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**PYROLYSIS OF AGRO WASTE FOR PRODUCTION OF CHARCOAL
BRIQUETTES**

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Declaration

We the under signed declare that this project entitled as “pyrolysis of agro waste for production of charcoal briquette” is a result of our efforts and hard work. This project has never been presented for a degree at any university and that all the source of materials used for the project has been cited and duly acknowledged. This is to certify that the project Prepared by:

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Abstract

Wood charcoal has been the primary fuel for cooking in Ethiopia because it is cheap and easily available. However, using wood charcoal has consequences on health and pollution due to smoking. This study aims at providing a biomass as an alternative to wood charcoal using agricultural wastes (cob and sawdust) converted into charcoal briquettes to provide much needed source of cheap fuel that is cleaner in burning.

In this project method for carbonizing of charcoal briquette from agricultural waste (cob and saw dust) with locally available material and investigation side product essential charcoal briquette is carried out. The briquette was carbonized from cob and sawdust by employing the combustion steps. During carbonization process the smoke changes its color from dark grey smoke to white yellow a more translucent hue, this color changing is a critical point which implies the ending of combustion of gas and the beginning of combustion of the char. By visual observation we then controlled the combustion of the solid char from turning in to ash. The char is then milled, bind with different agents (starch and rice water) and molded then dried at 105°C for 6hr in an oven.

The fuel briquette quality evaluated in a participatory manner in terms of yield, ash content, moisture content, time taken to ignite, time needed to cook and time taken to burn completely to ash. sawdust briquette was received the highest yielding (9%). In terms of smoke realize during burning and cob with binding agent starch and saw dust with binding agent starch briquette has higher quality and has no smoke but sawdust with binding agent rice water briquette does. Therefore, we conclude that using sawdust as a raw material and starch as binding agent is preferable.

Investigation on the technical and economic feasibility of the work for briquette production was performed. Results from the feasibility study indicated that the proposed work was feasible with return on investment (ROI) 14% and the payback period of the project is estimated to be 3.2 years.

Key words; Agricultural Waste, Briquettes, Carbonization Process, Binding Agent

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List of Abbreviations and Acronyms

PVM	percentage volatile matter
PAC	percentage ash content
PFC	Percentage Fixed carbon
PMC	Percentage moisture content
TIC	Total investment cost
WC	Working capital
FCI	Fixed capital investment
R.O.I	Return on investment
NPV	Net Present Value
TCI	Total Capital Investment
PBP	Payback period
NPW	Net present worth

CHAPTER ONE INTRODUCTION

1.1 Background

Charcoal has been manufactured since pre-historic times. Around 5,300 years ago, a hapless traveler perished in the Tyrolean Alps. Recently, when his body was recovered from a glacier, scientists found that he had been carrying a small box containing bits of charred wood wrapped in maple leaves. The man had no fire-starting tools such as flint with him, so it appears that he may have carried smoldering charcoal instead.

As much as 6,000 years ago, charcoal was the preferred fuel for smelting copper. After the invention of the blast furnace around 1400 A.D. charcoal was used extensively throughout Europe for iron smelting. By the eighteenth century, forest depletion led to a preference for coke (a coal-based form of charcoal) as an alternative fuel. [1]

Charcoal's transition from a heating and industrial fuel to a recreational cooking material took place around 1920 when Henry Ford invented the charcoal briquette. Not only did Ford succeed in making profitable use of the sawdust and scrap wood generated in his automobile factory, but his sideline business also encouraged recreational use of cars for picnic outings. Barbecue grills and Ford Charcoal were sold at the company's automobile dealerships, some of which devoted half of their space to the cooking supplies business [2].

Historically, biomass briquetting technology has been developed in two distinct directions.

Europe and the United States has pursued and perfected the reciprocating ram/piston press while Japan has independently invented and developed the screw press technology. Although both technologies have their merits and demerits, it is universally accepted that the screw pressed briquettes are far superior to the ram pressed solid briquettes in terms of their storability and combustibility. Japanese machines are now being manufactured in Europe under licensing agreement but no information has been reported about the manufacturing of European machines in Japan.

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

Many of the developing countries produce huge quantities of agro residues but they are used inefficiently causing extensive pollution to the environment. The major residues are rice husk, coffee husk, coir pith,

jute sticks, bagasse, groundnut shells, mustard stalks and cotton stalks. Sawdust, a milling residue is also available in huge quantity. Apart from the problems of transportation, storage, and handling, the direct burning of loose biomass in conventional grates is associated with very low thermal efficiency and widespread air pollution. The conversion efficiencies are as low as 40% with particulate emissions in the flue gases in excess of 3000 mg/Nm³ in addition, a large percentage of unburnt carbonaceous ash has to be disposed of. In the case of rice husk, this amounts to more than 40% of the feed burnt. As a typical example, about 800 tons of rice husk ash are generated every day in Ludhiana (Punjab) as a result of burning 2000 tons of husk. Briquetting of the husk could mitigate these pollution problems while at the same time making use of this important industrial/domestic energy resource.

Biomass is plentifully available in Ethiopia specially the rural regions. It is already being used by the rural people as a major source of energy, mainly in cooking food, which constitutes almost over 90% of the total energy consumption [3]. Assuming that the population of Ethiopia are about 105[4] million in Ethiopia, 85% of the population in Ethiopia lives in rural area [5], and assuming that each family consists of five persons and uses annually about 3 tons of biomass as fuel, one comes to the figure of about 53.55 million tons of biomass utilized annually only for domestic cooking in rural areas only. The urban populations of Ethiopia (15%) are also uses biomass and assuming that 78% of the urban population uses this biomass as a fuel, one comes to the figure of 7.26 million tons of biomass as fuel. There is also a third dimension to fuel use, and that is the pollution arising due to burning of biomass. As cooking is done within the confines of a house, the pollution caused by cooking fires is generally not taken very seriously. But according to statistics published by the World Health Organization, annually about 500,000 women and children die prematurely in India due to air pollution caused by cooking fires in rural households [6]. Considering the fact that almost 90% of our population is in rural areas, giving the rural women a cleanly burning bio fuel is a major task.

One way of tackling the pollution and health problems of the consumers of wood charcoal is producing briquette charcoal using agricultural wastes by making simple extruder and effective carbonize.

Agricultural waste is an ideal source of charcoal. When one harvests any crop, one generally harvests only grain, fruits, coffee, pods, and tubers. This constitutes only about 30 to 40% of the total biomass. This means that about 60 to 70 % of the total agricultural biomass is the waste biomass produced annually in Ethiopia. A small part of it is used as fodder for cattle, but the rest is just wasted. The produced char is healthy, environmental-friendly and economical. Briquettes can be produced with a density of 1.2 g/cm³

from loose biomass of bulk density 0.1 to 0.2 g/cm³ These can be burnt clean and therefore are eco-friendly and also those advantages that are associated with the use of biomass are present in the briquettes. Briquetting technology is yet to get a strong foothold in many developing countries because of the technical constraints involved and the lack of knowledge to adapt the technology to suit local conditions. Overcoming the many operational problems associated with this technology and ensuring the quality of the raw material used are crucial factors in determining its commercial success. In addition to this commercial aspect, the importance of this technology lies in conserving wood, a commodity extensively used in developing countries and leading to the widespread destruction of forests.

1.2 Statement of the problem

By using the waste as a fuel source that slows the advance of deforestation by eliminating the need to cut down trees for fuel wood and to improve the burning process of dry agricultural waste to produce charcoal briquette. The forceful idea for doing this project is the raw materials are wastes (corn cob and sawdust) which has low energy content as they burn simply by fire. To use without smoke and with higher energy content, we want to change into advanced usable form of charcoal briquette.

The smoke produced by wood fire in an indoor cooking environment pollution can lead to multiple respiratory illnesses, therefore using briquette charcoal solves this problem because it is smokeless fuel.

1.3 Significance of the research

Some of the benefits of using agricultural wastes, such as sugarcane trash, grass, saw dust and so on, as an alternative cooking fuel are described as follows: Unlike wood, briquette charcoal is a smokeless fuel. The smoke produced by wood fires in an indoor cooking environment can lead to multiple respiratory illnesses. Instead of burning agricultural wastes in the fields, using the wastes as a fuel source slows the advance of deforestation by eliminating the need to cut down trees for fuel wood. Charcoal briquettes are viewed as an advanced fuel because of its clean-burning nature and the fact that it can be stored for long periods of time without degradation.

1.4 Scope of the project

In our project by using agro waste (sawdust and cob) as a main raw material for production of charcoal briquette. The production of charcoal briquette is by using carbonation process. The experiments were carried out in a furnace which can heat up to a temperature of about 450°C. The experiment is to determine the ash content, burning time, moisture content, PH and yield of the product (charcoal briquette). This project will address high quality charcoal briquette to the society and will solve environmental, health and economic problems by converting agricultural waste (sawdust and corn trash) into useful product

(charcoal briquette) within laboratory scale and the small scale production of charcoal briquette would be scaled up into large industrial scale. And also we have to do material and energy balance.

1.5 Objectives

1.5.1 General objective

- ✓ The general objective of this project is to produce charcoal briquette by using pyrolysis of agro waste.

1.5.2 Specific objectives

- ✓ To compare the yield of charcoal briquette obtained from corn trash(cob) and sawdust.
- ✓ To characterize the property of cob briquette and sawdust briquette.
- ✓ To produce economically feasible charcoal briquette from cheap raw material.

CHAPTER TWO LITERATURE REVIEW

2.1 History of charcoal briquette

Historically, charcoal was produced by piling wood in a cone-shaped mound and covering it with dirt, turf, or ashes, leaving air intake holes around the bottom of the pile and a chimney port at the top. The wood was set afire and allowed to burn slowly; then the air holes were covered so the pile would cool slowly [7].

North east institution of science and technology(CSIR) they state that the single-use charcoal pit can be replaced by a stone, brick, or concrete kiln that would hold 25-75 cords of wood (1 cord = 4 ft. x 4 ft. x 8 ft.). A large batch might burn for three to four weeks and take seven to 10 days to cool. This method of charcoal production generates a significant amount of smoke. In fact, changes in the color of the smoke signal transitions to different stages of the process. Initially, its whitish hue indicates the presence of steam, as water vapors are driven out of the wood. As other wood components such as resins and sugars burn, the smoke becomes yellowish. Finally, the smoke changes to a wispy blue, indicating that charring is complete; this is the appropriate time to smother the fire and let the kiln's contents cool [8].

Henry Ford, Department of Mechanical Engineering developed an alternative method of producing charcoal, Called the retort method, this involves passing wood through a series of hearths or ovens. It is a continuous process where in wood constantly enters one end of a furnace and charred material leaves the other; in contrast, the traditional kiln process burns wood in discrete batches. Virtually no visible smoke is emitted from a retort, because the constant level of output can effectively be treated with emission control devices such as afterburners [9]. The article demonstrates the possibility of producing both household charcoal briquettes with a minimum use of starch as a binding material, and technological briquettes with no added binder [10].

