ADDIS ABABA UNIVERSITY

ADDIS ABABA INSTITUTE OF TECHNOLOGY

CENTER OF ENERGY TECHNOLOGY

Production and Quality Characterization Fuel Briquette Manufactured from Khat Waste at Dire Dawa

BY

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A thesis submitted to the Energy Center

For the partial fulfillment of the requirements for the Degree of Master of Science in Energy Technology

Addis Ababa University

Addis Ababa, Ethiopia

July 2018

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ABSTRACT

Production and quality characterization of fuel briquette manufactured from khat waste at dire dawa site

Addis Ababa University, 2018

This study aimed to produce fuel briquettes from khat waste at Dire Dawa site, which is most serious invasive plant waste, spreading throughout the world particularly at alarming rate in Ethiopia. Utilization of biomass like invasive waste plant such as khat waste in Ethiopia have greater advantage for discovery of clean renewable energy sources and for reduction of deforestation of indigenous trees. Producing of the fuel briquetting of khat waste branch and the raw material of khat waste branch of plant is carried out by using ASTM procedure. The mean average value for fixed carbon content (FCC) and calorific value of the khat waste branch of fuel briquette of sample were 39.268% and 4143.269 (cal/g) respectively. Also, the result for fixed carbon content(FCC) and calorific value of khat waste branch of raw material waste 20.9% and 3688.3946(cal/g) respectively. The finding shows that by eco-friendly utilization of khat waste plant as a clean energy fuel briquette. It is possible to manage the spread of such type alien invasive plant as well as to increase farmer's crop production, access for livestock grazing land; reduce deforestation of indigenous trees and reduce indoor air pollution.

Key words: Biomass, Briquette, Fuel quality, khat waste branch

ACKNOWLEDGEMENTS

First and for most I would like to thank the almighty God for helping me to realize this project to this stage. Next, my special thanks and appreciation goes to my advisor Dr. Solomon Kiros and Co-advisors Mr. Tewodros Wall respectively, for their supervision and motivational encouragement as well as for their unreserved advice and skill full contribution to this Project and their careful comments I received throughout my thesis work.

I also owe a lot of appreciation and thanks to Ministry of Water, Irrigation and Energy Alternative Energy Development and Promotion Directorate especially the Laboratory and workshop center at Gurd Sholl, AAIT center of energy technology, Dire Dawa Institute of Technology and School of Mechanical And Industrial Engineering, for giving this M.Sc Scholar.

Finally, I would like to appreciate all my friends for contributing to this work in one many way for their individual support for completing this thesis to Mr. Teklu Bekele (MOWIE), Mr. Adnew Mangesha (MOWIE Work Shop Center), Mr. Yisak Seboka (MOWIE Work Shop Center) and all My family.

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List of Acronyms and Abbreviations

AAU	Addis Ababa university
AAIT	Addis Ababa Institute of Technology
AC	Ash Content
ACB	Ash content of briquette
ACR	Ash content of raw material
AEDPD	Alternate Energy Development and Promotion directorate
ASTM	American Society for Testing and Materials
BD	Bulk Density
BDB	Bulk Density of briquette
BDC	bulk density of charcoal
CV	Calorific Value
EC	Ethiopian calendar
FAO	Food and Agriculture Organization
FCC	Fixed carbon content
FDRE	Federal Democratic Republic of Ethiopia
GHG	Green House Gas
MC	Moisture Content
MCB	Moisture Content of briquette
MCC	Moisture Content of charcoal
MCR	Moisture Content of raw material
MOWIE	Ministry of Water ,Irrigation and Energy
MSW	Municipal solid waste

CHAPTER ONE

1 INTRODUCTION

1.1 Background

Higher standard of living as well as population growth has resulted in an increasing demand of food and new form of clean energy throughout the world. Energy is a vital input for development and an essential ingredient for the survival of humankind. Among the major energy issues today are that of energy security, environmental implication of fossil fuel consumption and deforestation. Among the clean energy source, the use of biomass resource can be one alternative energy resource, since energy from biomass waste is a proven renewable energy technology that recovers energy from waste. However, the use of biomass energy sources in most developing countries including Ethiopia is mostly traditional that lead to indoor air pollution as a result causes health and environmental problems.

In Ethiopia, the issues of energy security and municipal solid waste management are more prominent. Ethiopia relies mainly on traditional biomass burning supplies more than 85% of national energy consumption. This has been causing different environmental and socio-economic impacts. In contrary, there is no denying that non-oil resource countries like Ethiopia, is bound to face a severe energy crisis in the near future because of its over dependence on imported fuel.

Therefore, there is huge demand for the development of alternative biomass energy technologies in Ethiopia to utilize biomass wastes to energy through the popularization of the briquetting technology, among others. The briquetting process is the physical transformation of loose raw organic materials into high-density fuel briquettes through a compacting process, which increases the calorific value, and combustion efficiency of the product. In Ethiopia, the available biomass resource such as wood, agro-industrial residues and municipal waste, which is expected to meet the country's growing energy demand, can provide huge opportunity for the adoption of the briquetting technology. The manufacture, repair and maintenance of briquette equipments can be addressed using local capacity. Thus, there is a need for strengthening cooperation among all stakeholders concerned with energy and environment to promote the briquetting technology there by contribute towards efficient and environmentally sustainable energy supply.

Historically, biomass has been a major source of household's energy in Ethiopia community. Biomass meets the cooking energy needs of most rural households and half of the urban household's demands. Despite significant adoption of commercial energy in Ethiopia during last few decades, biomass continues to dominate energy supply in rural and traditional sectors. Biomass energy constitutes wood fuels (including charcoal, and wood wastes), crop residues (such as coffee husk, bagasse, rice husk and crop stalks) and animal dung (including biogas). Ethiopia's energy system is characterized mainly by biomass fuel supply, which covers 85% of the energy consumption, with households being the greatest energy consumers [2].

The heavy dependence on traditional biomass in Dire Dawa is leading to different environmental and socio-economic problems including deforestation, soils erosion, water pollution, and indoor air pollution, deforestation and most importantly deforestation which affecting the limited forest resources of the country (Lakew*et al*., 2011; Bekele*et al*., 2013; Bizzarri, 2010). In addition dependence on biomass energy involves a trade-off in agricultural productivity, the crop residues and animal wastes being diverted from farms, where they supplement soil nutrition, to provide energy needs. Furthermore, the growing demand for traditional use of biomass energy and lack of access to modern energy services is expected to impose pressure on the limited biomass and forest stock of the country. Hence there is a need for the adoption and promotion of alternative modern biomass conversion technologies that can result in more efficient and eco-friendly energy supply. [5]

Worldwide, both technologies are being used for briquetting of sawdust and locally available agro-residues. Although the importance of biomass briquettes as substitute fuel for wood, coal and lignite is well recognized, the numerous failures of briquetting machines in almost all developing countries have inhibited their extensive exploitation.

Briquetting technology is yet to get a strong foothold in many developing countries because of the technical constraints involved and the lack of knowledge to adapt the technology to suit local conditions. Overcoming the many operational problems associated with this technology and ensuring the quality of the raw material used are crucial factors in determining its commercial success. In addition to this commercial aspect, the importance of this technology lies in conserving wood, a commodity extensively used in developing countries and leading to the widespread destruction of forests.

Therefore, municipal solid waste management is one of huge challenge around and in Dire Dawa city. Initiative for the current research came from city administration, mainly small and medium enterprise, environment and energy offices were interested in the treatment of municipal waste into compacted forms suitable for gasification. Utilization of municipal waste such as "chat wastes" as a substitute renewable alternative energy-carrier to reduce deforestation, environmental pollution and flooding due to clogging of ditches and drainage by the wastes is very advantageous from economic as well as from ecological point of view. The basic ecological reason for stopping disposal of chat wastes on ditches and drainage, and deposition of the combustible waste in dumps is the fact that led to flooding during raining season and biological decomposition process forms methane gas, which is harmful for the environment. Methane as a greenhouse effect gas is 23 times more harmful than carbon oxide [15]. The energetic value of non-recyclable municipal waste can be recovered by gasification process.

1.2 Problem of Statement

For household cooking purposes, most households in Dire Dawa still use solid biomass fuels, chiefly wood and charcoal. Due to several reasons, most of the villages and city of households are not getting enough electrical energy for cooking. As a result, most households were forced to use wood fuel and charcoal, and this in turn causes deforestation, environmental pollution due to emission, resource scarcity and high cost of biomass fuels. In addition, stress on women and children who usually are supposed to collect fuel was increased yearly.

The heavy dependence on traditional biomass in Dire Dawa is leading to different environmental and socio-economic problems including deforestation, soils erosion, water pollution, and indoor air pollution. Due to lack of appropriate waste management and technology such as briquetting, biomass wastes mainly Khat wastes are found everywhere disposed around ditches, drainages and open areas in and around the city. Among the disposed wastes in and around Dire Dawa city, about 60 % of waste is solid waste from which more than 70 % is khat waste. Khat chewing is merely a social event in Dire Dawa city and is usually takes place in-group in a social setting and only few of the chewer regularly chews alone. The fertile Hararghae high lands are the most suitable area for the production of *Khat* in Ethiopia, such that Dire Dawa is the main area of destination for Khat that brought from different areas of Harerghae. According to the information obtained from Dire Dawa revenue and custom authority, the amount of khat entered to city reached around 20 to 30 ton per day (II appendix) which is only taxable. From these tones of khat, 16.2 to 24.3 tones are thrown as waste after used by Dire Dawa city living population. Some of the Khat waste were collected by city administration, whereas the remaining were found everywhere in the city such as along the road sides, ditches, drainages and open areas along the street which affects the cleanness or esthetic value of the city. Serve as good breeding sites for pests and insects, clogging ditches and drainages and release bad oudor. In addition, studies on briquette technologies using tree products such as sawdust and branches were available, but there is lack enough knowledge on the utilization organic wastes using briquette technology. Therefore, the present study was tested the viability of briquette production in operation with the utilization of Khat waste found at different site using appropriate technologies and analyzed the performance for small scale Khat charcoal application. In addition, it was investigated the capacity to perform feasible briquette production concerning relevant technical and socio-economic considerations. The findings of the present work, which was utilized Khat waste to energy, can play crucial role to minimize deforestation, create smooth flow of flood in ditches and drainages, minimize greenhouse gases, create job opportunity for unemployed youth by implementing the briquette technology and improve the quality of the city.

1.3 Objectives of the study

1.3.1 General objective

The general objective of the project was to produce and characterize fuel briquette manufactured from khat waste (Gerebe of khat) at dire dawa site.

1.3.2 Specific objectives

- ✓ To characterize the caloric value, moisture, volatile matter content, fixed carbon content, bulk density and ash content of Khat waste charcoal
- ✓ To produce charcoal briquette from khat waste
- ✓ To evaluate its fuel quality through proximate analysis and combustion test;
- ✓ To determine the bulk density and calorific value of the briquette produced from chat waste
- ✓ To compare fuel briquette made from *chat waste* biomass with other similar source of energy and charcoal quality standard

CHAPTER TWO

2 LITERATURE REVIEW

2.1 Taxonomy and its Ecological Distribution

The scientific study shows the following biological classification, scientific name synonyms, common names or taxonomic position: division:

Scientific name: khat

Common name; Khat ,Catha Edulis, Chat,Qat, Mirra,

Chat	in Ethiopia
Qat	in Yemen
Mirra	in Kenya

In Ethiopia, Khat has other local names such as “Beleche”, “Aweday”, “Abo Mismar”, “Gelemso”, “Bahirdar” and others based on place of cultivation. Because of the chemical profile of khat leaves determined by the environmental and climate conditions, the stimulating power and cost of the product varies depending on its source. It was claimed that the “Aweday” and “Abo Mismar” varieties, which are cultivated in Harar highlands of Eastern Ethiopia are the most potent and costly among the local brands and hence are chosen for export (Belew, 2000; Gebissa, 2008). The leaves have an aromatic odor, astringent & slightly sweet taste.

