INTEGRATED HEAT ENERGY AND NUTRIENTS RECOVERY IN SUGARCANE WASTES

BY

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SES/PGH/05/08

A THESIS SUBMITTED TO THE SCHOOL OF ENVIRONMENTAL STUDIES IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTERS OF SCIENCE IN ENVIRONMENTAL STUDIES (ENVIRONMENTAL HEALTH)

UNIVERSITY OF ELDORET

NOVEMBER, 2013

DECLARATION

DECLARATION BY CANDIDATE

This research report is my original work and has not been presented for a degree in any other university.

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DEDICATION

I wish to thank my parents, Mr. and Mrs. Ndung'u, my son Jason and husband Gideon for the unending support throughout this entire journey. Thank you God for giving me the wisdom and for my overall well-being.

ABSTRACT

Sugarcane processing industry produces bagasse, molasses and press mud as wastes. Both bagasse and press mud have high energy content while press mud is rich in nutrients phosphates, calcium and nitrates. However, when bagasse is abandoned in heaps and left to decompose, it creates negative environmental conditions and often leads to fires owing to formation of alcohol after fermenting. Attempts have been made to make bagasse briquettes using clay (usually from swamps) as a binder. Clay has low heat energy value and its excavation in turn leads to land degradation. Sugar mill wastes comprise of bagasse, press mud and molasses, and usually the latter is used economically. This study endeavored to find ways of enhancing heat energy and nutrients recovery from bagasse and press mud by incorporating press mud and molasses as binders in the making of bagasse briquettes. Optimum bagasse, press mud and molasses formulation ratios for maximum heat energy recovery were determined. From the trial experiments, the formulation with 52.6% bagasse, 26.3% press mud and 21.05% molasses was found to be the best formulation with 3.75 kCal/g. After complete combustion of the briquettes, the ashes of the briquettes were acid digested and nutrient content determined. Nutrient levels in the resultant ash from the briquettes formulation of 40% bagasse, 20% press mud and 40% molasses were highest with 15.97% Nitrogen, 23.66% Phosphorous, 3.19% Potassium, 1.68% Sodium, 0.28% Calcium, 0.25% Magnesium, 1.38 % Manganese and 0.1% Iron respectively. Calorific value and presence of nutrients in the briquettes, is a possible indicator of the viability of adoption of this form of waste management of integrated heat energy and nutrient recovery. When adopted, it can makes a positive contribution to environmental conservation, energy access and food security.

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ACKNOWLEDGEMENT

I acknowledge and thank my supervisors Dr. Gelas M. Simiyu and Prof Kirimi Kiriamiti for the guidance, constant support, and mentoring throughout my studies and more so for my professional growth.

I am indebted to Chemelil sugar Industry, the entire staff at Kenya Forest Research Institute (KEFRI) has indeed provided all material and guidance freely.

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LIST OF ABBREVIATION

UNFAO - United Nation Food and Agriculture Organization

KSA - Kenya sugar authority

KSI - Kenya Sugar Industry

UNDP - United Nation Development Programme

WEC - World Energy Council

SANS - South African National Standards

UNEP - United Nation Environmental Programme

CHAPTER ONE

INTRODUCTION

1.1 Background

At a global level, industrialization has been characterized by increase in use of fossil fuel as energy carriers, thus there is tendency to think that countries with large biomass dependency are poor countries characterized by low level of industrialization. In the past decade, the old rule was that the richer and more industrialized a country is, the more it depends on fossil fuel for heat energy. This rule has been broken and many countries have realized the need to harness local resources including biomass energy to increase security of energy supply, reverse fossil fuel dependency and improve trade balance and even to curb harsh global warming adversities. The global environmental agenda by the in the form of Agenda 21 of United Nations Conference on Environment & Development adopted by the Plenary in Rio de Janeiro, on June 14, 1992, and the COP 13,Climate, Kyoto Protocol on Climate Change Convention of 1997 has played a role in this process for more than 10 years. As a result, there is a general trend to search for energy alternatives involving locally available renewable resources, while simultaneously pursuing increased energy efficiency throughout the economy. Reliance on fossil fuel is hampered by continuous escalation of prices, depleting oil reserves and greenhouse effects (DOE, 2009; MOE, 2006).