The paper presents the results of the research on thermos briquetting of dense brown and gaseous coals from Kansk-Achinsk basin, brown and gaseous coal mixtures with no binding agent as well as a mixture of brown coal with hydrolyzed lignin as a binding agent. The heating values of the products were shown to increase 1,3-1,5 times in comparison with the raw coals and the volatile yields causing black smoke decrease by 11-13 %. Most efficient, strong moisture proof briquettes with the heating value of 25,50 MJ/kg were produced of the mixture of the B3 brown and gaseous coals. The addition of lignin to the brown coal allowed lowering the pressing temperature from 380-400°C to 200-250°C, thus improving the reliability of the press operation [11].

There is no difference in flavor between charcoal and gas because a perfect charcoal burn produces little or no smoke, and all grilling flavor comes from the vaporization of drippings. In practice, charcoal produces smoke when, If the coals are not yet fully ignited at the start of a cook, if new coals have been added to the fire, there will be smoke. So the theory holds that a balanced burn of pure charcoal and adequate oxygen will produce little or no flavor without drippings. But in practice, that is rarely the case [12].

2.2 Agricultural residues

Agricultural waste can be defined as wastes normally associated with the production and processing of food and fiber on farms, feedlots, ranches, ranges, and forests which may include animal manure, crop residues, and dead animals; also agricultural chemicals and their residues and containers, which contribute contaminants to surface and subsurface water.

Agricultural waste is an ideal source for charcoal. When we harvest any crop, we generally harvest only grain, fruits, coffee, pods, and tubers. This constitutes only about 30 to 40% of the total biomass. This means that about 60 to 70 % of the total agricultural biomass is the waste biomass produced annually. All kinds of tropical crops are in cultivation and residues such as maize cobs, rice husks, palm branches, shells and nut are major potential fuel used in many parts of the country. They are normally popular fuels that burn rapidly and well and are usually used in relatively small quantities to supplement or augment ignition when the main fuel is forest wood or charcoal.

The potential agro-residues which do not pose collection and drying problems, normally associated with biomass are rice husk, groundnut shells, coffee husk and coir waste (obtained by dry process). At present, loose rice husk, groundnut shells and other agro-residues are being used mostly by small scale boilers in process industries. Apart from being inefficient, these boilers do not have provision to capture fly ash and unburnt carbon, with the result that extensive air pollution is being created. In Ludhiana, one of the industrialized cities of Punjab (India), about 2,000 tonnes of rice husk is burnt every day. [6]

2.2.1 Appropriate raw material properties for Briquetting

There are many factors to consider before a biomass qualifies for use as feedstock for briquetting. Apart from its availability in large quantities, it should have the following characteristics:

1. Low moisture content

Moisture content should be as low as possible, generally in the range of 10-15 percent. High moisture content will pose problems in grinding and excessive energy is required for drying.

2. Ash content and composition

Biomass residues normally have much lower ash content (except for rice husk with 20% ash) but their ashes have a higher percentage of alkaline minerals, especially potash. These constituents have a tendency to devolatilizes during combustion and condense on tubes, especially those of super heaters. These constituents also lower the sintering temperature of ash, leading to ash deposition on the boiler’s exposed surfaces. The ash content of some types of biomass are given in Table1.

Table2. 1: ash content of different biomass types [13]

Biomass	Ash content (%)	Biomass	Ash content (%)
Corn cob	1.2	Coffee husk	4.3
Jute stick	1.2	Cotton shell	4.6
Sawdust(mixed)	1.3	Tannin waste	4.8
Pine needle	1.5	Almond shell	4.8
Soya bean stalk	1.5	Areca nut shell	5.1
Bagasse	1.8	Castor stick	5.4
Coffee spent	1.8	Groundnut shell	6.0
Coconut shell	1.9	Coir pith	6.0
Sunflower stalk	1.9	Bagasse pith	8.0
Jowar straw	3.1	Bean straw	10.2
Olive pits	3.2	Barley straw	10.3
Arhar stalk	3.4	Paddy straw	15.5
Lantana camara	3.5	Tobacco dust	19.1
Subabul leaves	3.6	Jute dust	19.9
Tea waste	3.8	Rice husk	22.4
Corn trash	4.2	Deoiled bran	28.2

The ash content of different types of biomass is an indicator of slugging behavior of the biomass. Generally, the greater the ash content, the greater the slugging behavior. But this does not mean that biomass with lower ash content will not show any slugging behavior. The temperature of operation, the mineral compositions of ash and their percentage combined determine the slugging behavior. If conditions are favorable, then the degree of slugging will be greater. Minerals like SiO₂ Na₂O and K₂O are more troublesome. Many authors have tried to determine the slagging temperature of ash but they have not been successful because of the complexity involved. Usually slagging takes place with biomass fuels containing

more than 4% ash and non-slagging fuels with ash content less than 4%. According to the melting compositions, they can be termed as fuels with a severe or moderate degree of slagging.

3. Flow characteristics

The material should be granular and uniform so that it can flow easily in bunkers and storage silos. Some of the appropriate agro-residues are described below.

2.2.2 Different types of agricultural residues

1. Rice husk

When compared to sawdust, agro-residues have a higher ash content, higher potash content and have poor flow characteristics. However, rice husk is an exceptional biomass. It has good flow ability, normally available with 10 percent moisture and the ash contains fewer alkaline minerals, thereby it has a high ash sintering temperature. In fact, it makes an excellent fuel although its calorific value is less than wood and other agro-residues.

2. Groundnut shell

Because of low ash (2-3%) and a moisture content less than 10%, it is also an excellent material for briquetting.

3. Cotton sticks

This material is required to be chopped and then stored in dry form. It has a tendency to degrade during storage. Also, it has a higher content of alkaline minerals and needs to be used with caution.

4. Bagasse/bagasse pith

These residues have high moisture content of 50% after milling, hence drying is energy intensive. They have low ash content and a correspondingly high heating value of the order of 4400 kcal/kg.

Pith is the small fibrous material which has to be removed from bagasse before bagasse is used as feedstock for making paper. Due to shortages of wood and increasing demand for paper and pulp, an ever increasing number of paper units are switching over to bagasse as feed material. The amount of pith available is almost equal to the tonnage of paper produced by a paper mill. For example, a 60 TPD mill will generate 60 TPD of bagasse pith. This material does not require milling before it is briquetted. At present, this pith is available from sugar mills at much lower costs. This is a potential material for briquetting.

5. Corn trash

An excellent material for briquetting having low ash and available with 10 percent moisture content. The material is available in the corn growing areas of Karnataka and Keral.

6. Others

Other potential biomass residues suitable for briquetting are lentil stalks, sawdust, lantana camara in hilly areas, tea wastes, and coir pith. [8]

2.2.3 Compaction Characteristics of Biomass and Their Significance

In order to produce good quality briquettes, feed preparation is very important. Feed parameters are discussed in this section, as these play a practicable role in briquetting technology. For densification of biomass, it is important to know the feed parameters that influence the extrusion process. For different briquetting machines, the required parameters of raw materials like their particle size, moisture content, temperature are different. These are discussed below. [8]

1. Effect of particle size

Particle size and shape are of great importance for densification. It is generally agreed that biomass material of 6-8 mm size with 10-20% powdery component (< 4 mesh) gives the best results. Although the screw extruder which employs high pressure (1000 - 1500 bar), is capable of briquetting material of oversized particles, the briquetting will not be smooth and clogging might take place at the entrance of the die resulting in jamming of the machine. The larger particles which are not conveyed through the screw start accumulating at the entry point and the steam produced due to high temperature (due to rotation of screw, heat conducted from the die and also if the material is preheated) inside the barrel of the machine starts condensing on fresh cold feed resulting in the formation of lumps and leads to jamming. That is why the processing conditions should be changed to suit the requirements of each particular biomass.

2. Effect of moisture

The percentage of moisture in the feed biomass to extruder machine is a very critical factor. In general, it has been found that when the feed moisture content is 8-10 %, the briquettes will have 6-8% moisture. At this moisture content, the briquettes are strong and free of cracks and the briquetting process is smooth. But when the moisture content is more than 10%, the briquettes are poor and weak and the briquetting operation is erratic. Excess steam is produced at higher moisture content leading to the blockage of incoming feed from the hopper, and sometimes it shoots out the briquettes from the die. Therefore, it is necessary to maintain an optimum moisture content.

In the briquetting process water also acts as a film type binder by strengthening the bonding in briquettes. In the case of organic and cellular products, water helps in promoting bonding by van der Waals' forces by increasing the true area of contact of the particles. In fact, the surface effects of water are so pronounced that the success or failure of the compaction process solely depends solely upon the moisture content of

the material. The right amount of moisture develops self-bonding properties in lignocelluloses substances at elevated temperatures and pressures prevalent in briquetting machines. [5]

It is important to establish the initial moisture content of the biomass feed so that the briquettes produced have a moisture content greater than the equilibrium value, otherwise the briquettes may swell during storage and transportation and disintegrate when exposed to humid atmospheric conditions.

3. Effect of temperature of biomass

By varying the temperature of biomass the briquette density, briquette crushing strength and moisture stability can be varied. In a screw extruder, the temperature does not remain constant in the axial direction of the press but gradually increases. Internal and external friction causes local heating and the material develops self-bonding properties at elevated temperatures. It can also be assumed that the moisture present in the material forms steam under high pressure conditions which then hydrolyses the hemicelluloses and lignin portions of biomass into lower molecular carbohydrates, lignin products, sugar polymers and other derivatives. These products, when subjected to heat and pressure in the die, act as adhesive binders and provide a bonding effect “in situ”. The addition of heat also relaxes the inherent fibers in biomass and apparently softens its structure, thereby reducing their resistance to briquetting which in turn results in a decreased specific power consumption and a corresponding increase in production rate and reduction in wear of the contact parts. However, the temperature should not be increased beyond the decomposition temperature of biomass which is around 300 °C.

4. Effect of temperature of the die

The distinctive feature of a screw type briquetting machine is that heat is applied to the die ‘bush’ section of the cylinder. This brings about two important operational advantages. The machine can be operated with less power and the life of the die is prolonged. Further, the surface of the briquette is partially carbonized / terrified to a dark brown color making the briquette resistant to atmospheric moisture during storage. The temperature of the die should be kept at about 280-290 °C If the die temperature is more than the required one, the friction between the raw material and the die wall decreases such that compaction occurs at lower pressure which results in poor densification and inferior strength. Conversely, low temperature will result in higher pressure and power consumption and lower production rate.

5. Effect of external additives

The briquetting process does not add to the calorific value of the base biomass. In order to upgrade the specific heating value and combustibility of the briquette, certain additives like charcoal and coal in very

fine form can be added. About 10-20% char fines can be employed in briquetting without impairing their quality.

Further, only screw pressed briquettes can be carbonized. When carbonized with additives in the briquette to make dense char coal, the yield is remarkably increased. However, depending upon the quality of charcoal and coal powder, various formulations can be evolved for optional results. In piston press technology the effect of particle size and moisture content is similar to that of the screw press. But in this case preheating of raw material is not employed and the die is not heated. In fact, the die needs cooling for smooth briquetting.

