WOLKITE UNIVERSITY

COLLEGE OF ENGINEERING AND TECHNOLOGY

DEPARTMENT OF CHEMICAL ENGINEERING

Production of charcoal from bamboo & partially substitute for coal required in cement pyro process

A Thesis Submitted to Wolkite University, Department of Chemical Engineering in partial fulfilment of the requirements for the attainment of Bachelor of Science in Chemical Engineering under Process Engineering Stream.

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DECLARATION

We hereby declare that the thesis is based on our original work except for flotation's and citations, which have been duly acknowledged. We also declare that this work has not been submitted, previously or currently for any other schools at Wolkite University or other higher institutes

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ACRONYMS

ACF:	Annual cash flow
BCB:	Bamboo charcoal briquette
CRICPP:	Coal required in cement pyro process
CV:	Caloric value
DC:	Direct cost
ETB:	Ethiopian birr
MC:	Moisture content
MMR:	Mass of moisture removed
OL:	Operating labor
PAC:	Percent of ash content
PEC:	Purchased equipment cost
PFC:	Percent of fixed carbon
PLC:	Private limited company
PMC:	Percent of moisture content
PVM:	Percent volatile matter
Re:	Recovery
ROI:	Return on investment
TDPC:	Total direct production cost
TFC:	Total fixed capital
WCI:	Working capital investment

ABSTRACT

The aim of this study was to produce a charcoal from bamboo and partial substitution for coal required in cement pyro processing to attain energy consumption. The effect of temperature and residence time on the yield of bamboo charcoal, mixing ratio of charcoal to binder ratio on the best binding mixture, and the ratio of mixing natural coal with bamboo charcoal to determine which percent of blending was promisingly substitute coal required in cement pyro processing was being investigated. Research sample collected from local and prepared. 60g of bamboo was be used as a basis for different trials with temperatures of, 350℃, 450℃ and retention time of, 10min, 15 min, and 20min. After six trials, we conclude that at a temperature of 450℃ and a retention time of 15min gives a yield of 32.5% that was be better compared, to the other trials. Then clay was be used as a binder and making briquette at different mixing ratio of charcoal to binder ratio (90:10, 80:20, 70:30) charcoal with better binder ratio and good combustion characteristics, was determined at 80:20, ratio. Finally we under take the proximate analysis by mixing natural coal with bamboo charcoal at different % ratio (90:10, 85:15, 80:20) here, concluded that 85% to 15% of natural coal to bamboo charcoal was promisingly substitute for coal required in cement pyro processing with fuel standard characterization limit . We have used design expert for data analysis. Generally, we were get high yield of charcoal briquettes by using clay as a binder at; temp 450ºC, retention time 15 min, charcoal to binder ratio 80:20 and 85:15 coal to bamboo charcoal that promisingly partial substitute for coal required in cement pyro processing to attain energy consumption with rate on return 48.7% and payback period of 1.84.

Key word: Pelleting, Briquetting, Extrude, Pyrolysis, Pyro process.

CHAPTER 1

INTRODUCTION

1.1 Background

Energy is the hot issue of the twenty first century. Today, factories are utilizing both renewable and non-renewable energy sources extensively, which is bringing unrecoverable damage to the ecosystem and the human kind. Cement factories are principal energy exhaustive industry in the world. Portland cement is one of the most commonly used construction materials in the world. The manufacture of Portland cement is requiring the temperatures between 1450ºC and 1500ºC (Worldmeters, 2016). The manufacture of Portland cement accounts for approximately 5% of the annual carbon dioxide output. Half of these emissions originate from the burning of fuel and half from the calcination reactions (Worldmeters, 2016). Ethiopia import 539,255 tons of coal/yr from this above 90% coal imported is for cement pyro processing that leads for carbon dioxide emission and huge capital to import. (Worldmeters, 2016).

Around 1970's, alternative fuels began to be used by the cement industry. Alternative fuels are typically waste products from other industries that are destined to be land - filed or incinerated. Examples that has be successfully used in cement manufacture include used oils, municipal solid waste, tires, solvents, plastic and biomass. Biomass accounts for 14% of the world's energy consumption and more than half of the world population used it as primary energy source. Bamboo is one of the most rapid growth rate biomass. It is native to Ethiopia, which has possibly the largest bamboo growing area in Africa. Bamboo is a rapidly renewable natural resource and can represent a sustainable source for industrial fuel. Increased use of bamboo would significantly reduce pressure on local timber resources and contribute to afforestation and soil conservation efforts. Total bamboo covered hectare in Ethiopia is 1.44 million hectare (Kassahun, 2018). From this thesis total consumption of bamboo 2, 48,886ton/yr this gained from 8,889 hectare this is consumption of 0.62% of total bamboo covered hectare in Ethiopia currently and able to save 13,912,736USD/yr.

The utilization of alternative fuels has proven to be both economic benefit to the cement industry, green development economy, suitable environment and sustainable development. Generally, the Substitution of coal by bamboo charcoal that qualifies carbon crediting, bamboo charcoal can substitute 15% of process heat requirement without the need for major capital investment. It will have its own significance to reduce amount of imported coal used for cement production and reduction of greenhouse gas emission.

1.2 Statement of the problem

Currently in Ethiopia many cement industries use only fossil fuel mostly coal, this leads the cement factory to supply huge economy to buy coal since it imported from abroad. Ethiopia import 539,255 tons of coal/yr this means 92,751,860 USD/yr since 1ton of coal is 172USD/ton from this above 90% coal imported is for cement pyro processing (Worldmeters, 2016). Use of coal without alternative fuel leads: lack of foreign currency to be happen, political crises, continuous use fossil fuel without alternative energy leads also for greenhouse gas emission, coal is nonrenewable energy resource expected to last for 100 years for this reason many coal based energy source searching for the best promise alternative fuel (World Energy councel, 2004). Taking this as a reference this project aimed to substitute 15% of coal by bamboo charcoal that promisingly substitute for coal required in cement pyro processing without need of high capital investment.

1.3 Objective

1.3.1 General objective

The general objective of our study is production of charcoal from Bamboo tree & partially substitute for coal required in cement pyro process.

1.3.2 Specific objective

- To produce bamboo charcoal and vinegar by carbonizing.
- To estimate the temperature and residence time high yield production among six trails.
- Briquetting bamboo charcoal by using clay as a binder.
- To carry out proximate analysis of charcoal briquettes and compare with coal.

- To mix and characterize bamboo charcoal with coal at different percentage of mixture.

1.4 Significance of the project

Cement is the energy dissipative factory especially on the pyro-process unit. This study mainly focuses on replacing 15% coal by bamboo charcoal that has great significance on:

- Minimize the fear of energy source that arise due to continuous depletion of fossil fuel.
- Minimizing lack of foreign currency happen due to coal consumption.
- Minimize economic and political crises.
- Minimize greenhouse gas emission.

1.5 Scope of the study and limitation

This study will carry out at Wolkite University. Major methodologies that we will have under take to gather data and proceed well are Gathering data and selection of material, Laboratory work, proximate analysis of bamboo charcoal, Perform material balance, and plant design and economic calculation. During perform the task there is the limitation to perform all characterization since there is no bomb caloric meter that used to determine the caloric value of fuel and limitation of source that difficult for us during documentation.

CHAPTER 2

LITERATURE REVIEW

2.1General over view of Bamboo

In taxonomy, bamboo falls to family Poaceae (grass family), subfamily Bambusoideae that contains 1250 species. Despite of being a grass, they still have "woody stem" or culm that can reach 15-20m in height or even 40m with the largest species known (*Dendrocalamus giganteus*). Bamboo considered the fastest growing plant in the planet with the recorded grows speed of 91cm per day ("Fastest growing plant," n.d.). The harvestable time for bamboo is about 3-5 years in comparison to 10-20 years for most softwood (*Cultivation of Bamboo and its bio energy production,* n.d.) It also has high biomass productivity; self-regeneration and can tolerate poor soils so that it can grow in degraded land that which makes it one of the best-known biomass resource (Kassahun, 2018)

. The inventory of bamboo resource worldwide illustrated, in table 2.1.

Table 2.1Inventory of bamboo resource worldwide.

Continent	Area of bamboo (1000ha)			
	1990	2000	2005	% of global total (in 2005)
Asia	21,230	22,499	23,620	65
Africa	2,758	2,758	2,758	28
Latin America	-	10,399	10,399	7
Global total	23,988	35,656	36,777	

Source: (Kassahun, 2018)

Figure 2. 1 Bamboo tree

Bamboo is native to Ethiopia, which has possibly the largest bamboo growing area in Africa. It is a rapidly renewable natural resource and can represent a sustainable source for industrial fuel. Increased use of bamboo would significantly reduce pressure on local timber resources and contribute to afforestation and soil conservation efforts.

Greater use of bamboo would act to offset current deforestation of other tree species; this in turn would lead to the conservation of trees and the rebuilding of the natural resource wealth of the country and the environment. Although bamboo is wood, it differs in one important respect that it can be harvest annually, despite being a perennial plant. Such annual harvests (or even monthly harvests), if undertaken sustainably, do not affect the health of the plant or its future growth and productivity. This on-demand harvest potential provides the material for use when needed and the income when needed – not just annually but even monthly (Kassahun, 2018).

Table 2.2 Distribution of Bamboo charcoal in Ethiopia source.

Region	Specific Area	Covered Area (ha)
Amhara	Injibara	-
	Hinde	8,670
Benishangul Gumuz	Asosa	77,947
	Bambesi	64,245
	Begi	21,509
	Demi	27,612
	Dibate	14,200
	Guba	7,757
	Kamashi	33,723
	Pawe	53,830
Oromiya	Agaro	-
	Gera	-
	Bale mountains	56,851
	Shenen, Jibat mountain	1,774
	Gimbi	29,125
	Guten	6,044
	Gera bamboo forest	1,052
	Gera-Lola	34,493
SNNPR	Agere Selam- Bore	-
	Chencha	-
	Indibir-Jembero	-
	Jima-Ameya	-
	Mizan Teferi- Kulish	-
	Wushwush- Bonga	-
	Bonga-Ameya	7,997
	Masha	18,652
	Shashemene	4,183

Source: (Sori, 2009)

2.2 Criteria of alternative fuel

The specific criteria that a material must meet in order to considered as the individual typically sets a fuel cement producer according to their own needs. In general, the production of clinker requires an even combustion of fuels in order to constantly heating the raw materials. Considering this, the fuels must be processed and conditioned to have the following characteristics (Chaney, 2010).

- Even particle size distribution
- Less chlorine and Sulphur content
- Less ash value
- Handling and its cost
- High and uniform calorific value
- Free of detrimental contents like some metals, glass, and minerals, and
- Low moisture content.

2.3 The current uses of these biomass residues

Crop and agro-industrial residues have low bulk and energy density and, for these reasons, it cannot be transport far from production sites. Where residue supply exceeds local demand, residues are usually disposed of wastefully and harmfully (typically burnt in the field or at agro-industrial sites, or dumped into streams). Crop residues such as teff, wheat and barley are important sources of animal feed and additionally used for soil nutrient recycling. Bamboo tree used currently for furniture, and traditional charcoal (Mekonnen, 2018).