Kenya, which is basically an agro-based economy with agricultural operations and processes hence large quantities of agricultural, agro-industrial residues are generated and often have limited industrial applications. The potential for the exploitation of these residues is enormous due to (a) rising fossil fuel prices (b) their availability in relatively high abundance (c) their availability at almost zero cost and (d) their contribution to environmental protection and conservation (Massaquoi, 1990). One such agro-based industry is the sugarcane processing industries in Kenya. Over the past 10 years, bagasse production in the country has increased by nearly 30% (KSB, 2009). In 2008, the sugar factories in the country crushed over 5 million tons of sugarcane thereby producing just above 2 million tons of bagasse implying that the conversion ration are about 40% of total cane milled. Every sugar mill has an inbuilt boiler that is meant to utilize these wastes but operating efficiencies are low so that there is always surplus of bagasse that poses environmental concerns. The significant amount of bagasse produced should be utilized profitably either by cogeneration of electricity and, producing briquettes for use at household levels. The significantly high amounts of lignin make bagasse particularly difficult to decompose.

It is estimated that currently about 1.6 million tons of bagasse is generated annually in Kenya although potentially about 2.6 million tonnes could be generated. Out of this quantity, only 25% is economically utilized for the generation of process heat for internal use in factory boilers (KSB, 2009). The factories not only incur huge operational costs in transporting bagasse to dumpsites but the residues also pose many environmental problems and impact negatively on human health and safety (Onchieku et al., 2005). Given the growing amounts of sugar milled, there exists a potential formulation of charcoal briquettes and the rapidly growing interest in energy derived from biomass residues and due to local global environmental concerns and technological advances. Environmentally this will reduce deforestation because biomass produced from natural and plantation forests will be supplemented.

The formulation of charcoal briquettes from bagasse is further justified because of its low or zero value yet concentrated at points of processing; its availability throughout the year with minimal storage problems and at almost bone-dry condition; and its continuous supply for years ahead to allow successfully amortization of the plant used for production of the briquettes (UNFAO, 1985).

Briquetting technology is also termed as densification, it enhances physical, and combustion characteristics Briquetting involves converting loose biomass combustible, and compressing them into high-density blocks in a convenient shape that can be burned like wood or charcoal. Studies have been done on the use of carbonized agricultural residues for briquettes such as corncob (Oladeji, 2010), sawdust (Rotich, 1996), rice husk (Jindaporn and Songchai, 2007) and hazelnut shell charcoal (Demirbas and Sahin, 2001). The material is compressed to form a product of higher bulk density, lower moisture content, and uniform size, shape and material properties. Briquettes are easier to package and store, cheaper to transport due to higher density, more convenient to use, and their burning characteristics are better than those of the original organic waste material.

Brazil, Sri Lanka, India and Thailand are some countries that successfully briquette biomass materials. Regionally, there are some countries in Africa, such as Sudan and Mauritius, that have successfully used sugarcane residues to manufacture important products or even use it to co generate electricity (WEC, 2003a). Locally, Mumias Sugar Company has successfully installed electricity cogeneration plant that utilizes a portion of cane residues. By design, all sugar factories in Kenya have an inbuilt cogeneration plant. However, historically, due to age of the equipment, poor maintenance, inefficient sugar production processes and lack of a ready market for available electricity, sugar factories in Kenya have operated relatively inefficient boiler to limit the amount of excess bagasse in their backyards. The factories were essentially using boilers as incinerators of bagasse. (Karekezi, 2009). Though Mumias and Muhoroni Sugar Companies produce 1,070,000 tonnes of bagasse, only 753,000 tonnes are used annually while the rest are disposed off in landfill (Owino, 2009).