2.3 Charcoal Briquettes

Agricultural wastes (grass, dry leaves, sugarcane trash, etc.) and residue which are produced in huge quantities in Ethiopia is put to little use. The conversion of agricultural wastes to char, by an environment friendly, continuous batch process, briquetting of the char into a solid fuel form and use as an efficient, clean source of fuel. Charcoal can be made from anything containing carbon. The traditional material has been wood [13]. but due to the adverse effect this is having on the environment as a whole there is the need for alternative material for making charcoal. A given quantity of charcoal produces approximately twice as much heat as the same weight of wood [14]. The briquetting system is the conversion of agricultural waste into uniformly shaped briquettes that are easy to use, transport and store. The idea of briquetting is to use materials that are otherwise no usable due to lack of density compressing them into a solid fuel of convenient shape that can be burned like wood or charcoal. The briquettes have better physical and combustion than the initial waste.

Table2. 2: comparison of briquette charcoal and wood charcoal [14].

Briquette charcoal	Wood charcoal
Smokeless	Smoke
It exhibits faster heat release and greater heat value	Less heat release and smaller heat value
Reduce impact of deforestation	Enhance deforestation impact
It can burn for long time (2-3 hr.)	It can burn for short time (1-2)

2.4 Pyrolysis of Biomass

Thermal decomposition occurring in the absence of oxygen. At temperature above 300°C biomass polymeric building blocks undergo cross linking as well as partial de-polymerization and fragmentation to form smaller molecules which are released as gases and vapors that can react with residual solids producing more condensed structures.

Pyrolysis always produces solid (charcoal), liquid (water and organics), and gaseous (CO, CO₂, CH₄, H₂) products at proportions and composition dependent on feedstock and on process conditions.

2.5 Briquetting technologies

1. Briquetting Plant

The briquetting plant can be operated in two ways. In the first case while pre-processing the raw material, the temperature of the feed material is not considered. In fact, the temperature is not at all critical for the production of briquettes. But if we take into consideration the power consumption, the wear behavior of the screw and the temperature of the die, then the temperature of the raw material at the time of feeding to the screw extruder plays a significant role.

The capacity of the feed preparation section of the plant must match with the briquetting capacity of the machine. In a commercial plant, the feeding of the raw material to the flash dryer is done through a screw conveyor. Components of a typical flash dryer are an air heater and a fan to produce a flow of heated air upwards through a long vertical drying duct. The material to be dried is introduced into the airstream by the feeder, and the hot air conveys the particles through the duct in a concurrent flow. [10] The dried material is then passed through a cyclone to separate particles from air and transported into the collecting hopper. The storage hopper should be given adequate attention regarding its capacity and to ease the flow of the material. Bridging in the hopper may cause fluctuations in operating conditions and may also lead to a production halt. The dry material is then fed to the screw extruder through a screw conveyor for its briquetting. In the case of briquetting with preheating of biomass, the material is control fed to a pre-heater to heat it to a desired temperature.

2. Material Processing Equipment

A production plant has to be properly designed and engineered such that breakdowns and operational bottlenecks are minimal or thoroughly eliminated by a following proper preventive maintenance schedule. Material processing equipment plays a vital role in the smooth production of briquettes and any compromise on their quality to save on costs would be counterproductive. At the same time, these should

not be over-designed as this would increase the initial costs and make this technology economically unviable.

3. Raw material storage

All biomass feeds are relatively very light with bulk densities ranging from 0.05 to 0.18 g/cc (50 to 180 kg/m³). Because of their bulky nature these are normally stored in the open. Where the location lies in heavy rain fall region, these should be stored in ground level bins which can be covered by heavy waterproof sheets or alternative, a side open shed could be provided. Depending upon the availability of supply, feed material for 15 days to 3 months' period should be stored at the plant site. It should be stored in a manner that the heaps are naturally aerated and heavy wind effects are minimized. About 3-4 square meter open space is needed to store one tone of material.

4. Inclined screw feeder/Elevator

The function of this screw is to feed the material from ground level to either the top feed end of a vibratory screen or the hammer mill. A standard enclosed screw conveyor or elevator made in M.S. is most suitable for this operation. It can be custom built by numerous vendors. It should preferably have variable speed so that its capacity can be varied to match the capacity of related equipment.

5. Vibratory screen

Screening of feed is essential for materials like sawdust which may contain many wooden cut pieces. These screens are standard items and available in many types and sizes. These should be of enclosed type to eliminate dust problems and preferably with a self-cleaning arrangement having elastic balls. Various mesh sizes of screens can be used depending upon the type of material. For sawdust a screen of 10 mm may be used. For coffee husk, rice husk and groundnut shells, screens may be employed to avoid contamination by extraneous materials like stones and steel pieces etc. and the screen mesh should be based on the largest size of the feed. Another advantage of using a vibratory screen is that it can also act as a control gravity feeder either to a hammer mill or a flash drier. For capacities greater than five tones/hour, rotating screens known as trammels may be employed.

6. Hammer mills

Hammer mills are employed to reduce the particle size of the feed material. Except sawdust, bagasse pith, coir waste and other materials of similar size, all other materials should be crushed to 6-8 mm size with 10-20% fines to achieve optimum briquetting results. While many types of crushing and grinding equipment's are available in the market, for biomass materials, hammer mills are considered the most suitable. These are available in various sizes from a few kg/hrs. to 10-15 TPH. Maintenance is rather

routine and heavy in these machines and it is advisable not to operate these machines for more than 20 hours per day. Some hammer mills are symmetrical so the direction of the rotor can be reversed. In this case, more running time is possible without maintenance.

The output size is governed by the clearance between the lower end of the hammers and the housing and openings of cylindrical grating positioned beneath the rotor. It retains material until reduced to a size small enough to pass between the bars of the gratings. The impact parts are built using high chromium alloys to provide requisite wear resistance to abrasion and impact normally encountered on multiple hammers, casing and spherical grating or sieve. The speeds of these mills vary from 600-1500 rpm.

For biomass materials, it is essential to avoid gravity discharge from the hammer mills; instead, suction is produced by an induced draft blower to suck and convey the material pneumatically. Basically, hammer mills are bought out items and are supplied complete with a pneumatic conveying discharge cyclone, a blower and dust separators by many vendors. Most of these vendors have pilot plant facilities to test new materials and then recommend an appropriate machine complete with rpm and power ratings of the motor.

7. Dryers

Drying is normally not required for materials like coffee husk, groundnut shells and rice husk. If feed is wet and drying becomes essential, integrated drying cum disintegration should be carried out by using the hot flue gases from the thermic fluid preheating furnace. However, drying is essential for sawdust, wet coir pith, bagasse and bagasse pith and some other agro-residues like mustard stalk.

The types of drier employed for biomass materials are paddle indirect drier, flash, direct type, pneumatic or flash, and direct or indirect type rotary driers. Direct driers are those in which hot air or flue gases are intimately mixed with material and indirect ones are when heat is transferred to materials through a metallic surface and material is not mixed with the hot streams. Indirect driers are normally inefficient and require a large heat transfer area making the equipment bulky and expensive. Rotary driers are highly reliable but tend to be an order of magnitude more expensive than a flash drier, especially at a capacity less than 3-4 TPH. On the other hand, flash driers are highly suitable provided care is taken to avoid hot spotting within the system. This can easily be achieved by controlling the temperature and flow rate of hot steam and ensuring that there is no accumulation of solids at any stage of drying. Otherwise, as the material is highly combustible, a spontaneous fire might occur in the drier. For this reason, fluidized bed driers are not recommended. Another main advantage of a flash drier over a rotary drier is that the former can simultaneously dry, disintegrate and convey the material.

8. Flash dryers

Flash dryers are custom built equipment which can be supplied by many vendors who also have pilot plant facilities to test the material. It is recommended that one should purchase this equipment integrated with a hammer mill (if required), furnace, material handling, material collection system necessary blowers and dust collection bag filter assemblies. If the feed has high moisture content, it is sometimes necessary to mix it with some dry finished product to improve its crushability and conveying properties. All biomass materials are amenable to drying by flash driers with or without disintegration. [13] Even though biomass materials are heat sensitive these can be satisfactorily dried at relatively high temperature because of short drying time. Most of the moisture is removed either in a disintegrator or at the entry point of the feed into the gas stream. Entry temperature of gases up to 300-400 °C can be conveniently employed even though the decomposition temperature of most biomass materials is between 250-350 °C. One precaution that must be taken is that sparks must not be allowed to proceed along with flue gases before gases are mixed with feed material. It is therefore essential to have a spark arrestor at the outlet of the furnace especially when solid fuels are deployed in the furnace.

9. Intermediate storage bin

Once the feed material is sized and dried it is to be stored in an intermediate storage bin. It is important that this storage bin has a capacity of at least four hours of production. This is essential to isolate the two main sections of the briquetting plant viz. feed preparation and briquetting sections. In case of a short breakdown in either section, the production of the plant is not affected. The bin design should be such that there is free flow of material and no bridging and choking of material should be allowed to take place. This bin is placed at ground level. If the bin is placed above ground level, then the inclined portion of the screw is not required and the material can be gravity fed into the main material distribution screw feeder.

10. Main distribution screw feeder

This is a standard screw feeder required to convey the material, fed by the screw feeder of the intermediate storage bin, and distribute it to the individual preheated attached to briquetting machines. The carrying capacity of this screw feeder should be at least 15-20percent higher than the production rate of the briquettes. This is essential so as not to starve the feed to the machines. The excess material is discharged into a return feeder which conveys the material back into the intermediate bin. If multiple materials are required to be briquetted by the plant, it is advisable that this main screw feeder is fitted with a variable drive. This arrangement will ensure consistent supply to the briquetting machines.

11. Return feeder

The function of this return feeder is to convey the excess material, not utilized by the machines, back to the intermediate storage bin. It could be either a straight overhead standard conveyor or could be an inclined conveyor discharging at the top portion of the intermediate bin. After the briquettes are produced they need sizing and cooling before storage. The following sections describe the cutting and cooling of briquettes and also the equipment to control the fumes.

12. Briquette Storage

Once the pre-processed feed is introduced to the machine, the briquettes are extruded in a continuous length. They are then cut to the desired length. In a screw press, as the briquettes come out of a heated die, the temperature of the briquettes is very high, requiring them to be cooled before storage. There is also lot of associated steam and hot gases which escape through the hole of the briquette and a fume exhaust system is generally used to take these up to the atmosphere so that the briquetting site remains free from polluting gases and hot steam. Piston press briquettes do not need cutting or cooling as they come out in small pieces produced by strokes and they are not hot. [12] These briquettes come out of a water cooled die and can be immediately stored. There is also no associated steam or hot gases. The hot screw press briquettes are usually cooled over the conveying belt during their transportation to the storage site. They are stacked length-wise and do not cause any fire hazard due to spontaneous combustion as is the case with heaps of agro-residues. The briquettes should be protected from water and it is ideal to store them under a shed.

13. Briquette Cutter

To cut the briquettes to the desired length there are two technological options. One option is to provide an automatic circular cutter which will cut the hot-extruding into uniform lengths with smooth ends before these cut briquettes are allowed to fall on a cooling conveyor. This is desired if the briquettes are to be attractively packed in small bundles (6-10 briquettes) for sale through retail outlets (including supermarkets) as practiced in Europe. The other option is to allow the extruding to touch a smooth and inclined obstruction whereby it breaks due to the bending force. By this simple technique, fairly uniform lengths are produced but the edges are not smooth. In case smooth edges are required, a bundle of 8-10 briquettes are taken to a separate twin saw cutter which can cut both sides simultaneously. This, however, results in the production of rejects in the form of small (20-30 cm thick) end cuts, which can be burnt in the furnace. When briquettes are meant for firing in a boiler/furnace, it is not desirable to incorporate cutters of any type.