2.4 Technologies for Briquetting of Biomass and Biomass Residues

2.4.1 Collection

Depending on the agricultural residue, collection can be a major component of the densification process.

2.4.2 Storage

The type of storage required will depend on the residue and the environmental conditions it subjected. Usually, the residue will be stored in an open-air heap, a shed, a bin or within retaining walls or fences. If the collected residue is dry and open-air storage would result in the accumulation of moisture, then closed or sheltered storage is necessary.

2.4.3 Cleaning

Cleaning is necessary if the residue contains foreign materials (such as stones, soil or metal) that could damage the processing and densifying equipment. Cleaning can be usually be achieved with pneumatic, mechanical and / or magnetic screens.

2.4.4. Drying

In general, most extrusion-type densification equipment requires that the feedstock be in the range of 10-20% moisture content on a wet basis (% mcwb). If the moisture content of the feedstock is too high (above 20% mcwb) the excess water becomes a superheated liquid because of the high pressure required for densification and the resultant frictional heat build-up.. Stored at moisture contents above 20% for extended periods, any biomass will begin to decompose, reducing its calorific value and posing a risk of spontaneous combustion. Because of this, drying of the residue prior to densification is required if the material as received is above 20% mcwb. The method of drying will depend on several factors, including environmental conditions, the initial moisture content of material, the level of throughput, the size of material, the type of densifying equipment, etc. (Gebremedhin, 2003).

2.4.4 Biomass pyrolysis processes

Table 2.3 Biomass pyrolysis processes.

Process	***Char***	***Liquid***	***Gas***
CARBONISATION Low temperature ,Long residence time	35%	30%	35%
FAST PYROLYSIS Moderate temperature, Short residence time	12%	75%	13%
GASIFICATION Low temperature, Long residence time	10%	5%	85%

Source: (Amy Smith, 2003)

Bamboo vinegar

Bamboo vinegar is a byproduct liquid produced during pyrolysis of bamboo. Its color is puce; the smell is strong and irritant. The composition of the bamboo vinegar is very complicated, mainly include water, organic acids, phenols, ketones, alcohols, etc., there are in total more than 200 components. The formation of bamboo vinegar is also a complicated process. The yield is largely depending on the specie of the bamboo, the moisture content of the material as well as the pyrolysis techniques. The components of the vinegar also changes, it depends on the method of collection, the pyrogenic temperature, and the storage method, etc… (Matsunaga K, 1999)

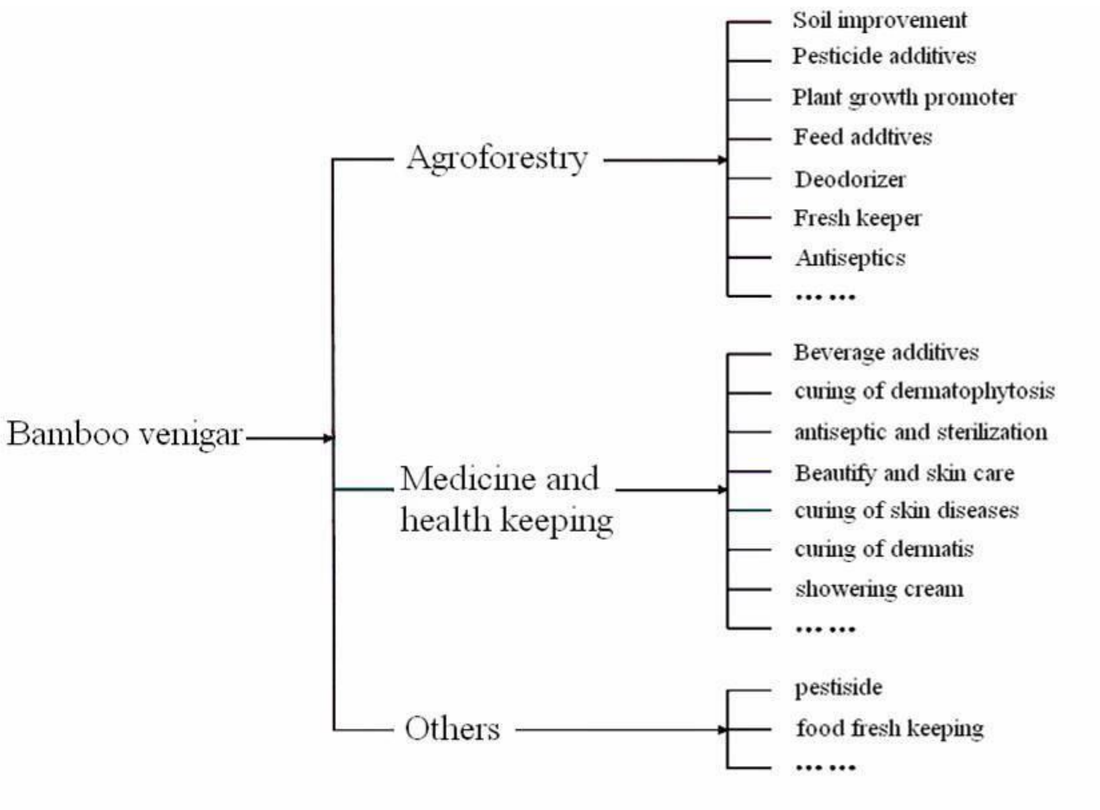


Figure 2. 2 Use of Bamboo vinegar (Matsunaga K, 1999)

2.4.5 Binder and types

These are materials added to heat fuel and accelerants to draw them together in such a way that it maintains a uniform consistency. The best binders are starch, and gum Arabica or acacia gum starch (cassava, corn, and potatoes), pulped waste paper, red soil, ball clay and molasses (Amy Smith, 2003).

Types of binders

Starch

Starch is the most common binder though it is usually expensive. It does not have to be a food grade. In general, about 4-8% of starch is used to make the briquettes. Starch sources can be Cornstarch, wheat starch, maize flour, wheat flour, rice flour, cassava flour, potato starch, etc. To use the starch as a binder, you must first gelatinize the starch, which is added to water and heated to form a sticky consistency, then adding to the mixer to be mixed with the charcoal powder (Ebo T.Q, 2010).

Gum Arabic

Gum Arabic, also known as acacia gum, is a natural gum harvested from acacia tree, which is very common in Africa Sahel, especially Senegal, Sudan, Somalia, etc.

Gum Arabic successfully used as binder material for charcoal briquette. It does not emit heavy smoke, nor is thermal treatment needed.

Molasses

Molasses is a by-product of the sugarcane industry. One tone of briquettes needs about 20-25% molasses. Briquettes bonded by molasses burn well, but have an unpleasant smell during combustion. To avoid this, thermal treatment can applied before using the briquette that called "curing" (Amy Smith, 2003).

Wood Tar and Pitch

Wood tar arises, during the carbonization process and recovered from stationary kilns retorts. Pitch is a viscous liquid that remains after the distillation of coal tar. Tar is liquid while pitch is more solid. Both of them require re-carbonization to avoid the emission of heavy smoke, which may generate adverse health.

Besides, cow dung and paper pulp also can be the binding material for briquettes. Cow dung is available mainly in rural areas. Waste paper torn to small pieces and soaked in water to form a gelatinized paste. (Amy Smith, 2003)

Clay

Clay is widely available at almost no cost in many areas. Clays are the main binders of earth and made up of very small mineral particles (<2 microns), leached out during erosion of rock. The molecular structure of clays consists of sheets of silicate and aluminate ions.

Electrostatic forces set up within such structures produce binding properties. Clays have a variety of uses, especially for ceramics, but it is their use as binding materials in the unfired state, which described in this leaflet. Although they have the limitation that they soften when wetted, they are also undoubtedly the cheapest binders, with very low energy consumption, and deeply embedded in traditional building cultures in many parts of the world. It estimated that over a third of the world's population are living in houses of earthen construction. It used as a binder in making charcoal briquettes. A briquette can contain about (10-30)% of clay. Clay does not add to the heating value of the briquette. If too much clay is added, the briquette will ignite and burn poorly or not at all. Besides, clay will turn into ash after burning, which blocks the passage of radiant heat, resulting in the loss of heating value of the charcoal (Amy Smith, 2003).

2.4.6 Densification, Briquetting/Pelleting

There are essentially four main types of extrusion densification process:

- ❖ Piston press briquettors
- ❖ Screw press briquettors
- ❖ Roll briquettors;
- ❖ Pellet mills

There follows a brief description of each of these processes

Piston press briquetting

In this process, a reciprocating piston forces the feed material into a die, where pressure and friction heat the feedstock to 150-300°C before it extruded through a die 25-100 mm in diameter. In most cases, the die is water-cooled to reduce wear. The briquettes then enter a cooling line, which, by friction, provides a backpressure on the material exiting the dies so that the cooling takes place with gradually diminishing pressure. A sudden pressure drop can cause the high temperature water to flash to steam, exploding the briquettes. The backpressure could be adjusted, to allow optimum production for fuels with varying moisture contents. As they exit the cooling line, briquettes may be cut or broken off at any desired length. Capacity ranges from 150kg-1.5 tons per hour (Dr. A.G.T. Sugathpala, 2013).

Screw Press Briquetting

- ❖ Low production capacity (750-1,000kg) per hour
- ❖ High capital cost per tons of output

- ❖ High amount of friction heating by the screw, resulting in higher die temperatures and increased wear on the screw and die head.

This cited from (Dr. A.G.T. Sugathpala, 2013)

Roll Briquetting

Feedstock is pre-compressed with the screw feeder and compacted between two rollers with opposing cavities to form pillow-shaped briquettes 25-50 mm in size (Dr. A.G.T. Sugathpala, 2013).

- ❖ This method requires little energy input since there is little friction heating of the material.
- ❖ Maintenance requirements are lower.
- ❖ Rolled briquettes are generally less durable than extruded product.

Pellet Mill

In a pellet mill, a hard steel die, cylindrical or disc-shaped, is perforated with a dense array of holes 5-15 mm in diameter, and a press roller forces the biomass through the holes. As the pellets is extruded, from the holes, they may be cut off at a specified length, usually less than 30 mm. The unique characteristics of the pellet – its small size, smooth rounded edges, high bulk density and durability – make it most suitable for bulk storage and handling (Dr. A.G.T. Sugathpala, 2013).

2.5 Assessment of the Suitability of Bamboo Biomass as a Source of Energy

2.5.1 Compare to traditional fossil fuels

Traditional fossil fuels considered as a portable form of energy so that they are easy to use, store and transport. They are the concentration form of energy so that they are very combustible and produce a large amount of energy in comparison to other type of fuels such as biofuel or wood fuel. However, biomass has its own advantages over fossil fuel. The two importance advantages of biomass over fossil fuel are sustainability and level of CO2 emission (Chaney, 2010).

Bamboo biomass is a renewable source, which means it can re-generated, in a sustainable rate for extraction. Another aspect need to discuss is the price. Currently, the electricity price of power plant using fossil fuel is higher than electricity generated from biomass. However, due to fossil fuel shortage, the situation will reverse in the future. When this happen, biomass will be more cost-effective than fossil fuel and the transition will occur naturally.