Sugarcane wastes comprise bagasse, tops, filter mud and molasses. Bagasse is the fibrous waste left after crushing of cane stalks and extraction of juice. It is known to comprise of cellulose, pentosans and lignin. Typically, immediately after juice extraction, bagasse contains 40-50% moisture content depending on technology used, and 1-3% sugar. If not used rapidly, storage becomes problematic, (Paturau, 1989). Owing to presence of moisture, sugar and microorganisms, fermentation quickly occur producing alcohol. Fire is a hazard at the storage site, while storm water runoff from stocked pile causes severe environmental problems (Allen et al, 1997). There is a problem of high BOD owing to high levels of organic material.

Additionally, bagasse is usually difficult to decompose so as to be used as composite manure. Bagasse cannot be used as fuel at household levels, owing to high moisture content. Thus, to increase the calorific value, moisture content must be reduced and compacted to increase its density. Other uses of bagasse are in production of methane, furfural, paper, particleboard and related products, components of aquaculture systems, chemicals and activated carbon (Paturau, 1989).

Filter mud (filter cake, scum or cachaza), is recovered from press and vacuum filters when sludge from clarification process is dewatered. The clarification process separates the juice into a clear juice that rises to the top and goes to manufacture, and a mud that collects at the bottom. The mud is then filtered to separate the suspended matter, which includes insoluble salts and fine bagasse. There are 3 types of filters: the press filters (used in carbonatation factories), mechanical filters and rotary vacuum filters (Hugot, 1986). The yield of filter cake is variable, from 1 to 7 kg (wet basis) / 100 kg of cane (Van der Poel et al., 1998). It comprises 3.5% per weight of cane processed, contains colloidal organic matter (15-30%), fiber (5-15%), crude proteins (5-15%), sugar (5-15%), crude wax and fats (5-15%)(Paturau, 1989). It can be harnessed as combustible binder in briquette due to its high fat and wax contents. It can also be utilized as fertilizer as it contains approximately about 1 percent by weight of phosphate (P_2O_5) and about 1 percent of nitrogen on a dry basis (Paturau, 1989), animal feeds and source of wax.

Molasses is a residue produced after repeated crystallization of sugar. It is waste syrup from which no further sucrose can be extracted (Panda 2011). The yield of molasses is approximately 3.0 percent per ton of cane but it is influenced by a number of factors and may vary within a wide range (2.2 to 3.7 percent) (Paturau 1989). It can be used to produce dextran or as a filler in bagasse briquettes and several other uses.

1.2 Problem Statement

Sugar industries in Kenya have over the years been faced with the problem of disposal of bagasse especially due to efficiency ratio of boilers during processing (Karekezi 2010), hence cannot completely exhaust all bagasse. Besides, press mud is produced as a wastes and accounts for approximately 3.5% per cane processed (Paturau 1989), depending on efficiency. The two wastes products are dumped in heaps and left to rot in the open with adverse consequences to human and environment.

There have been attempts to utilize these wastes especially bagasse to produce charcoal briquettes using clay, from swamps, as a binder (Onchieku, 2012). This leads to land degradation and accompanying loss of biodiversity. Clay is also known to inhibit the briquettes combustion by producing ash and smoke due to presence of incombustible matters and volatile matter by inhibiting flame propagation (Chirchir et al., 2013). There is little information existing on characteristics of composite briquettes made using press mud and molasses binders while investigating the nutritional value of the resulting ash after briquette combustion.

Bagasse briquettes ash could have higher nutrient content as compared to wood and charcoal because of nutrient accumulation due to fertilizer addition during sugarcane growth (Paturau, 1989). The use of resultant ash residue could be used in the garden to maintain soil fertility, leading to increased crop production hence directly improve food security. This study was aimed to assess the potential of using press mud and molasses as binders in bagasse briquette making to enhance energy recovery and determine the nutrient composition in the resultant ash.

1.3 Purpose

The purpose of this study is to determine how press mud and molasses can be used in place of clay in bagasse briquette formulation.

1.4 Objectives

1. To determine optimum ratio of bagasse, press mud and molasses to optimize calorific value in briquettes.
2. To characterize physico-chemical properties of press mud briquettes in terms of moisture content, ash content, fixed carbon content, volatile matter.
3. To determine nutrient content in the resultant briquette ash and compare with known threshold nutrient parameters for specific crops.

