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Fuel briquette potential of *Lantana camara L*. weed species and its implication for weed management and recovery of renewable energy source, in Ethiopia

BY

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Abstract

Fuel briquette potential of Lantana camara. L. weed species and its implications for weed management and recovery of renewable energy sources in Ethiopia

Sintayehu Abebe

Addis Ababa University, 2015

This study aimed to produce fuel briquettes and weed management in ecofriendly manner from *Lantana camara*, which is most serious invasive weed, spreading throughout the world particularly at alarming rate in Ethiopia. Utilization of biomass like invasive weed such as *lantana camara* L. species in Ethiopia have greater advantage for discovery of clean renewable energy sources and for reduction of deforestation of indigenous trees. Producing and evaluation of the fuel briquetting potential of root, stem, branch and leaves and the charcoal potential of root, stem,and branch of *Lantana camara* L. weed species were carried out by using ASTM procedure. The mean average value for fixed carbon content(FCC) and calorific value of the root, stem ,branch and leaves fuel briquette of *Lantana camara* L sample were:53.89±1.84(%)and6525.54±250.03(cal/gm); 52.77±0.39% and 6479.59± 1004.51(cal/gm);50.22 ± 3.21(%) and 5135.36± 150.29 (cal/gm); 37.56 ± 0.69 (%) and 3690.67 ± 182.32 (Cal/gm); respectively. The result for fixed carbon content(FCC) and calorific value of the root, stem and branch of charcoal produced *Lantana camara L* sample were:65.6(%)and 7483.99(Cal/gm);6.44(%) and 7483.99(Cal/gm);64.89(%) and 7222.66(Cal/gm);respectivelyThe finding show that by ecofriendly utilization of lantana camara weed as a clean energy fuel briquette. it's possible to manage the spread of such type alien invasive weed as well as to increase farmers crop production, access for livestock grazing land;reduce deforestation of indigenous trees and reduce indoor air pollution.

Key words: Biomass, Briquette, Fuel quality, *Lantana camara*.

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List of Acronyms and Abbreviations

AAU	Addis Ababa university
AV	Acids Value
AC	Ash Content
AEDPD	Alternate Energy Development and Promotion Directorate
APFISN	Asia-Pacific Forest Invasive Species Network
ASTM	American Society for Testing and Materials
BD	Bulk Density
CDM	Clean Development Mechanism
CRGE	Carbon reliance green economy
CV	Calorific Value
EARO	Ethiopian agricultural research organization
EC	Ethiopian calendar
EE	Energy equivalent
EHNRI	Ethiopian Health and Nutrition Research Institute
EPA	Environmental Protection Authority
FAO	Food and Agriculture Organization
EREDPC	Ethiopia Rural Energy Development and Promotion Centre
FCC	Fixed carbon content
FDRE	Federal Democratic Republic of Ethiopia
GHG	Green House Gas
GTP_2	Growth transformation plan two
LC	*Lantana camara*
MC	Moisture Content
MDG	Millennium development goals
MOWIE	Ministry of Water ,Irrigation and Energy
NREL	National Renewable Energy Laboratory

ODW	Oven dry weight
RMS	Root mean square deviation
SD	Standard deviation
UNDP	United Nation Development Program
VM	Volatile matter

1 INTRODUCTION

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. Among the clean energy source, biomass is one. The use of biomass energy sources in most part of developing country is mostly traditional one but now days due to many health and environmental problems, the world tend to shift to modern renewable biomass energy utilization.

*Lantana camara*L. weed or commonly known as Sleeper weed (*Yewof_Kolo or YeragnaKolo in Amharic*). It is a typical weed plant which is most persistent andthat are alien or non-native to the ecological unit and its introduction threaten agriculture productivity of most arable area mainly in Africa and Asia. This impact even extended to food security of the community, on the health of domestic animal and has impact on the biodiversity of the native valuable tree.

Its impact extended to many parts of Ethiopia such as east ShewaOromia region like most part in Ada district up to Shashemene and some part ofWondogentin southern part of Ethiopia;Alien invasive species are one of the major factors threatening biodiversity resources in north Shewa especially Kewet district.
The prominent alien species that cause damage across the country include *Partheniumhysterophorus, Prosopisjuliflora, Eichorniacrassipes*and *Lantana camara. Lantana camara* L.is becoming a major problem by replacing natural vegetation in to shrubby areas(AbiyouTilahun*et al.*,2015*).*

The increase in the demand for clean energy, the limited nature of fossil fuels,itsimpact on environment and the concern about global warming due dependence on fossil fuel, such as petroleum, coal, or natural gas etc. and the increase in the price of petroleum and crude oil product, have driven the attention to alternative, non-fossil fuel –based energy source. Replacing petroleum with bio-fuel can reduceindoor air pollution, improve rural economies by creating job opportunities and raising farm incomes, diversify energy portfolios, minimize dependence on foreign oil and improve trade balances in oil-importing nations.

Biomass is a potential renewable energy sources that could replace fossil energy for transportation and capable of making a large contribution to the world's future energy supply. Land availability for biomass production should not be blockage, provided it is combined modernization of conventional agricultural production. In Ethiopia, for instance, biomass, in the form of wood, charcoal, crop residues, animal dung and agro-industrial wastes, accounts for more than 93 percent of the national energy supply (World Bank, 1984).

The use of food crops (like corn, maize, sorghum) for bio-fuelproduction may cause inflation of cost of these crops leading to food insecurity. To improve such problems, alternative and non-edible agricultural products must been investigatedby(AyeleKefale, 2012).

The way to reduce the cost of the feedstock is to switch from the traditional starch-based feed stocks to cellulosic biomass, but which is an attractive feedstock for future supplies of bio oil, bio fuel and ethanol(Gray *et al.*,2006). Lignocellulose-based technological developments can help to move the price of bio ethanol closer to or even less than that of petroleum-based fuel. However, a major obstacle to the effective utilization of lignocellulose is the chemically unreactive nature of cellulose (Fan*et al.*, 1982; Wyman *et al.*,2005).

The aim of this research is to evaluate and characterized the fuel briquettepotential from*Lantana camara L.*as an option for bio-fuel(briquette and biooil) and weed management in Ethiopia.

1.1 Statement of the problem

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 sources 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).

Ethiopia one of the developing countries, where the economy is agricultural based and even though there is a shift from agriculture led economy to industry led economy, the fact that still agriculture is the major source of income for the country. It is also mainly traditional one attributing for low productivity. Theimpact of invasive weed species(plant that are non-native (alien) to the ecosystem) in agricultural activity mainly on crop productivity is huge.

Major invasive alien species of plants identified in Ethiopia are *Lantana* weed,*Parthenium*weed, *Prosopisjuliflora*, and water hyacinth (*Eichhorniacrassipes*), most of these weed are worstweed in Ethiopia (Tamado T.,2001;Tamado*et al.*,2004) and the process of weed management by utilizing as a clean energy sourcehave a great role in Ethiopia in many cross boundary nature.

Ahmed Yasin, (2009) reported that *Parthenium*weed management by utilizing it as a clean energy source and recommended *Lantana camara* L.weed to be test for its clean energy potential and its management byutilization ,since it’s not possible to manage this weed by most weed management mechanism yet the technology reached Weed management by utilization as clean energy have many advantage like increasing the availability of farm land,grazing landsand many indigenous herbs, increaseland productivity,reduction of deforestation of indigenous tree,it will upgrade one step ahead by adding the weed as one biomass energy source.

In Ethiopia the destructive impacts of invasive alien species were identified in Kewet, YifratanaGidim districts towards Afar and Dessie. Among the invasive species *Lantana camara* L.was replacing all of the shrubby plant species with a very rapid rate. It quickly takeover valuable grazing lands and most of the mountainous areas which was covered by many indigenous herbs, shrub species and the major cause of deforestation and losses of biodiversity threats and major cause of forest depletion are Anthropogenic Pressure, Invasive Species and Over Grazing by Livestock (AbiyouTilahun*et al.,*2015).

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Therefore,converting this alien invasive weed species to value added material like generating clean energy is one of the objective of this study, Since most weed controlling methods are not effective and if it continues erratically then very soon it would be beyond rectification. Thus, management of weed by utilization, therefore, becomes very important in order to minimize the adverse effect of such weed in many aspect of agricultural food security of one country.

1.2 Significance of the study

Lantana camara (Verbenaceae) is a noxious weed which has imposed a great threat to land productivity, grazing livestock, biodiversity and consequently to the overall ecology (Sharma *et al.,*1988; Pass,1991). It is widely acknowledged that attempts to manage this weed using mechanical, chemical and biological means have met with limited success (Sharma, 2004). Alternatively, luxuriant growth and vigorous survival make this weed of potential economic value for utilization of its abundantly available biomass into value added products such as ethanol (Misra and Sharma,1999) and cellulose derivatives (Varshney*et al.,*2006). During the last few years, research has been conducted to utilize the *Lantana camara* L. biomass for development of furniture products, baskets, mulch, compost, drugs and other biologically active agents (Sharma 2004; Varshney*et al.,* 2006).

Many related research shows that most invasive weedslike *Lantana camara* Lcannot be removed effectivelywith the common method removing most weed. Sochanging it into valuable material likebriquetteproduction, bio-oil, biogas and bioethanol production give as many other multi socio economic benefit like saving agricultural land, increasing agricultural production, clean energy, Save time spent by women and children for collection fire wood and they in turn will get enough time for their school or for other social activity.

Many research shows that most indoor-air pollution at a household level resulted from traditional biomass fuel usage andinefficient cooking stoves; which emits many air pollutant mainly carbon monoxide due incomplete burring of charcoal or wood. Since carbon exist in everything that is living or has ever lived. There is a perpetual cycle of carbon being confiscate on the earth and eliminated back into the atmosphere.

The adaptation of biomass to energy (also called bio energy) encompasses a wide range of different types and sources of biomass, conversion options, end-use applications and infrastructure requirements(Berthiaume *et al.*,2001).Biomass can be derived from the cultivation of dedicated energy crops, such as short rotation crops (SRC), perennial grasses, etc.; by harvesting forestry and other plant residues (forest thinning, straw, etc.); and from biomass wastes such as sludge from organic industrial waste,concerning the bioethanol production is to make the process economically viable at low cost of feedstock is a very important factor in establishing a cost-effective technology(Pimentel 1991; Rosenberger *et al.,*2001) and organic domestic waste or the wastes themselves. In each case the biomass feedstock has to be harvested/collected, transported and possibly stored, before being processed into a form suitable for the chosen energy conversion technology.

Human kind increasingly influence this carbon cycle through the traditional burning of biomass and also by burning of ever greater quantities of oil ,gasoline and Coal and the large amount of cutting down of indigenous tree species. It is argued that the human induced accumulation of carbon dioxide (CO_2) and other greenhouse gas in the atmosphere are strongly driving to days climate change to much worth than the past .