14. Cooling Conveyor

Briquettes extruding out of the machines are rather hot with surface temperatures exceeding 200°C. They have to be cooled and conveyed to the storage area. For this operation a perforated steel belt conveyor of suitable length is required. It is dangerous to allow hot briquettes to get stock piled in heaps near the machine because of their combustible nature. The outbreaks of self-igniting fires are frequent unless precautions are taken to cool the briquettes before stacking them. The width of this open belt conveyor should be at least 30 percent greater than the maximum length of the briquettes. The conveyor length should be a minimum of 5 meters but a greater length may be needed depending upon the proximity of the storage and packing area from briquetting presses. [10]

2.6 Current status of Briquetting in Ethiopia

In Ethiopia, one of the few private plants known to exist in Africa was started in mid-1985 in Addis Ababa. A low-pressure piston machine supplied by Eco-Briquette was bought by private individuals after they had obtained information about similar plants in India. The raw-material is saw-dust (60%) plus some coffee parchment and cotton-seed husk. The briquettes are sold mainly to middle-class hotels in Addis which have installed wood burning stoves of some sophistication.

The machinery is reported to function reliably but has the draw-back of requiring a binder material which must be imported from abroad. There are difficulties in obtaining a foreign exchange allocation for this and the binder cost a significant part of the operating costs of the plant. Nevertheless, in 1988, the owners were hoping to expand their production to about 3 thousand tons annually if they could obtain sufficient raw material.

Dilla Briquette Factory

A major programmed of briquetting is planned for Ethiopia based upon various agro-residues from state-farms. These have not yet begun operations in 1985, the Government of Ethiopia (GOE) signed a cooperation agreement with the World Bank to implement the ENERGY I project, which incorporated an initiative to install a number of briquetting plants across Ethiopia, including one in Dilla. However, there were some issues experienced with installation of the plants and Dilla briquetting plant was not installed at all, although the construction for the plant was completed and all the machinery and accessory equipment delivered. [4]

Once finished, the plant will have a manufacturing capacity of 1.5 tons of material per hour, and the yearly capacity will range from 1,800 to 5,400 tones.

Over the last 20 years, Dilla briquette plant has changed hands and remained unused until July 2011. In July 2010, HOA-REC&N learnt about the existence of the Dilla briquette plant, and discussions began with the Gedeo Development Association (GDA) officials, and a year later, a project to restore the plant started

Project area: Southern Nations, Nationalities, and Peoples' Regional State (SNNPRS), Gedeo Administration Zone, Dilla City, 361 kilometers south of Addis Ababa.

Partners for the project: Gedeo Administration Zone and Gedeo Development Association. HOA-REC&N was the project developer and financier.

2.7 Major application and advantages of briquette

❖ Briquettes Applications

Briquettes have a wide variety of use from household to industrial. The fuel has not been fully exploited as there has not been scarcity of fuel in the past. However, with the current fuel shortage and ever rising prices, consumers are looking for affordable alternative fuels and briquettes fill this gap for:

- ✓ Cooking and water heating in households;
- ✓ Heating productive processes such as tobacco curing, fruits, tea drying, poultry rearing etc;
- ✓ Firing ceramics and clay wares such as improved cook stoves, pottery, bricks etc;
- ✓ Fuel for gasifiers to generate electricity;
- ✓ Powering boilers to generate steam.

❖ Briquette advantage

1.Concentrated. Since briquettes are created from compressing combustible materials, they are denser, harder, a more compact.

2.Slow-burning. The compression process allows the briquettes to burn for a lot longer than if it was loose in its original condition.

3.More efficient. Along with the compactness of the briquettes is the increase in heating value. Briquettes can relatively produce more intense heat than other fuel. They have a higher practical thermal value and much lower ash content (2-10% compare to 20-40% in coal).

4.Smokeless. This is a unique property of briquettes. Using them creates no smoke, soot, or carbon deposits. Depending on the base material, they produce no or little fly ash.

Further, briquettes do not emit gases or any toxic chemicals like sulfur.

5.Availability. Biomass is the main component in producing briquettes.

6.Easy to make. There are presently commercial briquettes sold in the market. However, ordinary households can produce briquettes. You must only have a stock of combustible matter, a binder, and a molder to shape the briquettes.

7.Easily stored. The size and shape of briquettes make them easily be stored.

8.Easily transported. Compacting biomass waste into briquettes reduces the volume by 10 times, making it much easier to store and transport than loose biomass waste.

9.Cheaper. Since briquettes can be domestically made from plants and animal wastes, they are consequently less expensive to produce, and thereby sold at lower prices.

10.Renewable. Briquettes make use of organic materials which are common and renewable. Hence, we are ensured of the sustainability of such fuel source.

2.8 Process description

Raw material properties: The chemical compositions of raw material which are Cellulose, hemicelluloses, Lignin and extractives generally are given 38–50%, 23-32%, 15-25% and 1-5% respectively.

Process description of charcoal briquette

The main unit operations in the production of Charcoal briquette were presented below.

1. Selection and collections of raw material

The first step of the charcoal briquette making process is to acquire raw materials from natural sources as well as from industrial by-product which are eco-friendly and good availability called corn trash and bagasse. And collect/prepare the raw material to the production plant.

2. Drying

The humidity content of the fuel is driven off with heat from the combustion step. The water content within a particle is bound in several ways:

- ✓ It can be enclosed in cavities;
- ✓ It can be capillary;
- ✓ It can be chemically bound with the particle substance.

The chemically bound water requires more energy to vaporize. During the drying process, water leaves dry fuel behind through vaporization. The vaporization takes place at almost constant temperature (100°C atmospheric pressure), but some water will leave at temperatures lower than the vaporization temperatures

lower than the vaporization temperature due to the fact that water within the fuel has a higher partial pressure than the atmosphere.

The drying process is endothermic, i.e. it requires heat. This heat is obtained from the combustion sub-process or from an external heat source.

The higher is the humidity content, the more heat is needed to dry the fuel the unless will be the useful energy. Drying at normal conditions requires 2256 KJ per kilogram of water evaporated (latent heat).

3. Carbonization Process

Pyrolysis

Pyrolysis is an endothermic process in which particle structure decomposes due to heating. Decomposition products come out in gas form and are called volatile gases. Pyrolysis always takes place after the drying has finished. Pyrolysis takes place at the temperature range of 250°C to 900°C. During pyrolysis, a particle decreases in volume and mass. The volatile products are mainly CO, CO₂, CH₄, C_nH_m, NH₃, some H₂ and tars (also called pyrolysis oils). In biomass, the volatile content is about 70-80wt%, while coal has only 10-30 wt%. The solid residue left after pyrolysis is called char, which mainly consists of elemental carbon and ash. Charcoal for barbequing is pyrolysis of wood. To start a particle pyrolysis, an external heat source is needed. In case of a very wet particle, the pyrolysis will not start until enough heat has been added so that the not start until enough heat has been added so that the particle becomes dry and the produced gases ignite.

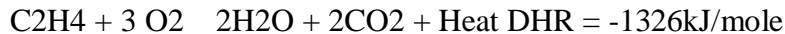
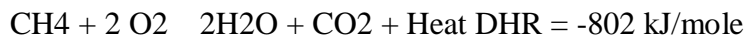
After ignition of the pyrolysis gases, the de-volatilization is self-sustained with heat from the combustion of these gases (exothermic reactions).

Combustion of Gasses

When the combustible volatile gases (which are hot when leaving the particle surface) mix with atmospheric oxygen, they ignite and combust. Pyrolysis and gas combustion are normally two simultaneous processes; as long as the pyrolysis goes on, there will be gases on the particle surface that are burned. These combustion reactions provide heat to the pyrolysis so that it proceeds. The combusting gases are seen as a flame around the particle. The gas combustion creates a gas film around the particle, so that oxygen will not have the possibility to reach the particle surface; thus no solid combustion occurs during this phase. The gas combustion finishes when pyrolysis finishes.

The gas combustion consists of a series of homogeneous reactions, which means that all included substances are in the same phase, i.e. gas phase

Example of reactions and heat generated (The minus sign indicates that heat is generated). [7]



When the pyrolysis is finished, and thus the gas combustion is finished, the atmospheric oxygen is able to reach the char surface then combustion of solid char will occur, in order that not to happen all possible air supply inlets and outlets must be sealed and shut down.

4 Milling

It is desirable to crush larger particles to get a random distribution of particle size so that an adequate amount of sufficiently small particles is present for embedding into the larger particles.

The presence of different size particles improves the packing dynamics and also contributes to high static strength. Only fine and powdered particles of size less than 1 mm are not suitable for a molding machine because they are less dense, more cohesive, non-free flowing entities.

5. Binding Process

The binder material is used for strengthening the briquettes and for every 30 kg of total weight of carbonized charcoal powder; prepares a binder mixture by adding 1.5 to 2 kg of a special mud (Merete cheka in Amharic) and a little water based on the weight of the raw materials.

Mixing

Mix such that every particle of carbonized charcoal material is coated with binder. It will enhance charcoal adhesion and produce identical briquettes.

6. Molding Process

Briquetting is one of several compaction technologies to form a product of higher bulk density, lower moisture content, and uniform size shape, and material properties. The charcoal mixture is made into briquettes using extruder machine.

Extruder machine

The charcoal extruder is designed and manufactured to make a small size of 20mm diameter and produce six briquette charcoals at a time. The case and parts of the extruder are made from sheet metals and angle iron. To support the person while working with the extruder fly wheel made of concrete and sheet metal steel is added at free end of the extruder. The extruder is a screw type press, made of a sheet metal which is welded on a solid steel shaft, designed to produce high density briquette. After feeding the mixed char into the screw type extruder one can rotate the handle which is attached to the fly wheel. In this case, the

raw material is mixed in a well manner and at the same time it is transported to the end of the extruder. Since the end of the extruder is a type of circular die with six holes, the materials can be pressed against those holes to produce compact and uniform size briquettes. The mixing time and rpm of the extruder depends on the person who works on the machine. [9]

7. Drying

The briquettes well collected in a tray and dried under the sunlight for about 1-2 days, the moisture must be removed by sun from the briquette otherwise it is difficult for burning and reduces efficiency of burning, finally the briquette is packed and sealed in plastic bag.

CHAPTER 3

MATERIAL AND METHODS

3.1 Frame work of experiments

Use to analyze the properties of raw material and the characteristics of final product.

Characteristics of final product: Is basis weight, moisture content, PH value, ash content, carbon content and yield.

3.2 Raw material and equipment needed for the production process

3.2.1 Equipment's used for production of charcoal briquette

- ❖ Furnace
- ❖ Oven
- ❖ Weight Balance
- ❖ PH recorder

3.2.2 Raw material for production of charcoal briquette

The raw material needed for charcoal briquette; -

- ✓ Agro waste specifically sawdust and cobs.

A binding agent needed for binding char powder; -

- ✓ Rice boiled water or as another alternative mud.

3.2.3 Equipment needed for molding

- ✓ Simple extruding equipment.