Table 2.4 Comparison of bamboo biomass with fossil fuel

Criteria	Fossil fuel		Bamboo biomass	
Availability	+	Extracted directly from existing reserve and use directly after extraction	–	Have to plant and harvest after a period of 3-4 years
Energy produced (per same mass)	+	Much larger	-	Much smaller
Logistic (transportation, storage)	+	Easy to transport and store	-	More difficult (need larger space for transportation and storage)
Quality	+	Unified	-	Vary
Sustainability	-	Non-renewable source	+	Renewable source
CO_2 emission	-	Increase the concentration of CO_2 in the atmosphere	+	Not increase the concentration of CO_2 in the atmosphere

Source: (Chaney, 2010)

2.5.2 Compare to other types of renewable energy biomass

Bamboo biomass has relatively higher heating value than other type of biomass & moisture contain of bamboo is similar to rice husk and rice straw but much less than bagasse and corn stalk. The fuel characteristic of some biomass feedstock is provided in table below.

Table 2.5 Thermal energy characteristics of different biomass source.

Biomass	LHV	Ash content	Volatile matter	Moisture cont.
Coffee husk	16.4	11.4	69.4	11.4
Saw dust	18.8	58.4	80.1	1.6
Cotton stack briquette	19.1	3.2	NA	5.9
Bamboo tree	19.49	0.53	75.5	9.54

Source (B., 2009)

2.6 Current Situation of Bamboo Biomass for Energy

2.6.1 Bamboo biomass energy in international context

Recently, bamboo has emerged as a new source of biomass for energy production. Many studies and research has conducted to evaluate the suitability of bamboo as a source of energy. Studies have be carried out in many countries (mostly where bamboo is abundant such as China, India, Indonesia and Thailand). Many studies referred to bamboo as a competent alternative for biomass resource. However, research on bamboo potential at country level is not adequate in some countries, which have substantial bamboo resources such as Vietnam and Thailand. These studies together with implementing projects will provide us a clearer look to the future of bamboo biomass as a sustainable energy source (Kassahun, 2018).

2.6.2 Biomass energy for the cement industry in Ethiopia

2.6.2.1 Cement production process and energy use

Cement production is an energy-intensive process. In pyro processing the production of clinker needs huge amount of energy. Pyro processing is the process by which raw meal converted to cement clinker at high temperature that needs huge amount of coal for burning purpose. Most cement factory use 40% of total energy source in pre-heaters and 60% in kiln (Worldmeters, 2016).

2.6.2.2 Technical options relating to the use of biomass energy in the cement industry

Among the alternative fuels available for fuel switching in cement plants, biomass is the only carbon-neutral fuel. The following technical options are available when using biomass in cement plants (Gebremedhin, 2003):

a) Direct combustion of biomass in pre-heaters. This can happen in two ways:

- ❖ By mixing crushed and pulverized biomass with coal or pet-coke for use in the kiln.
- ❖ By direct feeding of biomass in solid lump.

b) Transforming biomass into producer gas (also known as 'synthesis gas' or syn-gas) and co-firing it in the kilns using a gas burner (Worldmeters, 2016).

Throughout this guide, reference will be made to Ethiopian Cement plant as an indicative to produce bamboo charcoal and partially substitute for coal required in cement pyro processing.

CHAPTER 3

METHODOLOGY

3.1 Material and chemical used

This chapter briefly discusses the methodology and materials used to accomplish the objectives set. The materials used perform laboratory tests are: Bamboo is the raw material that collected from local. Briquetting machine that was be used to make briquettes, Clay used as a binder, Furnace is used for the carbonization process, Mixer used to mix the carbonized bamboo with binder, Water for many purpose, Silica crucibles to hold the sawdust in to the furnace for the carbonization process, Pair of tongs used to hold sample to furnace and an Electric oven used to remove moisture.

3.2 Methods

3.2.1 Raw material preparation

The bamboo was collected and cutting in to pieces.

Figure 3. 1 Preparation of raw material

3.2.2 Drying

The moisture content needs to reduce from an initial moisture content of 24%, the sample was be dried using an oven and was dried for 24 hours under the temperature of 80℃.

3.2.3 Carbonization (pyrolysis)

The dried up bamboo was be carbonized, in a furnace that changed the bamboo into charcoal. A 60g of bamboo sample was be measured and placed on the crucible and then fed to the furnace that set at different temperature (350, 450) and time (10min, 15min, 20min).

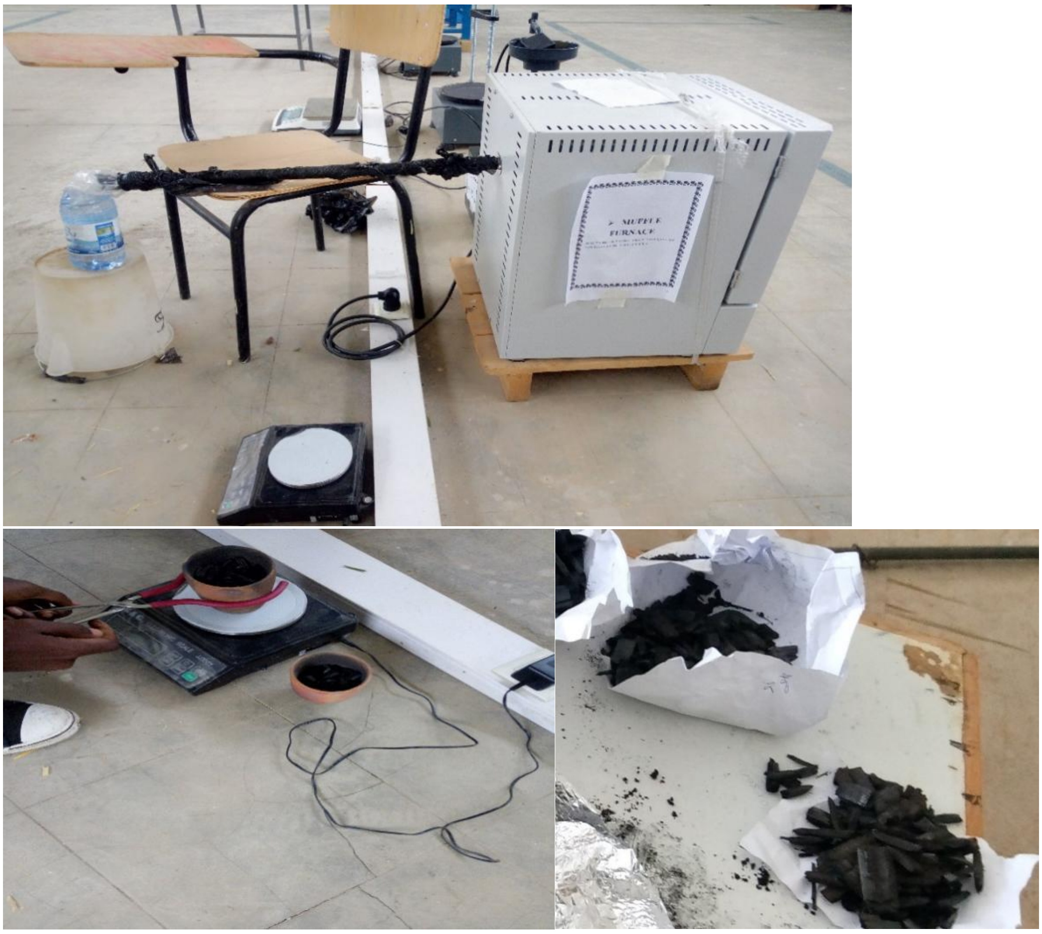


Figure 3. 2 Pyrolysis process by using furnace

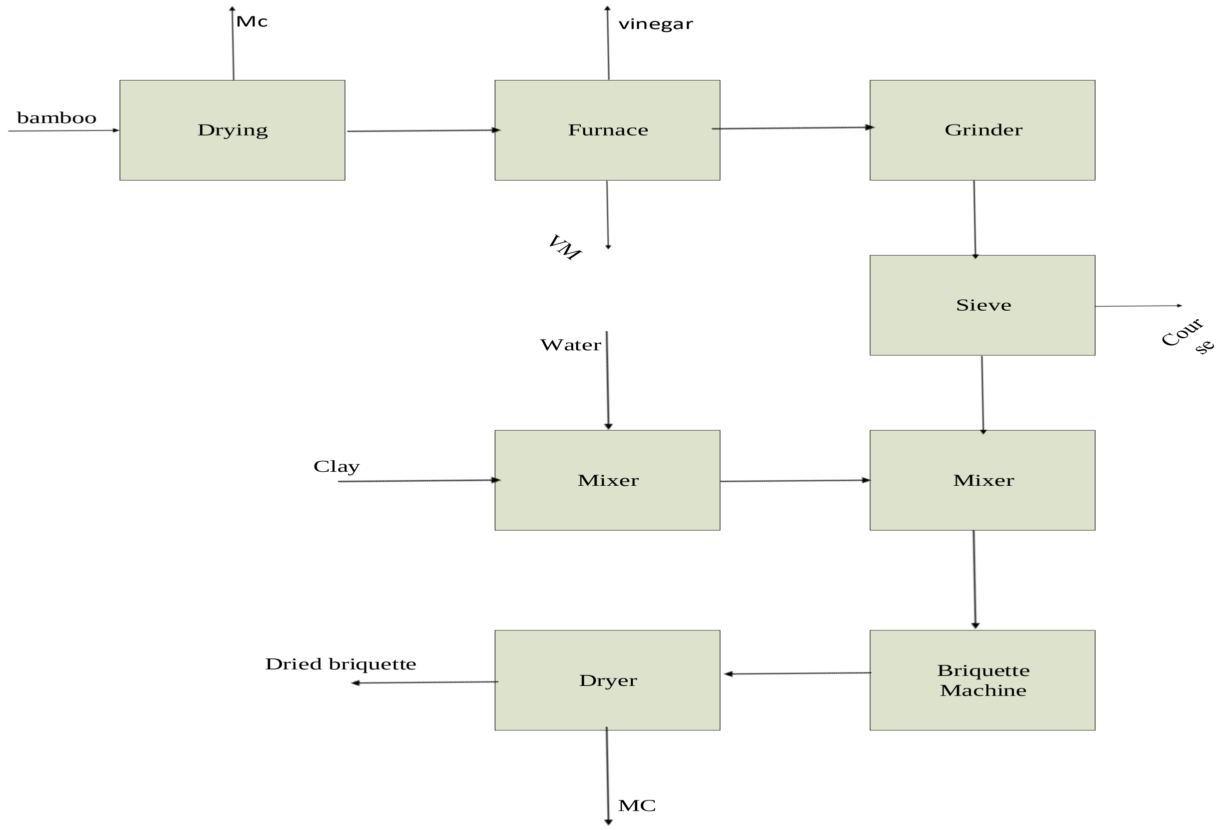


Figure 3. 3 Block flow diagram of bamboo charcoal production.

3.2.4 Grinding

After carbonization process, the size of charcoal reduced, by using grinder. This process is used to suit the charcoal to mixing with binder.