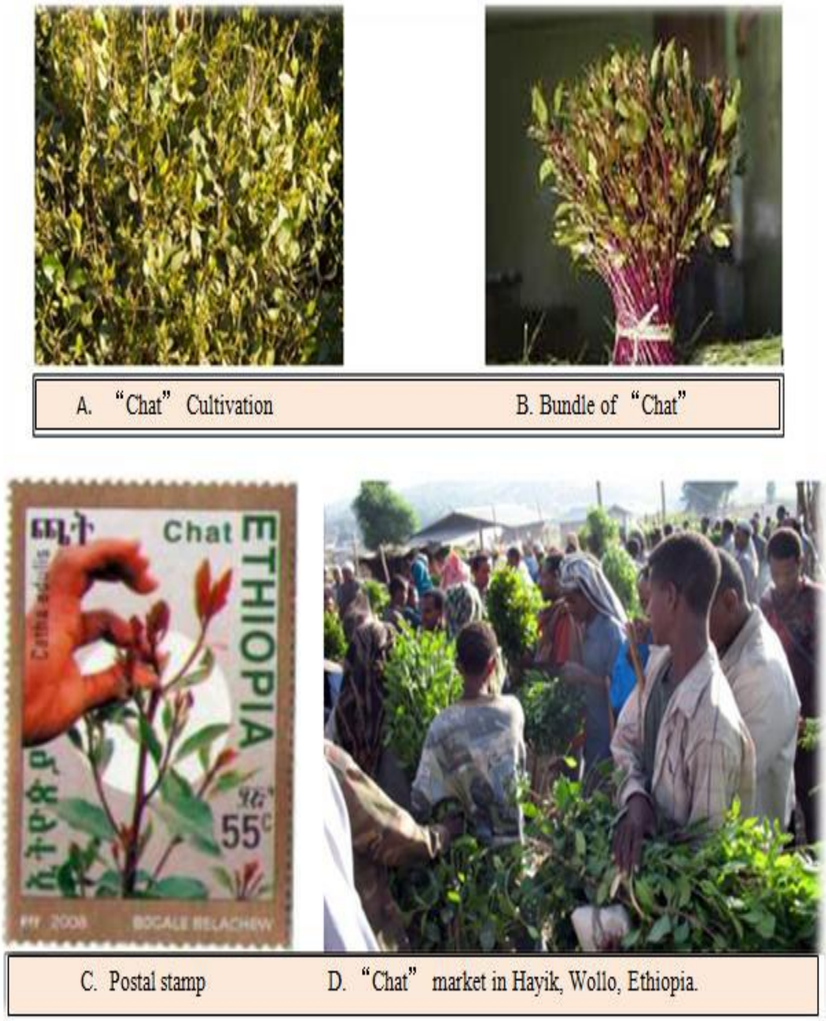

Figure 1: “Chat”in Ethiopia. (A) “Chat” cultivation, (B) Bundle of “Chat”, (C) Postal stamp, and (D) “Chat” market in Hayik, Wollo, Ethiopia (Photos taken from Gessesse Dessie, 2013). (Brenden, 2013)

2.2 Ecological and Socio-Economic Importance of Khat Plant Species

2.2.1 .Ecological Importance of Khat Plant Species

Historically, the original source of khat seems to be obscure. However, there is general agreement that its use was prevalent in Ethiopia and from there, around the 15^{th} century, the practice spread to the south-west of the Arabian Peninsula (Peters, 1952 and Radt, 1969 *(By ZewduMinwuyelet G/Mariam)*). Later on it also grows in Somalia, Kenya, Malawi, Uganda, Tanzania, Congo, Zambia, Zimbabwe, Afghanistan, Yemen and Madagascar.

It is estimated that about 20 million people consume khat leaves around the world. Every day, an estimated six million people chew khat all over the world (Odenwald et al., 2005). Its use traditionally has been confined to the regions where it is grown, because only the fresh leaves have the desired stimulating effects. However, in recent years it becomes more common in western countries due to migration of people from those 13 endemic khat-chewing countries like Ethiopia, Somalia and access of air transportation have increased. The global distribution of this perishable commodity, and as a result, the plant has been reported in Amsterdam, Australia, Canada, England, Israel, Rome, New Zealand, Wales, and the United States.

The effects of khat chewing were reported as early as 1237 by the Arabian physician Naguib Ad din (Lebras and Fretillere, 1965), who proposed the use of khat for the treatment of depressive states. By the same year, other writers also reported that it was effective in blunting the sensation of hunger and fatigue (Krikorian, 1984; Lebras and Fretillere, 1965).

People chew chat since khat contains psychoactive components namely, Cathinone and Cathine which are able to stimulate CNS, increases locomotors activity and results in sympathomimetic effect which are analogous to the effects of amphetamine (Kalix, 1990). Because of their psycho-stimulant properties, fresh, young shoot and tender leaves of khat are commonly chewed in eastern Africa and Arabian Peninsula countries for hundreds of years to attain a state of euphoria as well as to alleviate fatigue, enhance work capacity, stay alert, reduce hunger, and to enhanced self-esteem (Nasrulla, 2000; Al-Kamel, 2001; Ageely, 2009; Luqman, 1976). Yemeni khat chewers also believe that khat is beneficial for treatment of minor ailments such as headaches, colds, body pains, fevers, arthritis and also depression (Kennedy, et al., 1983). Workers on night shifts also use it to stay awake and postpone fatigue. Students have chewed khat in an attempt to improve mental performance before exams. It is habitually used in informal meetings (khat sessions) in which the participants are engaged in discussions and maintain social contact. Due to that, Khat chewing usually takes place in groups in a social setting. Only a minority frequently chew alone. The psycho stimulant component of khat, which is Cathinone, released within 15–45 min during chewing (Graziani et al., 2008). Following this, the user can experience an increase in blood pressure and heart rate, anorexia, insomnia, alertness, elevated mood and loquacity (Al-Mamary et al., 2002). Furthermore, chronic khat chewing for many years results in unpleasant effect of cognitive defects and psychosis associated with severe neurological illness.[23]

2.2.2 Socio –Economic Impact of khat

The major economy of developing Africa countries depends mainly on agriculture for sustainable growth and poverty reduction, in addition to this, agriculture will remain a major source of economic growth for these countries in future. Agriculture sector in Ethiopia expected to have a growth rate of 8.1% in 2011/12(African Economic Outlook 2010).

The productivity of most agricultural environmental area of most of the world faced many problems including invasive alien weed and the methods used for removing theses alien invasive weed, like chemical or burring; which are very poor on their role of removing and result in negative effect on the environment. Especially, food security has a primary focus not only in Ethiopia but also all over Africa and small farm systems providing food for more than 70% of the global population (World Economic and Social Survey 2011).

The Socio-economic impact of khat waste *a* species includes the prickly variety in particular; hinder human's access to invaded habitats

Historically, the original source of khat seems to be obscure. However, there is general agreement that its use was prevalent in Ethiopia and from there, around the 15th century, the practice spread to the south-west of the Arabian Peninsula (Peters, 1952; Radt, 1969). Later on it also grows in Somalia, Kenya, Malawi, Uganda, Tanzania, Congo, Zambia, Zimbabwe, Afghanistan, Yemen and Madagascar.

Khat chewing has a history of at least seven centuries in Ethiopia as a mild-stimulant plant. A survey of 3200 respondents across Ethiopia had shown that, the use of khat has become popular among all segments of the population and in all parts of Ethiopia (Selassie and Gebre, 1996). Recently khat chewing estimates of the prevalence of the country (Alem et al., 1999) approach 50%, with 17% self-described as daily users, predominantly men (a reported 5:1 male to female ratio). Ethiopia is the world’s largest producer of khat, which is the country’s fastest growing export. About a third of the production is exported to Djibouti and Somalia, but the bulk of it is marketed and consumed within the country, mostly in the Somali administrative region (Green, 1999).

It is estimated that about 20 million people consume khat leaves around the world. Every day, an estimated six million people chew khat all over the world (Odenwald et al., 2005). Its use traditionally has been confined to the regions where it is grown, because only the fresh leaves have the desired stimulating effects. However, in recent years it becomes more common in western countries due to migration of people from those 13 endemic khat chewing countries like Ethiopia, Somalia and access of air transportation have increased. the global distribution of this perishable commodity, and as a result, the plant has been reported in Amsterdam, Australia, Canada, England, Israel, Rome, New Zealand, Wales, and the United States.

Even though the chemical profile of khat leaves determined by the environmental and climate conditions, fresh Khat leaves contains more than 40 alkaloids, glycosides, tannins, amino acids, vitamins and minerals (Halbach, 1972). Due to that, In the Yemen Arab Republic, about 44 different types of khat exist originating from different geographic areas of the country (Al-Motarreb .et al, 2002). However, the phenylalkylamines (Cathinone and Cathine) are the major alkaloids which are structurally related to amphetamine, responsible for many different effects (Nencini et al., 1984). The Phenylalkylamines content of khat leaves varies within wide limits. In spite of this fact, fresh khat from different origin contained on the average 36 mg Cathinone, 120 mg Cathine, and 8 mg norephidrine per 100 gram of leaves (Geisshusler, Brenneisen, 1987). It also contains considerable amounts of tannins (up to 10% in dried material) and flavonoids (Hassan, et al 2002). [23]

2.3 Energy Potential of Khat Species

Ethiopia's energy consumption was predominantly based on Traditional biomass such as firewood agriresidues, dung and charcoal. Traditional biomass supplies more than 92% of the total energy demand in the country while the remainder is supplied by oil products, hydro and geothermal (IEA, 2016; Edwards, 2010; Ethiopian panel on Climate Change, 2015). Biomass is used as the primary source of energy at households, commercial services and industries. The energy sector in Ethiopia was characterized by the predominance of the household sector, accounting for 93% of gross energy consumption (MWIE, 2013; Ethiopian panel on Climate Change, 2015). Majority of the total biomass consumption is used for domestic purpose, which accounts 99%, and the remainder 1% is used for industries commercial and public services. Domestic cooking in both rural and urban areas is dominated by the use of traditional fuel with 96% of the population depend on firewood, agricultural residue, dung and traditional charcoal to meet their energy needs (Bizzarri, 2010). The use of modern source of cooking fuel such as butane gas, electricity and kerosene for cooking covers only 0.4 % for rural and about 16% for urban areas (MWE, 2012). Biomasses were burned in a traditional way using energy inefficient stoves with a conversion efficiency of less than 10% (MWIE, 2013). Moreover, due to lack of other alternative energies the demand for biomass is high and increasing by 6% annually (Edwards, 2010; Lakew*et al*, 2011).

In Ethiopia the briquetting technology has been introduced in 1980s.The first briquetting plant installed in Ethiopia was low-pressure piston machine installed by private individuals.

The raw material is primarily sawdust (60%) and the rest 40% were coffee husk and cotton-seed husk. The briquettes ware sold mainly to middle-class hotels in Addis Ababa, which have installed wood-burning stoves of some sophistication (FAO, 2013; EEP, 2013).

The other significant effort on the briquetting technology in Ethiopia was the cooperation agreement signed by the Ethiopian government with the World Bank to implement the ENERGY I Project in 1985 in Dilla. However, the plant was not installed and remained idle for more than 20 years. The plant was installed and begun koperation on September 2012, with a capacity of producing 120 quintals of briquette (12 tones) in one work shift. The project has a capacity manufacturing of 1.5 tons of material per hour, and the yearly capacity ranges from 1,800 to 5,400 tones. The direct project beneficiaries of the plant are the members of the Gedeo Development Association. The briquettes are distributed in Dilla and its surroundings, as well as in deforestation prone zones and fuel scarce areas like Arsi-Negelle in the Central Rift Valley (Horn of Africa Regional Environment Centre and Network and Addis Ababa University available at: www.aau.edu.et/hoarecn/majorprojects/dilla-briquette-factory/)

In Ethiopia Currently there are encouraging efforts are being made to promote biomass briquetting in Ethiopia by different government institutions and private sector. Based on the visit institutions working on briquetting and discussion with staffs of institutions, the efforts on briquetting in Addis Ababa are presented as under. The principal government institutions working to promote the technology are Addis Ababa city Environmental Protection Authority (EPA) and Alternative Energy Development and Promotion Directorate (AEDPD) (within the Ministry of Irrigation, water and energy).

Briquettes are compact materials produced in the process of densification of loose biomass material such as wood charcoal dust, sawdust, crop residues and other solid biomass waste.

Moreover, briquettes can be produced from any type of biomass residues which is readily available. This has also contributed towards the popularization of briquettes in many developing countries where biomass is primary source of energy. Therefore Briquettes can be considered as one of the most important modern biomass technologies for its wider and diversified environmental, social and economic benefits. Ultimately, wide adoption of biomass upgrading technologies in Ethiopia can contribute efficient utilization of the currently wasted biomass resources, thereby contributing toward improving domestic energy supply, enhancing environmental protection and sanitation and reducing GHG emissions. In general the adoption and promotion of briquetting can yield the following environmental, social and economic benefits:

- Can be produced in uniform size and quality and desired size and shape to fit stove and burners
- It is smokeless and Minimizes Indoor air pollution (avoids health impacts)
- The process increases the net calorific value per unit volume of biomass
- Briquette product is easy to handle, transport and store
- The process helps to solve the problem of residue disposal
- The fuel produced is uniform in size and quality
- Has long burning time/to save the consumption and dependency on fuel wood thereby Reduces fuel wood and deforestation.
- The process helps to solve the residual disposal problem (sanitation)
- The process can help to creates source of income and employment opportunity from production and marketing of briquettes
- Lower overall fuel costs for users as they are made from biomass waste, etc.(5)

Therefore, in this study the available material for manufacturing briquette from khat at Dire Dawa city is khat waste. *Khat* is ever green shrub that grows on high altitudes in the region extending from Eastern Africa to Southern Africa, as well as on the Arabian Peninsula. *Khat* acquires the status of cash crop in Ethiopia the country thought to be the place-of-origin of the use of *khat* (Cox and Rampes, 2003: 456–463). *Khat*(Catha edulis) is a slow growing stimulant shrub or tree that grows in rainy area of highlands.

Ethiopia is the world's largest producer of *Khat*, which is the country's fastest growing export. About a one- third of the production is exported to Djibouti and Somalia. In many parts of Ethiopia, *Khat* sometimes called *(Chat) or* (*Catha edulis*) has emerged from an incomprehensible garden tree to an intensively cultivated, openly grown, high value crop. Today in Ethiopia, all societal groups regardless of Religion, Age, Sex, and Wealth, peer Group, Education, and Occupation consume *khat*. In *Khat* chewing the leaves are effective ways of extracting Cathinone.