3.3 Methodologies

3.3.1 Raw material collection and transportation

The raw material (sawdust & Cobs) used for this project was obtained from gubrye and wolkite wood work house and market respectively. After collecting the raw material, then transported to wolkite University chemical engineering department. The briquetting Sample preparation was done in wolkite university of chemical engineering department. And product characterization is done in chemical engineering department laboratory.

3.3.2 Sample analysis

3.3.2.1 Determination of moisture content of the raw material

1.5 kg of sawdust and 0.715kg of cob were weighed and dried in an oven at 105°C for 6 hrs. Using Petri and then the weight was measured. The percentage moisture in both raw materials calculated using the following:

$$\text{Moisture \%} = \frac{W_1 - W_2}{W_1} \times 100\%$$

Where, w1 = weight in gram before drying,

w2= weight in gram after drying,

3.3.3 Sample preparation

The moisture content of the sample was removed by placing the sample in an oven with 150°C for 4hrs. The dried raw material then passed to carbonization process.

1. Carbonization process

Pyrolysis (carbonization) is an endothermic process in which particle structure decomposes due to heating. Carbonization and gas combustion are normally two simultaneous processes; The combusting gases are seen as a flame around the particle. The gas combustion creates a gas film around the particle, so that oxygen will not have the possibility to reach the particle surface; thus no solid combustion occurs during this phase. The gas combustion finishes when pyrolysis finishes.

To conduct the carbonization process we used corn trash and sawdust as raw material. Then the raw materials are filled into the furnace.



Figure3. 1: carbonization of agro-waste

2. Milling

The purpose of milling is to decrease particle size and to make the char uniform. We use simple milling equipment by using mechanical force.

3. Binding process

The binder material is used for strengthening the briquettes. The carbonized char powder is mixed such that every particle of char is coated with binder. It enhances charcoal adhesion and produce identical briquettes. The binder we used is rice boiled water, which is readily available. The starch is added to water in ratio of 10:1 then heated for 10 minutes or when the solutions feels sticky and after poured on the char and mixed until all particles of the char are coated with the binder.



Figure3. 2: Mixing of char

4. Molding process

The blended material is dropped into a rectangular metal pipe and striked by hammer using mechanical force. Because of the moisture content, the binding agent, the temperature and pressure from hammer, the briquettes hold their shape as they drop out the bottom of the metal tube.



Figure3. 3: Molding of briquettes

5. Drying process

The briquettes are dried in the oven for 1hrs at 210°C and packed.

3.4 Product analysis

Determination of the yield of charcoal briquette

The production briquetting yield from biomass residue is given by the following equation:

$$\text{Briquetting yield (\%)} = \frac{\text{final briquetting production (g)}}{\text{biomass residue}} \times 100$$

Determination of density

To measure the density of the charcoal briquette:

- ✓ First we measure the mass of briquette by using weight measuring equipment
- ✓ Then measure radius and length of briquette to determine the volume of the briquette

$$V = \pi r^2 * L \text{ or } V = L \times W \times h$$

Therefore, the density of the briquette can be calculated as:

$$\text{Density} = \frac{\text{Mass (g)}}{\text{Volume (cm}^3\text{)}}$$

Determination of volatile matter (PVM)

The PVM was determined by pulverizing a gram of briquettes sample in a crucible and placing it in an oven until a constant weight (A) was obtained. The briquettes were then kept in a furnace at a Temperature of 550°C for 10 minutes and weighed after cooling in a desiccator to obtain (B).

The PVM was then calculated using equation below;

$$\text{PVM} = \frac{(A-B)}{A} \times 100$$

Determination of ash content

To determine the ash content of the briquette first we measure the mass of the briquette and burnt to get ash, then measure the mass of the ash.

$$\text{ASH} = \frac{\text{weight of ash (g)}}{\text{weight of brequitte (g)}} \times 100$$

Determination of moisture content

An empty crucible dish was dried in an oven, cooled in desiccators and weighed. A gram of briquette sample was put at the dish and placed in a hot air oven set at 120°C for 5 hr. There after the Petri dish was removed, then we measure the dried briquette. The moisture content can be calculated as:

$$\text{Moisture \%} = \frac{W1-W2}{W1} \times 100$$

Where, w1 = weight in gram before drying,

w2= weight in gram after drying,

Determination 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 from 100 as shown in equation

$$\text{Fixed Carbon} = 100\% - (\text{PAC} + \text{PMC} + \text{PVM})$$

Determination of PH value

2g of the sample was poured into a clean dry 25ml beaker and 13ml of distilled water was added to the sample in the beaker and stirred slowly. It was then cooled. The pH electrode was standardized with buffer solution and the electrode immersed into the sample and the pH value was read and recorded.

Determination of burning time

Type I briquette (cob with binding agent starch) which has mass of 33g was first burn and then we observe the time that takes the briquette to turn in to ash. We also follow the same step for other type of briquettes.

CHAPTER 4 RESULT AND DISCUSSION

4.1 Characterization of Briquette and Determination of Cooking Qualities

Three types of briquettes were tested with different binding agent and principle raw materials. Type I: and Type II: briquettes use different raw material with similar binding agent and also

Type II: and Type III: briquettes contained similar raw material with different binding agent.

- ✓ Type I: corn trash(cob) with binding agent starch
- ✓ Type II: sawdust with binding agent starch
- ✓ Type III: sawdust with binding agent rice boiled water

The parameters measured were; yield, ash content, moisture content, density, burning time and PH. This was replicated three times and the means are presented in table.

Table4. 1: characterization of different types of briquettes

Properties	Type I: corn trash(cob) with binding agent starch 33g (one briquette)	Type II: sawdust with binding agent starch 43g (one briquette)	Type III: sawdust with binding agent rice water 81g (one briquette)	The standard value of briquettes
Density (g/cm ³)	0.35	0.66	0.9	0.97
Moisture content (%)	17(%)	15%	20(%)	10-15%
Ash content (%)	3.2	1.9	1.8	3.5-7.5
Burning time(hrs.)	1;17	1:33	2;05	2-3
PH	4.13	4.3	4.11	
Yield (%)	7.4	9.1	9.1	15-20
Volatile mater (%)	75	76	83	70-85
Fixed carbon (%)	4.8	15.1	11.2	52

4.2 Comparison and characterization of charcoal briquette of corn trash and sawdust with different binding agent

The properties such as moisture content, density, PH, ash content, burning time, of the charcoal briquette produced from sawdust and corn trash(cob) and as binding agent rice water and starch are characterized as followed.

1. Yield

Table4. 2: weights of agricultural waste and subsequent charcoal yield

	corn trash(cob)		Sawdust	
	kg	%	kg	%
Burn1	1.4	3.598	0.42	0.56
Burn2	1.46	3.753	0.63	1.16

Through different trials burn 1 and 2 the values of 3.598 and 3.752 obtained from cob and 16.3 and 11 from sawdust respectively. From the yield result of ultimate analysis, the yield of briquette obtained from cob is greater than the yield obtained from sawdust.

2. Density

The values of 0.35 g/cm³, 0.66 g/cm³ and 0.9g/cm³ were obtained from Type I, Type II, Type III briquettes produced respectively, while the corresponding values of commercial briquettes is 0.97g/cm³. The density of type I and type II briquettes are above the limit of 15% (obtained from literature) which is 64% and 32% respectively. Therefore, the density obtained in this study is unsatisfactory, we assumed that this deviation come from the equipment which is used for molding is not good enough for compress the mixed char and the other reason is using starch as a binding agent also affect the density.

In other case the density of type III briquette is within the limit of 15%, which is 7%. Therefore, the density obtained in this study is satisfactory this because of using rice water as a binding agent.

As indicated on the result table the density of Type III briquette is greater than the other briquettes types and the density of Type I briquette is least dense.

3. Moisture content

From the result of ultimate analysis, the moisture content of 17%, 15%, and 18% where recorded for Type I, Type II and Type III respectively while the commercial value of moisture content of the briquette is within the limit of 10 to 15%. [2] The deviation between the experimental value and the commercial value is little; therefore, the work done in this study is almost satisfactory.

4. Ash content

The ash content of the sawdust with binding agent starch have higher amount than the other type of briquettes. Type I Fuel briquettes produced the highest ash content (3.2%), followed by Type III (1.8%). while Type II produced 3.2% (Table4). The characteristics of the briquettes are likely to be associated with amounts and types of waste used, for example, briquette which is produces by corn trash results in higher amount of ash than sawdust briquette.

5. Volatile mater

From the proximate analysis, the percentage content of volatile matter for Type I: Type II: and Type III: briquette was 75%, 76% and 83% respectively. As described in the literature review section biomass generally has a volatile content of around 70-86% of the weight of the dry biomass which makes biomass a more reactive fuel giving a much faster combustion rate during the de-vitalization phase than other fuels such as coal. [5] therefore the work done in this study is satisfactory.

6. Fixed carbon

The fixed carbon of a fuel which is the percentage of carbon available for char combustion For Type I, Type II and Type III was determined to be 4.8,15.1and 11.2 respectively. This is not equal to the total amount of carbon in the fuel (the ultimate carbon) since a significant amount is released as hydrocarbons in the volatiles.

7. PH value

Using the PH meter the PH value of the Type I: Type II and Type III briquette was determined as 4.13, 4.3 and 4.11 respectively which indicates the acidity nature of the charcoal briquette.

Participatory briquette testing and demonstration

Table4. 3: briquette testing and demonstration

Type of briquette and experiment procedure	Average time to fully ignite/light(minute)	Smoke produce by the briquette	Flame characteristics	Time to taken to burn in ash
Type I: corn trash with binding agent starch 33g (one briquettes)	10	No smoke	Small hot yellow flame	1hr 17min
Type II: sawdust with binding agent starch	13	No smoke	Small hot yellow flame	1hr 33min
Type III: sawdust with binding agent rice water	18	Have smoke	Small yellow flame	2hr 5min
Wood charcoal weighing 50g	12	Little smoke	Hot yellow flame	30min

Type I: briquettes with an average weight of 33g each took 10 minutes to ignite and burned with short tongues of hot yellow flame with almost no smoke. The briquette took 1hours and 30 minutes to burn to ashes.

Type II: briquettes weighing 43g each took 13 minutes to ignite and burned with hot yellow flame very little smoke and the briquette took 1 hour and 8 minutes to burn to ashes.

Type III: briquettes weighing 81g each took 18 minutes to ignite, burned with hot yellow flame and produced white smoke.

These briquettes took 2hours and 5 minutes to burn to ashes. Wood charcoal weighing 400g took11 minutes to ignite burned with a hot yellow flame and took 1hour to burn to ash.

In terms of Smoke produce by the briquette, the ordering of briquette types quality is as follows: Type I and Type II have no smoke but Type III have smoke. And in terms of time taken to burn in ash by the briquette, the ordering of briquette types quality is as follows:

Type I <Type II < Type III.

The results presented in Table 5 showed that briquettes had a longer burning time. The briquette which is produces by sawdust using rice water as binding agent has higher burning time than the other briquettes produced using sawdust and starch as binding agent has the second largest time of burning.

8. Color

As shown in the figure the color of charcoal briquette produce is black due to the burning effect of raw materials.