It is likely that current atmosphere is concentrations are at a 20-million year high and those current rates of accumulation are unprecedented. Thus the use of renewable energy have a great role for climate change mitigation,CRGE and in addition to this direct benefit it is important for carbon finance not only for Ethiopia and also it is very important at global level since allies weed species like *Lantana camara*Species are common problems in many parts of the world like Asia and Africa(APFISN2014).

These no doubt the application of biomass technology like briquette charcoal production from biomass such as allies weed species like*Lantana camara* L.beside removing this weed have additional importance for carbon trading,climate change mitigation and increasingthe food security locally or globally by protecting the Agricultural land from such invasive weed.

The use of biomass to producefuel briquette or biofuel is one form of renewable energy that can be utilised to reduce the impact of energy production and use on the global environment. The key issue concerning the biofuel production is to make the process economically viable (Berthiaume*et al.,*2001). A low cost of feedstock is a very important factor in establishing a cost-effective technology (Pimentel 1991; Rosenberger *et al.,*2001).

Fuel briquette produced from alien weed species like*Lantana camara L.* are economical and environmentally friendly, healthy (no smoke at all) by reducing GHG emission, reduce impact of deforestation especially indigenous tree and also enable to solve food security problem with dual nature.

Production of fuel briquette and bio fuel from *Lantana camara* L. and similar weed enable saving agricultural farm land from being invaded and reduce the impact of such similar weed species; and beside this all the description of physicochemical properties enable to know the status and to make decision on whether it requires further treatment to produce biofuel. Utilizing biofuel from linguistics biomass like invasive alien weed will solve the computation between crop for food (maze, wheat, sorghum other similar food item for bio-fuel production) and they are less expensive or almost no cost than conventional (Gupta 2008).

Agricultural feed-stock for biofuel production and basically helps us controlling weed by utilization So, the spread and impact of this alien weed *is a* current threat for further economic development in most rural areas of Ethiopia in other word one can conquer the impact of such type of weed by converting it to such value added material.

Different *Lantana camara* weed controlling methods were established and applied in many part of Asia, Africa even Ethiopia, but no single method appeared successful as each suffered with one or more limitation(Sharma ,1989).

In short summary applying this technology; that is converting this type of alien weed for bio-fuel like fuel briquette production will meet multiple goal, the first main it meet the demand of green or clean energy, the second one is reducing the impact of this alien weed types by utilization ,. Thus, all mentioned goal are critical to meet the MDG at global,local or regional level and sustained access to clean and cheap energy sourceand food security by increasing the availability of lantana camara free farm land for increase livestock grazing and increasing agricultural productivity. Beside this allbio-fuel, have the following major advantages:

(a)They are easily available from common Biomass sources;(b) they are better represented in the CO_2 cycle on combustion; (c) they are more economical than Conventional fuels, and (d) they are biodegradable and contribute to sustainability.Biomass has been recognized as a major world renewable energy source to supplement declining fossil fuel resources. Biomass appears to be an attractive feedstock for three main reasons. First, renewable resource could be sustainably develop in the future. Second, it appears to have formidably positive environmental properties resulting in no net release of carbon dioxide (CO_2) and very low sulfur content. Third, it appears to have significant economic potential provided that fossil fuel prices increase in the future (CadenasandCabezudo 1998).

Charcoal constitutes the primary urban fuel in Africa, and is a major source of income and environmental degradation in rural areas. With a lack of alternatives, demand for biomass in Africa is expected to double over the next ten years. Methods, material and resource (input) used in charcoal production in Africa are in urgent need of upgrading and substitution with other waste biomass like weed.

During the traditional process of carbonization, only around 40 % of the wood carbon is fixed in charcoal, while the rest is released into the atmosphere as smoke and non-condensable gases (CO_2, CO, CH_4, etc.). Because most of the energy of the fuel wood is lost in the production, process, charcoal users ultimately use much more fuel wood than direct fuel wood users. Traditional biomass usage especially traditional wood charcoal and petroleum by product kerosene has been the primary fuel for cooking in Ethiopia for a long time because of it is cheap and easily available nature. However, using traditional wood charcoal has consequences on health and pollution because of its smoke and it resulted deforestation up on removing indigenous tree species and resulting soil erosion and that of the kerosene is expensive, have foreign currency and cancer-causing gas emission.This is therefore can be also improved with the application of clean energy source like briquette.

The application of lantana camara weed for briquette production as clean energy source at a household level means adding a new biomasssource that reduce the deforestation of indigenous tree. In addition to thisit will save time for women and children, who were mostly engaged in many house hold activity like cooking food by burning traditional biomass,time that were spent for collection of fire wood.

In this study upon controlling, the propagation of *Lantana camaraL*species weed incrop productive agricultural land andit is possible to protect the invaded area from substantial loss of fertility and agricultural product. This inturn associate with the food security of one county like Ethiopia and it’s possible to utilize invasive alien weed like lantana camara into valuable by–products like briquettefor a clean biomass energy source conversion. The remaining after briquette production the ash even can beused as a soil fertilizer to adjust soil pH, soil conditioner or land filled. The other excepted potential of this alien weed species is utilizing it as multipurpose essential oil and bio ethanol source.

1.3 Objectives of the study

1.3.1 General objective

The general objective of this research is to examine briquettepotential of *Lantana camara*L.species andits implicationsfor weed management and recovery of renewable energy source in Ethiopia.

1.3.2 Specific objectives

1. To produce fuelbriquette from root, stem, branchand leaves part of*Lantana camara*L.weed species,
2. To evaluate its fuel qualitythrough proximate analysis andcombustion test;
3. To determine the bulk density and calorific value of the briquette produced from *Lantana camara*L.weed species;
4. To compare fuel briquette made from *Lantana camara*L. biomass with other similar source ofenergy and charcoal quality standard;

2 REVIEW OF RELATED LITRATURE

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	*Lantana camara*
Common names	Sleeper weed,lantana,wild stage
Domain	Eukaryota
Kingdom	Viridiplantae
Phylum	Spermatophyta
Subphylum	Angiospermae
Division	Magnoliophyta
Class	Magnoliopsida
Order	Lamiales
Family	Verbenaceae

Although *Lantana camara* is the most common scientific name of the species, it has different alternative names in use in different countries. Other scientific names include *Lantana aculeata*and*Lantana scabridaait*. *Lantana camara L*. have the following physical feature erect herbs or shrubs, stems sometimes armed with pickles. Leaves are opposite or in spirals of, usually with strong spicy smell when crushed. Inflorescence auxiliary of single flowersor dense cylindrical or capitates spikes flowers bisexual, sessile in the dry axis of bracts (Hedberg*et al.,* 2006).

Flower heads contain 20 - 40 flowers, usually 2.5 cm across; the color varies from white, cream or yellow to orange pink, purple and red. Flowering occurs between August and March, or all year round if adequate moisture and light are available.

2.2 Ecological and socio-economic importance of *Lantana camara* L. weed species

2.2.1 Ecological importance of *Lantana camara* L. weed species

Since the 19th century, *Lantanacamara* L.has been one of the main tropical and subtropical garden ornamentals. Under temperate climes it has been, and still is, widely used as a glasshouse ornamental and a pot plant. Apart from its ornamental value, *Lantana camara* L.has few redeeming features. In some mountainous areas (e.g. in Tanzania and India), the presence of *Lantana camara*L.was once considered a good ground cover preventing erosion. In parts of east Africa, in locations where it is not weedy, it has effectively been use as a live fence (Howes, 1946).

Lantana camara is native to central and South America nevertheless its original distribution is indistinguishable due to the introduction of a number of ornamental varieties (Cruz *et al.,*1986). The species hasbeenpoorly investigated in its native range, where it is not usually considered a serious pest, and the extent of its original native range is unclear. In the West Indies, it is found in dry thickets (Adams 1976*)*. The weed noted to be present in the Galapagos Islands of Ecuador (Cruz*et al.*, 1986).

Moreover, accidental introduction via contaminated soil is possible but not been documented and as *Lantana camara L.*is such a key ornamental plant, new varieties, some of which have invasive potential, can readily be bought and introduced throughout the tropics. The transport pathways for long distance movement this species enhanced by soil, gravel, water, etc (Broughton, 1999).

Its distribution affected by soil type. It has a low tolerance for boggy and saline soils but grows well on poor soils. *Lantana camara* L. has a marked ability to compensate for herbivore as plants survived experimental defoliation for two years (Broughton, 2000*)*.

However, in parts of Ethiopia where the idea of establishing a live lantana fence to protect crops from domestic animals have taken up by local villagers in the 1990s, this quickly led to the loss of rough grazing land through the rapid spread of lantana

(Binggeli P. and DesalegnDesissa, 2002). A number of minor uses of *Lantana camara* L. include using the seeds as a source of food for lambs, using lantana straw mixed with dung for biogas production, and using the twigs as fuel.

The plant is still widening its range. Fruit dispersal is through frugivorous birds, fox, number of bird species, rodents, also sheep and goats disperse the seeds, sometimes over long distances(Broughton,1999).

Germination rate of fresh seed is generally low, but the germinabilityis improved, when the seed passes through the digestive system of birds and animals. High light intensity and soil temperature will stimulate germination of seeds which means that clearing of forest areas, inappropriate burning and other disturbances will help spread of the weed. Seeds are capable of surviving the hottest fires.

The diverse and broad geographic distribution of this species is a reflection of its wide ecological tolerance. It occurs in diverse habitants and on variety of soil types.*Lantana camara* L. generally grows best in open, un-shaded conditions such as wastelands, the edges of rain forests, on beachfronts, in agricultural areas, grasslands, scrub/shrub lands, urban areas, wetlands and forests recovering from fire or logging. Roadsides, railway tracks and canal banks arefavored by the species. It does not grow at ambient temperatures below 5^{o}C. The plant is found at altitudes from sea level to 2,000 m and can thrive very well under rainfall ranging from 750 to 5000 mm per annum. *Lantana camara* L.does not invade intact rain forests, but found on their margins (Neely M. C., *et al.*,2001).

In parts of East Africa, in locations where it is not weedy, it has been effectively been used as a live fence (Howes, 1946*).* However, in many parts of Ethiopia where the idea of establishing a like lantana fence to protect crops from domestic animals was taken up by local villagers in the 1990s, this quickly led to the loss of rough grazing land through the rapid spread of lantana (Binggeli P. and DesalegnDesissa, 2002).

In 1999s theses invasive weed was widely spread in Eastern Ethiopia, close to Addis Ababa like Adama and Dukam, and reported to be spreading onto western Ethiopia. The

Awash National park and the Yangud _ Rase National park (Afar region) are currently at risk, due to the spread of this weed (EARO 2002).