In Ethiopia, *Khat* is commonly known as cash crop grown by great majority of smallholder farmers in Eastern and Southern Ethiopia. Despite the daily use and consumption of *Khat* by millions of people and *khat*, left over by livestock in Ethiopia and other countries chewing it has deep-rooted social and cultural tradition (Kalix and Braenden, 1985)

Dire Dawa is the main area of destination of *Khat* that brought from different areas of Harerghae, after it reached Dire Dawa most of it exported to the neighboring countries the rest is ready for local consumption.”*Khat*Tera”, “FeresMagala”, ”Ashewa” etc are the main market places of *Khat* in Dire Dawa. The people, who were/are addicted with it, flow to the areas where *Khat* was is sold to consume their daily fresh *Khat (6)*. Therefore, fuel briquette produced from khat waste in this site has the following advantage for population living in and around this city.

- ✓ Job opportunity for community
- ✓ Minimize greenhouse gas emission
- ✓ Minimize coast they pay rather than previous one
- ✓ Increase quality of city
- ✓ It is time sever than previous one

At present two main high pressure technologies: ram or piston press and screw extrusion machines, are used for briquetting. While the briquettes produced by a piston press are completely solid, screw press briquettes on the other hand have a concentric hole which gives better combustion characteristics due to a larger specific area. The screw press briquettes are also homogeneous and do not disintegrate easily. Having a high combustion rate, these can substitute for coal in most applications and in boilers.

The process of briquetting consists of applying pressure to a mass of particles with or without a binder and converting it into a compact product of high bulk density, low moisture content, uniform size and shape and good burning characteristics. Briquettes can be produced with a density of 1.2 g/cm³ from loose biomass of bulk density 0.1 to 0.2 g /cm³. These can be burnt clean and therefore are eco-friendly arid also those advantages that are associated with the use of biomass are present in the briquettes. Agricultural residues have bulk densities, which typical are less than 100 kg/m^3. This particular physical characteristic makes most agricultural residues difficult and expensive to transport, store and use in simple combustion devices. Where agricultural residue are produced in large quantity and where the potential use of such residues, as a substitute commercial biomass fuel is high, the production of charcoal briquettes could be justified. BTG, (2004) study show that mature or sufficiently proven technology for charcoaling and briquette of agricultural and other biomass residues are available and used in several countries (Eriksson *et al.,*1989).

To enhance the supply of Briquette Charcoal Production and charcoal, it is important not to limit the choice of input (raw material) only to the commonly used wood species such as *Acacia*. Other options, including the sustainable exploitation of other (short-rotation) tree species such as *Eucalyptus* as well as various types of plantation and industrial (or process) in residues, should be assessed and evaluated. Organic material, including wood, straw, coconut husks and shells, rice husks, cotton stalks, coffee husks, castor husks, bagasse, saw dust, bones, and others. Among woods, usually the hardwood species are preferred for Briquette Charcoal (BTG, 1999).

Production of charcoal (e.g. *Acacia*, Mangrove, oak, Beech, birch, Hard maple, hickory and Prosopis) or from some fast-growing trees, such as bamboo, also make excellent briquette charcoal production and charcoal. Some of the biomass-types (tree species and agro-industrial wastes) used for quality charcoal or charcoal briquette-making in Ethiopia are described in

Table 1 Where crop residues have little alternative use, these residues can be converted to charcoal.

Table 1: Comparison of properties of biomass and biomass waste most commonly used for charcoal and fuel briquetting

Charcoal Type	Suitability for Charcoal Production	Availability of Biomass	Cost	Calorific Value(Kcal per kg)
Acacia	Any carbonisation technology can be used	Availability reduced in most countries Long period to mature. For example, *Acacia nilotica*takes 15 years to mature for charcoal in Sudan	Expensive	7900
Eucalyptus	Any carbonisation technology can be used	Available in abundance in many countries Matures in 4-5 years	Relatively inexpensive	6100
Prosopis juliflora	Any carbonisation technology can be used	In African countries, such as Ethiopia, Kenya and Sudan, it is an invasive exotic tree	Inexpensive	7150
Bamboo	Brick kiln, metal kiln or retort	Abundant in Latin America, Asia (China and India) and Africa. (More than 1 million ha is available in Ethiopia). In many African countries it is neglected and not utilised at all	Inexpensive	6920
Cotton stalk (briquette)	Metal kiln or retort	Can be freely collected since it is generally burned on-site	Freely collected	5300
Coffee husk (briquette)	Improved pit kiln or retort	Can be freely collected since it is generally dumped in rivers.	Freely collected	5100
Sawdust	Improved pit kiln or retort	Can be freely collected since it is generally burned on-site.	Freely collected	4980
Lantana camara L	Metal kiln or retort	Can be freely collected since it is generally burned on-site.	Freely collected	3690.6771

Source: (YisakSeboka and NegusseMequanint , 2006);(FAO, 1993)

However, unlike woody biomass, agricultural residues such as cotton stalk, or process residues such as sawdust and coffee husk, cannot be carbonized using earth mounds or pit kilns. Due to their physical characteristics, shape, size and bulk density, such biomass materials tend to flare up and hence appropriate charring units need to be employed and in addition the utilization of weed specifically alien weed like khat   (khat waste) or *Parthenium*weed (*Partheniumhysterophorus*) which is available in abundance in many countries especially in Ethiopia , freely collected and so must be considered as in put for biomass energy like Briquette Charcoal Production, biodiesel potential, bio oil and also ethanol potential.

2.3.1 Briquetting of Agricultural Residue

Depending on the type and quantity of residue available for charcoal production, and among others market price of wood charcoal, various types of charring technologies could be implemented Available technologies include simple, low cost and manually operated technologies such as the drum charring units and metal kilns, as well as the more expensive and continuously operated charcoal production technologies. The latter is expensive and requires skilled operators and technicians, and generally is not suitable for small-scale production schemes. Simple charring units suitable for small-scale operation include the drum and metal kiln charring units (BTG, 2004).

Without briquetting, the small sized and brittle charcoals produced from agricultural residues would be very difficult to handle, and not suitable for use in household stoves. Households use lump charcoal and therefore charcoal from agricultural residues need to be densified to appropriate size and shape suitable for household uses (YisakSeboka, 2009).

2.3.2 Manual Briquetting Unit

Manual briquetting units can be designed and manufacture to produce various sizes and shapes of briquettes. Depending on the design briquettes of cylindrical or cube shape could be produce. In its simplest form, manual briquetting unit would involve compacting of char-binder mixture in a tube or cylindrical body to produce cylindrical briquettes (about 20 cm long and 5 cm in diameter). Such unit known as “pipe mould” consists of a female and male cylindrical parts.

The productivity of pipe moulds is very low. Relatively better productivity and quality of briquettes is produced using lever assisted hand briquette; this unit produces eight briquettes in a single operation. Due to mechanical advantage provided by the lever, the unit produces relatively denser and stronger briquettes. Briquettes made using such unit are cube shaped with each side measuring 6 cm, and depending on the type of charcoal dust and binder, the weight of each briquette may vary from 60 to 80 gms (BTG,2004).

Other briquetting unit, which has been tried in other countries, includes the beehive briquetting unit. Unlike the above two types of manual briquetting units, the design and fabrication of this unit demand better manufacturing facility and skill. Beehive briquettes are cylindrical in shape (13 cm in diameter and 8 cm long), can produced about 2000-2500 briquettes per hour and each briquette have a number of holes (usually 12 longitudinal holes of 13 mm diameter). A single beehive char-briquette will weigh about 400 to 500 grams after drying.

Such briquettes due to their size are suitable for where heating for relatively longer hours is required. Beehive briquettes also require a specially made beehive briquette-burning stove and are suitable for activities that require continuous heat for relatively longer hours than is demanded from common charcoal stoves (BTG, 2004). Beehive briquettes or honey comb briquettes have excellent burning qualities as they burn from the inside out through small holes so the energy release is gradual and uniform, giving a blue flame.

2.3.3 Mechanized briquetting unit

Commonly employed charcoal briquettes manufacturing technologies are roll presses and agglomeration technologies. Due to high abrasive nature of charcoal, the commonly used briquetting technologies such as piston or screw press are not suitable for briquetting of charcoal (BTG, 1999).

2.3.3.1 Roller briquette machine

Roll presser used in the USA and western countries for briquetting of a wide variety of products including charcoal. In a Roll press a mixture of charcoal and binder were feed to the tangential pockets of two rollers presses to produce pillow shaped briquettes shown in Figure1.

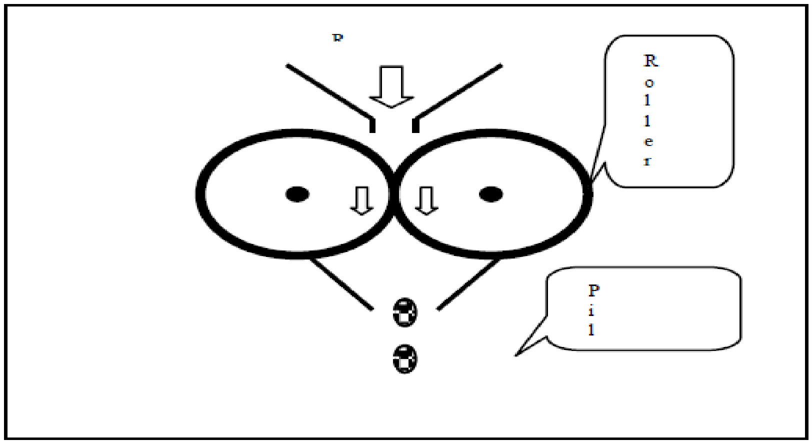

Figure 2: Roll briquette machine

The smooth production of briquettes using this technology requires high quality rollers with smooth surface in which the briquettes are shaped. Currently available roll presses have minimum production capacities in the range of 1 to 4 ton/hr. The one-ton/hr capacity press with controlled feeding device costs about USD 320,000 (BTG, 2004)

2.3.3.2 Agglomerate Briquette Machines

Unlike the roll press technology which is characterized by high production output, a costly and automated equipment, agglomeration technologies are small-scale (50 kg/hr), less expensive and labor intensive, it however requires a skilled operator if optimum production capacity is achieved and quality of product is to be maintained at high level. Agglomeration technology shown in Figure 2 involves size enlargement of a nucleus/balls of charcoal formed within a rotating cylinder. Charcoal and binder were continuously feed in to the rotating cylinder to form nuclei, which will grow gradually as more powder and binder sticks to the surface of the nuclei. The balls of charcoal of appropriate sizes depending on the design and operation of the system will then be thrown out of the rotating pan/drum/ (BTG, 2004).

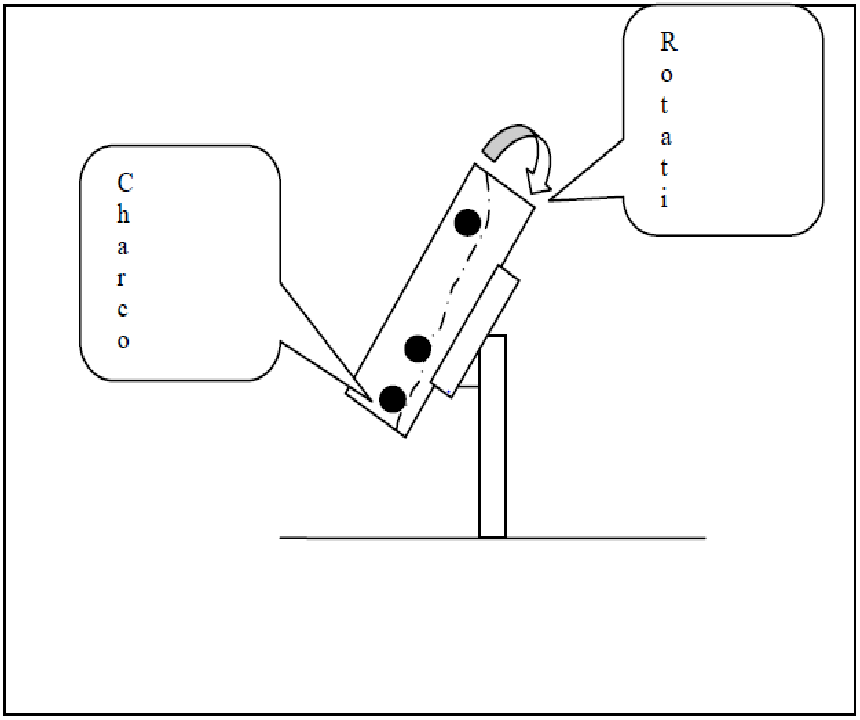

Figure 3: Agglomeration briquettes machines

2.3.4 Charcoal Briquettes

Production of high quality charcoal briquettes demands that a suitable binder is used and sufficient pressure were imparted such that the physical characteristics are comparable with or even are better than wood charcoal (FAO, 1985).

In mechanized units starch is the preferred binder as it has very good binding property and also when combusted produce no smell or smoke but using clay as binder will yield much more clean and low cost fuel briquette than starch or molasses one (BTG ,2004;FAO ,1985).Starch, however, is costly in countries such as Ethiopia. Experience in other countries and recently in Ethiopia has shown that molasses would be an important low cost binder. However, briquettes produce from molasses when burned in simple charcoal stoves produces smell and smoke, which may not be acceptable for some briquette charcoal users. Smoking the briquettes however could eliminate this undesirable quality but will add to the total cost of production and these producing briquettes by using clay as a binder should be applied for low cost and much more clean (with no smell and smoke)production (FAO,1987;Yisak Seboka,2009).