Figure4. 1: Charcoal briquette

CHAPTER 5

TECHNO-ECONOMIC ANALYSIS

Process description

The general flow of the process is described in the figure below. The process includes carbonizing biomass, mixing and molding the followed by drying the briquette

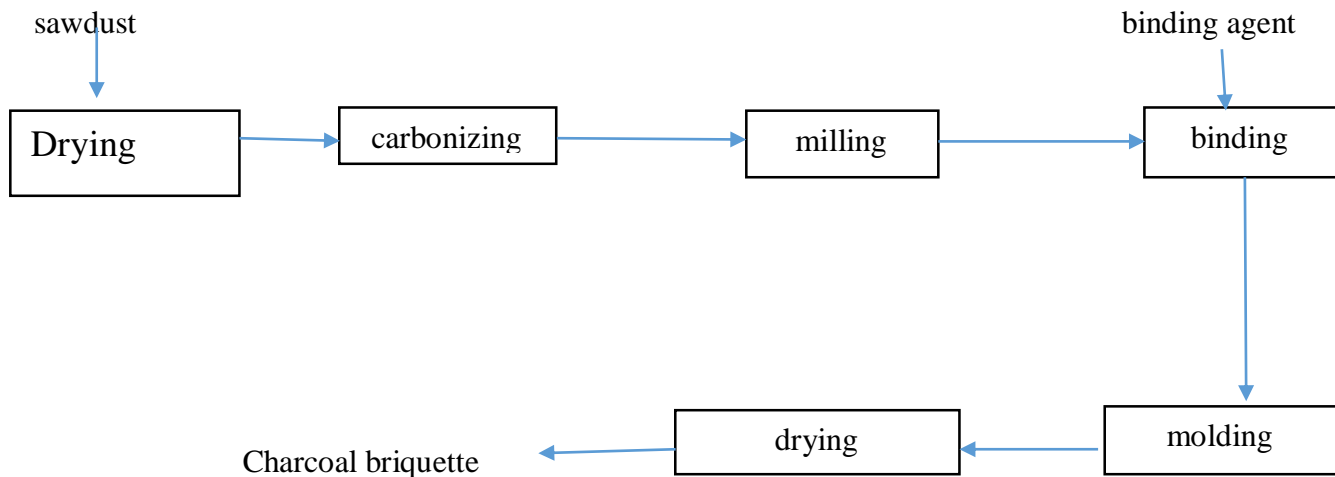


Figure4. 2: block flow diagram of charcoal briquette

5.1 Material Balance and Energy Balance

5.1.1 Production of briquettes in laboratory scale

Design basis

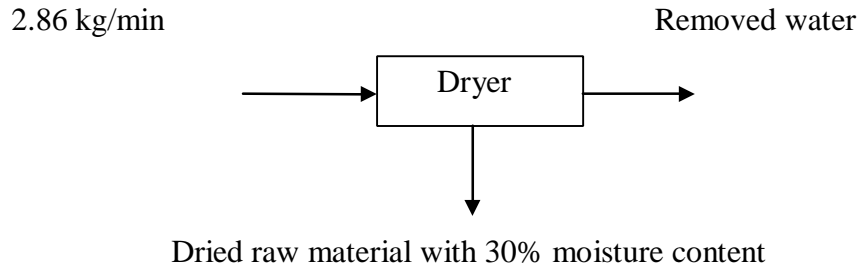
The laboratory experiment to manufacture briquettes was based on 2.86kg of cob and 2 kg of sawdust. For industrial level the amount of biomass rises to about 4 tons per hour. From the above statement the scale up factor is about 1398.6 x and 2000y.

- ✓ Design capacity of charcoal briquettes
- ✓ tones per hour
- ✓ Final product: charcoal briquettes
- ✓ Recovery yield of charcoal briquettes
- ✓ Biomass contains 10-20% of char on a dry matter basis.

5.1.2 Material Balance

➤ **Material balance on corn trash(cob):**

Raw material Drying: the raw material has 80% moisture and dried to 30% moisture content.



The water in raw material is = $0.8 \times 2.86 \text{ kg/min} = 2.288 \text{ kg/min}$. here, since the density of water is 1000 Kg/m^3 , ton/hr is equal with m^3/hr .

Amount of water in the dried raw material is calculated as follow.

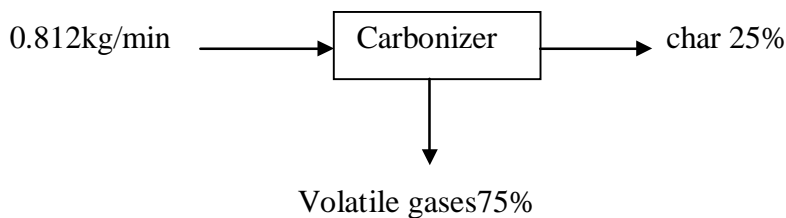
Y

_____ = 30%, then $Y = 0.245 \text{ kg/min}$

$0.572 + Y$

And $2.288 - 0.245 \text{ kg/min} = 2.043 \text{ kg/min}$ water is removing in the drier. And the total flow rate to burning $2.86 \text{ kg/min} - 2.043 \text{ kg/min} = 0.812 \text{ kg/min}$ with 30% moisture content.

Material balance on carbonization process: In biomass, the volatile content is about 75wt%, while coal has 25wt%.



The amount of volatile gases in corn trash is calculated: $0.75 \times 0.812 = 0.6.9 \text{ kg/min}$

The amount of char is calculated as: $0.25 \times 0.812 \text{ kg/min} = 0.203 \text{ kg/min}$

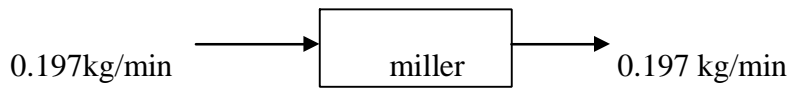
3% of char is wasted during the collection of the char from the Carbonizer.

$0.03 \times 0.203 \text{ kg/min} = 0.00609 \text{ kg/min}$.

Therefore, the net char that goes to the next step calculated as:

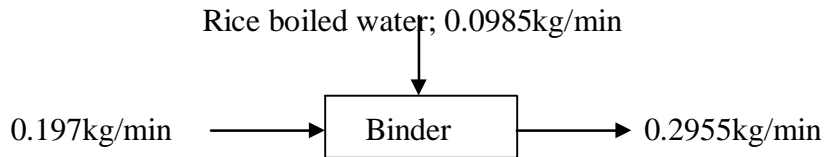
$0.203 \text{ kg/min} - 0.00609 \text{ kg/min} = 0.197 \text{ kg/min}$.

Material balance on milling



Material Balance on Binding

The char is mixed with rice boiled water with the ratio 1:0.5.



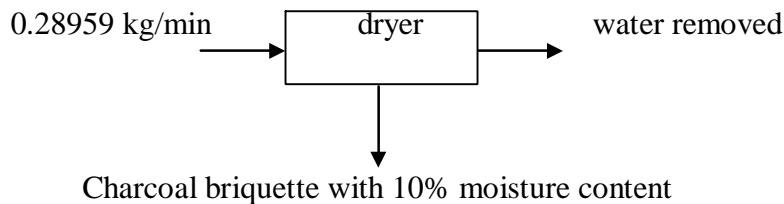
The mixed char moisture content is calculated as;

$$(0.0985/0.2955) * 100 = 33.3\%$$

2% of the mixed char is wasted during molding process therefore the balance on molding can be Calculated as: $0.02*0.2955=0.00591\text{kg/min}$.

The net mixed char= $0.2955\text{kg/min}-0.00591\text{kg/min}=0.28959\text{kg/min}$.

Material Balance on drying



The water in raw material is $= 0.333 \times 0.28959 \text{ kg/min} = 0.0964 \text{ kg/min}$. here, since the density of water is 1000Kg/m^3 , ton/hr is equal with m^3/hr .

Water amount in dried briquette $\frac{y}{y+0.193\text{kg/min}}=0.17$, then $y=0.02146\text{kg/min}$

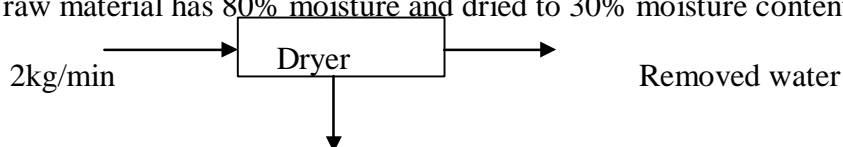
And $0.0964 - 0.02146\text{kg/min} = 0.0749 \text{ kg/min}$ water is removing in the drier. And the total flow rate to burning $0.28959 \text{ kg/min} - 0.0749\text{kg/min} = 0.21469\text{kg/min}$ with 17% moisture content.

From total of 214.69gm/min we made 5 small briquettes each weighted 43g/min.

➤ **Material balance on sawdust**

Raw material Drying

The raw material has 80% moisture and dried to 30% moisture content.



Dried raw material with 30% moisture content

The water in raw material is $= 0.8 \times 2 \text{ kg/min} = 1.6 \text{ kg/min}$. here, since the density of water is 1000 Kg/m^3 , ton/hr is equal with m^3/hr .

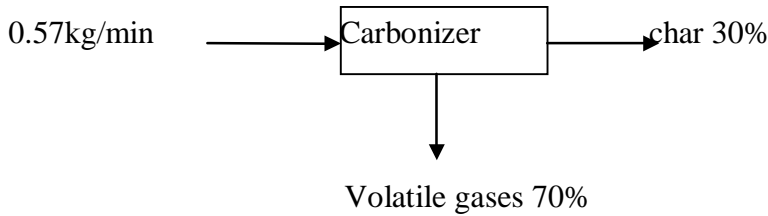
Amount of water in the dried raw material is calculated as follow.

$$\frac{Y}{1.4 + Y} = 30\%, \text{ then } Y = 0.172 \text{ kg/min}$$

And $1.6 \text{ kg/min} - 0.172 \text{ kg/min} = 1.43 \text{ kg/min}$ water is removing in the drier. And the total flow rate to burning $2 \text{ kg/min} - 1.43 \text{ kg/min} = 0.57 \text{ kg/min}$ with 30% moisture content.

Material balance on carbonization process

In biomass, the volatile content is about 70wt%, while coal has 30wt%.



The amount of volatile gases in sawdust is calculated: $0.7 \times 0.57 = 0.399 \text{ kg/min}$

The amount of char is calculated as: $0.3 \times 0.57 = 0.171 \text{ kg/min}$

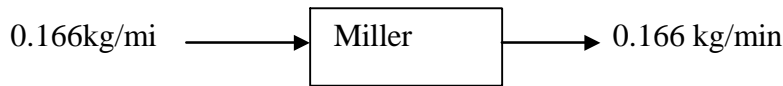
3% of char is wasted during the collection of the char from the carbonizer.

$$0.03 \times 0.171 \text{ kg/min} = 0.005 \text{ kg/min}$$

Therefore, the net char that goes to the next step calculated as:

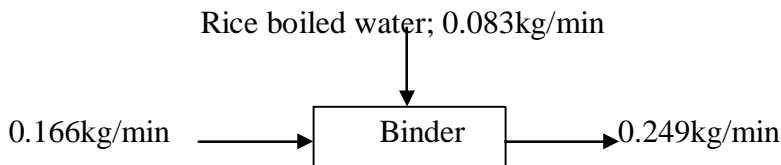
$$0.171 \text{ kg/min} - 0.005 \text{ kg/min} = 0.166 \text{ kg/min}$$

Material balance on milling



Material Balance on Binding

The char is mixed with rice boiled water with the ratio 1:0.5.