Figure 3. 4 Grinding of bamboo charcoal

3.2.5 Preparation of binder

The clay was mixed, with water at 1:1.5 ratio to acquire clay its viscous state.

3.2.6 Mixing

The grinded charcoal become sieved to separate fine particle from course one and the fine charcoal become mixed with the prepared binder at different ratio to determine the effect of charcoal to binder mixing ratio.

Figure 3. 5 Mixing process

3.2.7 Briquetting

After the binder and the grinded carbonized charcoal mixed and then the mixture was compressed using briquetting device to form the briquette.

Figure 3. 6 Briquetting process.

3.2.8 Drying

After needed shape acquired, the briquette dried with an oven at temperature of 60℃ for 24 hours.

3.2.9 Characterization of Bamboo charcoal

We was analysis dried bamboo charcoal, the analysis undertaken is proximate analysis (volatile matter, moisture content, ash content, fixed carbon) , 2g of sample was taken To oven at 105℃ for 1 hour and moisture content determined, volatile matter 550℃ for 10 minutes, fixed carbon determined by taking 2g of sample to the furnace at 600℃ for 4hr and completely burned and the ash taken from the sample fixed carbon determined by using the formula $fixed\ carbon = 100\% - (PAC + PMC + PVM)$. Then we undertake proximate analysis by mixing bamboo charcoal with natural coal at different mixture ratio to determine the best mixture that promisingly substitute for natural coal that is briefly discuss in result and discussion.

The caloric value is also the main criteria to be discussed by using bomb caloric meter here we are discuss the caloric value of bamboo charcoal from literature review and analysis with that of natural coal this is the potential limitation of our project.

CHAPTER FOUR

RESULT AND DISCUSSION

4.1 Result

Six different experiments carried out at laboratory scale for two different temperatures and for four different residences time. To estimate the optimum temperature and residence time for a better yield of charcoal.

Table 4.1 Result for experiment at different temperature and time.

Exp no	Sample	Weight	Time(min)	Temp(°C)	product	Prod type
1	Bamboo	60g	10	350	16	Charcoal+ unburn
2	Bamboo	60g	10	450	16.5	Charcoal +unburn
3	Bamboo	60g	15	350	18.5	Charcoal + unburn
4	Bamboo	60g	15	450	19.5	Charcoal
5	Bamboo	60g	20	350	18.8	Charcoal
6	Bamboo	60g	20	450	17	Charcoal

4.1.1 Yield determination

For experiment 1

At 350°C and 10min. product is 16g charcoal with unburned bamboo. Therefore, our product is 16g charcoal.

$$yield = \frac{product\ collected}{raw\ material\ feed}$$

$$yield = \frac{16g}{60g} = \mathbf{26.67}\%$$

For experiment 2

At 450°C and 10min. product is 16.5g charcoal with unburned bamboo. Therefore, our product is 16.5g charcoal.

$$yield = \frac{product\ collected}{raw\ material\ feed}$$

$$yield = \frac{16.5g}{60g} = \mathbf{27.5}\%$$

For experiment 3

At 350℃ and 15min. product is 18.5g of bamboo charcoal was not fully burned.

$$yield = \frac{product\ collected}{raw\ material\ feed}$$

$$yield = \frac{18.5g}{60g} = \mathbf{30.83}\%$$

For experiment 4

At 450℃ and 15min. product is 19.5g of bamboo charcoal it fully burned.

Yield was determined by

$$yield = \frac{product\ collected}{raw\ material\ feed}$$

$$yield = \frac{19.5g}{60g} = \mathbf{32.5}\%$$

Experiment 5

At 350℃ and 20min. product is 18.8g of bamboo charcoal it fully burned.

Yield was determined by

$$yield = \frac{product\ collected}{raw\ material\ feed}$$

$$yield = \frac{18.8g}{60g} = \mathbf{31.3}\%$$

The yield is high, but the material was fully carbonized.

For experiment 6

At 450℃ and 20min. product is 17g of bamboo charcoal it fully burned.

Yield was determined by:

$$yield = \frac{product\ collected}{raw\ material\ feed}$$

$$yield = \frac{17g}{60g} = \mathbf{28.33}\%$$

4.1.2 Binder charcoal mixing ratio determination

Electrostatic forces set up within such structures produce binding properties It used as a binder in making charcoal briquettes. A briquette can contain about (10-30) percentage of clay (Amy Smith, 2003). Based this reference we have made three charcoal briquette at different percentage of mixture 10-90, 20-80, 30-70 percentage of binder to charcoal ratio result in table below.

Table 4.2 result for experiment at binder charcoal different percentage ratio

Exp. no	Bamboo charcoal(gm)	Clay (gm)	Binder properties	Combustion characteristics' At (600℃ for 4hr)
1	50	5	Poorly bind	Complete combustion
2	50	10	Better bind	Complete combustion
3	50	15	Better bind	Poor combustion

For first experiment, (10-90) percentage of mixture the briquette made is less bind but it is easily combustible. For second experiment, (20-80) percentage of mixture the briquette made is better bind ratio with good combustion characteristics it is the best among three experiment and selected. For third experiment, (30-90) percentage of mixture briquette made is better bind and ignite for burning (poor combustion characteristics)

4.1.3 Proximate analysis of charcoal (physic-chemical properties of charcoal)

Proximate analysis was be done, to determine the percentage volatile matter content, percentage ash content, moisture content and percentage content of fixed carbon of the briquette.

Percentage of volatile matter

The PVM was been determined by crushing 2g of briquettes sample and placing it in an oven until a constant weight, (A) will obtained. The briquettes was then, kept in a furnace at a temperature of 550℃ for 10 minutes and weighed after cooling in a desiccator to obtain (B).

$$PVM = \frac{A-B}{A} * 100\%$$

$$PVM = \frac{2g-1.45g}{2g} * 100\% = \underline{\mathbf{27.5\%}}$$

Where A: is constant weight after sample dried

B: sample after 10 min in oven at 550℃

Percentage of ash content

The PAC was also determined by heating 2g of the briquette sample in the furnace at a temperature of 600℃ for 4hrs and weighed after cooling in a desiccator to obtain the weight of ash (C).

Percentage of ash content will be determined by:

$$PAC = \frac{C}{A} * 100\%$$

$$PAC = \frac{0.064g}{2g} * 100\% = \underline{\boldsymbol{3.2\%}}$$

When C: weight of ash

A: sample weight

Percentage of moisture content (PMC)

The moisture content was determined by weighing 2g of the briquette sample (E) and oven drying it at 105℃ until mass of the sample was constant (D) after 60 minutes. Then PMC calculated by:

$$PMC\ (db) = \frac{D}{E} * 100\%$$

$$PMC\ (db) = \frac{0.046g}{2g} * 100\% = \underline{\boldsymbol{2.3\%}}$$

E- Briquette sample

D=weight of sample- weight from oven after 60 min=2g-1.936g=***0.046g***

Percentage of fixed carbon (PFC)

The PFC was calculated by subtracting the sum of percentage volatile matter (PVM) and

Percentage ash content (PAC) and percentage moisture content (PMC) from 100%.

$$fixed\ carbon = 100\% - (PAC + PMC + PVM)$$

$$fixed\ carbon = 100\% - (3.2g + 2.5g + 27.5g)$$

$$fixed\ carbon = 100\% - (33.2) = \mathbf{66.8}\%$$

4.1.4 Analysis based on Caloric value

Since there is no bomb calorimeter in Wolkite University, the caloric value was not determined in laboratory but from literature review it's stated that the caloric value of bamboo briquette charcoal is range from (26 to 29MJ) here we have taken 27.5MJ and discussed.

Caloric value is determined by the below formula

$$(w2 - w1) * cv = (w3 - we)(t2 - t1)$$

Where

W1: weight of empty crucible

W3: weight of water taken in the calorimeter

W2: weight of empty crucible + weight of briquette sample

t1: temperature of water just before firing

t2: temperature of water after firing

CV: caloric value

4.1.5 Analysis based on % of mixture with natural coal

Analysis of percentage mixture of coal to bamboo charcoal briquette to use in cement pyro processing.

Table 4.3 Proximate analysis of the mixture

Mixture	**CV**	**Ash content (%)**	**VM (%)**	**MC (%)**	**Fixed carbon**
Coal	5455.5	21	24.9	4.1	50
BCB	6579	3.2	27.5	2.3	66.8
90C:10BC	5567.85	19.22	25.16	3.92	51.68
85C:15BC	5624	18.33	25.29	3.83	52.52
80C:20BC	5680.2	17.44	25.42	3.72	53.36

4.2 Discussion

4.2.1 Effect of temperature and residence time on yield

In this project tried to show the temperature and residence time for an optimum charcoal yield. Moreover, to carry out the task a laboratory scaled experiments were done' six trials by varying the temperature and the residence time.

The first experiment at a temperature of 350℃ for 10min have a conversion of 26.67% with partial conversion of bamboo to charcoal, this is less yield since it does not fully converted it may needs more time or further addition of temperature for full conversion.

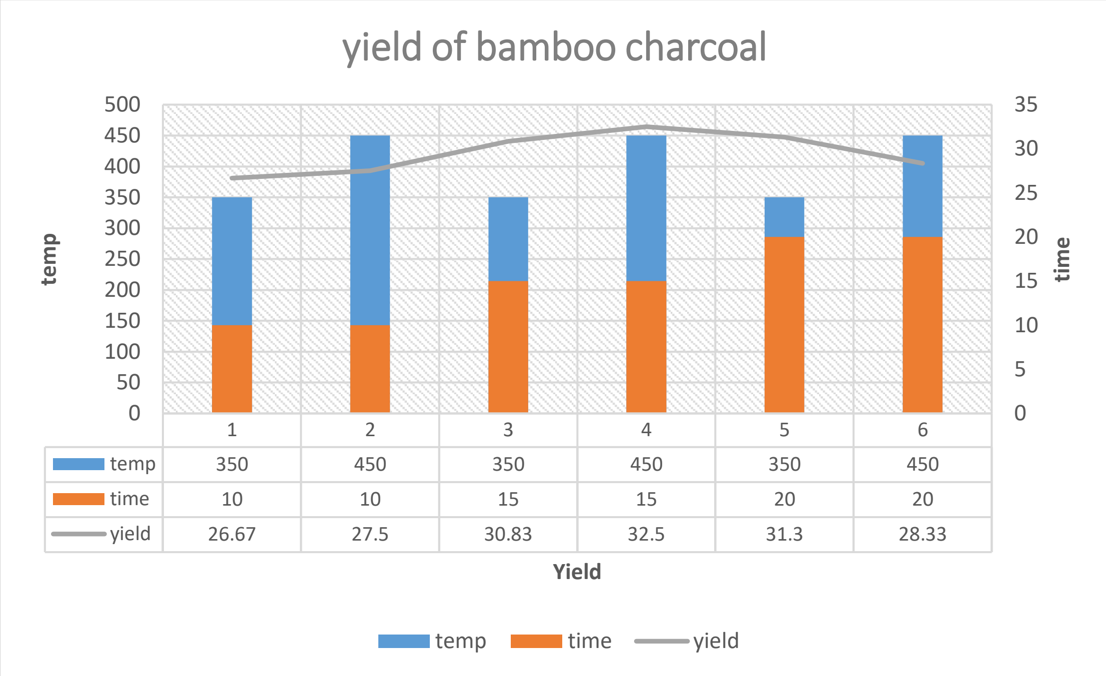
The second experiment was done' at a temperature of 450℃ for 10min have a conversion of 27.5% with full partial conversion of bamboo to charcoal but it's better than that of first experiment on the same time this implies at this time yield was increase as temperature increase.