The other most important property of briquettes is the bulk density. The bulk density of charcoal briquettes mainly depends on the type of briquetting technology than on the 22 raw material itself and hence briquettes made using mechanized units produce briquettes with higher bulk density (FAO, 1987).

2.3.5 Factors affect Efficiency of charcoal production process.

The major factors that influence the efficiency of charcoal production are:

- Moisture content of the biomass (drier is better) .
- Type of kiln
- Size of the kiln (larger is better)
- Type of biomass
- Loading of the biomass (denser is better)
- Skill and experience of the char coalers
- Climatic conditions and Temperature, oxygen supply and pressure

2.3.6 Weight-Based Carbonization Efficiency

Weight-based carbonization efficiency (based on charcoal yield*)* is a percentage rate expressing the ratio between the weight of the charcoal output and the weight of the air-dry sample input. For instance, the typical yield of a brick kiln (at 15 % moisture content) is about 30%.

2.3.7 Flow Chart for Charcoal Briquette Production from Khat Waste.

Major process includes collection of khat waste, drying at the site temperature and transport to production site(fabrication laboratory) where it would be converted to charcoal and in this study, charring or carbonization was conducted using a small portable barrel metal kiln.

Then khat waste were crushed and chopped by using mechanized crushers or with locally available material like axe (Chopper) and big knife and then densified using thick wood like pestle like an agglomerates suitable for small scale mechanized charcoal production schemes. Typical process flow chart for production of char briquettes was described as shown in fig.1.

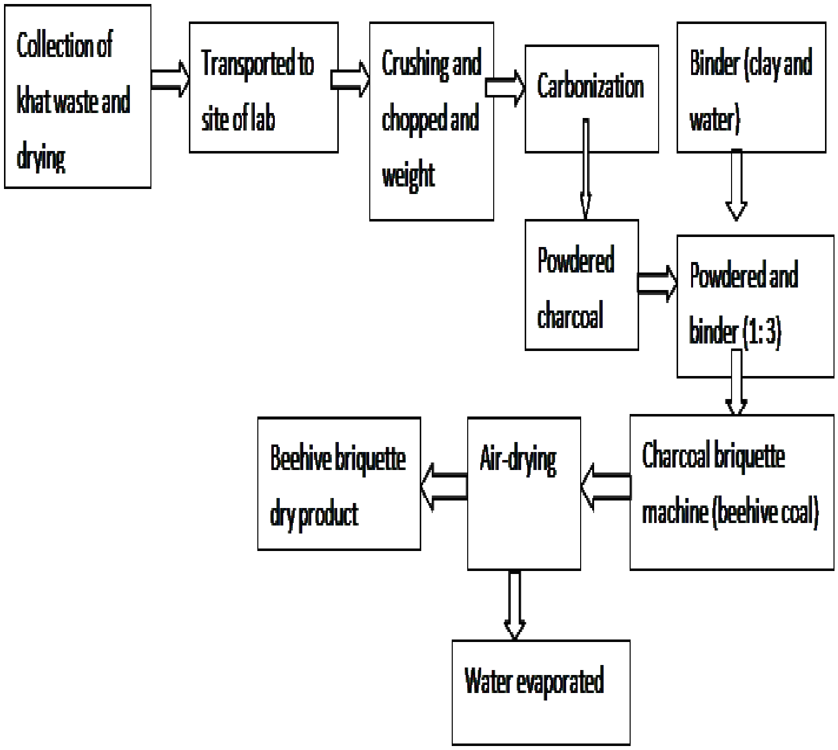

Figure 4: Production process flow chart of briquettes charcoal using Beehive coal Briquette machine

CHAPTER THREE

3 MATERIALS AND METHODS

3.1 Description of Study Area

Dire Dawa city administration was established in 1902 as a result of the Ethio-Djibouti railway line, which was built between 1897 and 1917. It was found in the eastern part of Ethiopia, located 515 km from Addis Ababa, 55 km from Harar, and 313 km from Port Djibouti and lies between 090 45' Latitude and 410 52' Longitude. Based on Central Statistical Authority (CSA) report (2008), the urban population of Dire Dawa City Administration is estimated to be 232,854 with 2.5% annual growth rate. The City Administration covers a total area of 1332.62km^2 and has an altitude of 1160m above sea level. The city receives a mean precipitation rate 676.3 mm per annum and the annual mean maximum and minimum temperature of the city for the year 2007 were 32.7 and 18.7 ^{0}C respectively (CSA, 2008). . The administration is bordered by the Shinile Zone of the Somali National Regional State on the northwest, and northeast, and eastern Hararghie Region of the Oromia National Regional State on the south, southeast, and east.

3.2 Sampling Procedure

3.2.1 Collection of Khat Waste Biomass and Sampling

In this study, the biomasses of *khat wastes* were collected as a source for briquette production and from January 25 to 25, February 2018 from in Dire Dawa city, Ethiopia.

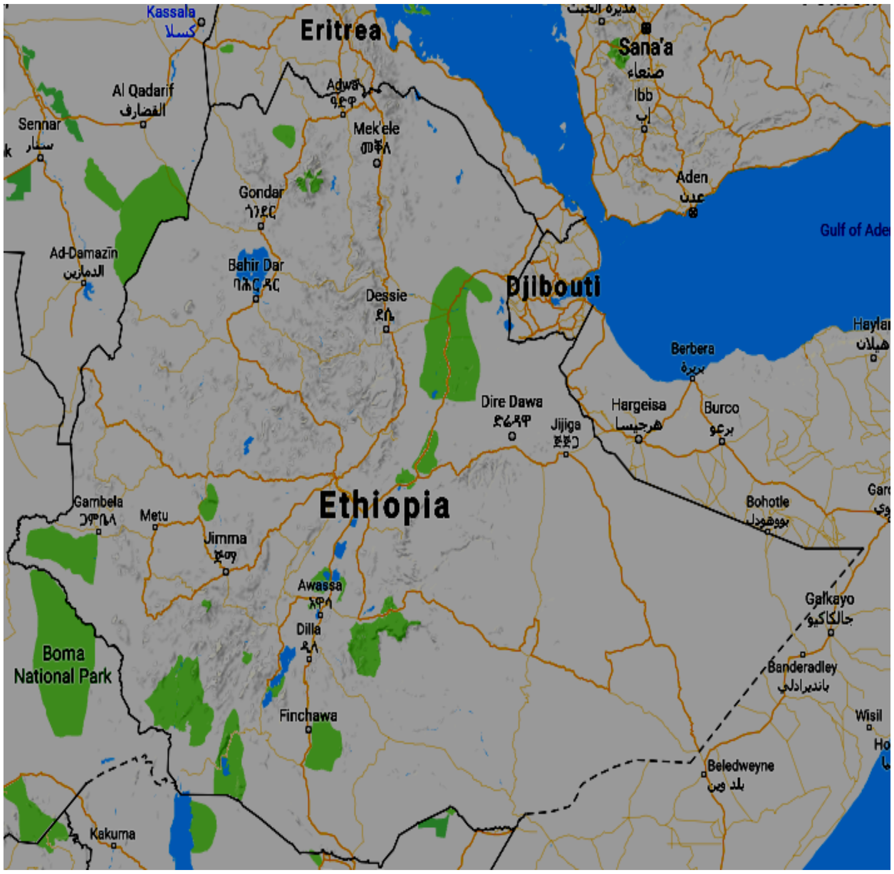

Figure 5: Map of the study area, from Google

The sample of khat waste would take from its branch part and dry at air temperature. The collected sample was chopped to dimension that fit the carbonization metal kiln. Then it was transported to Alternative energy development and promotion laboratory and workshop center, Ministry of water, irrigation and energy **(MOWIE)**, Addis Ababa, for carbonization, determination of proximate analysis, bulk density and calorific value of the briquette.

3.2.2 Sample Analysis

In this study khat waste fuel briquette was evaluated for its fuel briquette quality by fuel quality determining parameter expressed in terms of proximate analysis and physical properties.

The amount of wastage found at the selected site is obtain from questioner paper by asking questions the khat sellers that percentage of waste found from their daily sell.

Samples would collected from site, with appropriate safety using like glove then sorted with its type such as branch then chopped with proper size to fit the kiln for carbonization processes and dried for a fifteen days. The carbonization process proceed with proper way feeding to the kiln and cleaning of the kiln followed by proper controlling of the air for proper dehydration and carbonization and following the chimney smoke type and closing the whole opening that show completion of carbonization and cooling to proceeded (YisakSeboka, 2009)

The amount of khat wastage disposal calculated from the total amount khat entered to city time's percentage of total wastage obtained from questioner divided to total amount khat from questioner. Mathematically

$$total\ amountofwastage = \frac{amount\ khat\ entered\ to\ city \times amount\ of\ wastege\ fromseller}{amount\ khat\ sold\ by\ seller} \ldots\ldots\ldots\ldots$$

3.1

In addition, the total amount wastage after drying is calculated by multiplying monthly wastage before dry by sample after dry divided to sample before dry. Mathematically

$$total\ amount\ of\ w.\ after\ drying = \frac{w.before\ dry \times sample\ after\ dry}{sample\ before\ dry} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 3.2$$

Where w, wastage

In addition, the amount of charcoal calculated by multiplying wastage dried by sample charcoal divided to sample dried. Mathematically

$$amountofcharcoal = \frac{wastage\ dried \times sample\ charcoal}{sampledried} \ldots\ldots\ldots 3.3$$

Finally, total amount of briquette is calculated by multiplying total amount charcoal monthly from selected site by amount briquette from sample divided to amount of charcoal from sample.

Mathematically

$$amountofbriquette = \frac{amount\ of\ charcoal \times sample\ briquette}{sample\ charcoal} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots .3.4$$

Data required;

It is two type of data required to complete the above equation;

A. Sample data; which is the sample data prepared to manufacture sample briquette. These are;

Amount of waste before drying (kg)

Amount of waste after drying (kg)

Amount of charcoal produced from waste combustion (kg)

Drying time (day)

Amount of binder (clay) (kg)

Amount of briquette from sample (pcs)

B. Questioner data result; which is sample data obtained from questioner. These are attached as appendix

Total amount of khat from seller (kg)

Total amount of wastage from seller (kg)

Average wastage in (%)

Generally, it is detail done in the next chapter.

3.3 Fuel Briquette Production Process

3.3.1 Briquetting

Briquetting charring procedures includes crushing of charred biomass to finer particles, mixing of char dust with binder and the actual densification or briquetting process using beehive coal briquette machine press mold with 2000 briquettes per hour capacity.

The overall production process starts with collecting of the biomass khat waste, which was used as raw material and sun drying for more than 15 days after chopping to obtain homogeneous size for carbonization then branch with trunk of khat waste *were* placed in barrel kiln about dried sample 11.017 kg.

In this study, the process of carbonization were carried out in oxygen-limited condition in barrel kiln which have long chimney; which used to control the proper air for carbonization process. Then with screw when dehydration completed just when cloudy smoke become closely to blue or black so as limited oxygen environment was created and the chimney also covered by clay mud for charcoal production and cooling in controlled manner. The resulted charcoal were ground to fine particles by using charcoal grinder or charcoal mill to produce charcoal powder which is about 3.025 kg.

3.4 Characterization of the Produced Fuel Briquette

The proximate analysis of the raw material (moisture content, ash content, volatile matter content, fixed carbon content) was conducted following ASTM D-standards.

To determine calorific value, , the briquette specimens were milled with 1.0633 gram and then placed in a capsule and combusted in and analyzed by an adiabatic oxygen bomb calorimeter Parr 6200-calorie meter of Parr M39889 and Parr M39805 oxygen bomb, which were used following the Parr instruction manual according to(ASTM D-5865-95, 1996) and calorific values were measured.

The bulk density was determined by placing the charcoal powdered in metal cub with size of cub x =y=z dimension and then the weight of powdered measured and the result computed as the weight of charcoal divided by the volume of the container.

The proximate analysis (the chemical property) of the briquettes was determined according to (ASTM D-1762-84, 1996) protocol and on the other side the fixed carbon content was computed following Anon equation (1987) procedures.