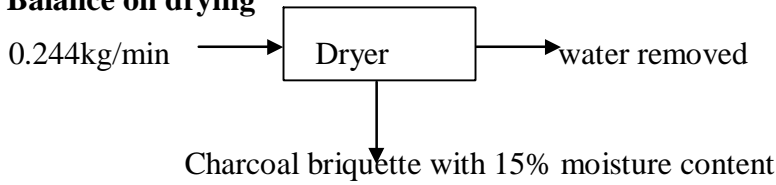
The mixed char moisture content is calculated as;

$$(0.083/0.249) * 100 = 33\%$$

2% of the mixed char is wasted during molding process therefore the balance on molding will be Calculated as: $0.02 \times 0.249 = 0.00498 \text{ kg/min}$.

The net mixed char = $0.249 \text{ kg/min} - 0.00498 \text{ kg/min} = 0.244 \text{ kg/min}$.

Material Balance on drying



The water in raw material is $= 0.333 \times 0.244 \text{ kg/min} = 0.0813 \text{ kg/min}$. here, since the density of water is 1000 Kg/m^3 , ton/hr is equal with m^3/hr .

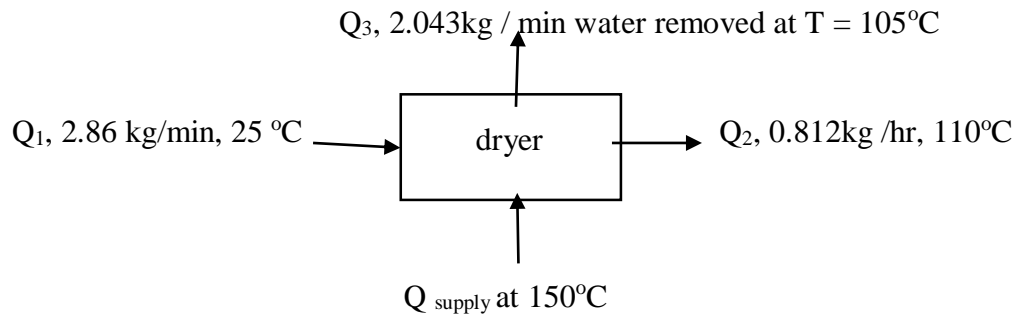
Water amount in dried briquette $= \frac{y}{y+0.163 \text{ kg/min}} = 0.15$, then $y = 0.0287 \text{ kg/min}$

And $0.0813 - 0.0287 \text{ kg/min} = 0.053 \text{ kg/min}$ water is removing in the drier. And the total flow rate to burning $0.244 \text{ kg/min} - 0.053 \text{ kg/min} = 0.191 \text{ kg/min}$ with 15% moisture content.

From total of 191g/min we made 5 small briquettes each weighted 33g/min.

5.1.3 Energy Balance

Raw material dryer:



$$Q_1 + Q_{\text{supply}} = Q_2 + Q_3$$

Where: c_p of corn trash = 1.4 KJ/Kg k , T_o = outlet temperature of the raw material,

T_i inlet temperature of the raw material, T_v = out let temperature of the water vapor and

Assume: for all dryers T_{sta} = standard/reference temperature = $25 \text{ }^\circ\text{C}$

Latent heat of vaporization (h_v) at $105 \text{ }^\circ\text{C} = 2244 \text{ KJ/Kg}$

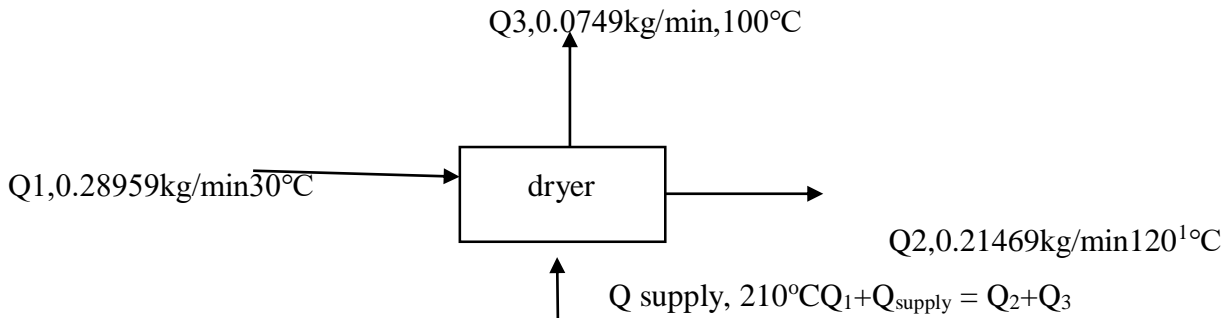
$$Q_1 = M_{\text{corn trash in put}} * C_p (T_o - T_{\text{sta}}) = 2.86 \text{ kg/min} * 1.4 \text{ KJ/Kg k} (25 - 25) = 0$$

$$Q_2 = M_{\text{dried corn trash output}} * C_p (T_o - T_i) = 0.812 \text{ kg/min} * 1.4 \text{ KJ/Kg k} (110 - 25) \text{ k} = 96.63 \text{ KJ/min}$$

$$Q_3 = M_{\text{water}} (h_v + C_p (T_v - T_{\text{in}})) = 2.043 \text{ kg/min} (2244 \text{ KJ/Kg} + 4.18(105 - 25)) = 5267.6 \text{ KJ/min}$$

$$\text{Then; } Q_{\text{supply}} = Q_2 + Q_3 - Q_1 = 96.63 \text{ KJ} + 5267.6 \text{ KJ} - 0 = 5364.3 \text{ KJ/min}$$

Briquette dryer:



Where: T_o = outlet temperature of the briquettes, T_i inlet temperature of the briquettes, T_v = outlet temperature of the water vapor. **Assume:** T_{sta} = standard/reference temperature = 25 °C

$$Q_1 = M_{\text{briquettes}} C_p (T_{in} - T_{sta}) = 0.28959 \text{ kg/min} * 1 (30^\circ\text{C} - 25^\circ\text{C}) = 1.448 \text{ kJ/min}$$

$$Q_2 = M_{\text{dried briquette}} C_p (T_o - T_{in}) = 0.21469 \text{ kg/min} * 1 (105 - 30) = 16.1 \text{ kJ/min}$$

$$Q_3 = M_{\text{water}} (h_v + C_p (T_{os} - T_{is})) = 0.0749 \text{ kg/min} * (2259 \text{ kJ/Kg} + 1(100 - 30) \text{ k}) = 174.44 \text{ kJ/min}$$

Then; $Q_{\text{supply}} = Q_2 + Q_3 - Q_1 = 16.1 \text{ kJ/min} + 174.44 \text{ kJ/min} - 1.448 \text{ kJ/min} = 189.1 \text{ kJ/min}$

5.2 Equipment lay out for briquette production

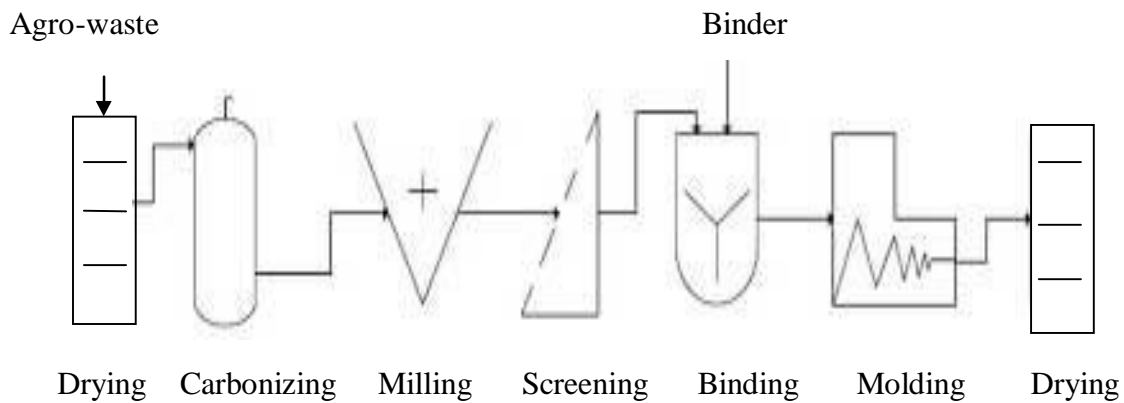


Figure5. 1: process flow diagram of charcoal briquette

5.3 Equipment Sizing

1. Size of inclined screw feed/elevator

From literature review we know that for one tone biomass about 3.5m³ volume is needed

$$V = 4 \text{ tone} * 3.5 \text{ m}^3 / 1 \text{ tone} = 14 \text{ m}^3$$

2. Size of Row material dryer

From energy balance Q (of drier) = 5364.3kJ/hr = 1490J/sec

Assume $U = 250\text{J/sec.m}^2 \text{ } ^\circ\text{C}$

$$Q = UA\Delta T$$

$$A = Q/U\Delta T$$

$$= 1490/250 * 45$$

$$= 0.132\text{m}^2$$

From material balance of row material dryer mass flow rate of corn trash = 2.86 kg/min Area= 4 tone/hr*

$$0.132\text{m}^2/2.86\text{kg/hr}$$

$$=184.6\text{m}^2$$

3. Size of Carbonizer

✓ the size of carbonizer which is 0.064m^3 by volume has a capacity of 1.43kg/hr. by using scale up technique we can determine the capacity of carbonizer.

$$V = (4\text{tone/hr} * 0.064\text{m}^3) / 1.43\text{kg/hr}$$

$$=179.02\text{m}^3$$

4. Hammer miller

✓ From literature review we know that for one tone biomass about 3.5m^3 volume is needed and also from material balance as described earlier

$$\text{Mass on miller} = 0.166\text{kg/hr} * 2000$$

$$= 332\text{kg/hr}$$

$$V = (697.6\text{kg/hr} * 3.5\text{m}^3) / 1000\text{kg}$$

$$=1.16\text{m}^3$$

5. Sizing blender

✓ Mass on blender = $0.166\text{kg/hr} * 2000$

$$= 332\text{kg/hr}$$

$$V = (697.6\text{kg/hr} * 3.5\text{m}^3) / 1000\text{kg}$$

$$= 1.16\text{m}^3$$

6. Sizing on molder

✓ From litterateur review and mass balance as described earlier

Mass on molder = $0.166\text{kg/hr} * 2000$

$$= 332\text{kg/hr}$$

5.4 Purchased Equipment

Table5. 1: Type of Equipment used and their cost [16]

Types of equipment	Number	Capacity (unit)	Individual cost (\$)	Sub-total cost(\$)	Construction Material
Inclined screw/ elevator	1	14m ³	20,200	20,200	Carbon steel
Dryer	8	23.3m ³	24,500	196000	Carbon steel
Carbonizer	5	120.85m ³	7,300	36,500	Carbon steel
Hammer miller	3	2.4m ³	3000	9,000	Carbon steel
Blender	1	2.4m ³	10,700	10,700	Carbon steel
Molder	2	697.62kg	14,500	29,000	Carbon steel
Total cost				301,400	

The total purchased equipment cost of the whole plant is \$301,400

Assume:

- ✓ the total purchased equipment cost is 28% of the fixed capital cost
- ✓ the working capital is 15% of the total investment cost
- ✓ 260 working days/year

Purchased equipment cost (Pec) = 28% fixed capital investment cost (FCI)

$$$, 301,400 = 0.28FCI$$

Then FCI = \$1076428.57= fixed capital investment cost.