The third experiment took place at a temperature of 350℃ for 15 min have a conversion of 30.83% with partial conversion of bamboo to charcoal it is higher than at experiment one at the same temperature but yield increase as time increase.

The fourth experiment took place at a temperature of 450℃ for 15 min have a conversion of 32.5% with full conversion of bamboo-to-bamboo charcoal this is an optimized yield when compared to the other experiment. Our project were focused' to get the optimum temperature and residence time for a good charcoal product. Incase this is the optimum, material balance, energy balance and cost estimation was done by this experiment.

The fifth experiment was done' at a temperature of 350℃ for 20 min have a conversion of 31.3% it is better than other except fourth experiment this means the yield increase with increase in time at 350℃.

The last experiment was done at a temperature of 450℃ for 20 min have a conversion of 28.33% with full conversion of bamboo to charcoal this is gradually decrease as time increase above 15 minutes for 450℃. Form those all six experiments we can understand that the fourth experiments have a maximum yield at the temperature of 450℃ and a residence time of 15 min. At the end of this all experiment we can understand that the fourth experiment have the best yield and the graph shows that the fourth experiment have the pick level of conversion and the graph starts to decline after the residence time of 15 minutes.



	1	2	3	4	5	6
temp	350	450	350	450	350	450
time	10	10	15	15	20	20
yield	26.67	27.5	30.83	32.5	31.3	28.33

Figure 4. 1Yield determination of bamboo charcoal

4.2.1 Proximate analysis

The proximate analysis of the briquettes examined in this study were limited to percentage Volatile matter, percentage ash, percentage fixed carbon and moisture content. Moisture content.

a) Moisture content

Moisture content is one of the main parameters determining briquette quality as lower moisture content of briquettes implies higher calorific value. Moisture content affects both the internal temperature history within the solid. For this experiment, the moisture content of the bamboo charcoal briquette was 2.3%. This is within the limits of 5% that recommended (Matsunaga K, 1999).

b) Volatile matter, ash content and fixed Carbon

Volatile matter represents the components of carbon, hydrogen and oxygen present in the biomass that when heated turn to vapor, usually a mixture of short and long chain hydrocarbons Volatile content has been shown to influence the thermal behavior of solid Fuels and it results in incomplete combustion which leads to significant amount of smoke and toxic gases being released. From the proximate analysis of our project the percentage content of volatile matter for the Bamboo charcoal briquette was 27.5% that in standard limit of coal from (20% to 50%) (Matsunaga K, 1999). Ash which is the non-combustible' component of biomass was determined to be 3.2% that is better with the limit of 5% (Matsunaga K, 1999). The fixed carbon of a fuel, which is the percentage of carbon available for char combustion, was determined to be 66.8 with the limit of 63% (Matsunaga K, 1999). Higher fixed carbon indicate that the presence of higher mineral matter that minimize the combustion performance of fuel the fuel with high fixed carbon the better with caloric value but above the limit of higher fixed carbon it become ignite and difficult for simply firing in cement pyro processing. From our study all parameter indicates that the bamboo charcoal is potentially substitute fully for coal required in cement pyro processing except that of bamboo charcoal having higher fixed carbon. Due to this bamboo, charcoal must be blending with natural coal in the limit of standard range of coal required in cement pyro processing than direct shift the coal required in cement pyro processing by bamboo charcoal. So the study indicate that bamboo charcoal is promisingly substitute for natural coal at the ratio of 85% natural coal to 15% bamboo charcoal that has in the limit of required standard parameter.

4.2.2 Caloric value

The caloric value of bamboo briquette charcoal is range from (26 to 29MJ) from literature here we have taken 27.5MJ this is better even when compared to that of natural coal it is around 24.6MJ.

In this the result indicate that 1kg of natural coal generate heat energy of 5455.5kj/kg while 1kg of bamboo charcoal generate heat energy of 6579kj/kg (World meters, 2016)..

4.2.3 Percent of mixture with natural coal

Bamboo charcoal briquette and natural coal is grinded separately and mixed at different percentage. For first experiment 1.8g of coal mixed with 0.2g of bamboo charcoal and sample taken to the furnace set at 600℃ for 4hr to undertake proximate analysis. For second experiment, 1.7g of coal mixed with 0.3g of bamboo charcoal, for third experiment 1.6g of coal with 0.4g of bamboo charcoal, and the same procedure with first experiment is applied and the result summarized in table 4.3. The percentage of mixture 85% natural coal to15% bamboo charcoal was fulfill all requirements of standard and concluded that high percentage of mixture to substitute bamboo charcoal for natural coal that required in cement pyro processing.

CHAPTER FIVE

TECNO ECONOMIC FEASIBLITY

5.1 Material and Energy balance

5.1.1 Material Balance

The material balance at industrial scale plant capacity is designed to take in 6500 kg/day of Bamboo to convert into charcoal the plant carries out its production in 24 hrs. Through six batch processes.

Basis: 2000kg of bamboo with a moisture content of 20% (from laboratory result)

All the formula under this chapter was be cited from (SINNOT, 2005)

Material balance on the mills

Assumed that Mass entering is the same as mass exiting

Min=Mout

2000kg=2000kg

Material balance on the sieve

Assumed that 2% of the feed is removed therefore 40 kg is removed.

Material balance on the mills

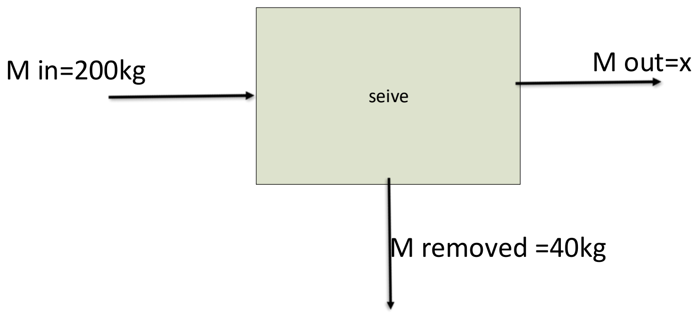
Assumed that Mass entering is the same as mass exiting

Min=M out

2000kg=2000kg

Material balance on the sieve

Assumed that 2% of the feed is removed' therefore 40 kg removed



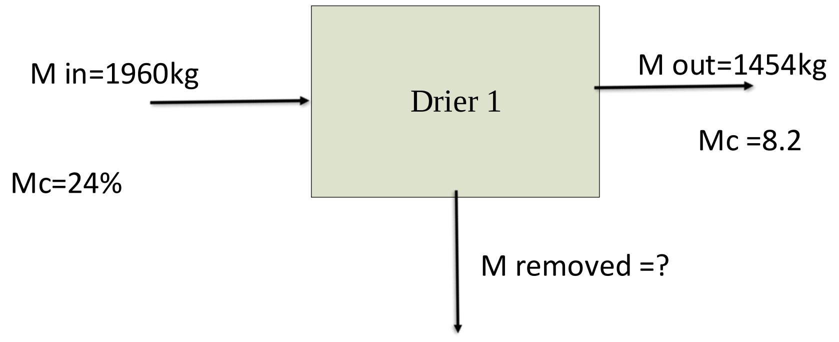
Min=Mout+ MRemoved, since Mremoved =2%*Min

2000kg= X +0.02*(2000kg)

X=2000kg-40kg

X=1960kg

Material balance on the first drier.



Input =out put

Min=Mout + Mremoved

Mremoved= Min-Mout

=1960kg-1454.3kg

=505.68kg

Mremoved=MS.L+MM.C

If it is assumed that, the first drier has a 1% system loss (S.L),

One% of 1960kg =196kg

Therefore, the mass lost due to vaporization of the moisture ($M_{M.R}$)

MM.R = Mremoved - MS.L

=505.68kg-196kg

=309.68kg

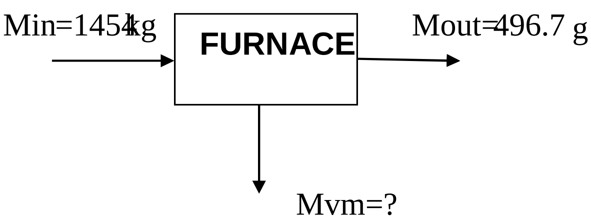
Which is a 15.8%% moisture removed from the total moisture content (M.C.) of the Bamboo.

Therefore 24%-15.8%=8.2% the moisture content of the bamboo.

Material balance on the furnace

The carbonization yield is 32.5% (from laboratory calculation)

That means 32.5% of the feed is converted to charcoal.



M out=32.5% Min charcoal+1.67%Min vinegar

M out =472.55kg+24.15kg=**496.7kg**

Where Mvm is the mass of volatile matter,

Min =Mout

Min=Mcharcoal + MV.M

$M_{V.M}$ = Min - Mcharcoal

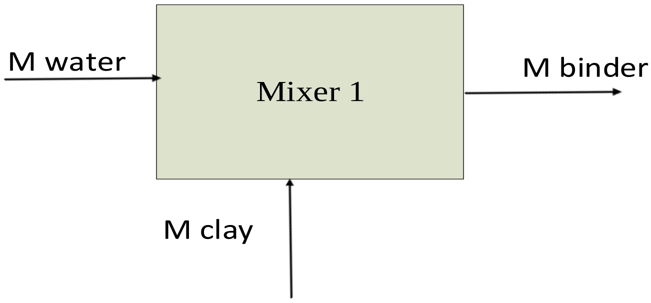
=1454kg-578.7kg

=875.3kg

Material balance on the first mixer

From our laboratory experiments, we know that the ratio of charcoal to clay is 3:1, therefore the amount of clay needed for 578.7 kg of charcoal would be 192.9kg Also from literature we know that for 100kg of charcoal 30-35kg of water is needed 100kg of charcoal=32.5kg of water 578.7kg of charcoal=?