All proximate analysis of the produced fuel briquette includes moisture content, Volatile matter content, ash content and Fixed carbon content were carried out in the Alternative Energy Development and Promotion Directorate Laboratory, MOWIE, Addis Ababa, Ethiopia and all proximate analysis were carried out accordance with (ASTM D-1762-84 ,1996) protocol and theses proximate term can be defined as follow:

3.4.1 Moisture content

The moisture content determined by heating a sample of powdered *khat waste* briquette and determined as a loss in weight in a drying oven at 105^0C to constant mass, then the moisture content computed and reported on weight basis. And percentage of moisture content calculated as the difference between the weights before moisture removal i.e. in this study three gram were taken plus the mass of crucible and the weight after moisture removal and dividing the result by the sample weight taken i.e. Three gram for measuring moisture and multiplying the whole with hundred(FAO, 1999). Equation 3.5 was used.

$$MC = \frac{weigt\ sample\ before\ moisture\ removal - weight\ sample\ after\ moisture\ removal}{sample\ weigt(gram)} 100 \ldots .3.5$$

3.4.2 Volatile Matter Content

The volatile matter content of powdered khat waste briquette charcoal would be determined by heating oven-dried sample for moisture content at 950^0C for six minute in covered crucible of specimen by lid or metal box prepared for this purpose. Then the percentage of volatile content of the sample is computed as the difference between initial (Oven dry weight of charcoal specimen for moisture determination or weight after moisture removal) and final weight of the sample after removal of volatile matter and dividing the result by the total sample weight taken and multiplying the whole with hundred.

$$VM = \frac{weight\ sample\ after\ moisture\ removal - weight\ sample\ after\ VM\ removal}{sample\ weigt(gram)} 100\% \ldots .3.6$$

3.4.3 Ash content

The ash content of a sample of powdered khat waste charcoal and briquette charcoal were determined after burning of specimen obtained to a constant weight at 750°C for six hours in uncovered crucible of specimen. Ash content was, computed as a proportion of the residue to the oven-dry weight of charcoal. Then the percentage of ash content of the sample is computed as the difference between initial (Oven dry weight of charcoal specimen for moisture determination or weight after moisture removal) and final weight of the sample after removal of ash and dividing the result by the total sample weight taken and multiplying the whole with hundred.

$$\%AC = \frac{weigt\ sample\ before\ moisture\ removal - weight\ sample\ after\ ashing}{sample\ weigt(gram)} 100\% \ldots\ldots\ldots .3.7$$

3.4.4 Fixed (pure) carbon content

The fixed carbon content in sample of powdered khat waste charcoal and briquette charcoal were calculated as the difference between 100% and the sum of the percentage of moisture content, volatile matter content and ash content or subtracting these value from the total sample weight taken for analysis and converting the result in to percentage according to(Anon,1987).

$$\%FCC = 100\% - (MC + VM + AC)\% \qquad 3.8$$

OR

$$FCC = total\ sample(3\ gram) - (MC + VM + AC)$$

Where

%Mc = Percentage Moisture content

%VM = Percentage Volatile matter content

%Ac = Percentage Ash content

%FCC= Percentage of Fixed carbon content

3.5 The Physical Property of Briquette Charcoal Produced from Khat Waste

3.5.1 Standardization of Calorie Meter for Calorific Value Determination

The term standardization of calorie meter denoted for the operation of calorimeter using graded one-gram benzoic acid as a test sample up running a number of test. In this study adiabatic bomb calorie meter used with model Parr 6200 and with Bomb ID 39905 and M3980, which were ISO 9001 certified.

The procedure for the calorie meter standardization used in this study for determination of calorific value of the produced briquette were standardized for ten times with pellet of calorie graded benzoic acid with weight not less than 0.9 gram and not more than 1.25 gram or mostly graded one gram benzoic acid were used.

The Central Power Unit of the calorie calculated gross heat value of a sample and all result meter and the result was obtained as printed out.

The physical property of the produced khat waste fuel briquette like bulk density, calorific value and weight(g)immediate after removal from briquette machine and up to 15 days were done in the same laboratory, Alternative energy development and promotion directorate; MOWIE.

Beside this all physical property test durability, the cooking time of fuel briquette or time taken to turn ash and time taken to boil for 1L and 2 litter water also carried out with so called „Merichaye‟ briquette stove. The stove is designed and produced in Alternative energy development and promotion directorate of MOWIE, Ethiopia.

Some of the term used in physical property charcoal defined as follow:

3.5.1.1 Bulk density

The bulk density of charcoal or fuel briquette charcoal were determined by many ways, The first one by filling charcoal or briquette powder into a cube-shaped container with each size 75 ml and measuring the weight of charcoal contained in the container. Then it was computed as the weight of charcoal divided by the volume of the container. The second one, which is applied in this study the bulk density of charcoal or fuel briquette charcoal, can be determined by filling briquette charcoal powder in to known volume or marked container like volumetric flask or measuring cylinder and measuring the weight of charcoal contained in the container. Then it computed as the weight of charcoal divided by the volume of the container and calculated using Equation 3 .5.

$$bulk\ density = \frac{mass\ of\ charcoal\ or\ produced\ briqutee\ powder}{volume\ of\ container\ used} \ldots\ldots\ldots\ldots\ldots\ldots\ldots 3.9$$

3.5.2 Calorific value

The calorific value of fuel briquette charcoal was carried out in the Laboratory at Alternative Energy Development and Promotion Directorate Laboratory, MOWIE, the briquette specimens were analyzed by an adiabatic oxygen bomb Calorimeter Parr 6200 and with Bomb ID 39905 and M39889 were used for powdered khat waste fuel briquette charcoal calorific value determination.

The charcoal specimens were milled with 0.5-1gram of each as pellets then placed in a capsule and combusted in the oxygen bomb. The gross calorific value produced after combustion of sample was recorded in MJ and converted into calories per gram.

The calorific value of fuel briquette charcoal is closely linked to its chemical composition, especially its fixed carbon content, and it therefore varies appreciably. The calorific value is measured using Bomb Calorimeter (Hood*et al.*, 2003) and in this case digital adiabatic bomb calorie meter with Parr 6200 Model with Bomb ID 39905 and M39889 were used for powdered khat waste charcoal and fuel briquette charcoal calorific value determination.

In this study with the same procedure and instrument mentioned above some Proximate, analysis and physical test were done for charcoal produced from branch part khat waste. Charcoal for checking its fuel potential in replacing other charcoal produced from different input like *Eucalyptus*, *Acacia*, Bamboo and other indigenous tree.

3.6 Combustion and Heat Efficiency Test of Khat Waste Fuel Briquette Charcoal

Combustion test were conducted to cheek properties of the produced fuel briquette such as flame color, production of dangerous spark formation, smoke and odor. The produced briquettes water boiling capacity or heat efficiency test was conducted by using measured amount of Water half or one liter and boiling and from this we can predicted the practical cooking time for a better and efficient application or usage of the produced fuel briquette.

The combustion and boiling tests, for khat waste briquettes, was conducted using Merchayae - Stove (The “Merchaye” an improved briquette charcoal stove has an efficiency of more than 75% and a fuel saving stove compared with traditional charcoal stoves). The stove is popular among urban dwellers and now a day such briquette charcoal and stoves have been disseminated by many micro investor / interpurner / and energy sake holder in urban and rural part of Ethiopia(YisakSeboka, 2009).

CHAPTER FOUR

4. Results and Discussions

4.1 The Proximate Analysis of Fuel Briquette Produced from Khat Waste

The quality determining parameter of briquette and charcoal produced from biomasses expressed in terms of proximate analysis and physical properties. Since, these paroameters such as moisture content (MC), volatile matter (VM), ash content (AC), fixed carbon content (FC), calorific value (CV), bulk density (BD) and sulphur content (SC) were verifying the quality of briquette to decide for utilization . Hence, characterization of briquette for their proximate and physical properties is very important (Oladeji, 2010).

As we have seen from Table 2 below the moisture content of briquettes produced from branch of *khat waste* were lower than the moisture content of briquette produced from wood which has moisture content of 12% (Malatji*et al.*,2011).

4.1.1 Moisture content

As we have seen from Table 2 below the moisture content of raw material for briquetting khat waste by using three samples each have 3-gram weight and oven dried at 105^{o}cfor four hours. Therefore, the result of raw material with different mass of conic shape cup as shown below in detail.

Table 2: Moisture content of raw material, charcoal and briquette

No	MC tested	MC value (%)
1	MCR	7.2
2	MCC	5
3	MCB	6.4

Where, *MCR = moisture content of raw material*

MCC = moisture content of charcoal

MCB = moisture content of briquette

MC = moisture content

The moisture content of the charcoal determine the physical properties of the briquettes consequently, if the moisture content is low the briquette will have resistance to biodegradation and less vulnerable to the attack of biological agents as well as not flexible to atmospheric conditions and it becomes durable (Heya*et al., 2014).* If briquette charcoal containing high of moisture content will lead to the swelling and the disintegration of the briquette charcoal (Singh, 2004). Normally, fresh charcoal from an opened kiln contains very little moisture content, which, is usually less than 1%. but it can absorb the moisture content from the humidity of air itself rapidly with time, a gain of moisture even without any rain wetting and even the charcoal in well burned situation can take the moisture content about 5 to 10% (FAO, 1987); (FAO, 1999).

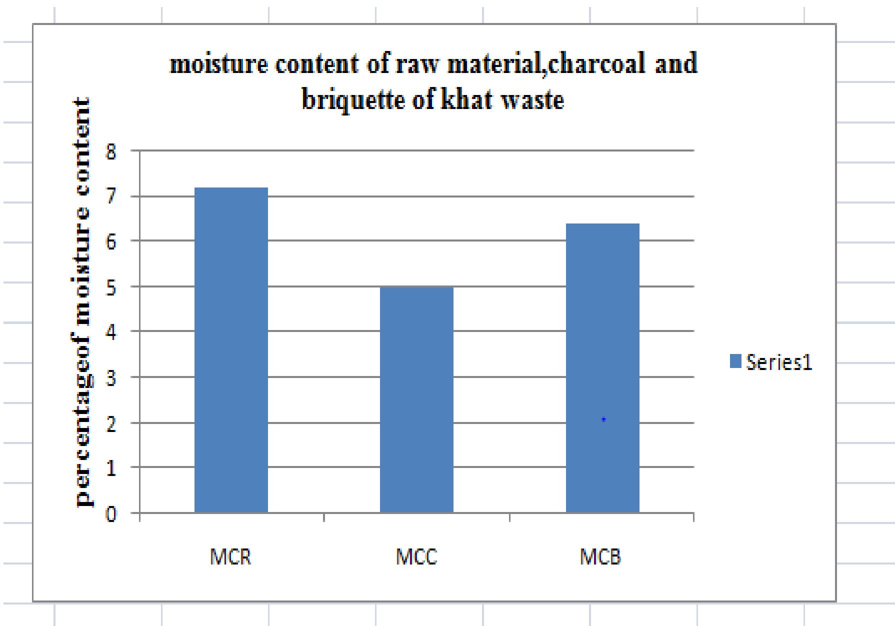

Figure 6: moisture content of raw material, charcoal and briquette

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 the moisture content is 10% maximum. On the other hand, there is some evidence concerned that charcoal with high moisture content at 10% or more than 10% tends to shatter when heated in the blast furnace (FAO, 1987). In this study the result khat waste branch charcoal table 2 above showed moisture contents of raw material 7.2%, moisture content of charcoal 5% and its briquette moisture is 6.4%, which is fit within the; desirable criteria set by (FAO, 1987).Moisture contents of the raw material, charcoal and briquette of khat waste was as shown in Figure 6 above. The high moisture content gives the result of low calorific value and the lower the moisture content the higher will be it is calorific value (FAO, 1985).

4.1.2 Volatile matter

Table 3: volatile mater of raw material and briquette

No	VM tested	VM value(%)
1	VMR	68.51
3	VMB	24.862

Where, VMR = volatile mater of raw material

VMB = volatile mater of briquette

VM = volatile mater

Similarly, the volatile matter of briquettes in this study (Table 3) 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).Hence the briquette produced in this study is contributing minimal indoor air pollution due to their small amount of smoke generation during combustion relatively as they compared with briquettes produced from Coconut pith and Sawdust.

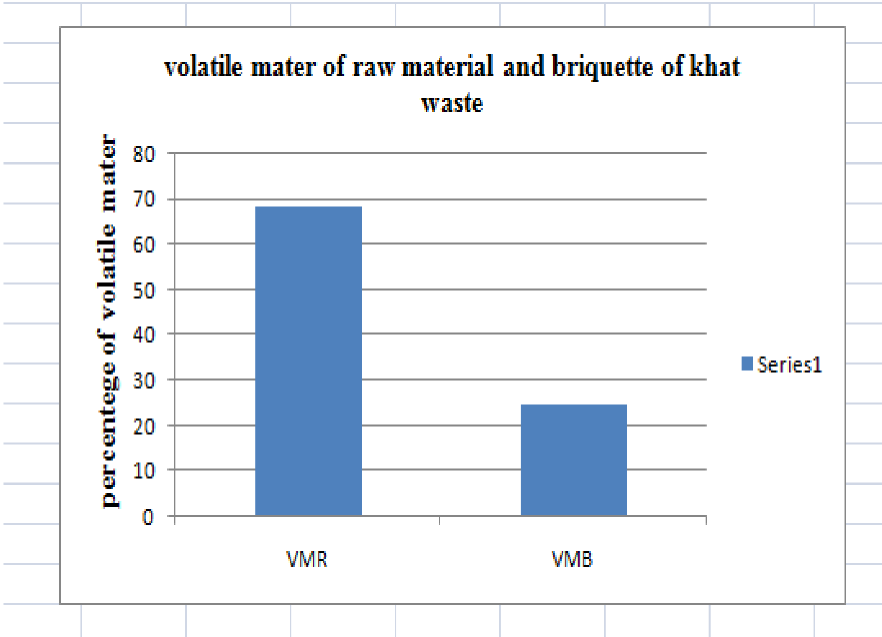

Figure 7: volatile mater of raw and briquette waste of khat

Volatile matter in charcoal can vary from a high value of 40% or more down to 5% or less than 5% (FAO, 1985). Good quality charcoal should have volatile matter range from 20 to 25% (FAO, 1987). As shown in Figure 7 the raw material of khat waste branch in this study the highest volatile matter with 68.51 % and its briquette 24.862%, which fit within the desirable criteria set by (FAO, 1987).

4.1.3 Ash Content

The ash content of the briquettes in this study Figure 7 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 might be due to the binder type that we were used.