In Tanzania and Uganda, *Lantana camara L.* can be consideredas a serious health hazard, as its thickets provide breeding grounds for tsetse flies, vectors of trypanosomiasis(Leak, 1999).*Lantana camara* thickets are potential breeding places for rats, wild pigs, insect pests and plant diseases. When ingested by cattle and sheep it may cause photosensitive reactions, diarrhea, jaundice, hepatitis and poisoning. Children have been known to die after eating unripe berries and stems have been used as for toothbrushes (Morton JF, 1994; Swarbrick *et al.,*1995).There is some evidence, although conflicting in nature that extracts from lantana may have value as biocides(Ahmed and Agnihotri , 1977). In addition, essential oils from the flowers and leaves may have some value to the perfume industry and as beneficial drugs (Ahmad *et al.,*1962).

In parts of itsnative range, *Lantana camara L.*used as a source of medicinal cures, for example, in Ecuador the leaves areingested to treat stomach disorders (Ellison and Evans, 1996).It is viewed in many regions as an important honey plant (FichtlR.andAdmasuAdi, 1994). Leavesextracts have strong insecticidal and antimicrobial activity, for example, storing potatoes with lantana leaves almost eliminate damage by the potato tuber moth *Phthorimaeaoperculella*(Lal, 1987).

2.2.2 Socio –economic impact of *Lantana camara*

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 *Lantana camara*species includes the prickly variety in particular; hinder human's access to invaded habitats. In Central America *Lantana camara* speciesis common in pastures, waste areas and roadsides; it is also a weed in a number of crops (Schemske , 1983), although infestations are unlikely to be composed of native biotypes, but rather re-introduced cultivars that have become invasive (Stirton, 1977).

In many countries,*Lantana camara L.* species influence on agricultural land reduces the carrying capacity of pastures and is a weed in many agricultural crops. In Australia, *Lantana camara* L. has invested about 4 million ha of pasture (Parsons and Cuthbertson, 1992). In the early 1980s this resulted in economic losses of a $7.7 m Swarbrick*et al.*,(1995); Holm*et al.*,(1977) reported that in some areas of India the invasion of cultivated lands by this weed led to the shifting of several villages. In forestry, it tends to over-run young plantations, prevent access to older ones and increase fire hazards. In Indian sandalwood forests, the shrub competes with sandalwood trees and favors the spread of the sandal spike disease.

In contrast to the widely held view that *Lantana camara* L.is detrimental,farmers have considered the plant as highly beneficial as it has enhanced soil fertility and soil conditioning. This resulted in a reduction in fallow periods under *Lantana camara* L.from 15 to 5 or 6 years. Another benefit was the supply of firewood (Mc Williams2000).

The fruit is a greenish blue-black color, 5-7 mm in diameter, drupaceous, shining, with two nutlets; seed setting takes place between Septembers to May with 1 - 20 seeds on each flower head. Mature plants produce up to 12,000 seeds annually. Seed germination occurs when sufficient moisture is present; germination is reduced by low light conditions. The root system is very strong with a main taproot and a mat of many shallow side roots (APFISN, 2004).

The idea that *Lantana camara L.* enhances soil fertility has yet to be demonstrated and has postulated that the Pitcairners' selection of sites with thriving *Lantana camara* L.stands for home gardens reflects the species preference for fertile sites rather than its ability to increase fertility (Binggeli,2001).

In natural and semi-natural vegetation *Lantana camaraL.* is a major conservation problem. It may overwhelm vegetation and increase fire intensity (due to an increase in dry biomass), thus displacing native scrub communities. Its extensive seed production favors rat populations. There are many unsubstantiated statements suggesting that *Lantana camara L* slows erosion, but it is likely that this may be the case when the plant become established on bare ground but not when it displaces native vegetation. It can grow through the pestiferous grass *Imperatacylindrica* and suppress it and thus has some potential in forest restoration (Morton JF, 1994*).*

The impact on native vegetation were mainly viewed as negative, i.e. reducing species diversity, threatening endemics (Cruz *et al.,* 1986) and leading species to extinction. In Australia, *Lantana camara* L.causes allelopathic suppression of indigenous tree species. It generally considered hindering the regeneration of native tree species but there are some occasional references to regeneration of some tree species under its canopy.

The spread of *Lantana camara* L. on the Galapagos Islands is seen as a threat to bird breeding populations (Cruz*et al.,*1986).The impact of *Lantana camara* L.on biodiversity is mostly negative but a few instances of a positive impact have been reported. That it often provides habitat for some birds and thus provides refuge for wildlife (Mullen *et al.,*1993).As it is such a variable species, including variability in stature, specific varieties or forms can be expected to have different impacts on native biodiversity, as well as cropping systems and other human activities; however, no information is available regarding these potential differences.

To sum up the negative impact can be seen on: biodiversity; environment; livestock production; forestry production; human health; native fauna; native flora; transport / travel; tourism.

2.3 Energy potential of *Lantana camara* L.weed species

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 Productionand 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) inresidues, 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	7,900
Eucalyptus	Any carbonisation technology can be used	Available in abundance in many countries Matures in 4-5 years	Relatively inexpensive	6,100
Prosopis juliflora	Any carbonisation technology can be used	In African countries, such as Ethiopia, Kenya and Sudan, it is an invasive exotic tree	Inexpensive	7,150
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	6,920
Cotton stalk (briquette)	Metal kiln or retort	Can be freely collected since it is generally burned on-site	Freely collected	5,300
Coffee husk (briquette)	Improved pit kiln or retort	Can be freely collected since it is generally dumped in rivers.	Freely collected	5,100
Sawdust	Improved pit kiln or retort	Can be freely collected since it is generally burned on-site.	Freely collected	4,980

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 carbonised 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 *Lantana* weed (*Lantana camara*) 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 manufactured 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.

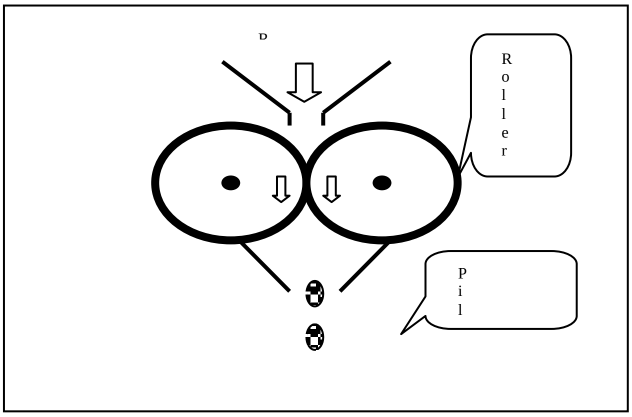

Figure 1: Roll briquette machine

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 continuouslyfeed 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).

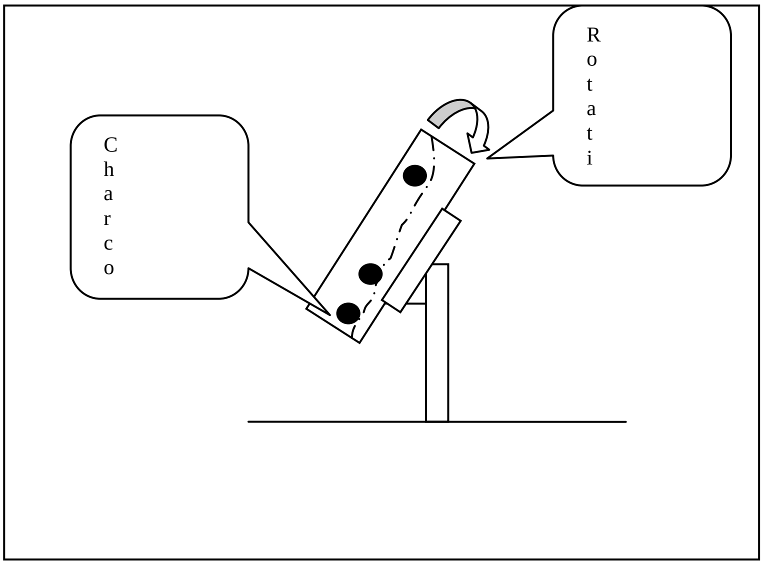

Figure 2: Agglomeration briquettes machines

2.3.4 Charcoal Briquettes

Production of high quality charcoal briquettes demands that a suitable binder is used and sufficient pressure wereimparted 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 raw material itself and hence briquettes made using mechanized units produce briquettes with higher bulk density (FAO, 1987).

2.3.5 The efficiency of the charcoal productionprocess.

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 charcoalers
- 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%.

3 MATERIALS AND METHODS

3.1 Description of the study area

3.1.1 Geographic location of the study area

The studysite is called Adele MechoKebele. It is one of 18ruralKebelesof LibenChukaladistrict, which is one of the 10 districts in East Showa administrative zone, Oromia regional state, Ethiopia. Adulala is the administrative center of the districtthat is 80 km far away from south east of Addis Ababa and 78 km from capital city of the zone, Adama.

The study site is found south of Adulala town and is located at latitudes 8^{o}45'36" – 8^{o}54'07" N and longitudes 38^{o}87'49"– 38^{o}95'47" E (Figure.3). It is found in altitude ranges from 1656m to 1932m(Figure.3).This value was extracted from Digital Elevation Model (DEM) of Shuttle Radar Topography Mission (SRTM) 30 m spatial resolution (http://edcsns17.cr.usgs. gov/Earth Explorer/)viewed on date February 1st, 2015.

The study site covers an area of 3802 ha; while the sample data was collected from nearly one hectare. Rainfall varies between 450-1600 mm. However, the general pattern shows the highest precipitation during the rainy seasons from July to August and there is low precipitation from February to March. Forty percent of the total area of the districtis lowland while 52% is classified as mid altitude and the remaining 8% is classified under highland (GirmaGemedi,2013*)*.

3.2 Sampling

3.2.1 Collection of *Lantana camara* Biomass and Sampling

In this study the biomasses *Lantana camara* L. were collected as a sources for briquette production and bio oil production during January 25 to 25, February, 2015 from Adele MechoKebele, LibenChukala district, in East Showa administrative zone, Oromia regional state, Ethiopia.