The amount of water needed is 188.1kg



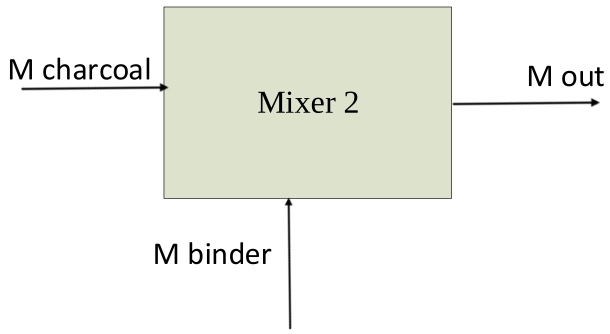
Min=Mout

M_{binder}=Mclay + Mwater

=192.9kg+188.1kg

=380.9kg of binder

Material balance on second mixer



Min=Mout

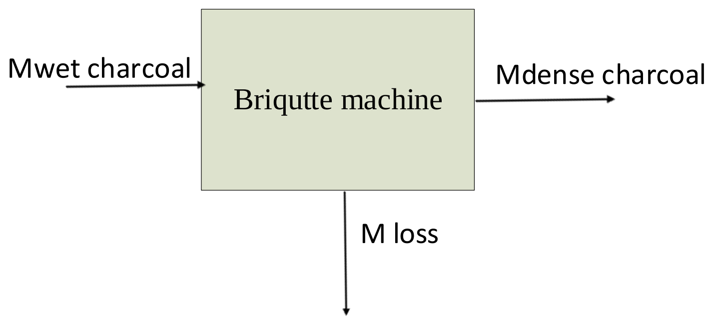
Mout= Mcharcoal + Mbinder

=596.7kg+380.9kg

=977.6kg

Material balance on the briquetting press

The briquetting process is a mechanical operation, so there is a loss of water (Mloss) in the process due to the densification effect of the machine.



Min=Mout

$M_w=M_d+M_l$

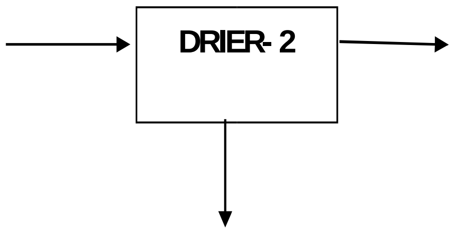
Mloss=Mw-Md

=959.7kg-834.9kg

=124.75kg

Mass balance on the second drier

M dense charcoal= 834.9kg M dry charcoal= 762.3kg



Mml=?

Min=Mout

Min=Mml + Mdc, where Mml is mass of moisture loss and Mdc is mass of dry charcoal Mml =Min – Mdc

=834.9kg-762.3kg

= 72.6kg

Therefore, the moisture content of the dry charcoal calculated as:

$$M.C = \frac{\min - mdc}{min}$$

$$Mc = \frac{834.9kg - 762.3kg}{834.9kg} * 100\%$$

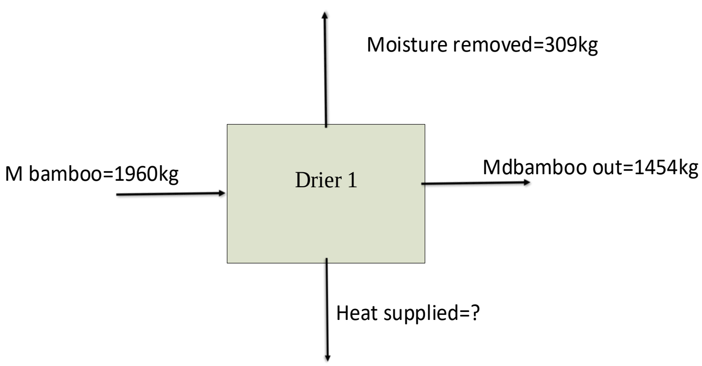
=***8.7%***

5.1.2 Energy Balance

0 0 0

Energy output= Energy input + Energy generation – Energy consumption – Energy accumulation

Energy balance on the first drier



Mass of the bamboo 1960kg

Specific heat capacity of bamboo=1.8 kj/kgk (IngHeinoVest, 2003)

Change in temperature =36^{o}c-25^{o}c

$$Q_{supplied}=mcp\Delta T + Q_{latent\ heat}$$

$$=mcp\Delta T + m_w h_{fg} \text{ (hfg from steam table @ 90°c)}$$

$$= (1960kg*1.8kj/kgk*55k) + (309.68kg*2307.94kj/kg)$$

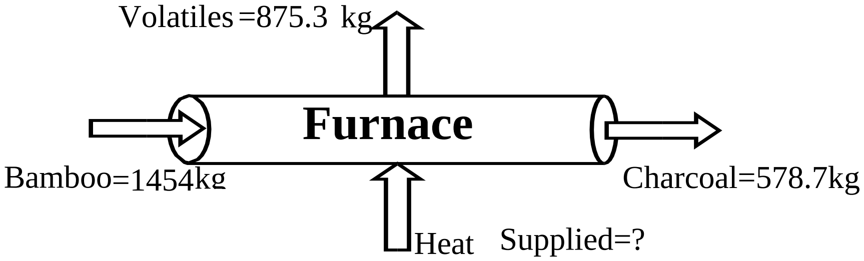
=908,762.86kj

P=Q/t, it took 24 hrs to dry

= 908,762.86kj /900sec

=1,009.7kw

Energy balance on the furnace



Mass of Bamboo entering the kiln =1454kg

Specific heat capacity of bamboo=1.8kj/kgk

Change in temperature =450^{o}c-36^{o}c

$$Q=mcp\Delta T$$

$$=1454kg*1.8kj.kgk*414k$$

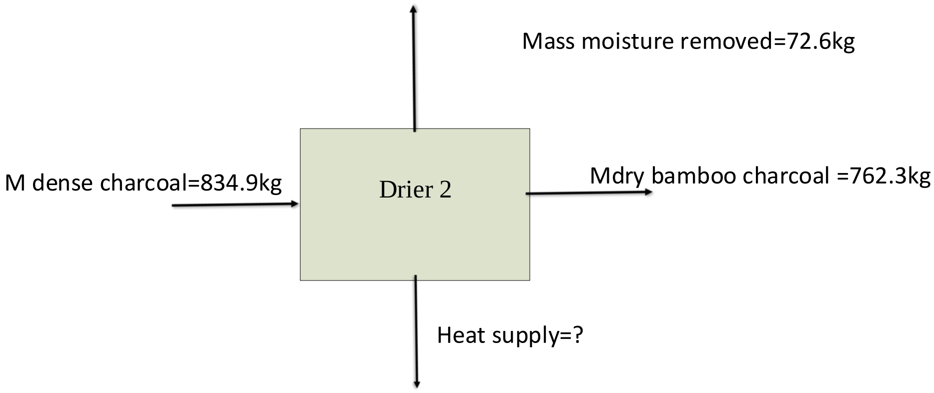
=1,083,520.8kj

The power can calculated by

$$P= \frac{Q}{t} = 1{,}083{,}520.8kj/900sec$$

=1203.9kw

Energy balance on the second drier 2



Mass of dense charcoal=834.9kg

Mass of moisture removed (Ml) =72.6kg

Cp of the clay=1.381kj/kgk

Cp dense charcoal=2kj/kgk

$\Delta T=90^{o}c-25^{o}c$

$=65^{o}c$

5.2 Sizing and Design on the Major Equipment

Sizing on the first dryer

Density of the bamboo=210kg/m^3

Mass of the bamboo=1960kg/m^3

Volume of the tank = Mass of the bamboo/Density of bamboo

=1960kg/210kg/m^3

=9.33m3

Sizing on the kiln

Density of bamboo =210kg/m^3

Mass of bamboo=1454kg

Volume of the kiln= Mass of bamboo/Density of bamboo

=1454kg/210kg/m^3

=6.923m^3

Sizing on the first mixer

Density of water@25^{o}c =1000kg/m^3

Mass of water= 188.1kg

Density of clay=817kg/m3

Mass of clay=192.9kg

Volume of mixer= V water + V clay

= (M water/ρ water) + (Mclay/ρ clay)

= ($188.1kg/1000kg/m^3$) + ($192.9kg/817kg/m^3$)

=***$0.42m^3$***

Thickness design

Assumptions

Assuming the mixer is a cylindrical vessel

H: D =1.5

Pi=14bar

Welded joint efficiency, (E) =1

Material of construction =carbon steel

Maximum allowable stress for carbon steel @ 100°F, (S) =12.9psi or $89N/mm^3$

$V= (\pi D^2H)/4$, H=1.5D

$=0.42m^3$

$= (3.14*1.5*D^3)/4$

$0.391m^3=D^3$

D=0.71m it is approximated to 1m

H=1.5*D =1.5m

$$t = \frac{PiDi}{2SE - 1.2Pi}$$

$$t = \frac{(1.43 * 1 * 10\hat{}3mm)}{(2 * 89 * 1) - (1.2 * 1.43)} = \mathbf{8mm}$$

Sizing on the second mixer

Density of the binder = $\frac{mass\ of\ binder}{density\ of\ binder} = \frac{380.9kg+17kg}{0.42m\hat{}2} = 906.9kg/m\hat{}3$

Mass of the binder=380.9kg

Density of charcoal=$1075kg/m^3$(calculated in the laboratory)

Mass of the charcoal=578.7kg

Volume of the mixer =volume of the binder + volume of the charcoal

$$= \frac{mbinder}{density\ of\ binder} + \frac{mcharcoal}{density\ of\ charcoal}$$

$$= \frac{380.9kg}{914.17kg/m^3} + \frac{578.7kg}{1075kg/m^3} = \mathbf{0.95m^3}$$

5.3 Plant design and feasibility

Purchased equipment cost

Table 5.1 Purchased equipment cost

Equipment	Quantity	Construction material	Cost(ETB)
Furnace	1	Carbon steel	210,000
Sieve	1	Carbon steel	6,488
Dryer	2	Carbon steel	87,470
Miller	1	Carbon steel	86,631.5
Mixer	2	Carbon steel	15,000
Briquetting machine	1	Carbon steel	721,627.5
Total			**1,113,717**

[1] *Source:* (Alibaba, 2020)

All the formulas taken here is cited from (SINNOT, 2005)

Purchased equipment cost (PEC) =1,113,717ETB

Installation (25-55% of PEC) we take 40% of PEC= ***445,486.8ETB***

Instrumentation and control (6-30%) we take 18% of PEC=***200,469.06ETB***

Electricity (10-40% of PEC) we take 25% of PEC = ***278,429.25ETB***

Building process and auxiliary (10-80% of PEC) we take 45% of PEC=***501,172.65ETB***

Land (4-8% of PEC) we take 6% of PEC=***66,823.02ETB***

Service facilities 15% of PEC=***167,057.55ETB***

Yard improvements 10% of PEC=***111,371.7ETB***

Table 5.2 Total direct cost

ITEM	COST(ETB)
Purchased Equipment Cost Delivered	1,113,717
Purchased Equipment Installation	445,486.8
Instrumentation And Control	200,469.06
Electrical (Installed)	278,429.25
Building (Including Service)	501,172.65
Land	66,823.02
Service Facilities (Installed)	167,057.55
Yard Improvements	111,371.7
Total Direct Costs	***2,884,527.03***

Engineering and supervision (5-30% of DC) we take 15% of DC=***432,679ETB***

Construction expense we take 12% of DC =***346,143.24ETB***

Contractor fee we take 6% of DC =***173,071.62ETB***

Contingency we take 10% of DC=***288,452.7ETB***

Table 5.3 Total indirect cost

ITEM	COST(ETB)
Engineering & Supervision	432,679
Construction Expense	346,143.24
Contractor Fee	173,071.62
Contingency	288,452.7
Total	***1,240,346.56***

Fixed capital investment =total direct costs + total indirect costs

FCI= 2,884,527.03+1,240,346.56

=***4,124,873.59ETB***

Total capital investment = fixed capital investment + working capital investment

But for most plants the working capital investment=0.15(total investment cost)

TCI=FCI + WCI

TCI=FCI+0.15(TCI)

TCI=FCI/0.85 =4,124,873.59/0.85

=4,852,792.46ETB

WCI=0.15(TCI) =.15*4,852,792.46

=***727,918.87ETB***

Total production cost estimation=manufacturing cost + general expense

Manufacturing cost=direct production cost + fixed charge + plant overhead cost

Fixed charge= depreciation + local taxes + insurance

Depreciation=10% (FCI) =10% (4,124,873.59)

=412,487.36ETB

Local taxes, [1-4%] of FCI we take 2.5% (FCI)

Local taxes=2.5%FCI =2.5%*4,124,873.59ETB

=***103,121.84ETB***

Insurance =0.7% (FCI), [0.4-1%]

Insurance=0.7%*4,124,873.59ETB

=***28,874ETB***

Fixed charge=13%*FCI =13%*4,124,873.59ETB

Fixed charge =***536,233.57ETB***

Direct production cost

Raw materials Assumption

Plant capacity =6500kg per day of charcoal

Working days =300days

Production rate per year=1,950,000kg/yr.