Working capital + FCI = total investment cost (TCI)

$$0.15TCI + FCI = TCI$$

$$TCI (1-0.15) = FCI = \$1,076,428.6$$

TCI = \$1,266,386.5= total capital investment cost

Then working capitals is = 0.15X \$1,266,386.5= \$189,957.9

Total production cost

Cost of raw material:

The cost of raw material per ton is \$5 and the total raw material consuming per year = 4ton/hr * 16hr/day * 260 days/year = 16640 ton/year

PYROLYSIS OF AGRO WASTE FOR PRODUCTION OF CHARCOAL BRQUETTE

And the cost of raw material per year = \$5/ton * 16640 ton/year = \$83,200

Cost of total Binding agent

✓ **Starch:** cost starch per ton is \$2 and the total starch consuming per year = $0.0128\text{ton/hr} * 16\text{hr/day} * 260\text{days/year} = 53.25\text{ ton/year}$ and the cost of raw material per year = $\$2/\text{ton} * 53.25\text{ton/year} = \106.5

Therefore, total cost of the binding agent used = \$106.5 and then the total raw material cost and binding agent cost is = $\$83,200 + \$106.5 = \$83,306.5$

Table5. 2: Labor cost

Equipment	Quantity	P	N _{np}
Inclined screw/ elevator	1	1	-
Dryer	8	8	-
Carbonizer	5	5	-
Hammer miller	3	3	-
Blender	1	-	1
Molder	2	-	2
Total	20	17	3

Where; P is the number of unit operations related to solid and particle handling. N_{np} is the number of unit operation related to liquid handling.

- ✓ One operator works 52 weeks per year, 5days a week and 8 hours a day. Therefore, one operator covers 52 weeks per year * 5shift/week = 260 shift per year.
- ✓ The plant operating 260 days per year, 16 hours a day needs $260 * 2\text{shift} = 520\text{ shift per year}$.
Briquetting plant needs $520/260 = 2\text{ persons per one operator position}$.

No_{of total operators} = $20 * 2 = 40$

Assume the average cost of single labor per year is \$1333.3

Therefore, total cost of operators per year = $\$1333.3 * 40 = \$53,332$

Depreciation:

The service life of the plant is 15 years and fixed capital investment (FCI) of this plant is FCI = \$1,076,428.6. The salvage value is 10% of total purchased equipment cost = \$30,140. From this the depreciation (Dj) of the plant is;

$$D_j = (\text{FCI} - \text{salvage value}) / 15 = (1,076,428.6 - 30,140) / 15 = \$69,753$$

Utilities cost:

this cost includes the cost of electricity, processed water, waste water treatment. Then utilities cost can be calculated as follows:

Utilities cost = 10% – 20% of total production cost (TPC), take 15% then

$$\text{Utilities cost} = 15\% * \text{TPC} \dots\dots\dots (1)$$

Other costs:

this cost includes cost of maintenance and repairs, laboratory charges, patent and realities, insurance, rent, plant overhead, general expenses.

These other costs calculated as follow:

$$\text{Other costs} = 25\% \text{ of the total production cost} = 0.25 * \text{TPC} \dots\dots\dots (2)$$

✓ Then the total production cost can be calculated as follows:

$$\text{TPC} = \text{total raw material cost} + \text{operating labor cost} + \text{utility cost} + \text{other costs} + \text{Depreciation} \dots\dots\dots (3)$$

$$\text{TPC} = \$[83,306.5 + 53,332 + 69,753] + 0.15\text{TPC} + 0.25\text{TPC} = \$200,296.5 + 0.4\text{TPC} \quad \text{TPC} (1-0.4) = \$206391.5$$

$$\text{TPC} = \$206391.5 / 0.6 = \$343985.8$$

Then calculate equation (1) and (2), utility cost = \$51,597.87 and other cost = \$74,885.45

Product sales:

$$\text{Total annual product} = 0.36\text{ton/hr.} * 16\text{hr/day} * 260\text{day/year} = 1497.6 \text{ ton/year}$$

$$\text{Unit sell price} = \text{total production cost} / \text{annual production} = \$343985.8 / 1497.6\text{ton/year} = \$459.4/\text{ton} = \$0.459/\text{kg}$$

$$\text{Total production sale is} = 1497.6\text{ton/year} * \$459.4/\text{ton} = \$687997.44/\text{year}$$

$$\begin{aligned} \text{Annual gross earning} &= \text{total product sales} - \text{total production cost} - \text{depreciation} \\ &= \$687997.44 - \$343985.8 - \$69,753 \\ &= \$2,742,58.64 \end{aligned}$$

$$\begin{aligned} \text{Net profit} &= \text{annual gross earning} (1 - \phi); \text{ where } \phi \text{ is a tax rate. Assume tax rate is } = 35\% \text{ Net profit (Np)} \\ &= \$274,258.64 * (1 - 0.35) = \$178268 \end{aligned}$$

Profitability:

Are quantitative measures of profit with respect to the investment required to generate that profit.

Profitability Indicators:

Minimum acceptable rate of return (Mar)

Minimum acceptable rate of return (mar) for new capacity with established corporate with low levels of risk=12%

Rate on investment (ROI) is equals to average net profit per total capital investment.

$$ROI = \left(\frac{Np_{avg}}{TCI} \right) \times 100\% = (1 + x)^n = \frac{\$178268}{\$1266386.5} \times 100\% = 14.1\%$$

✓ ROI is greater than MAR, so it is feasible.

Payback period

(pb) is equals to depreciable fixed capital investment (FCI) per average net profit (Np) plus average depreciation per year (dj)

$$Pbp = \frac{FCI - SALVAGE VALUE}{NP + dj} = \frac{\$1,076,428.6 - \$301,400}{\$178,268 + \$69,753} = 3,12 year$$

$$Pay\ pack\ period\ reference\ (pbp_{ref}) = \frac{0.85TCI}{Np + dj} = 0.85 * \frac{\$1,266,386.5}{\$178,268 + \$69,753} = 5.1\ year$$

Pbp is less than pbp_{ref}. Therefore, our project is feasible.

Net present worth (NPW):

$$NPW = \sum_{j=1}^n (1 + i)^{-j} (Np_j + dj + rec_j) - TCI = P + Rec (1+i)^{-n} - TCI$$

Where:

- ✓ $P = \frac{R((1+i)^2 - 1)}{i(1+i)^n}$ and annual cash flow ®=net profit+depreciation
- ✓ Recovery (Rec) = WC+ salvage value
- ✓ service life, n =15
- ✓ i = 15%

Then the NPw can find as follows:

$$Annual\ cash\ flow\ (R) = net\ profit + depreciation = 178,268 + 69,753 = 248,021$$

$$P = \frac{\$248021((1+0.15)^{15} - 1)}{0.15 \times (1+0.15)^{15}} = \$1,450,270.6$$

$$Recovery\ (Rec) = WC + salvage\ value = \$189,957.9 + \$301,400 = \$491,357.9$$

$$And\ then = (Rec) * \{1+i\}^{-n} = \$491,357.9 * \{1+0.15\}^{-15} = \$60385.2$$

$$NP_w = P + \text{Rec} (1+i)^{-15} - \text{TCI} = \$1,450,270.6 + \$60,385.2 - \$1,266,386.5 = \$244,269.3$$

Since NPw is positive our project is feasible.

5.5 Site Selection

The location of plant can affect the profitability of a project, and the scope for future expansion. And other factors must be considered when selecting suitable site, some of them are: marketing area, raw material availability, transport facilities, availability of suitable land, availability of labor, and availability of utilities. Therefore, for our production suitable area is WAST GOJJAM BURA because the raw material corn trash(cob) which is more wasted from all of gojjam rural area.

CHAPTER 6

CONCLUSION AND RECOMMENDATION

6.1 Conclusion

Production of briquette using Carbonizer can be scale up to an industrial scale to manufacture more efficient smokeless cheaper and renewable fuel briquette in higher amount. The yield of briquette is directly related to the raw material used. In our case using of sawdust as a raw material gives higher yield than using corn trash(cob). The manufacturing technologies involved in each step are easy to implement in rural areas and the technology has a great potential for converting waste biomass into a superior fuel for household use, in an affordable, efficient and environment-friendly manner.

From the economic point of view, the Production of briquette from agro waste is feasible i.e. the rate of return on investment, (ROI) is greater than the minimum acceptable rate of return. The plant uses raw material from the municipality waste. Thus it brings no wastes that are dangerous to the environment and health. The by-product is also biodegradable and we can use it for the production of fertilizer.

6.2 Recommendation

The experimental result indicated that even though briquettes which is produced by rice water as binding agent has some good qualities like, higher burning time and more density, but it has also smoke when it is used. Therefore, we did not recommend using briquette with binding agent rice for indoor cooking purpose.

Further researches have to be done to improve the production of high quality and quantity of charcoal briquettes. Alternative raw materials and binding agents have to be studied in order to investigate the variation that could be arise on the quality and quantity of the briquetting yield. In our country Most of the solid wastes including corn trash(cob) and sawdust have no or very low conversion to different usable products and as such among the major problems of health especially for cities. Hence, it recommended that government or other investors to recover this very valuable product as well as to contribute to the country in reducing the highly rising demand of energy. Know days the demand of energy in Ethiopia has increasing in year to year. Due to this, the factory that stands on briquettes production has can get profit in short period of time. So that government and other stockholders has to encourage and attracting investors to participate in this sector.

Finally, since the field of briquetting production is nearly new idea in Ethiopia, our recommendation forwards to the government and/or non-governmental organization or private investors to give emphasis on the growing of briquette production further deep study in relation to varies raw material.

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Annexes / Appendices



A. Corn trash(cob)



B. Carbonization of agro-waste



C. Mixing of char



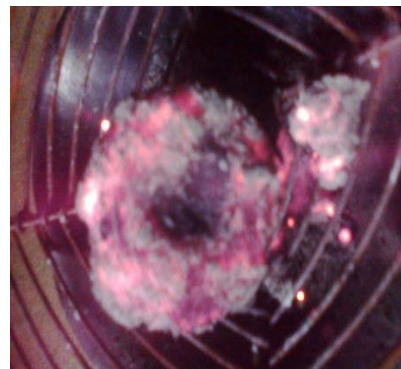
D. Molding of briquette



E. Briquette



F. Measuring of weight



J. Burning of briquette

Table 6. 1: Comparison of wood charcoal and briquette charcoal making process

Briquette charcoal	Wood charcoal
No need of digging a ground to prepare shallow pit of charring	Digging is required
Mobile (Its mobility allows working at a spot of harvesting, farmstead and anywhere)	Not mobile
It is not fire hazardous	sometimes it is fire hazardous
It is safe in the view of health factor	It is not safe