1.5 Hypotheses

H_{01}: Physico-chemical (PC) characteristics of the biomass do not significantly enhance calorific value (CV) of briquettes

H_{02}: There are no optimum ratios (R) that give optimum calorific value (CV).

H_{03}: Nutrient (N) content in the resultant briquette ash does not compare with known threshold nutrient content (N_{TH}).

1.6 Significance of the study

The importance of this study is to establish applicability of press mud in bagasse briquette formulation that enhances heat and nutrient recovery.

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

This chapter discusses the literature related to biomass energy, case study of sugar mill wastes in Kenya, the recovery of heat energy s from bagasse and potential benefits of utilization of briquettes in terms of crop nutrition and provision of heat energy at the household level.

2.2 Biomass

Biomass is a term for all organic material that stems from plants (including algae, trees and crops). Biomass is produced by green plants converting sunlight into plant material through photosynthesis and includes all land- and water-based vegetation, as well as all organic wastes. The biomass resource can be considered as organic matter, in which the energy of sunlight is stored in chemical bonds. When the bonds between adjacent carbon, hydrogen and oxygen molecules are broken by digestion, combustion, or decomposition, these substances release their stored, chemical energy. Biomass has always been a major source of energy for mankind and is presently estimated to contribute of the order 10–14% of the world's energy supply. The value of a particular type of biomass depends on the chemical and physical properties of the large molecules from which it is made (McKendry, 2002).

Energy is important for the provision of essential services for humanity such as lighting, heating and cooking, is broadly classified into renewable and nonrenewable. The demand for renewable energy which include hydro-power, geothermal, biomass, solar, wind and tidal energy, has been increasing over the years in the developing countries where 1.8 million people in rural and urban centers lack access to commercial energy (UNEP, 2000).Biomass energy accounts for about 14 % of the total world energy compared to coal (12 %), natural gas (15 %) and electric energy (14 %). In East Africa 84 % of the total energy used by 90 % of the population is derived from biomass sources such as charcoal, firewood, agricultural residues and animal/livestock wastes. Between 1970 and 1994, production and consumption of charcoal doubled and is expected to increase by 5 % up to the year 2010 (WEC, 2003c)

Wood in form of fuel wood, twigs and charcoal provides 90% and 85% of rural and urban households' energy requirements respectively (GOK, 2002). With the current forest cover of 1.7% and annual population growth rate of 2.7%, the demand for wood-based biomass is expected increase (Matiru, 2007). The high and rapidly increasing demand for wood fuel is considered as one of the contributing factors to the fuel wood crisis (Himraj, 2003). About 2.4 million tons of charcoal which is equivalent to 120,000 ha of woodland are consumed annually (GOK, 2002). This was at an estimated per capita consumption of 156 Kg and 152 Kg of charcoal in the urban and rural areas respectively. According to the rural and urban household energy survey by Mwichabe (1999), about 40 million GigaJoules (GJ) equivalent of energy was derived from farm residues comprising of vegetative materials from diverse agricultural operations and processes. At this rate of consumption, the traditional sources of biomass energy which include woodlands and shrublands – 37.6 million ha; farmlands and settlements –9.5 million ha; indigenous forests – 1.2 million ha; and plantation forests – 0.2million ha are diminishing at an alarming rate of 10 % per annum without replenishment leading to accelerated desertification and increased soil loss caused by de-vegetation and desertification.

Charcoal briquettes are any solid biomass charcoal made by thoroughly mixing powdered charcoal (charcoal fines) produced from any organic material with a binder and/or inorganic additives called fillers (Emrich, 1984).The formulation of charcoal briquettes from bagasse is further justified because of its low or zero value yet concentrated at points of processing; its availability throughout the year with minimal storage problems and at almost bone-dry condition; and its continuous supply for years ahead to allow successfully armotization of the plant used for production of the briquettes (UNFAO, 1995).