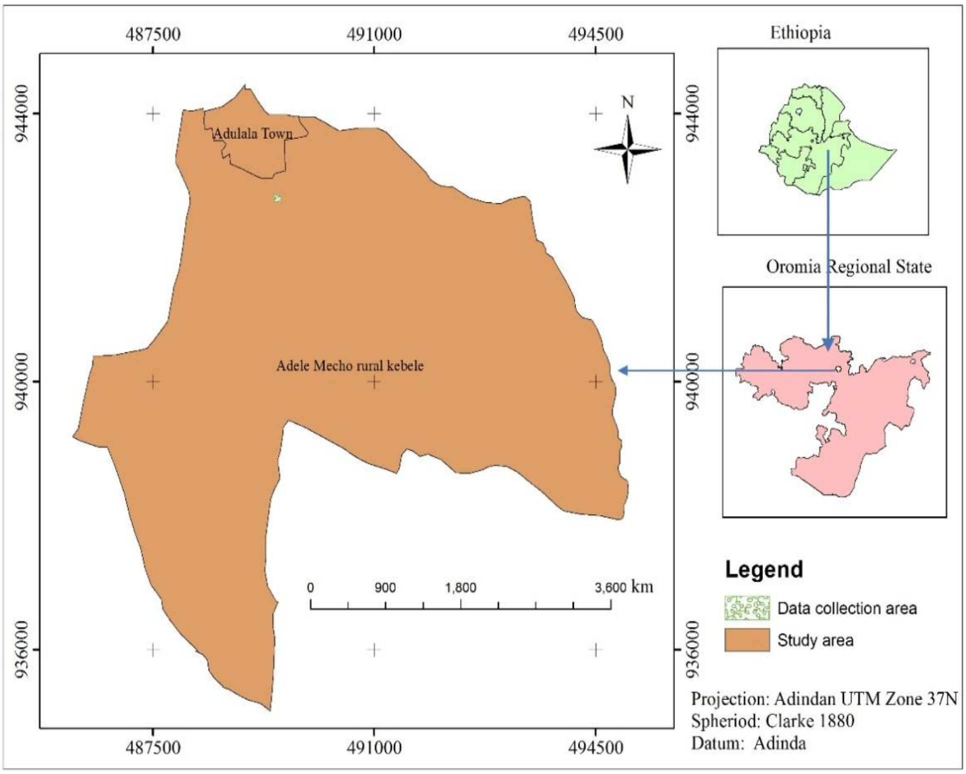

Figure 3: Map of the study area, by SintayehuAbebe, 2015

The samples of *Lantana camara*L.were taken from its root, steam, branch and leave with trunk and flower part.The collected samples were chopped to dimension that fit the carbonization metal kiln. Then it was taken to the Ministry of water, irrigation and energy at Alternative energy development and promotion laboratory and workshop center around GurdSholla; Addis Ababa) for carbonization, to determine proximate analysis, bulk density and calorific value of the briquette.

Samples were taken for bio oil extraction from its branch and leave and flower and taken to the laboratory of Addis Ababa University school of chemical and bioengineering and Centre for Environmental Science laboratory respectively.

3.2.2 Sampling quality control

Samples were collected from site, with appropriate safety using like glove then sorted with its type such as root, stem, branch, leave and flower then chopped with proper size to fit the kiln for carbonization processes and dried for a month.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).

3.2.3 Sample Analysis

The study conducted at the Addis Ababa University College of Natural Science in the Centre for Environmental Science laboratory. Soxhlet extraction part at school of chemical and bioengineering laboratory and briquette part of the study were conducted in Alternative energy development and promotion laboratory at MOWIE Energy laboratory and workshop center. The bio oil percentage and characterization were done at Addis Ababa University, Institute of Technology, School of Chemical and Bio Engineering Laboratory, Addis Ababa, Ethiopia.

In this study*Lantana camara*fuel briquette was evaluated for its fuel briquette quality by fuel quality determining parameterexpressed in terms of proximate analysis and physical properties.

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.

The overall production process starts with harvesting of the biomass: *Lantana camara*L.weed, whichwere used as raw material and sun drying for more than one month after chopping to obtain homogeneous size for carbonizationthenroot, steam, branch, leave with trunkof *Lantana camara* L. were placed in barrel kiln.

In this study, the process of carbonization was carried out in oxygen limited conditionin barrel kilnwhich have long chimney; which used to control the proper air for carbonization process. Then closed with screw when dehydration completed just when cloudy smoke become closely to blue or black so as limited oxygen environment iscreatedand the chimney also covered by clay mud forcharcoal production andcooling in controlled manner. The result charcoal were ground to fine particles by using charcoal grinder or charcoal mill to produce charcoal powder.

Finally, this mixture was fed into the beehive briquette machine press mold that press out 2000 briquettes per hour with the right amount of output each fuel briquette closely weigh 400-600g required dimensions with axial holes up on proper amount of feed to the behave machine.

3.3.2 Flow chart for briquette charcoal production from*Lantana camara* L.weed species

Major process includes collection of*Lantana camara L.*and transportation to production site where it wouldbe converted to charcoal and in this study, charring or carbonization was conducted using a small portable barrel metalkiln.

Then *Lantana camara* L. 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 agglomerator suitable for small scale mechanized charcoal production schemes. Typical process flow chart for production of char briquettes using beehive coal briquette machine press mold 2000briquettes per hour shown in Figure1.

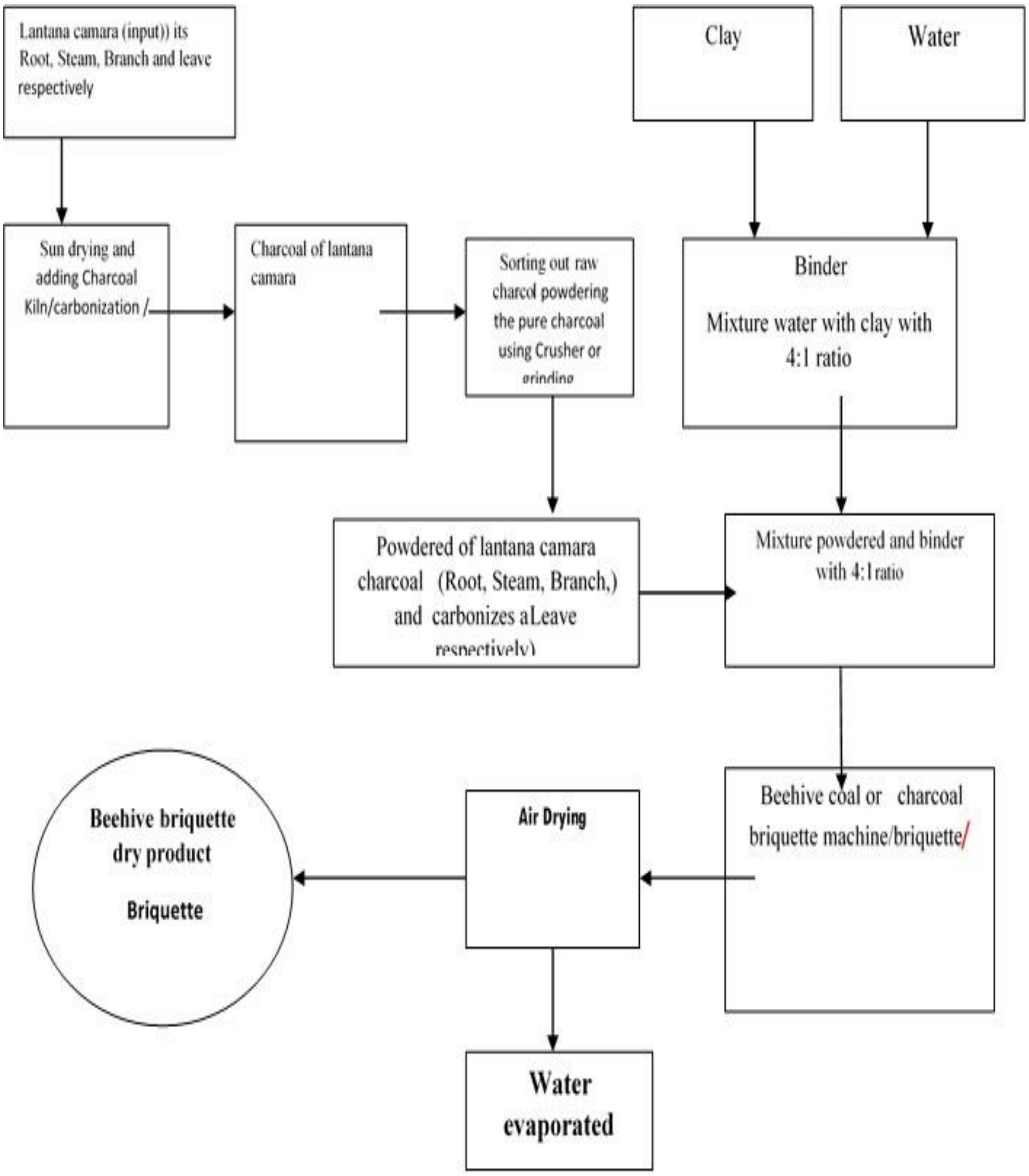

Figure 4: Production process flow chart of briquettes charcoal using Beehive coal Briquette machine

3.4 Characterization of the produced fuel briquette

To determine calorific value, Bomb Calorimeter at Alternative Energy Development and Promotion Directorate Laboratory, MOWIE,the briquette specimens analyzed by an adiabatic oxygen bomb Calorimeter Parr 6200 calorimeter of Parr M39889 and Parr M39805 oxygen bomb, which were used following the Parr instruction manual according to(ASTM D-5865-95, 1996). The briquette specimens milled with 0.7-1 gram and then placed in a capsule and combusted in andanalyzed by an adiabatic oxygen bomb Calorimeter Parr 6200-calorie meter and the resulting calorific value measured.
The bulk density was determined by placing the charcoal powdered in metal cub with size x =y=z 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 by using the(Anonequation ,1987).

3.5 The proximate analysis briquette charcoal produced from root, stem, branch and leaves of *Lantana camara* L.

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, Ethiopia Addis Ababa and all proximateanalysis were carried out accordance with (ASTM D-1762-84 ,1996) protocol and theses proximate term can be defined as follow:

3.5.1 Moisture content

The moisture content determined by heating a sample of powdered*Lantana camara* L.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. The same specimenused for volatile matter content and ash content determination 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).