Table 4: Ash content of raw material and briquette

No	AC tested	AC value (%)
1	ACR	3.39
2	ACB	29.4

Where, ACR = ash content of raw material

ACB = ash content of briquette

AC = ash content

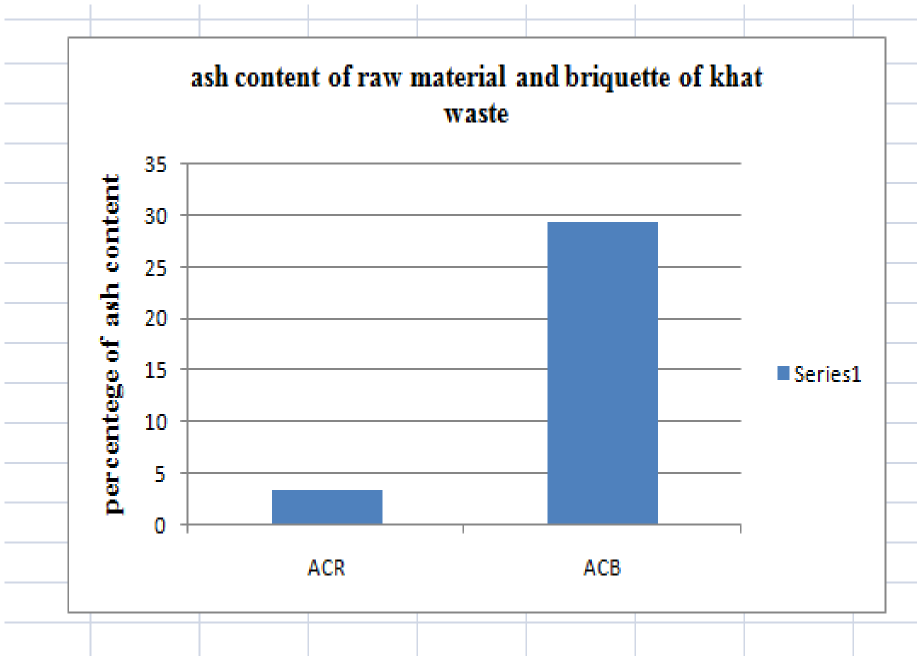

Figure 8: ash content of raw material and briquette of khat waste

In this study, clay soil was used, which is non-combustible during ignition and this is why high amount of ash content was found. 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. As observed from figure 8 above briquette of khat waste with higher Ash value meaning low quality fuel as compared to row material of khat waste (Akowuah*et al.*, 2012).

4.1.4 Fixed Carbon Content

A fixed carbon content of the briquette is the solid combustible residue that remains after the briquette was heated and the volatile matter was removed. The fixed carbon contents of briquettes in this study is greater than the fixed carbon content of briquette produced from wood which have the equivalent value of 1.6% (Malatji*et al.*,2011).

Table 5: Fixed carbon content of raw material and briquette khat waste

No	FCC tested	FCC value (%)
1	FCCR	20.9
3	FCCB	39.268

Where, FCCR = fixed carbon content of raw material

FCCB = fixed carbon content of briquette

FCC = ash content

Fixed carbon content of the row material and briquette produced in this study also differed significantly between row material and briquette produced from branch khat waste. The high fixed carbon content gives the result of high calorific value (FAO, 1985). It seems true where the produced fuel briquette and row material had higher fixed carbon content of 20.9 and 39.268 and had the higher gross calorific value of 3688.3946 and 4143.2549 cal/g ,respectively

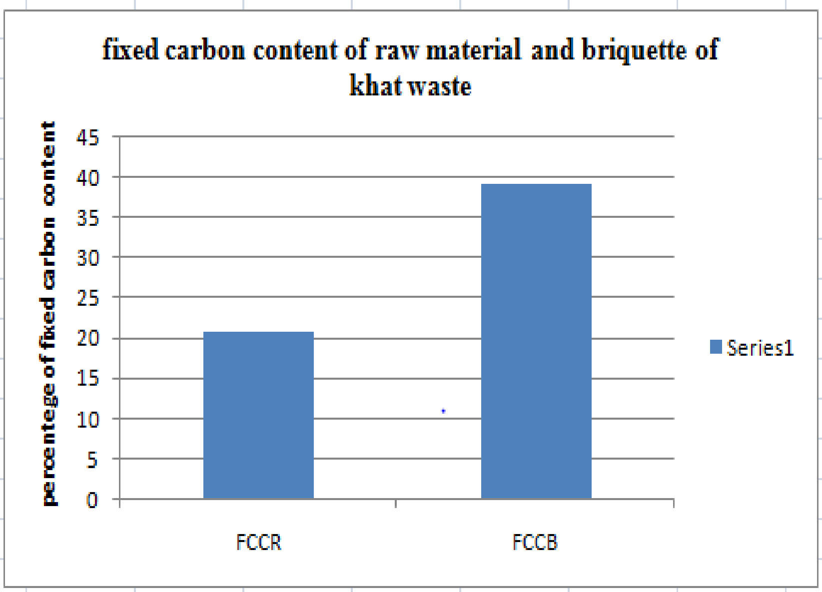

Figure 9: Fixed carbon content of raw material and briquette of khat waste

The fixed carbon of raw material of khat waste 20.9% and for briquette, it was about 39.268%. Thus, the charcoal contains slightly carbon.

4.2 Physical Property of the Produced Fuel Briquette from Khat Waste

4.2.1 Calorific value

calorific value determines the energy content of a fuel and it is the property of biomass fuel that rely on the chemical composition and moisture content of the material (Raju*et al.*,2014) as well as it is the most important fuel property determining parameter of the fuel (Aina*et al.*,2009). However, the calorific value of all fuel briquettes for this study was less than the calorific value of briquette produced from saw dust that have the equivalent value of 4,820 cal/g (Akowuah*et al.*,2012).

As shown in Figure.10 bellow for calorific value of the produce briquette which increase in similar manner with that of its fixed carbon content as compare to Figure 9 and there is also similar trend increment with bulk density and calorific value (Table 6).

Table 6: Caloric value of raw material and briquette of khat waste

No	Caloric value tested	Caloric value (cal/g)
1	CL.V.R	3688.3946
2	CL.V.B	4143.268

Where,

CL.VR = caloric value of raw material

CL.V.B = caloric value of briquette

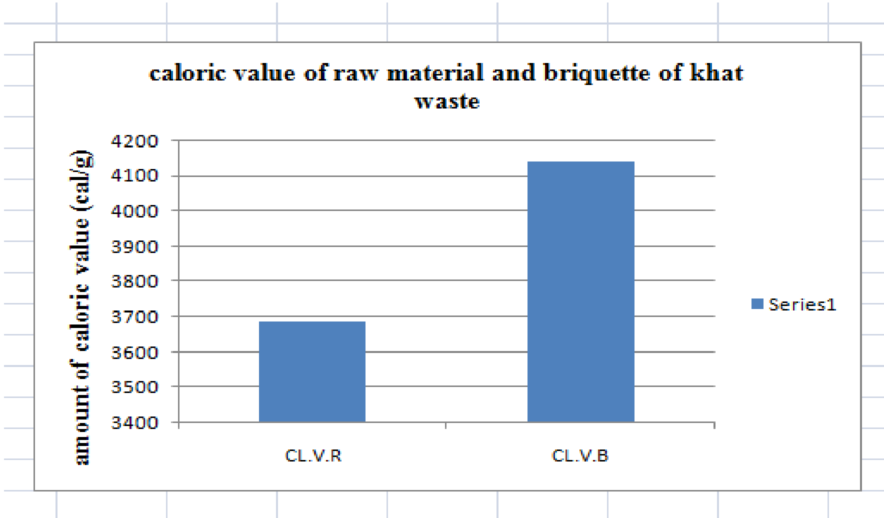

Figure 10: Caloric value of raw material and briquette of khat waste

4.2.2 Bulk density of charcoal

The other most important property of briquettes is the bulk density. The bulk density of charcoal briquettes mainly depends on the type of briquetting technology than on the raw material itself and hence briquettes made using mechanized units like Beehive briquette machine produce briquettes with higher bulk density than manual briquetting. Density is one of the important parameters that directly affect the fuel quality of a feedstock. The species having higher density are preferred as fuel because of its high-energy content per unit volume and its slow burning property (Goel*et al.,* 1996). This can be realized by comparing result in Table 7 and the two bar charting Figure11 and by comparing density result in Table 5 for the produced charcoal within its fixed carbon content and calorific value.

Table 7: bulk density of charcoal and briquette

No	BD tested	BD value(g/cm^3)
1	BDC	0.273 g/ml
3	BDB	1.58 g/cm^3

Where, BDC = bulk density of charcoal

BDB = bulk density of briquette

BD = bulk density

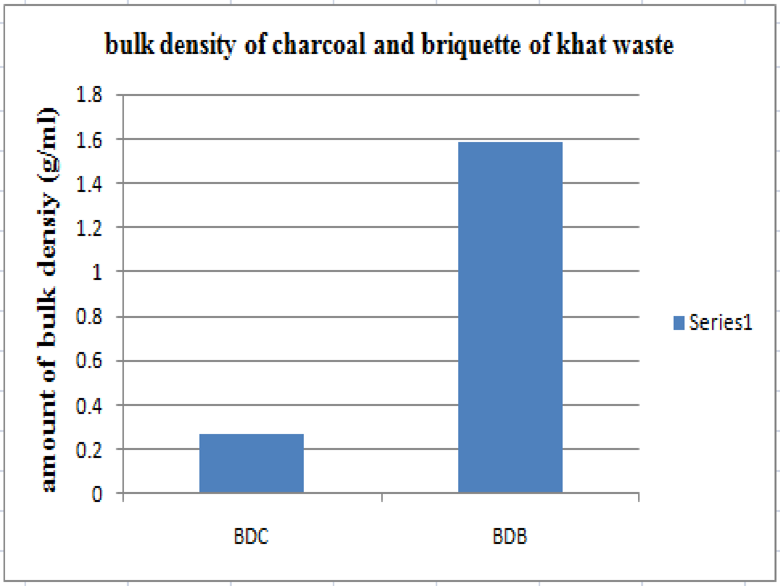

Figure 11: bulk density of charcoal and briquette of khat waste

The value for bulk density (g/cm3) of khat waste charcoal and briquette 0.273 and 1.58 g/ml respectively which is much higher than that of *Eupatorium* with bulk density 0.330 g/cm3(Ritesh*et al.*,2009).

4.3 Weight-Based Carbonization Efficiency

The carbonization efficiency can be affected with many factor like moisture content of the input sample or khat waste weed, number of air hole in the kiln that regulate the amount of air for the proper carbonization and cooling and personal skill. One of this all factor, moisture of the sun dried sample, it is also showed with figure 1a and 1b and have direct effect with the quality and quantity of fuel charcoal or fuel briquette production.

Weight-based carbonization efficiency (based on charcoal yield*)* is a percentage rate expressing the ratio between the weight of the charcoal output and the weight of the air-dry sample input. For instance, the typical yield of a brick kiln (at 15 % moisture content) is about 30%. Moreover, for carbonization I have done two experiments that have equal weight but different closing opening chimney for carbonization as shown in table blow

Table 8: Carbonization efficiency of metal kiln on weight based for khat waste plant input

No	Raw material weight input (gram)	Time of closing (in min)	Charcoal produced output (gram)	unburned(gram)	Ash(gram)	Remark
1	5508.5	45	1561	105	161	
2	5508.5	30	1464	766	322	
Total	***11017***		***3025***	***871***	***483***	

Therefore, the carbonization efficiency is calculated as follows

$$carbonazation\ effeciency\ (\%) = \frac{total\ charcoal\ output}{total\ waste\ input} * 100$$

$$carbonazation\ effeciency\ (\%) = \frac{3025}{11017} * 100 = 27.45\%$$

$$MC = \frac{weigtsamplebeforemoistureremoval - weightsampleaftermoistureremoval}{sample\ gram}\ 100\%$$

$$MC = \frac{18890 - 11017}{18890gram}\ 100\% \quad = 41.68\%$$

4.4 Combustion and Heat Efficiency Test of Khat Waste Fuel Briquette

Production of high quality charcoal briquettes demands that a suitable binder is used and sufficient pressure. Such that the physical characteristics are comparable with or even are better than wood charcoal.

In mechanized units starch is the preferred binder as it has very good binding property and also when combusted produce no smell or smoke but using clay as binder will yield much more clean and low cost fuel briquette than starch or molasses one.

The result for combustion test, flame and heat efficiency test of the produced *khat waste* fuel briquette confirmed that there is no smoke (smoke free) except at a startup. No spark formation,, no soot production, no smell or odor and strong heat which can boil one liter water in less than 15 minute and two liter water with less than 25 minute, respectively.

As shown in the Table 16 the time taken to boil a given amount of water vary with the amount of water they boil and as its highly related with the calorific value of the briquette and its density and also time taken to turn to ash shows the durability of the produced briquette.

Table 9: Comparative Time taken to boil Water; conducted using Lakech –stove

No	Average time taken to boil one litter Water in Minutes	Average time taken to boil two litters(2L) Water in Minutes	Average time taken to turn to Ash (Hour & Minutes)	Average Calorific Value for triplicate fuel briquette test (Cal/gm)
1	12	22	2hr and 25 min	4143 g/cl

Therefore, durability fuel briquette is its one advantage than other form of fuel charcoal further more predicting the practical cooking time is the important aspect in energy efficient way utilization and for a better way utilization and efficient application or usage of the produced *khat waste* fuel briquette and from practical cooking study done.

