex: 1) Male 2) Female

1.3) Age________years

1.4) Marital status: 1) Single 2) Married 3) Divorced (separated)

4) Widow 99) No applicable

1.5) Kebele

1.6) Distance to woreda market__________ (in minutes)

1.8) Social position in the kebele

1) Member of kebele council 2) Religious leader

3) Others, specify_____________________ 4) none

1.9) Education level________________grade

2. Household Characteristics

2.1) Household family members' information

Sex

Male__________ (No),

Female____________ (No)

Age

0-15yr__________ (No),

16-64yr___________ (No),

Greater than 64 _________ (No)

Education

0 grade_______ (No),

1-4_______ (No),

5-8__________ (No),

9-12______ (No),

Diploma graduate_____ (No),

B.Sc degree_________ (No),

Above_________ (No)

3. Questions raised for the respondents

1. How much is the production of coffee husk waste
   a. Bellow 10 kuntal   b. 11-20 kuntal   c. 21- 30 kuntal   d. above 30 kuntal
2. What type of waste management practice you apply for coffee husks
   a. Dumping   b. open burning   c. deranging to the river   d any other
3. For what purpose you are using these coffee husk wastes?
   a. For fertilizer
   b. For fuel
   c. For animal feeding
   d. Other usage (specify)……………………………………..
4. If you are using for multipurpose these coffee husks which one is/ are the most critical usage?
   a. For fertilizer
   b. For fuel

c. For animal feeding

d. Other usage (specify)……………………………………..

5. Did the coffee husk wastes used as fuel sources?

   a. Yes

   b. No

6. If you say yes on question number 5, how?(multiple answer possible)

   a. Direct combustion

   b. In charcoal form

   c. Any other form (specify)……………………………….

7. If you are using as a fuel sources in two or more forms, which one is more simple and easy to use?

   a. Direct combustion

   b. In charcoal form

   c. Any other

8. Have you ever noticed any health problem related to using direct combustion of coffee husk wastes as a fuel sources?

   a. Yes b. no

9. If yes ,What effect on your health can be coursed when you are using direct combustion of coffee husk wastes as a fuel sources

a. Headic

b. Sinise

c. Cancer

d. Any other health problem ………………………………………………

10. If there is any effect, do you think the reason is from high emission of smoke?
    a. Yes
    b. no
11. How can you compare the price of coffee husk with other sources of fuel? Such as, fire wood.

a. Smaller.
b. Comparative.
c. Higher

Survey on current application and management system of coffee husk by coffee processors in dilla town, Ethiopia

1. General information

Companies survey identification…………………………………………………………..

Interviewer: ……………………………………………………………………………..

Dateof interview……………………………………………………………………………….

Interviewer position…………………………………………………………………….

Checked by: ………………………………………..

Date checked: ………………………………………………………………………………..

1.1) Company name………………………………………………………………………..

1.2) company type

a. private
b. Mahi berate
c. share
d. any other

2. questions raised for the companies

1. what are the primary sources of your production
    a. from individuals farmers
    b. from suppliers
    c. from intermediaries
    d. any other
2. what proportion/ratio can be gain clean coffee bean to coffee husk waste
    a. below 30%
    b. 30 to 35%
    c. 35 to 40%
    d. 40 to 45%
    e. Above 45%
3. Approximately how much is your annual average production of clean coffee and coffee husk wastes?
4. What type management practice you are applying on coffee husk wastes?
    a. Simply dumping
    b. Open burning
    c. Deranging to the river
    d. Any other
5. For what purpose did you are using these coffee husk wastes
    a. Used as a fuel for reproduction for your processes
    b. Distributing for other costumers
    c. Using as sources of income by just selling

d. Any other

6. Who are the consumers of your byproduct coffee husk wastes?

    a. Individuals

    b. Groups

    c. Farmers

    d. The town’s residents

    e. Other companies

    f. Any other