The moisture content of sun dry leaves *Lantana camara L.* Was determined with same procedure for better carbonization but six gram were taken and the same equation 3.1 were used.

$$\mathrm{MC} = \frac{\mathrm{Weight}_{\mathrm{sample\ before\ moisture\ removal}} - \mathrm{weight}_{\mathrm{sample\ after\ moisture\ removal}})\times 100}{3\mathrm{gram}} ..Eq.3.1$$

3.5.2 Volatile matter content

The volatile matter content of powdered Lantana*camara L.*briquette charcoal weredetermined by heating oven dried sample for moisture content at 950^0C by preheating the specimen in the muffle furnace for two minute at 300 ^{0}C then heating for three minute at 500 ^{0}C,Finally for six minute at 950 ^{0}C 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.

$$\frac{\mathrm{Vm} = \mathrm{Weight}(_{\mathrm{sample\ after\ moisture\ removal}} - \mathrm{Weight}(_{\mathrm{sample\ after\ VM\ removal}})\times 100}{3\mathrm{gram}} ..Eq.3.2$$

3.5.3 Ash content

The ash content of a sample of powdered*Lantana camara* L.charcoal and briquette charcoal were determined from volatile matter content of the same sample and weighing it and the result obtained as the residue 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.

$$\%AC \quad = \frac{\text{Weight}_{\text{sample before moisture removal}} - \text{Weight}_{\text{sample after ashing}})\times 100}{\text{3gram}} ..Eq.3.3$$

3.5.4 Fixed (pure) carbon content

The fixed carbon content in sample of powdered *Lantana camara L.* charcoal and briquette charcoal were calculated as the difference between 100% andthe 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).

$$\%\text{FCC} = 100\% - (\text{Mc}\% + \text{Vm}\% + \text{Ac}).........Eq.3.4a$$

OR

$$\text{Fcc} = \text{Total sample (3 gram)} - (\text{Mc} + \text{Vm} + \text{Ac}) ...Eq.3.4b$$

Where

%Mc = Percentage Moisture content

% Vm = Percentage Volatile matter content

%Ac = Percentage Ash content

%FCC= Percentage of Fixed carbon content

3.6 The physical property of briquette charcoal produced from root, stem, branch and leaves of *Lantana camara*

3.6.1 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 timeswith pellet of calorie graded benzoic acid with weight not less than 0.9gram and not more than 1.25 gram ormostlygraded one gram benzoic acid were used.

Gross heat valueof a sample and all result were calculated by the Central Power Unit of the calorie meter and the final result were obtained as printed out.

The physical property of the produced *Lantana camara* L. fuel briquette like bulk density, calorific value and weight(g)immediate after removal frombriquette 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 fuelbriquette or time taken to turn ash and time taken to boil for 0.5L;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:

3.6.1.1 Bulk density

The bulk density of charcoal or fuel briquette charcoal were determined by many ways The first one by filling charcoal orbriquette powder into a cube-shaped container with each size 50 cm and measuring the weight of charcoal contained in the container. Then itwas computed as the weight of charcoal divided by the volume of the container. The second one, which is applied in this studythe 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.

$$Bulk\ density \quad = \frac{Mass\ of\ charcoal\ or\ produced\ briqutee\ \text{powder}}{Volume\ of\ \ container\ \ used} \ldots Eq\ 3.5$$

3.6.2 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 *Lantana camara L.*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*Lantana camara* L.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 root, stem and branch part *Lantana camara*. Charcoal for checking its fuel potential in replacing other charcoal produced from different input like *Eucalyptus*, *Acacia*, Bamboo and other indigenous tree.

3.7 Combustion and heat efficiency testof Lantana camara Fuel Briquette charcoal

Combustion test wereconducted 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 *Lantana camara* L.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).

3.8 Data analysis

Data weregathered from laboratory analysis of briquette and bio oil produced from *Lantana camara*. These resultswererecorded, processed and analyzed using Microsoft excels. Descriptive statistics and chart graph wereused to compare means and standard deviation (SD) of the result of analysis. All the analysis assays were done in triplicate (n=3).

4 RESULTS AND DISCUSSION

4.1 Theproximate analysis offuel briquette produced from *Lantana camara*

The quality determining parameter of briquette and charcoal produced from biomasses expressed in terms of proximateanalysis and physical properties. Since, these parameters 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 2below the moisture content of all briquettes produced from stem of *Lantana camara* L. were lower than the moisture content of briquette produced from wood which has moisture content of 12% (Malatji*et al.*,2011).

Table 2: Proximate analysis of briquette produced from *Lantana camaraL* .

Treatment	Proximate analysis (%) Mean ± SD			
	MC	VM	AC	FCC
Root briquette	7.56±0.19	18 ± 0.33	20.56±1.96	53.89±1.84
Stem briquette	2.67±0.58	21.11±1.92	23.56±1.93	52.77±0.39
Branch briquette	4.67±0.34	21.89±0.19	23.22±3.15	50.22±3.21
Leaves briquette	5 ±0.33	21.44±1.17	36 ±1.53	37.56±0.69

Data were means ± SD.

MC,Moisture content;VM ,Volatile matter; AC ,Ash content ; FCC, Fixed carbon contents.

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 moreover 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, the fresh charcoal from an opened kiln contains a 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).

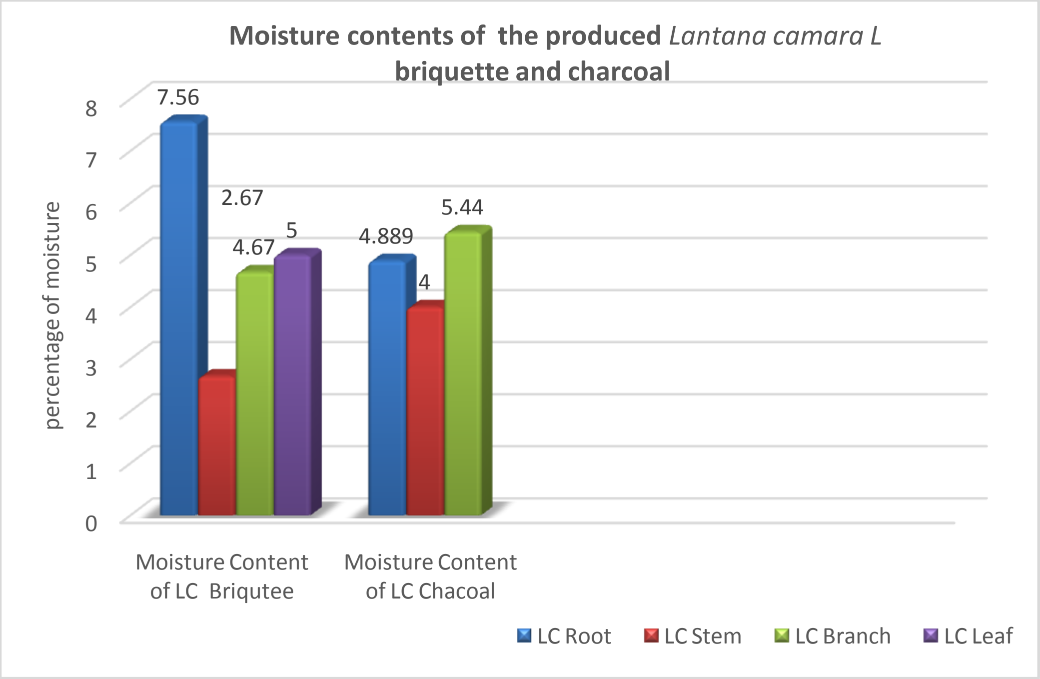

Figure 5Moisture contents of the produced Lantana camara L briquette and charcoal

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 contentis 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 studythe result from*Lantana camara L.* charcoal ((Table 8A in appendices) showed moisture contents of charcoal ranged 4% to 5.4 4 and its briquette moisture ranged 2.67% to 7.56%, which falls within the desirable criteria set by (FAO, 1987).

Moisture contents of the charcoal also differed significantly between charcoal or briquette produced from different biomass species and as shown in Figure 5. 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).

Table 3Proximate analysis and physical analysis of charcoal produced from roots, stems and branches *Lantana camara L.*

Treatment (Briquette type)	Proximate analysis (%)Mean ± SD				Physical property Mean ± SD	
	MC	VM	AC	FC	CV(Cal/gm)	BD(g/cm)
Root	4.89 ± 0.38	14.±0.67	15.8± 0.18	65.6± 1.53	7483.99± 140.432	0.58±0.05
Stem	4.00± 0.67	13.± 1.35	15.78±0.51	66.44±0.01	7323.10± 37.24	0.44± 0.01
Branch	5.44± 0.19	16.78± 0.0	12.89± 3.42	64.89±4.62	7222.66± 352.17	0.40± 0.01

Similarly, the volatile matter of all briquettes in this study(Table 2) 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 (Sotanndee*t 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.

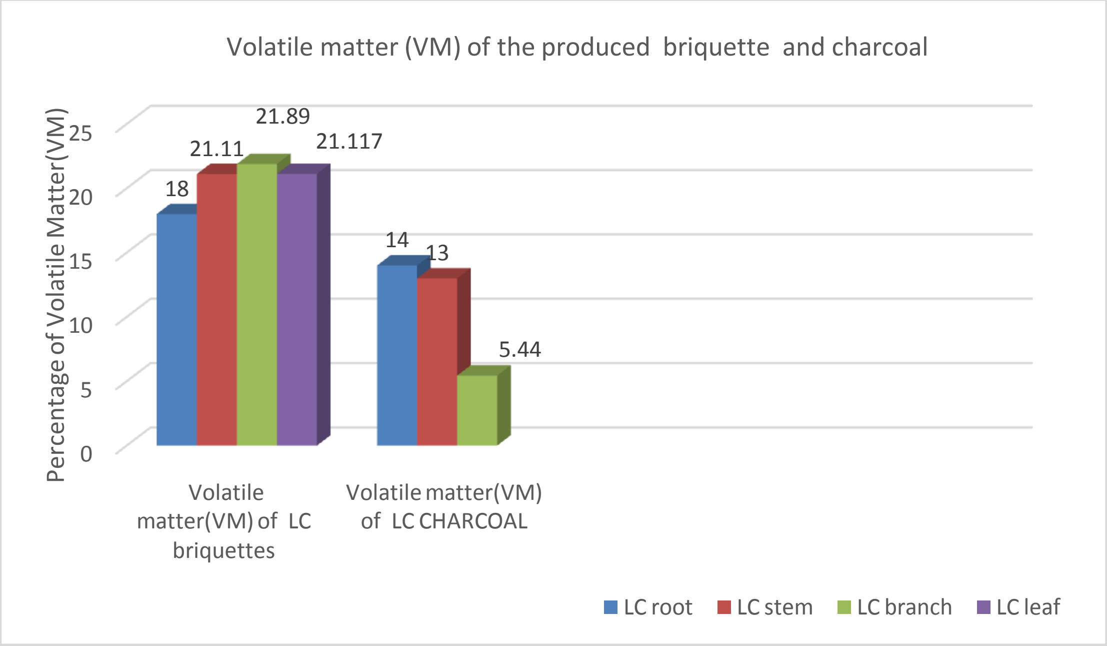

Figure 6: Volatile Matter contents of the produced LC briquette and charcoal

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 6 the charcoal produce from *Lantana camara* L.in this study the highest volatile matter with 14 % and with lowest value 5.44% and its briquetteranged 18% to 21.89 %, which fall within the desirable criteriaset by(FAO,1987). On the other hand, FAO, (1985) indicate that the value of volatile matter of the charcoal produced from mixed tropical hardwood ranged from 17.1% and 23.6 and this also in line with all volatile matter result for this study (Table 2) .

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.