Up on practical cooking laboratory experiment done, once the fuel briquette fired it is not possible to quit the fire for moment, there for, knowing the proper cooking time enable to minimize energy loss and even save money and time.

Boiling temperature versus 1L and 2L water test

This boiling test Accor in the Laboratory at Alternative Energy Development and Promotion Directorate Laboratory with room and water temperature 19.7 ^{o}C and 18.6^{o}C respectively. Thus detail test parameter is shown in table.

Table 10: list of material to boiling test of 1L and 2L water

No	Parameters	For 1L weight in gram (Stove A)	For 2L weight in gram (Stove B)
1	Stove weight	4494.5	3714.5
2	Container weight	186	196
3	Briquette weight	370	412
4	Container weight with water	1257.5	2492.5
5	Container weight with water at boiling point	1140	2146.5
6	Container weight with water at end of boiling	340.5	1575.5
7	Stove weight with ash of briquette at end	4568	3776.5

Also in table shown below the temperature, variation in every ten minute is interval until end of ash was shown in detail below. However, during this testing experiment similar stove have different weight because it has an error during manufacturing. Thus, difference cause durability of burning which was stove that has higher weight has higher of burning.

Stove A stove B

Figure 12: compression of two stoves

Table 11: Boiling temperature versus 1L and 2L water test at each ten minute

1L		2L	
Time	Temp.(^oC)	Time	Temp.(^oC)
5:15 – 5:25	65	5:15 – 5:25	40.7
5:25 – 5:35	90.5	5:25 – 5:35	67.5
5:35 – 5:45	91.8	5:35 – 5:45	87.2
5:45 – 5:55	90.5	5:45 – 5:55	90.5
5:55 – 6:05	88.5	5:55 – 6:05	91.5
6:05 – 6:15	83.2	6:05 – 6:15	90.3
6:15 – 6:25	76.1	6:15 – 6:25	90.2
6:25 – 6:35	73.5	6:25 – 6:35	89.5
6:35 – 6:45	65.4	6:35 – 6:45	86
6:45 – 6:55	50.8	6:45 – 6:55	81.6
6:55 – 7:05	45	6:55 – 7:05	73.3
7:05 – 7:15	40	7:05 – 7:15	66.6
7:15 – 7:25	35	7:15 – 7:25	63.6
7:25 – 7:35	32	7:25 – 7:35	60

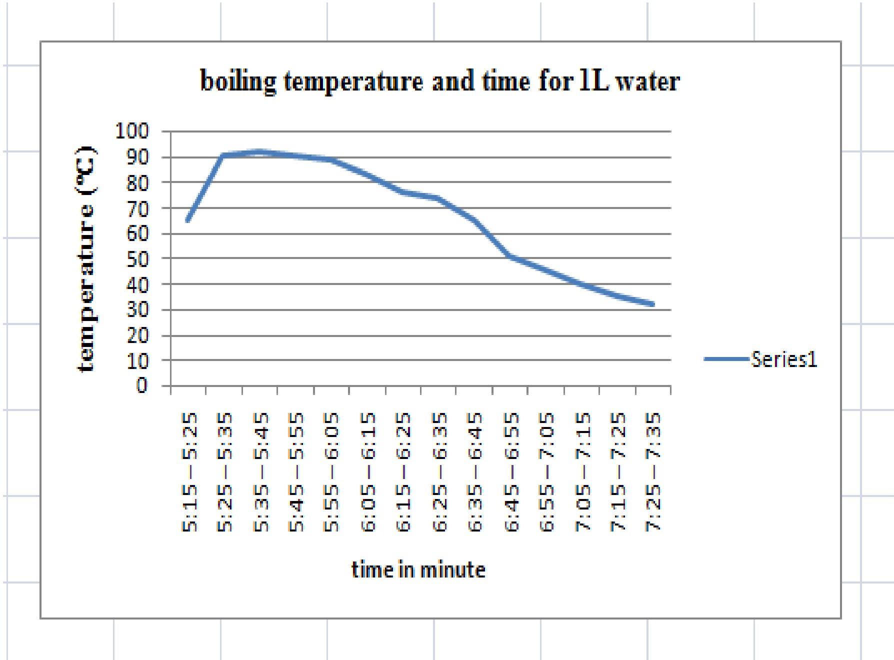

Figure 13: boiling test for 1L water

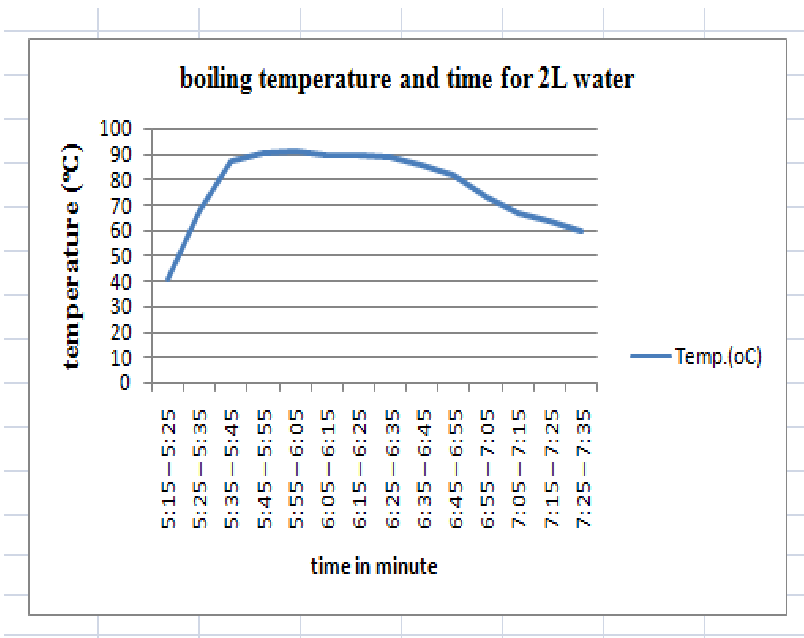

Figure 14: boiling test for 2L water

4.5 *Amount of Briquette Produced at Selected Site*

The amount of khat wastage disposal calculated from the total amount khat entered to city time's percentage of total wastage obtained from questioner divided to total amount khat from questioner. Mathematically

$$total\ amount\ of wastage = \frac{amount\ khat\ entered\ to\ city \times amount of wastege\ from\ seller}{amount\ khat\ sold\ byseller}$$

In addition, the total amount wastage after drying is calculated by multiplying monthly wastage before dry by sample after dry divided to sample before dry. Mathematically

$$total\ amount\ of\ w.after\ drying = \frac{w.before\ dry \times sample\ after\ dry}{sample\ before\ dry}$$

Where w, wastage

In addition, the amount of charcoal is calculated by multiplying wastage dried by sample charcoal divided to sample dried. Mathematically

$$amount\ of\ charcoal = \frac{wastage\ dried \times sample\ charcoal}{sample\ dried}$$

Finally, total amount of briquette is calculated by multiplying total amount charcoal monthly from selected site by amount briquette from sample divided to amount of charcoal from sample.

Mathematically

$$amount\ of\ briquette = \frac{amount\ of\ charcoal \times sample\ briquette}{sample\ charcoal}$$

Sample data

Amount of waste before drying = 18890 gram = 18.89kg

Amount of waste after drying = 11017 gram = 11.017kg

Amount of charcoal produced from waste combustion = 3025gram = 3.025kg

Weight of charcoal after crushed = 3000grm = 3 kg

Drying time = fifteen day

Amount of binder(clay) = 1kg

Amount of briquette from sample = 8pcs

Questioner data result

Total amount of khat from seller = 630 kg

Total amount of wastage from seller = 506.5 kg ***(APPDEX 2)***

Depending on the above data lets calculate amount of briquette obtain in for three concessive at the selected site monthly by using above equations. The amount of khat entered to city daily is obtained from the city revenue and this is changed to monthly by summation of all daily data.

For 2007 E.C

The following this table shows the description of data in the year. By using equation 3.1 through 3.4

Table 12: amount khat enter to city daily that is filled to amount of wastage and amount of khat obtained for 2007 E.C year

No	Month	Amount entered to city in (kg)	Amount of wastage before drying(kg)	Amount of wastage after drying(kg)	Charcoal obtained in (kg)	Amount of briquette obtained in (pcs)
1	Sept.	691014	555553.31	324009.04	88965	235279
2	Oct.	716070	575697.55	335757.54	92190.85	243811
3	Nov.	645290	518792.67	302569.55	83078.2	219711
4	Dec.	469364	377353.76	220079.744	60428.54	159811
5	Jan.	477832	384161.76	224050.3	61518.76	162640
6	Feb.	447649	359895.59	209897.8	57632.83	152417
7	Mar.	433617	348614.3	203318.4	55826.28	147639

8	Apr.	475952	382650.3	223168.79	61276.72	162054
9	May.	586573	471586.1	275037.8	75518.68	199718
10	June	689480.7	554320.6	323290.1	88767.6	234757
11	July	786197	632077.4	368639.3	101219.4	267687
12	Augest	784613	630803.9	367896.6	101015.45	267148
	Average	600304	482626	281476.2	77286.53	204389.3
	Sum	7203652	5791507	3377715	1004725	2657061

Generally, the amount of briquette found from the selected site for the selected year is shown in graph below in each month. By using above table.

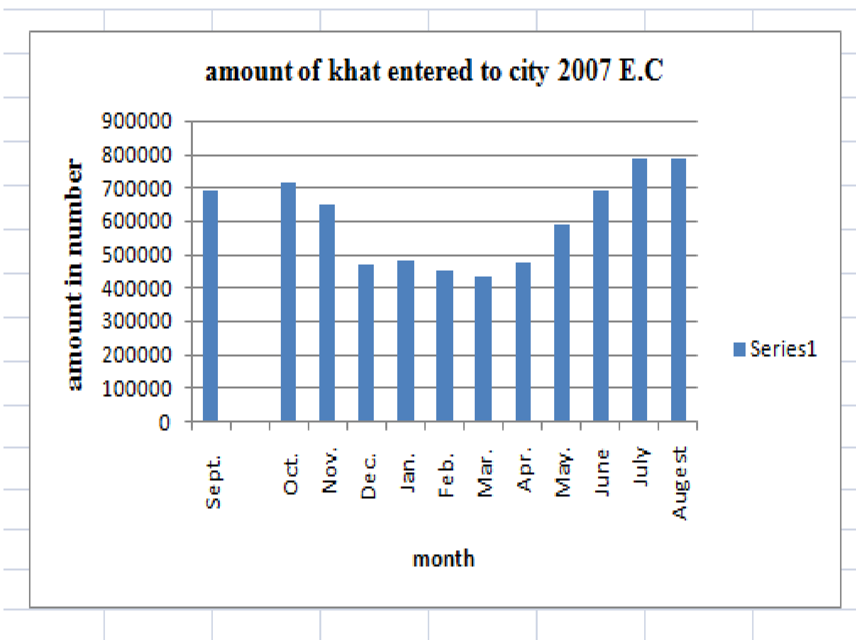

Figure 15: amount khat enter to city daily that is filled to amount of wastage and amount of khat obtained for 2007 E.C year

For 2008 E.C

Amount of briquette obtain in 2008 E.C at the selected site monthly using the same procedure for 2007 E.C above we obtain the following

Table 13: amount khat enter to city daily that is filled to amount of wastage and amount of khat obtained for 2008 E.C year

No	Month	Amount entered to city in (kg)	Amount of wastage before drying(kg)	Amount of wastage after drying(kg)	Charcoal obtained in (kg)	Amount of briquette obtained in (pcs)
1	Sept.	1094430	879887	513166.5	140903	372636
2	Oct.	805959	647965.5	377905.5	103763.7	274416
3	Nov.	706792	568238.3	331407.2	90996.35	240651
4	Dec.	551431	443333	258560	70994.3	187753
5	Jan.	441403	354874	206969.13	56828.7	150290
6	Feb.	486088	390799.3	227921.4	62602.4	165560
7	Mar.	570265.7	458475.5	267391.4	73419.2	194166
8	Apr.	691439.7	555895.6	324208.7	89019.8	235422
9	May	882750	709702.98	413911.5	113650	300561
10	June	783661.7	630039.2	367450.5	100893	266824
11	July	863196	693982.2	404743.4	111132.7	293905
12	Augest	980221	788066.6	459615.13	126199.13	333750
	Average	738136.4	593438.3	346104.2	95033.52	251327.8
	Sum	9595774	7714697	4499355	1235436	3267262

Generally, the amount of briquette found from the selected for the selected year is shown in graph below in each month. By using above table.