Daily consumption of bamboo=20,000kg/day

Annual consumption of bamboo=6,000,000kg/yr

Cost of bamboo=800ETBbirr/ton

Cost for bamboo per year =4,800,000ETB/yr

Daily consumption of clay=6666.67kg/day

Annual consumption of clay=2,000,000kg/yr

Unit cost of clay=0.04birr/kg

Cost of clay=80,000birr/yr

Table 5.4 Cost of operating labor (ol)

Equipment	*Quantity*	*Unit cost annually (ETB)*	*Total cost annually (ETB)*
RM preparation	6	40,000	240,000
Kiln	4	50,000	200,000
Mixer 1	2	50,000	100,000
Mixer 2	2	50,000	100,000
Miller	2	50,000	100,000
Sieve	2	50,000	100,000
Total			***840,000***

Direct supervisory & clerical labor = (10-25%) OL, we took 12%

= 12% (840,000ETB)

=100,800ETB

Utilities cost = (10-20%) FCI, we took 15%

= 0.15*(4,124,873.59ETB)

=618,731ETB

Maintenance and repair (M&R) = 2-10% FCI, we took 6%

=6% (4,124,873.59ETB)

=247,492ETB

Operating supplies = 15% (M&R)

= 37,124ETB

Laboratory charges= 10-20% (OL), we took 15%

=15% (840,000ETB)

=126,000ETB

Total Direct Production Cost

TDPC=RMC+ OLC+DSC+UC+MC+COS+LC

$$= (4{,}880{,}000 + 840{,}000 + 100{,}800 + 618{,}731 + 247, +37{,}124 + 126{,}000)ETB$$

=6,850,147ETB

Plant overhead costs

Plant overhead cost= (50%) (Operating cost + supervision + maintenance)

$$= 0.5 * (840{,}000 + 100{,}800 + 247{,}492)ETB$$

=594,146ETB

Manufacturing cost=Direct production cost+ Fixed charges +plant overhead cost

= (6,850,147+ 536,233.57+594,146) ETB

=7,980,526.57 ETB

General expenses (G exp.)=50-70% (total operating labor + supervision + maintenance), we took 60%

Gexp. =60 %(840,000 + 100,800 +247,492) ETB

=712,975 ETB/yr

Total production cost= Manufacturing cost + General Expense

=7,980,526.57+ 712,975

=8693501.57ETB

$$Annual\ product = 1{,}950{,}000 kg/yr$$

Unit production cost per kilo

He.re, unit cost of production assuming that there is no production cost for bamboo vinegar

UCP= total production cost/annual production rate

By assuming 1kg=1litre of bamboo vinegar in terms of weight since, density of vinegar is equal to that of water.

$$= \frac{8{,}693{,}501.6ETB}{\frac{1{,}950{,}000kg}{yr} + 100{,}000L/yr}$$

= *4.24ETB/kg*

Sales

Assuming the Unit selling price of charcoal to be 5ET/kg

Annual product sales = $Annual\ production\ rate * unit\ selling\ price$

APS=$1{,}950{,}000kg/yr * 100{,}000litre/yr$

=*11,750,000ETB/yr*

The service life of the plant is 15 years and fixed capital investment (FCI) of this plant is 4,124,873.6 ETB taking salvage value zero.

From this depreciation of the plant is:

Depreciation=$\frac{TFC}{Plant\ life}$

$=\frac{4{,}124{,}873.59ETB}{15yr}$

=***274,991.57 ETB/yr***

Annual gross profit=Annual sales-Total product cost-Depreciation

= (11,750,000-8,693,501.57-274,991.57)ETB/yr

=*2,781,506.86ETB/yr*

The current Ethiopian tax to be 15%

Net profit = Annual gross profit*(1-tax rate)

=2,781,506.86 ETB (1-0.15)

=2,364,280.83 ETB

Profitability standard

Minimum acceptable rate of return (MAR) for new capacity with established corporate with low level risk =12%, ROI > MAR

Return on Investment (ROI)

RIO=$\frac{NP}{TCI} * 100\% = \frac{2{,}364{,}280.83ETB}{4{,}852{,}792.46ETB} * 100\%$

=48.7%

ROI>MAR = 48.7%>12%

Payback and payback reference

We need to determine annual cash flow to get pay back reference

Annual cash flow (ACF) = Net profit + depreciation

ACF = (2,364,280.83+274,991.57)ETB/yr

=2,639,272.4 ETB/yr

Payback period (PBP)

$$PBP= \frac{TCI}{ACF}$$

$$\text{Payback period} = \frac{4{,}852{,}792.46ETB}{2{,}639{,}272.4ETB/yr}$$ ***=1.84 year***

The project is feasible since PBP<5 (SINNOT, 2005)

Minimum unit cost= [Total production cost]/ [annual products]

= (8,693,501.57/yr.)/ (11,750,000/yr.)

=0.74 ETB/kg

The assumed Price must be greater than minimum unit cost of the product.

Recovery (Re) = working capital + salvage value = working capital

=727,918.9ETB

Net Profit Worth (NPW) =$(ACF(1+i)^n - 1) + Re(1+i)\hat{} - n)/(i(i+1)$^n)

$$= 2{,}639{,}272.4((1+.12)^{15} - 1) + \frac{727{,}918.9(1{+}.12)\hat{}{-}15}{(.12*(1{+}.12)^{15})}$$

=18,178,183.61ETB

Where interest (i) =12% Service life (n) = 15years

NPW – TCI is positive the project is feasible or negative if the project is infeasible.

= (18,178,183.61-4,852,792)

=***13,325,391ETB*** +VE therefore project is feasible.

Cash =purchased cost + raw materials + utility cost + operating labor + General expense

= (1,113,717+4,880,000+618,731+840,000+712,975) ETB

=8,165,423 ETB

CHAPTER SIX

SITE SELECTION

Plant layout for bamboo charcoal production

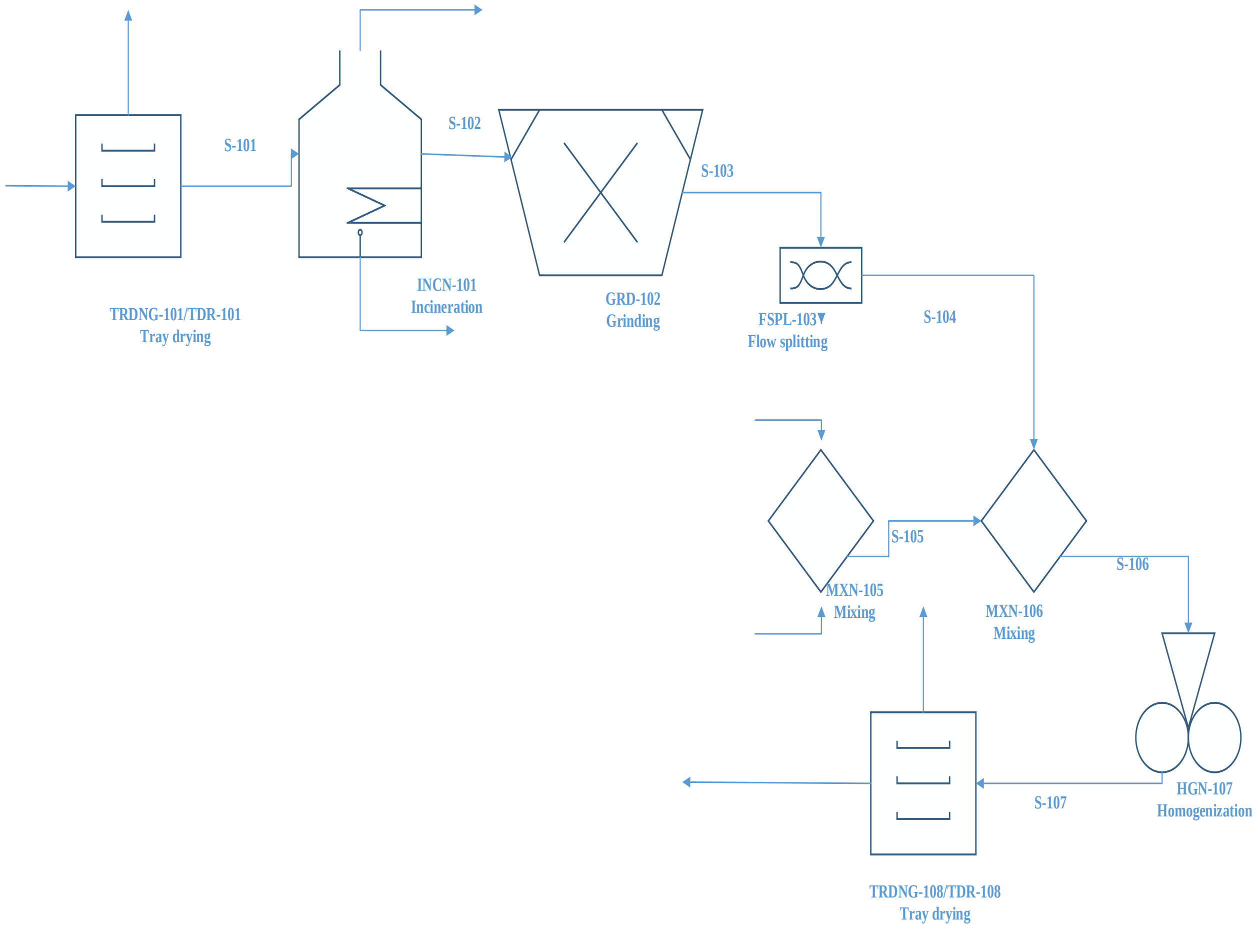


Figure 6.1 Plant layout for bamboo charcoal production

The geographical location of the production site has an influence on the profitability of the project, the exposure of the product to the customers. When choosing the Site of the Charcoal Briquetting Factory. You should select the size of the site according to the capital prepared for investment. However, briquette machine and carbonization furnace needs 25~30 square meters and the storehouse needs 40~60 square meters, plantation around 5 hectare.