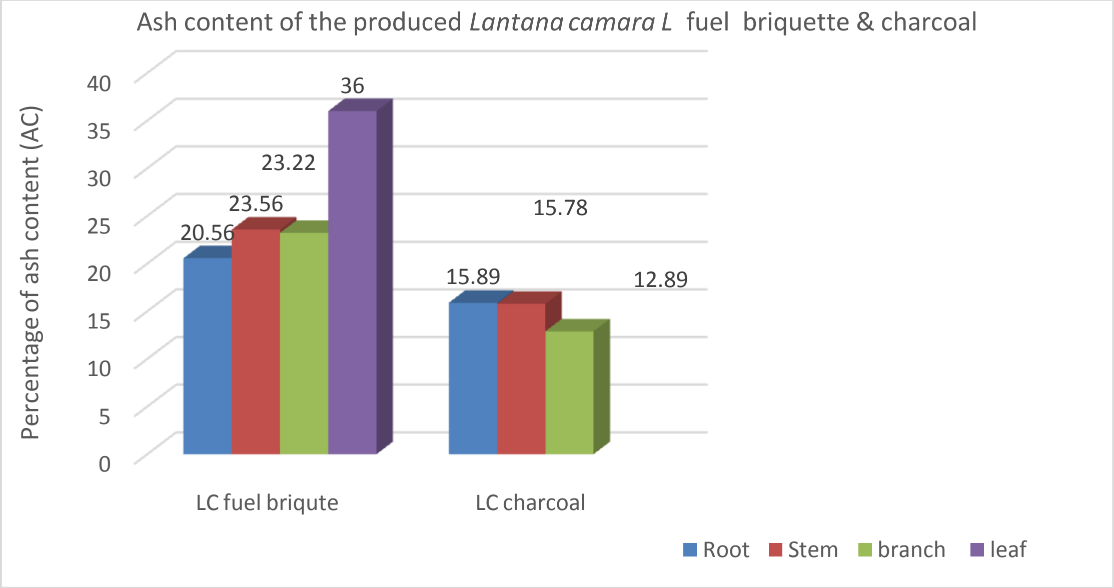

Figure 7: Ash contents of the produced *Lantana camara L*briquette and charcoal

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 and from the bargraphit's possible to observe leavesbriquette with higherAsh value meaning low quality fuel as compared to branch, stem and root briquette (Akowuah*et al.*, 2012).

Fixed carbon contents of the briquette is the solid combustible residue that remainsafter the briquetteswere 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).

Fixed carbon content of the charcoal and briquette produced in this study also differed significantly between charcoal and briquette produced from different part of latana camara wood part.. The high fixed carbon content gives the result of high calorific value (FAO, 1985). It seems true where the produced fuel briquette and charcoal had higher fixed carbon content of 53.89 and 65.6and had the higher gross calorific value of 6525.54 and 7,483.99 cal/g ,respectively.

The fixed carbon of charcoal ranges from a low of approximately 64.89% to a high of around 67% (FAO, 1985). Thus the charcoal contains mainly of carbon. FAO (1985) recommended that the charcoal produced from tropical hardwood had fixed carbon ranged 68.6% and 69.8% (Table 3).

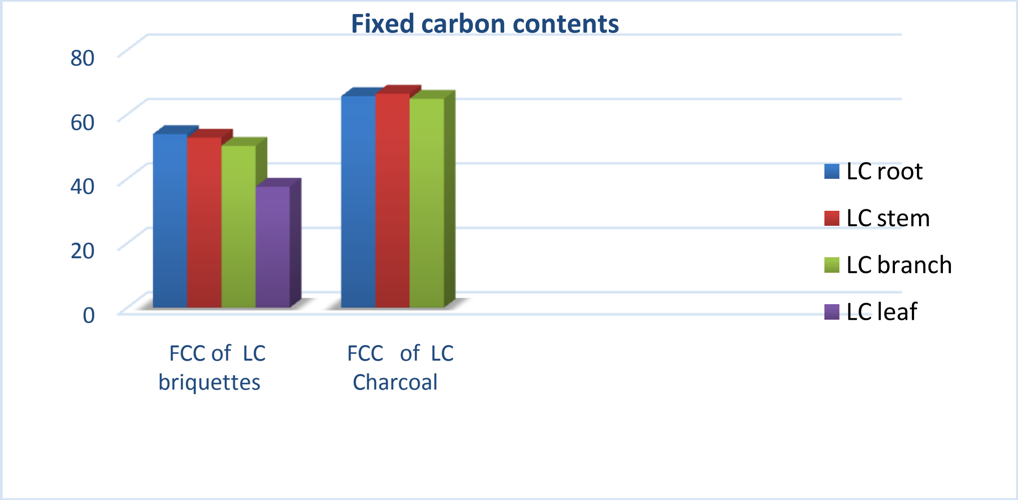

Figure 8: Fixed carbon content of the produce *Lantana camara L* briquettes and charcoal

4.2 Physical property of the produced fuel briquette from *Lantana camara*L. weed

Thecalorific 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 greater 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 8 and there is also similar trend increment with bulk density and calorific value (Table 3 and 4).

Table 4: Physical property ofbriquette produced from root, stem, branch and leaves

Treatment	Physical property Mean ± SD	
	CV (Cal/gm)	BD (g/cm3)
Root briquette	6525.54± 250.03	0.48 ± 0.01*
Stem briquette	6479.59±1004.51	0.44± 0.02*
Branch briquette.	5135.36 ± 150.29	0.43± 0.01*
Leave briquette	3690.68 ± 182.32	0.39± 0.01*

* BD calculation Volume measured by using 50ml measuring cylinder

Data were means ± SD.

CV, Calorific value content.

If compared to the charcoal produced in this study from lantana camara root, stem and branch had only 65.6%, 66.44% and 64.89%, respectively. The charcoal for domestic use is recommended that it should contain less than 80.5% of fixed carbon, while the industrial charcoal is recommended to have 86.7% of fixed carbon (FAO, 1985). On the other hand, the quality smokeless domestic wood charcoal has been specified to consist 75% of fixed carbon or more than this (Ugnay, 1983), while the industrial wood charcoal has been specified to contain not less than 85% of fixed carbon.

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

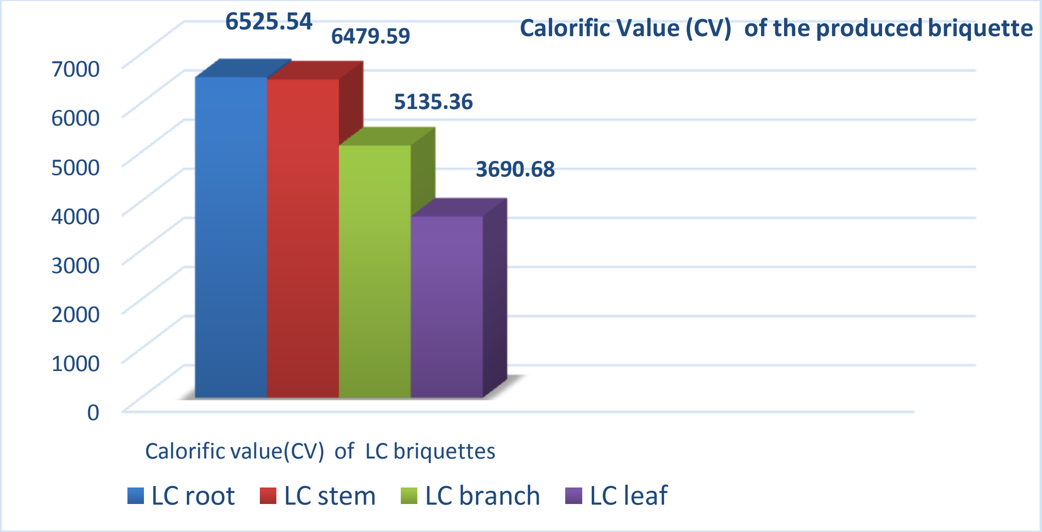

Figure 9: Calorific value (CV) of the produced LC briquette

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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 itshigh-energy content per unit volume and its slow burning property (Goel*et al.*,1996). This can be realized by comparing result in Table 4and the two bar charting Figure10 and 11 and also by comparing density result in Table 3 for the produced charcoal with in its fixed carbon content and calorific value.

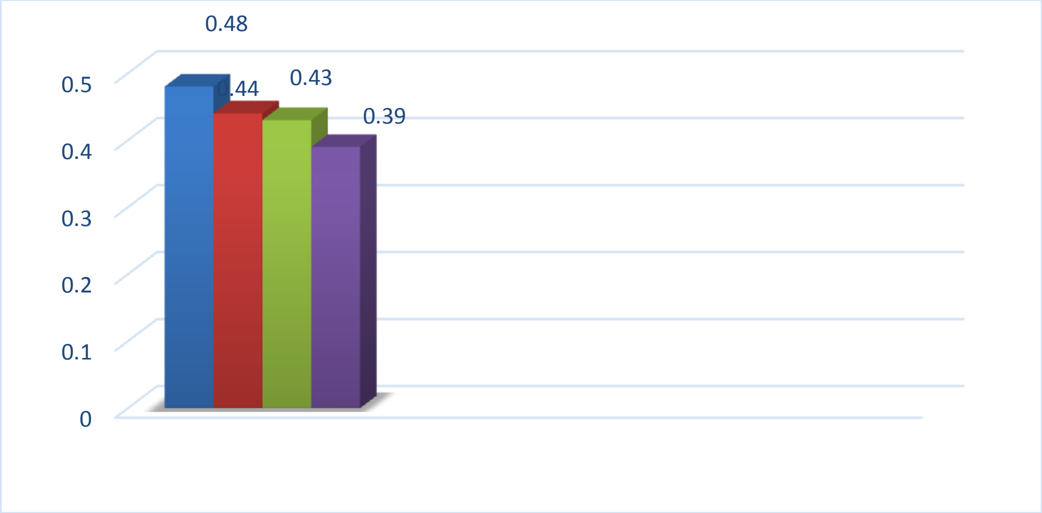

Figure 10: Bulk density of the produced L Lantana camara *LC* briquette

Thevalue for bulk density (g/cm^3) of *Lantana camara* L. biomass were found to range from 0.39± 0.01 to 0.48 ± 0.01,almost in line with the result for *Lantana camara* L.stem and branch which ranged from 0.497 to 0.520 g/cm^3 and all results were muchhigher than that of *Eupatorium*with bulk density 0.330 g/cm^3(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 *Lantana camara L.* weed, number of air hole in the kiln that regulate the amount of air for the proper carbonization and cooling and personal skill. Oneof this all factor , moisture of the sun dried sample, it's also showed with 1a and 1band have direct effect with the quality and quantity of fuel charcoal or fuel briquette production.