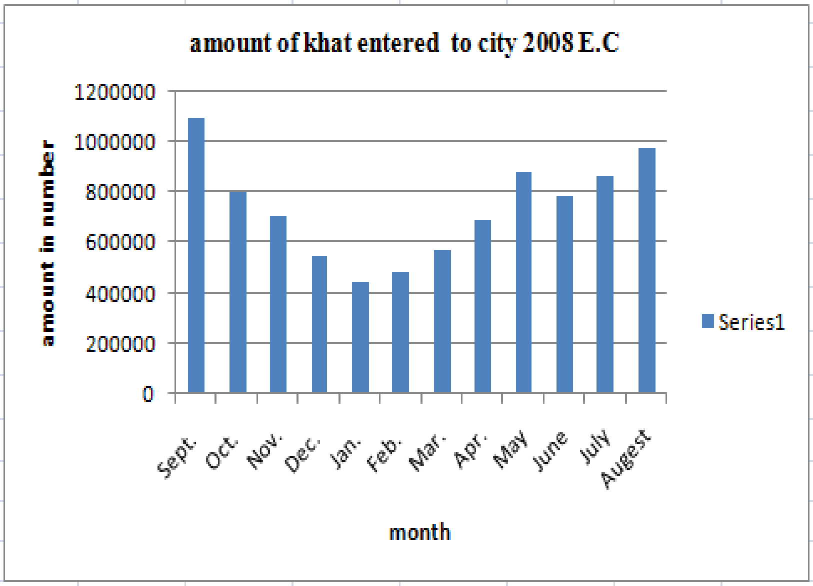

Figure 16: amount khat enter to city daily that is filled to amount of wastage and amount of khat obtained for 2008 E.C year

For 2009 E.C year

Amount of briquette obtain in 2009 E.C at the selected site monthly using the same procedure for 2007 E.C and 2009 E.C above we obtain the following data. By using equation 3.1 through 3.4

Table 14: amount khat enter to city daily that is filled to amount of wastage and amount of khat obtained for 2007 E.C year

No	Month	Amount entered to city in (kg)	Amount of wastage before drying(kg)	Amount of wastage after drying(kg)	Charcoal obtained in (kg)	Amount of briquette obtained in(pcs)
1	Sept.	1083426	871040.1	508006.8	139486.3	368889
2	Oct.	3467052	2787399.8	1625663.5	446367.6	1180476
3	Nov.	2735481	2199239.9	1282637.7	352181.1	931388
4	Dec.	1806902	1452691.8	847236.93	232630.64	615221
5	Jan.	1059777	852027.1	496918.1	136441.6	360837

6	Feb.	853838.2	686458.8	400355.6	109927.9	290718
7	Mar.	623779.9	501499.24	292483.7	80308.9	212387
8	Apr.	646664.5	519897.73	303214.04	83255.2	220179
9	May	1194922	960679.4	560286.13	153840.9	406852
10	June	927275.1	469664	273916.8	75210.9	198905
11	July	891969.2	717114.9	418234.8	114837.1	303701
12	August	1012895	814335.4	475366.7	130524.1	345187
	average	1358665.158	1069337.348	623693.4	171251.02	452895
	Sum	17662647.06	13901385.52	8108014.2	2226263.26	5887635

Generally, the amount of briquette found from the selected for the selected year is shown in graph below in each month. By using above table.

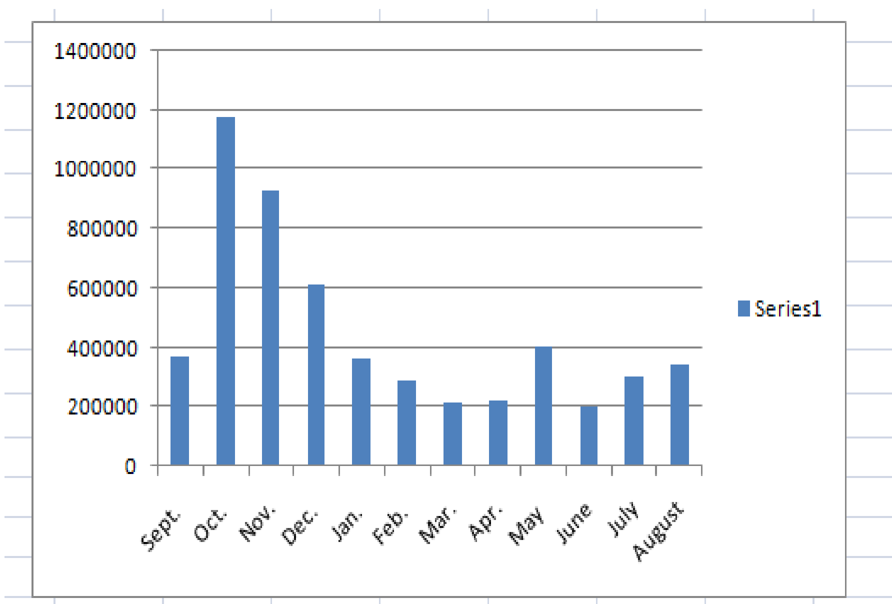

Figure 17: amount khat enter to city daily that is filled to amount of wastage and amount of khat obtained for 2009 E.C year

Finally, the total amount of briquette produced yearly at selected site is calculated by adding total amount briquette produced at each year and compeering it at each year to know the continuity of job for investor that establish the company at selected site.

Table 15: compression of amount briquette found for the three yeas

No	Year(E.C)	Total Amount of briquette at each year
1	2007	2657061
2	2008	3267262
3	2009	5887635

Thus can be shown graphically according to below.

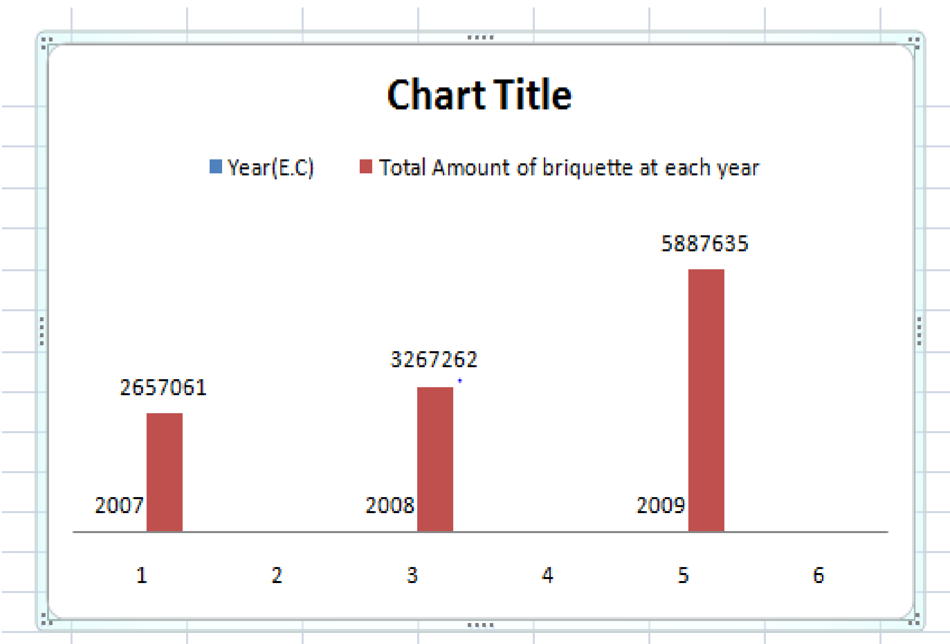

Figure 18: compression of amount briquette found for the three yeas

Generally, according to above figure shown the amount khat enter to city is increases from year to year. Thus shows that the amount of wastage increases from year to year. Therefore, any investors establish this briquetting technology at the selected site is profitable because of continuity of wastage.

CHAPTERFIVE

5. CONCULISION AND RECOMMENDATION

5.1 CONCULISION

This study showed that raw material and briquette produced from khat waste was found as quality sources of energy. Because, raw material and briquettes have higher caloric 3688.3946 cal/g and 4143.269 cal/g respectively, medium fixed carbon content 20.9% and 39.268%, respectively, medium volatile matter 68.51% and 24.862%,respectively, medium moisture 7.2% and 6.4%,respectively and low ash contents 3.39% and medium , 29.4% respectively. Similarly, utilization ofkhat waste as source of energy in terms of briquette production deliver clean energy that reduce indoor air pollution and respirator infectious disease that occurred due to the release of smoke during cooking . Besides, can solve the rural and urban household energy by supplying a clean renewable energy and reduce forest degradation.

The physical and chemical analysis of raw material and fuel briquette produced fromkhat waste were found a promising product can be obtained fromkhatthat can be generate income and job opportunity to the local community and micro enterprise.

Therefore, based on this finding using invasive waste likekhat wastefor clean renewable energy enable possible weed management option as well asincrease farmer’s crop production by allowing user free lands disposal.

5.2 RECOMMENDATION

Based on the present study the following recommendation was forward.

- ✓ Wide project like ultimate analysis should be undertaken to evaluate the chemical composition of briquette produced from khat waste.

- ✓ Economic analysis and feasibility of the overall production of khat waste fuel briquette, the impact of khat waste in human being, crop production and livestock product in Ethiopia have to be evaluated for effective utilization.

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I. APPENDENCES

A. Appendix 1: Ecological Foundation of Khat Waste

Figure 1a: wastage foundation at selected site

B. Appendix 2: Sample preparation and data collection for briquette production

Figure 1b: Questioner asking for khat seller at selected site.

<u>Questioner paper format for khat sellers sub-city of Dire Dawa, sabian</u>

1. Name of khat seller :_________________________________
2. Amount of khat he/she purchased ______________________
3. Amount of he/she sells_________________________________
4. Amount of wastage khat wastage found from he/she sells________

Table 1: questioner paper result for khat seller's sub-city of Dire Dawa, sabian

N_o	Name of seller	Amount khat he/she sell daily(kg)	Amount of khat waste found from he/she sells(kg)	Percentage of wastage (%)
1	Hayatuuumara	100	80	80
2	Kalkidanahmed	20	18.5	92.5
3	Ayentuyusuf	15	13.5	90
4	Alimaalii	10	8	80
5	Ibsamohammed	20	17.5	87.5
6	Rihanajamal	40	32	80
7	Manalecherinat	30	25	83.3
8	Lensatadessa	10	8	80
9	Daditudagaga	20	16	80
10	Munaahmed	40	32	80
11	Iteneshsiyum	40	32	80
12	Fatihamohammed	40	30	75
13	Bontuahmed	20	15	75
14	Dadituttaye	30	24	80
15	Fatumajibril	30	25	83.3
16	Nuradinahmed	40	32	80
17	Fatihausman	25	17	75
18	Rahimaaahmed	40	30	75
19	Cali mohammed	30	25	83.3
20	Jalanetolossa	40	33	82.5
Total		630	506.5	
Average		31.5	25.325	81.785

Appendix 3: sample preparation for khat production

Figure 1c: air-drying of sample for briquette production

Figure 2c: kiln preparation and wastage addition to kiln for combustion.

Figure 3c: combustion of wastage for briquetting.

Figure 4c: carbonization of khat waste in barrel kiln and it result

Figure 5c: Grinding and binder preparation for briquetting

Figure 6c: Binding of charcoal with binder and manufacture of briquette (beehive machine)

C. Appendix 3: laboratory testing for khat waste product

Figure 1d: sample preparation for moisture content, volatile mater, ash content and calorific value measurement.

Figure 2d: caloric value result for raw material and briquette of khat waste

Table 1d. Moisture content of raw material khat waste

No	Mass of cup(gram)	Mass of cup and sample(3-gram)			
		Before	After 3 hrs	After 4 hrs	MC
1	26.55	29.55	29.33	29.33	7.3%
2	15.83	18.83	18.61	18.61	7.3%
3	9.83	12.83	12.62	12.62	7%
				Average	***7.2%***

Table 2d. Moisture content of charcoal of khat waste

No	Mass of cup(gram)	Mass of cup and sample(3-gram)			
		Before	After 3 hrs	After 4 hrs	MC
1	26.55	29.55	29.40	29.40	5%
2	15.83	18.83	18.68	18.68	5%
3	9.83	12.83	12.68	12.68	5%
		Average			***5%***

Table 3d. Moisture content of briquette of khat waste

No	Mass of cup(gram)	Mass of cup and sample(3-gram)			
		Before	After 3 hrs	After 4 hrs	MC
1	15.7267	18.7888	18.5930	18.5930	6.4%
2	15.5	18.55	18.355	18.355	6.4%

Table 4d. volatile mater content of raw material of khat waste

Mass of cup(g)	Mass of cup with mass of sample(g)	Mass of cup with mass sample after moisture removal(g)	Mass of cup with mass of sample after vm (g)	Mass of sample(g)
18.2532	21.26370	21.0097	18.9471	3.0105

Table 5d. volatile mater content of briquette of khat waste

Mass of cup(g)	Mass of cup with mass of sample(g)	Mass of cup with mass sample after moisture removal(g)	Mass of cup with mass of sample after vm (g)	Mass of sample(g)
15.7267	18.7888	18.5930	17.8317	3.0621

Table 6d. The ash content of a sample of powdered khat waste raw material

Mass of cup(g)	Mass of cup with mass of sample(g)	Mass of cup with mass of ash(g)	Mass of sample(g)	Weight of ash (g)
19.2841	22.3272	19.3872	3.0431	0.1031

Table 7d .The ash content of a sample of powdered khat waste briquette

Mass of cup(g)	Mass of cup with mass of sample(g)	Mass of cup with mass of ash(g)	Mass of sample(g)	Weight of ash (g)
21.6504	24.6504	22.5344	3	0.884

Figure 3d: sample preparation and boiling test of khat waste briquette

Table 8d. Boiling test for briquette manufactured for 1L and 2L water

No	Parameters	For 1L weight in gram	For 2L weight in gram
1	Stove weight	4494.5	3714.5
2	Container weight	186	196
3	Briquette weight	370	412
4	Container weight with water	1257.5	2492.5
5	Container weight with water at boiling point	1140	2146.5
6	Container weight with water at end of boiling	340.5	1575.5
7	Stove weight with ash of briquette at end	4568	3776.5

II. APPENDIX

A. Appendix 2: Data from Dire Dawa City custom and revenue authority (25 pages)