The following are the main criteria's that we used to select the production site.

- Availability of raw material (based on climate condition and other parameter is tested and proved that Chanco is suitable for bamboo plantation)
- Availability of market.

- Transportation facilities
- Supply of utility. E.g. (electricity, water…)
- Water supply
- Climate condition

Based on the above criteria the production site was selected' to be Chanco. Around Addis Ababa city.

Raw material

Availability of Raw material is the main site selection criteria the main raw material of our project is bamboo and clay. Bamboo is the plant that growth in moderate climate zone. They available bamboo in Chanco but its only sample not adequate for production of charcoal by communicating with Chanco forest affair they tell us to afforestation around 6 hectare bamboo within next 2 years. Clay is cheapest and widely available at Chanco.

Availability of market

Availably of market is the main characteristics for the selection production area. For our production of charcoal, we think that we will get a good market opportunity for many reasons.

- ✓ Better fuel characteristics with cheapest price at local
- ✓ Free from carbon emission.
- ✓ Newly introduced for consumers and accepted.
- ✓ High demand in cement factory and the site is near to Ethio cement PLC and Debra MIDROK.

Transportation facilities

Transportation facilities easily available no need for longer transportation since site is selected by considering to plant raw materials and for product selling its near to demand.

Energy and utilities

A power source is needed for drying process, in furnace, grinding motors, lighting, and for general purpose.

- Grinding motors – an electric power is required during grinding process of raw materials (Bamboo and clay)
- Steam for drying – steam is needed during the process of drying and the steam generates in tube boiler with economical fuel.

Water supply

Water is required for the general purpose, plant growth and it will be taking from local water supply like river and underground water source.

Climate

Climate is also the main site selection criteria for plant operating in health and for raw material growth. Based on this Chanco is moderate climate condition that are better for growth of bamboo and plant operating condition.

Availability of land

Availability of land also the main criteria to select the site. Here since we need land for plantation and for plant site, it needs large land. Therefore, it is possible to get larger land with affordable price at Chanco.

CHAPTER SEVEN

ENVIRONMENTAL IMPACT

Using bamboo briquette charcoal as a source of energy in cement pyro processing has several positive impacts. Not only the positive impacts, there are also a few negative impacts related to the environment.

7.1 Positive impacts

- Less cost than that of natural coal
- Less greenhouse gas emission
- Using bamboo as alternative fuel leads for afforestation and minimize carbon emission since its better carbon absorber than that of other plant.
- Quality of both surface and groundwater will improved by reducing land erosion through increase Afforestation practice.
- By replacing polluting fossil fuels, environmental quality is improved and the impacts of climate change will reduced.
- Minimize the fear of diminished coal.
- Minimize the fear of political crises to import the coal from abroad
- Practicing partially substitution of coal required in cement pyro processing may leads to fully shift' the use of fossil fuel in cement pyro processing by using modern technology.

7.2 Negative impacts

To prepare bamboo charcoal briquette in higher production rate it leads for afforestation of huge hectare with bamboo this is leads for land catchment.

CHAPTER EIGHT

CONCLUSION AND RECCOMENDATION

8.1 CONCLUSION

This work was carried out to examine the effect of time, temperature, charcoal to binder ratio, and charcoal to coal ratio on the quality of charcoal briquette from bamboo to substitute coal required in cement pyro processing. The bamboo carbonization time (10min, 15 min, 20 min) and temperature (350^{o}c, 450^{o}c).

After different trials was made to find out at which temperature and at what carbonizing time that the best charcoal yield can be obtained, it was concluded that carbonizing a bamboo with a moisture content of 8.2% for 15min and at a temperature of 450^{o}c gives a 32.5% charcoal yield. The quality of the briquettes to use in cement pyro processing is also effected by the percent of charcoal to binder ratio this studies tasted by using(90:10, 80:20 and 70:30) tasted based on standard coal required in cement pyro processing and concluded that the 80:20 the better charcoal properties (better combustion characteristics with good bind). The coal to charcoal mixing ratio was be tested on (90:10, 85:15, 80:20) to determine the coal with bamboo charcoal in the limit of standard coal required in cement pyro processing. From our discussion, the mixture (85:15) coal to bamboo charcoal is better percent of mixture. The only parameter that leads for mixing of coal with bamboo charcoal rather than whole shift to bamboo charcoal is that of higher fixed carbon of bamboo charcoal. Higher fixed carbon indicate that the presence of higher mineral matter that minimize the combustion performance of fuel. The fuel with high fixed carbon the higher caloric value but above the limit of higher fixed carbon it become ignite and difficult for simply firing in cement pyro processing. From our study all parameter indicates that the bamboo charcoal is potentially substitute fully for coal required in cement pyro processing except that of bamboo charcoal having higher fixed carbon that leads ignite for firing in cement pyro processing. Generally, 15% of bamboo charcoal will promisingly substitute for coal required in cement pyro processing without need of large capital investment, with the characterization of standard limit, cost effective reliable minimize shortage of foreign currency and greenhouse gas emission. The project indicate that rate on return 48.7% and payback period of 1.84 year that is feasible and most profitable any interested governmental organization or private sector could invest on it.

8.2 RECOMMENDATION

Further study have to be done to improve production of charcoal from bamboo at high yield by maximizing run (temperature, time, binder effect, mixing ratio etc...). In this study caloric value was been taken the average from literature review due to lack of bomb caloric meter to study the caloric value of bamboo charcoal, since caloric value is the main criteria to be studied for substitution of coal required in cement pyro processing it must be studied. From our conclusion, the only characterization that leads for partial substitution of coal required in cement pyro processing than whole shift to bamboo charcoal is due to that of bamboo charcoal high fixed carbon present in bamboo charcoal. Further study needed on the way of minimizing the fixed carbon in bamboo charcoal briquette or by design modification of cement pyro processing, firing process of fuel with higher fixed carbon. During, production of bamboo charcoal there is a byproduct called vinegar, which collected from the smoke condensation during carbonization process. In case of our study the vinegar collected is not much enough as we revise from literature review that is due to lack of miss installation of condenser on furnace. For properly, know the yield of this byproduct furnace properly installed with condenser must be needed.

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APPENDIXES

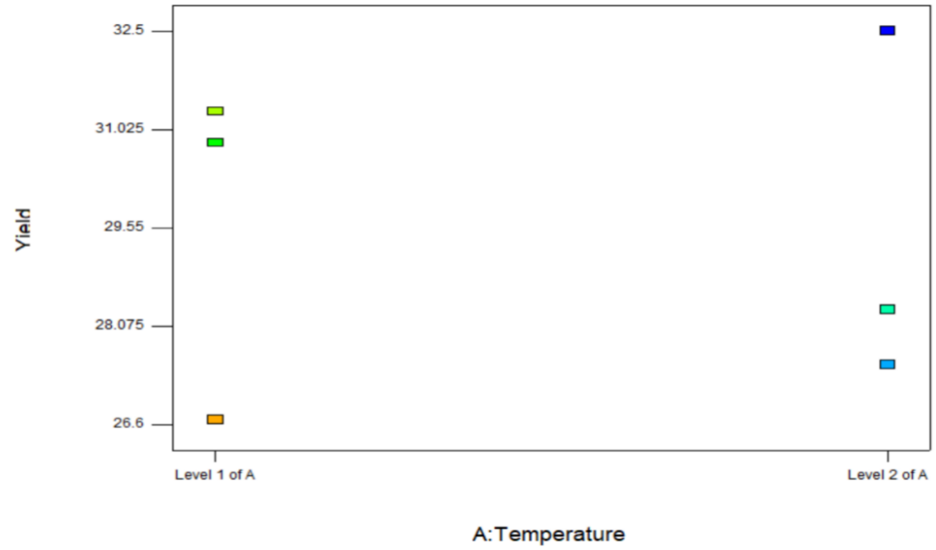

Figure A1.1.Effect of temperature on yield

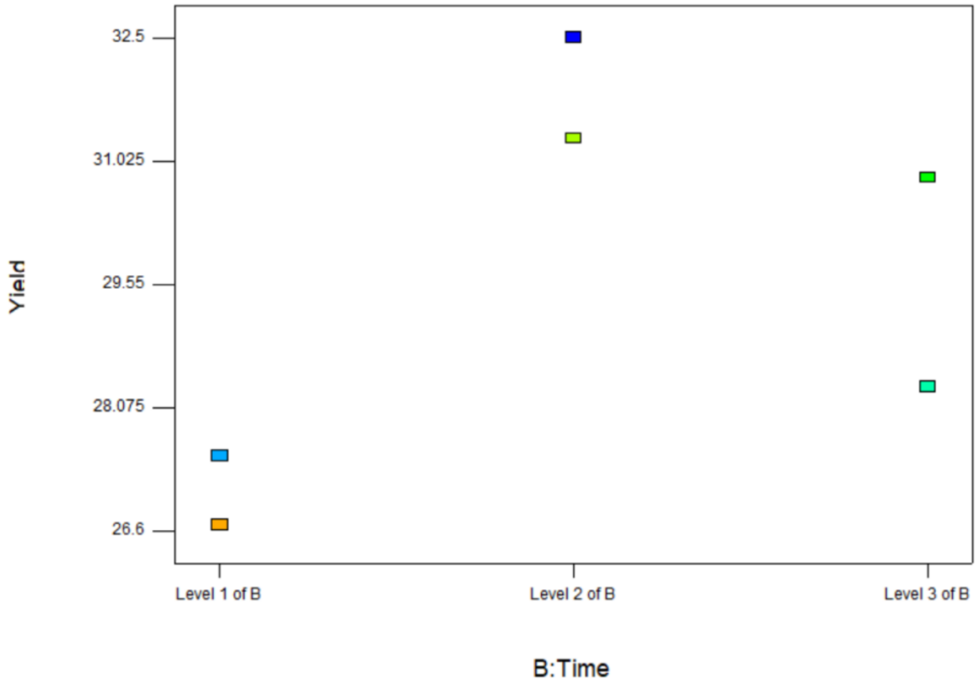

Figure A1.2 Effect of time on yield.

Design Summary

Study Type	Factorial	**Runs**	6
Initial Design	Full Factorial	**Blocks**	No Blocks
Center Points	0		
Design Model	2FI		

Factor	**Name**	**Units**	**Type**	**Low Actual**	**High Actual**		
A	Temperature	degree celcius	Categoric	Level 1 of A	Level 2 of A	**Levels:**	2
B	Time	minutes	Categoric	Level 1 of B	Level 3 of B	**Levels:**	3

Response	**Name**	**Units**	**Obs**	**Analysis**	**Minimum**	**Maximum**	**Mean**	**Std. Dev.**	**Ratio**	**Trans**	**Model**
Y1	Yield	%	6	Factorial	26.67	32.50	29.52	2.14	1.22	None	Mean

Figure A1.3 Design summary.

Table A.1 standard limit of coal characterization for cement pyro process.

	CV	MC	VM	FC	Ash content
Coal	5455.5	4.1	20-50	37-63	12.1-42

Source: (World meters, 2016).