The percentage of moisture on sun dry leaves sample were found 9.33 % ±0.87(Table 1b)and with this value the carbonization efficiency of the metal kiln were found 25.72% ±2.9 (Table 4 in appendices) and this the percentage of moisture value result were within the range 15% -35% and this is in line with (Malatji*et al.*,2011).

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Table 5: Carbonization efficiency of metal kiln on weight based for *Lantana camara* L.weed input

Description	Input/weight Kg/ Mean ± SD	Carbonized output /weight kg/ Mean ± SD	Carbonization Efficiency (%) Mean ± SD
Root part	39.07± 1.11	10.39± 0.97	26.57± 2.19
Stem part	36.34± 2.63	11.34± 0.73	26.61± 1.38
Branch	28.03± 1.81	6.32± 0.83	21.61± 1.47
Leaves part	15.48± 1.15	3.94± 0.17	25.72±2.93

Data were means ± SD.

Weight-based carbonization efficiency (based on charcoal yield) is a percentage rate expressing the ratio between the weights of Lantana camara L. weed root, steam, branch or leave with trunk charcoal output to the weight of the air-dry *Lantana camara L.*weed Root, steam, branch or leave with trunk input. For instance, the typical yield of a brick or metal kiln (at 15 % moisture sample content) is about 30% (YisakSeboka, 2009) and the carbonization efficiency result were presented in Table 4

The percentage range of carbonization efficiency (based on charcoal yield) were with minimum value 21.61± 1.47 for the branch and maximum value 26.61± 1.38 for stem part of *Lantana camara* L and similar finding for carbonization efficiency of metal kiln to get high charcoal yield (YisakSeboka and NegusseMequanint ,2006); (FAO,1993). This also have impact on the quality and quantity charcoal or briquette produced from biomasses (Oladeji, 2010).

4.4 Standardization of calorie meter

Standardization of the calorie meter used in this study for Gross heat value determination of the produced *Lantana camara* L.charcoal and briquette charcoal were done by using one gram pellet of graded benzoic acid and its run for ten Standardization and the corrected temperature raise determined from the observed data, the equivalent energy value(EE value),sample ID, weight of sample or benzoic acid,initial and final temperatures, sulphur content of sample, spike weight and the gross heat value with the required unit MJ/Kg or Cal/g Were obtained as an output or printed out and shown with appendix 4;Table 2 for benzoic acid;8A and 8B for the produced *Lantana camara* L charcoal and briquette.

4.5 Combustion and heat efficiencytest of *Lantana camara* Lfuel 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 *Lantana camara* 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 half a liter water in less than 10 minute ; one liter water in less than 15 minute and two liter water with less than 25 minute, respectively.

As shown in the Table 6 the time taken to boil a given amount of water vary with the type of briquette made of 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 6: Comparative Time taken to boil Water; conducted using Lakech -stove

Description Briquette type	Average time taken to boil(0.5L) Water in Minutes)	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)
Root briquette	3±0.97	9± 1.5	15± 2.05	4hr and 23 Min ± 0.08	6525.54± 250.03
Stem briquette	4± 1.05	10 ± 2.75	17± 0.95	4hr and17 min ± 0.34	6479.59±1004.51
Branch briquette	6± 0.75	13± 2.08	20± 1.25	3hr and 31min± 0.16	5135.36 ± 150.29
Leaves with trunk briquette	7± 0.85	15± 1.75	23± 2	2.hrand 58min ± 0.37	3690.68 ± 182.0

Data were means ± SD.

This result shows that the heat strength (boiling capacity) vary with the type of briquette made off root ,stem ,branch or leaves and this also highly related with the bulk density; which is directly related with the calorific value of the briquette. Time taken to turn to ash shows the durability of the produced *Lantana camara* L fuel briquette that it can be used for cooking, which took toolong timecooking, especially in Ethiopian traditional food like 'Doro wot' that need almost more than 3hr such fuel briquette can be used.

Since once the briquette fired it is not possible to quit the fire for any moment since its used long period time cooking for about 3 to 4 hr. and these proper cooking time must be known to managing in proper energy consumption .

Therefore;durability fuel briquette is its one advantage than other form of fuel charcoal furthermore 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 *Lantana camara* L.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.

The mean average for triplicate test for water boiling capacity (heat efficiency) tests of *Lantana camara* L.fuel briquette for 0.5L;1L and 2L (Table 5)and shows the time taken to boil a given amount of water vary with the type of briquette made off and its highly related with the bulk density and calorific value of the briquette.

5 CONCLUSIONSAND RECOMMENDATIONS

5.1 CONCLUSIONS

This study showed that Charcoal and briquette produced from *Lantana camara* was found as quality sources of energy. Because, all charcoal and briquettes have higher caloric value7483.99±140.432 and 6525.54± 250.03, respectively, high fixed carbon content66.44±0.01 and 53.89±1.84, respectively, low volatile matter13.± 1.35 and 18±0.33,respectively, low moisture4.00± 0.67 and 2.67±0.58,respectivelyand low ash contents12.89± 3.42 and 20.56±1.96, respectively. Similarly, utilization of *Lantana camara* L 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 Charcoal and fuel briquette produced from Lantana *camara* were found a promising product can be obtained from *Lantana camara* L that can be generate income and job opportunity to the local community and micro enterprise.

Therefore, based on this finding using invasive weeds like *Lantana camara* L. for clean renewable energy enable possible weed management option as well asincrease farmer’s crop production by allowing *Lantana camara* L free lands.

5.2 RECOMMENDATIONS

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 *Lantana camara L.*

- Economic analysis and feasibility of the overall production of *Lantana camara* L.fuel briquetting, charcoal,the impact of *Lantana camara* L.weed in human being, crop production and livestock product in Ethiopia have to be evaluated for effective utilization.

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APPENDICES

5.3 Appendix 1: Ecological impact of *Lantana camara*

Figure 1aRoot structure of *Lantana camara L.*

Figure 1bDried LC hard-coated seed; Photo by SintayehuAbebe, 2015

Figure 1cExtreme land coverage of LC on cereal crop farmland near Adama city, Ethiopia; Photo by SintayehuAbebe 2015.

5.4 Appendix 2: Sample preparation for briquette production and bio oil extraction

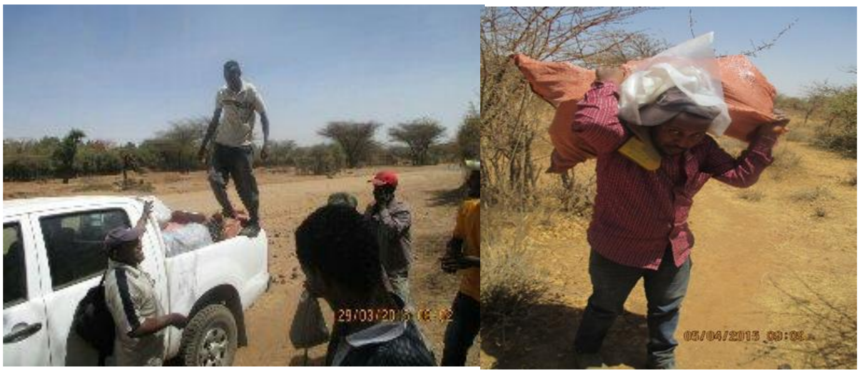

Figure 2a Sample collection from study site

Figure2b Separating and drying sample before chopping and carbonization

Figure 2c Sorting Cutting and splitting *Lantana camara L*. stem to uniform size to fit the metal kiln

Figure 2d Grindingthe Carbonized *Lantana camara L*. for briquette production

5.5 Appendix 3:Combustion and heat efficiency test for the produced briquette

Figure3a weighing the produced LC briquettes and its burning qualities, giving a blue flame. Photo by SintayehuAbebe, 2015

Figure3b Water boiling and cooking efficiency test on produced LC briquettes. Photo by SintayehuAbebe, 2015

5.6 Appendix 4: list of Table for raw dataform laboratory test results

Table 1a.

Moisture test data for ***Lantana camara* L.** sample for branch, steam, and root on sundry based using moisture test meter.

Lantana camara L.weedsample part	Random Sample	Treatment	Moisture measured(^{0}C)
Root part	Root 1	R_1	12
		R_2	19
		R_3	22
	Root 2	R_1	12
		R_2	11
		R_3	11
	Root 3	R_1	14
		R_2	16
		R_3	12
Mean ± SD			14.33+3.91
Steam part	Stem 1	R_1	17
		R_2	15
		R_3	18
	Stem 2	R_1	17
		R_2	19
		R_3	17
	Stem 3	R_1	19
		R_2	20
		R_3	17
Mean ± SD			17.67±1.50
Branch part	Branch 1	R_1	9
		R_2	11
		R_3	9
	Branch 2	R_1	8
		R_2	9
		R_3	9
	Branch 3	R_1	8
		R_2	8
		R_3	9
Mean ± SD			8.89±0.93

NB Moisture measured by moisture meter at MOWIE; AEDPD Laboratory.

Table 1b.

Moisture test for*Lantana camara L.* sundryleaves in an oven dry at 105 0C for 24hr for carbonization efficiency.

Moisture test for sundry*Lantana camara*L.leaves sample on oven dry	Treatment	Mass of leaves before oven dry(gram)	Mass of leaves after oven dry (gram)	moisture in leaves sample (%)
	R_1	6	5.5	8.33
	R_2	6	5.41	9.83
	R_3	6	5.41	9. 83
	Mean ± SD		5.44 ± 0.05	9.33 ±0.87

Table 2.

Calorific valuedetermination and standardization of calorie meter Parr 6200 with one gram pellets

Description Reagent used	Replicate standard	Bomb ID used	Energy Equivalent of calorimeter(Cal /0C	Weight of sample taken(gm)	Temperature raise (0C) (Tfinal_-Tinitial)	Calorific Value (MJ/Kg)
	S1	M39889	2361.7004	0.9861	2.0628	6545.75
Benzoic acid	S2	M39889	2361.7004	1.000	2.0986	6545.75
	S3	M39889	2361.7004	0.9842	2.6441	6545.75
	S4	M39889	2361.7004	1.0044	2.6977	6318.87
	S5	M39889	2361.7004	1.043	2.6977	6318.87
	S6	M39889	2361.7004	0.9865	2..1176	6318.87
	S7	M39889	2361.7004	0.9860	2.0417	6318.87
	S8	M39889	2361.7004	0.9769	1.9945	6318.87
	S9	M39889	2361.7004	0.9789	2.0091	6318.87
	S10	M39889	2361.7004	1.032	1.9756	6318.87
Mean ± SD				1.00±0.02	2.01± 0.02	6386.93
Benzoic	S1	M39989	2307.6194	1.0132	4.6193	6448.58
	S2	M39889	2307.6194	0.9861	2.6572	6448.58
	S3	M39905	2307.6194	0.9967	2.0457	6318.8647
	S4	M39905	2307.6194	0.9956	2.1660	6318.8647
	S5	M39905	2307.6194	1.9986	2.1852	6318.8647
	S6	M39905	2307.6194	1.002	2.3419	6318.8647
	S7	M39905	2307.6194	1.007	2.1883	6318.8647
	S8	M39905	2307.6194	1.006	2.1187	6318.8647
	S9	M39905	2307.6194	1.202	1.9667	6318.8647
	S10	M39905	2307.6194	0.9970	2.1886	6318.8647
Mean ± SD				1.12±0.32	2.206478±0.79	6344.81±54.69

Table 3.