2.3 Benefits of biomass energy

Biomass provides a clean, renewable energy source that could dramatically improve our environment, economy and energy security. Biomass energy generates far less air emissions than fossil fuels, reduces the amount of waste sent to landfills and decreases our reliance on foreign oil. Biomass energy also creates thousands of jobs and helps revitalize rural communities.The characteristics of the ideal energy crop are:

- High yield (maximum production of dry matter per hectare),
- Low energy input to produce,
- Low cost,
- Composition with the least contaminants,
- Low nutrient requirements.

2.4 Biomass-Energy Prospects in Kenya

2.4.1 Options available for energy sources in Kenya are

1. Biomass from existing agro-industries example sugar processing industries

2. Commercially grown crops for modern energy production example *jatropa Curcas*-80% of Kenya land mass is considered arid and semi-arid and development of this plant can produce biodiesel as cleaner substitute to crude oil-based diesel
3. Naturally occurring biomass example trees- this option is currently not advocated for because already the forests cover is below the 10% as anticipated.

2.4.2 Typical Sugar Cane Processing Industry

Sugarcane plant consists of a stalk, roots, growing leaves, the remains of dead leaves, and a growing leafy top. The typical composition of cane is as follows:

- 15% dissolved matter (13% sucrose; 2% are other sugars -mainly glucose and fructose)
- 15% fibre (insoluble), and
- 70% water.

For every 100 t cane crushed, approximately 30 t of fibrous residue (bagasse), and about 12 t sugar and 4 t molasses are made.

The farmers transport the cane *stalks* (i.e. cane without roots, without leaves and without tops) to the sugar mill in specially designed vehicles that facilitate easy loading and offloading.

Cane preparation

Juice can be removed from cane either by repeated crushing and washing (milling) or by washing alone, with a final squeezing simply to dry the spent fiber (diffusion). Better sucrose extraction can be obtained by crushing finely shredded cane rather than intact stalks and “Preparation” refers to cane being finely shredded before juice is extracted either by milling or diffusion. Cane is prepared by passing it through one or two sets of cane knives and then through a shredder.

Milling

A basic cane mill consists of three grooved rollers. Prepared cane is squeezed between the rollers, thus forcing the juice out of the fiber. The basic work of a mill is the separation of juice from fiber. Fiber, however, has the natural property of always retaining approximately its own weight of juice regardless of the pressure applied to it. To displace retained juice, water is poured onto the cane fiber before crushing. This is called imbibition. A single milling unit would give an unacceptably low extraction. Typically, six mills are set in tandem and cane is passed in series from Mill 1 to Mill 6.

Diffusion

A diffuser is an enclosed carrier through which a bed of prepared cane is slowly dragged, while copious quantities of water and juice percolate through the bed to wash out the sucrose -bearing juice. The fiber leaving the diffuser is saturated with liquid and has to be dewatered in a mill before being sent either to the boilers or to by-product processes.

Purification of juice

Juice from a milling tandem contains a large amount of cane fiber that falls out with the juice between the rollers of the mills. To remove the fiber, juice is poured over a wire-mesh screen, or cascaded over an inclined wedge-wire screen). Diffuser juice, because of the screening effect of the cane bed itself, is generally not screened.

The juice is heated and lime is added to neutralize the natural acidity. It is then placed in a large settling tank called a clarifier The purpose of clarification is to produce a clear juice that is light in color and free of suspended matter. To improve the precipitate formation, flocculent is added.

The settled precipitate, referred to as press mud, is pumped out of the trays of the clarifier and sent to the filtration station where the juice it contains will be recovered. If a diffuser is used, it is sent to the diffuser and filtered through the bed of bagasse.

Crystal growth

Before crystal growth can take place the clear juice must be concentrated to syrup by the removal of water by evaporation. To improve the efficiency of the water removal step a process known as multiple effect evaporation is used. Multiple effect evaporation is the scheme where juice is boiled in series in several vessels, with steam fed to vessel 1 only. Vapor from vessel 1 boils the juice in vessel 2, vapor from 2 boils the juice in 3, and so on until vapor from the final vessel goes to waste.

The syrup produced by the evaporators is concentrated further in specially designed vessels known as pans. As the concentration rises the dissolved sugar crystallizes and the work of the pans is to grow sugar crystals (from the sucrose in syrup) in several steps to maximize the amount of sucrose recovered in raw sugar.