Proximate analysis and physical test of**charcoal produced** from roots, stems and branches ***Lantana camara* L.**

Treatment (Briquette type)	Replication	Proximate analysis (%)				Physical property	
		MC	VM	AC	FC	CV(Cal/gm)	BD(g/cm)
Root	R1	4.67	13.33	15.00	67.00	7322.97	0.54
	R2	5.33	14.00	14.67	66.00	7547.90	0.64
	R3	4.67	14.67	18.00	64.00	7581.10	0.58
	Mean ± SD	4.89 ± 0.38	14.±0.67	15.8± 0.18	65.6± 1.53	7483.99± 140.432	0.58±0.05
Stem	R1	3.33	12.33	16.33	68 00	7307.91	0.44
	R2	4.00	15.00	15.33	65.68	7365.53	0.45
	R3	4.67	14.00	15.67	65.67	7295.85	0.43
	Mean ± SD	4.00 ± 0.67	13.± 1.35	15.78±0.51	66.44±0.01	7323.10± 37.24	0.44± 0.01
Branch	R1	5.33	14.33	16.67	63.67	7361.72	0.39
	R2	5.33	12.67	12.00	70.00	6822.19	0.40
	R3	5.67	23.33	10.00	61.00	7484.07	0.41
	Mean ± SD	5.44 ± 0.19	16.78± 0.0	12.89± 3.42	64.89±4.62	7222.66± 352.17	0.40± 0.01

Table 4

Carbonization efficiency of kiln on weight based for ***Lantana camara* L**.weed input

Description On LCPlant Part	Treatment	Sun Dry Fresh/raw/ input /weight Kg/	Carbonized charcoal output /weight kg/	kiln (charcoal yield)carbonization efficiency (%)
Root part	R1	39.360	11.425	29.07
	R2	40	10.25	25.63
	R3	37.85	9.50	25.01
	Mean ± SD	39.07± 1.11	10.39± 0.97	26.57± 2.19
Stem part	R1	36.82	10.38	28.19
	R2	33.50	8.60	25.67
	R3	38.70	10.05	25.97
	Mean ± SD	36.34± 2.63	11.34± 0.73	26.61± 1.38
Branch	R1	30.00	7.00	23
	R2	27.65	5.55	20.07
	R3	26.45	5.80	21.76
	Mean ± SD	28.03± 1.81	6.32± 0.83	21.61± 1.47
Leaves with trunk, flower and seed	R1	15.195	4.025	26.83
	R2	14.50	4.05	27.93
	R3	16.75	3.75	22.39
	Mean ± SD	15.48± 1.15	3.94± 0.17	25.72±2.93

NB: Carbonized charcoal output divided by sundry sample input to kiln times hundred or the ratio of output divided by input times hundred

Table 5

Bulky Density for ***Lantana camara L*** Briquette charcoal

Treatment (Description Briquette charcoal type)	Replication	Density Calculation		
		Wt (g)	Volume (cm3)	BD (g/cm3)
Root	R1	23.39	50	0.468
	R2	24.13	50	0.483
	R3	24.64	50	0.493
	Mean ± SD	24.05±0.629		0.481 ±0.013
Stem	R1	23.01	50	0.462
	R2	21.04	50	0.421
	R3	22.12	50	0.443
	Mean ± SD	22.06±0.987		0.442± 0.021
Branch	R1	21.08	50	0.426
	R2	21.07	50	0.424
	R3	20.98	50	0.420
	Mean ± SD	21.04± 0.055		0.423± 0.003
Leaves with trunk, seed and flower	R1	19.40	50	0.388
	R2	20.07	50	0.404
	R3	18.96	50	0.379
	Mean ± SD	19.48± 0.559		0.390± 0.013

Volume measured by using 50cc measuring cylinder

Table 6

Showing comparative time taken to boil of water conductedusing Lakech -stove

Description *LC* Briquette *charcoal*	Average time taken to boil half litter(0.5 L Water in Minutes)	Average time taken to boil one litter (1L) Water in Minutes	Average time taken for to boil twolitters (2L) Water in Minutes.	Average time taken to turn to Ash(Hour& Minutes)	Average Calorific Value for triplicate test (Cal/gm)
Root Briquette	3± .97	9± 1.5	15± 2.05	4hr & 23Min ± 0.08	6525.54± 250.03
Stem Briquette	4± 1.05	10 ± 2.75	17± 0.95	4hr&17min±0.34	6479.59±1004.51
branch Briquette	6± 0.75	13± 2.08	20± 1.25	3hr3&1min±0.16	5135.36 ± 150.29
Leaves with trunk	7± 0.85	15± 1.75	23± 2	2.hr&58min±0.37	3690.68 ± 182.32

Table7

Effect of sun drying on weight of produced charcoal over Time

Description Briquette charcoal (Average weight of R1,R2, and R3 test)	Mass immediately after removal from Beehive machine (g)	Mass After 2 Days of Removal(g) on sun dry	Mass After 3 Days of Removal (g)on sun dry	Mass After 7 Days of Removal (g) on sun dry	Mass After 15 Days of Removal(g) on sun dry
Root Briquette	873.3	715	593.3	505	500
Stem Briquette	860	736.67	599.33	511	500
Branch Briquette	790.3	655	523.33	450	440
Leaveswith trunk,	858.33	750	626.67	435	430

NOTE: All result taken from average mean of triplicated sample weight.

Table 8

The raw data for Calorificvalue (Cal/gm) determination of the produced *Lantana camara* L. weed species charcoal and Briquettes; by using Adiabatic bomb calorie meter Parr 6200 Model with Bomb ID 39905 and M39805

Table 8A

Calorific value (Cal/gm) determination for the produced *Lantanacamara*L.charcoal

Description charcoal made off	Replicate	Bomb ID	Energy Equivalent of the calorimeter (EE value in Cal /^{0}C)	Weight of sample taken(gm)	Temperature raise (Tfinal_-Tinitial) (^{0}C)	Calorific Value (Cal/gm)
Lantana camara L. root parts	R1	M39905	2307.6194	0.6598	2.1157	7361.717
	R2	M39905	2307.6194	0.6707	2.1860	7484.066
	R3	M39905	2307.6194	0.6498	1.9319	6822.186
Mean average				0.6601	2.0777	7222.656

Description charcoal made off	Replicate	Bomb ID	EE value in Cal /0C)	Weight of sample (gm)	Temperature raise (Tfinal_-Tinitial) (^{0}C)	Calorific Value (Cal/gm)
Lantana camara L. STEM parts	R1	M39905	2307.6194	0.6335	2.021	7322.967
	R2	M39905	2307.6194	0.6546	2.1519	7547.897
	R3	M39905	2307.6194	0.6628	2.1883	7581.103
Mean average				0.6503	2.1204	7483.99

Description charcoal made of	Replicate	Bomb ID	Energy Equivalent of the calorimeter (EE value in Cal /^{0}C)	Weight of sample taken(gm)	Temperature raise (^{0}C) (T final _T initial)	Calorific Value (Cal/gm)
Lantana camara L. branch parts	R1	M39905	2307.6194	0.5180	1.6513	7307.913
	R2	M39905	2307.6194	0.5897	1.8752	7365.53
	R3	M39905	2307.6194	0.5897	1.8685	7295.853
Mean average				0.5658	1.7983	7323.099

Table 8B

Calorific value (Cal/gm) determination for the produced *Lantana camara* L. Beehive fuel Briquettes charcoal

Description Briquette charcoal made off	Replicate	Bomb ID	Energy Equivalent of the calorimeter(EE value) in Cal /^{0}C)	Weight of sample taken(gm)	Temperature raise (T final_-T initial) (^{0}C)	Calorific Value (Cal/gm)
Lantana camara L. root parts	R1	M39889	3724.3945	1.0155	1.7295	6635.2056
	R2	M39889	3910.4116	1.0996	1.8910	6701.9861
	R3	M39889	3910.4116	1.0664	1.0664	6239.4197
Mean average				1.0605	1.5623	6525.5371

Description Briquette charcoal made off	Replicate	Bomb ID	Energy Equivalent of the calorimeter (EE value in Cal /^{0}C)	Weight of sample taken(g)	Temperature raise (T final_-T initial) (^{0}C)	Calorific Value (Cal/gm)
Lantana camara L. stem parts	R1	M39905	2307.6194	0.9943	2.2484	7625.2466
	R2	M39905	2307.6194	0.9778	2.2346	6063.7244
	R3	M39905	2307.6194	0.9793	2.1178	5749.7985
Mean average				0.9838	2.2003	6479.59

DescriptionBriquette *charcoal* made off	Replicate	Bomb ID	Energy Equivalent of the calorimeter (EE value in Cal /^{0}C)	Weight of sample taken(gm)	Temperature raise (T $_{final}$-T $_{initial}$) (^{0}C)	Calorific Value (Cal/gm)
Lantana camara L. branch parts	R$_{1}$	M39889	2307.6194	1.0892	2.1275	5193.1641
	R$_{2}$	M39889	2307.6194	1.0834	1.6864	5248.1749
	R$_{3}$	M39889	2307.6194	1.0846	1.6012	4964.7550
Mean average				1.0857	1.8053	5135.3646

DescriptionBriquette *charcoal* made of	Replicate	Bomb ID	Energy Equivalent of the calorimeter (EE value in Cal /^{0}C)	Weight of sample taken(gm)	Temperature raise (T $_{final}$-T $_{initial}$) (^{0}C)	Calorific Value (Cal/gm)
LC leave with trunk,seed and flower *charcoal* with PELLET form	R$_{1}$	M39905	2307.6194	0.9941	1.6346	3769.3588
	R$_{2}$	M39905	2307.6194	0.9793	1.6321	3820.4472
	R$_{3}$	M39905	2307.6194	0.9724	1.4782	3482.2326
Mean average				0.9819	1.5816	3690.6771

DECLARATION

This is to certify that the thesis entitled: **Fuel briquette and bio-oil potential of Lantana camara L weed Species and its implications for weed management and recovery of renewable energy sources, in Ethiopia**; is my original work and has not been presented for a degree in any other university and all sources used for the thesis have been duly acknowledged.

This is actual work done by **Sintayehu Abebe Koricho** under my guidance and supervision for the partial fulfillment of the award of the degree of Master of Science in Environmental Science.

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