This is typically done in three boiling steps; each step producing, after crystal/molasses separation, A-sugar and A-molasses, B-sugar and B-molasses, and C-sugar and C-molasses or final molasses.

Supersaturation is the "driving force" in all sugar boiling. Supersaturation is controlled by adding water or syrup to massecuite (crystal / molasses mixture) and by controlling the temperature. When the massecuite is discharged from the pans it is retained in stirred tanks called crystallisers, where the sugar crystals continue to grow through cooling rather than boiling.

Separation of crystals from molasses

Massecuite leaving the crystallisers has now to be separated into crystals and molasses. The more efficient this separation, the more sucrose will be recovered as sugar and the less sucrose will be lost in molasses. A centrifugal is a machine that separates crystals from molasses. Centrifugation involves spinning massecuite in a perforated basket; centrifugal force acts on the molasses, forcing it through the perforations while the sugar remains on the basket wall. Water and steam may then be sprayed onto the crystals to wash off the remaining molasses.

Sugar drying

Sugar leaving the centrifugals has excess moisture which has an extremely detrimental effect on the keeping quality of the raw sugar and drying is therefore important. In a drier, the moisture is driven off from the surface of the liquor layer covering the crystal by passing heated air around the sugar crystals.

The product from the process described so far is a raw sugar (Brown sugar) that can be used as is, or sent to a refinery to be converted to a white (refined) sugar.

Sugar refining

The purpose of the refinery is to remove impurities from sugar crystals. The refinery accepts raw sugar as its feed material. The sugar is dissolved (melted) and the colour is removed by various clarification processes.

Re-crystallisation (from higher purity mother liquor) is alone responsible for a considerable amount of colour removal but other techniques must be employed to obtain the low colour levels of white sugar. Two color removal processes may be applied before the crystallization,example carbonatation and ion exchange.

In carbonatation lime and CO_2 (carbon dioxide) gas are added to the melt to form a calcium carbonate precipitate. This precipitate absorbs colour, is removed by filtration. Further colour is then removed by ion exchange. Resin beads are held in tanks through which the liquor is allowed to percolate under pressure. The purified melt is evaporated and up to 4 crops of crystals are boiled from this. These crystals are combined to form the refined sugar product.

2.5 Sugarcane wastes

2.5.1 Bagasse

Bagasse is the fibrous residue of the cane stalk left after crushing and extraction of the juice. It consists of fibers, water and relatively small quantities of soluble solids - mostly sugar. The average composition of mill-run bagasse is fiber (including as) 48.0%, moisture 50.0% and soluble solids 2.0%. The fiber consists mainly of cellulose (27 percent), pentosans (30 percent), lignin (20 percent) and ash (3 percent).

2.5.2 Press Mud

The precipitated impurities contained in the cane juice, after removal by filtration, form a cake of varying moisture content called press mud or filter muds. This cake contains much of the colloidal organic matter anions that precipitate during clarification, as well as certain non-sugars occluded in these precipitates.

Filter cake has a highly variable composition due to the different technologies involved. The nature of precipitation or flocculation aids, temperature and the fineness of the filtration process are all factors that influence its composition. The product may be fresh (60-80 % water) or dried. Protein content and sugars are both in the 5-15 % DM range. It can also contain important amounts of fibre (probably due to the 15-30 % of fine bagasse). Ash content is comprised between 9 and 20 %, but some press cakes may contain up 60 % mineral matter, a large part of it being silicium. Calcium content is comprised between 1 and 9 % (Van der Poel et al., 1998).

The weight of wet filter muds (80 percent water) averages about 3.4 percent cane. Filter mud contains, on a dry basis, about 1 percent by weight of phosphate (P_2O_5) and about 1 percent of nitrogen. As a result, it has been used, especially since the turn of the century, as a fertilizer. The filter mud also contains a mixture of waxy and fatty lipids in a ratio of 5:2 and refined wax can be extracted by appropriate treatment by solvents. It should be noted, however, that only 386 kg of refined wax, which could be roughly equated to carnauba wax, can be obtained from 1 000 tons of cane. The process is not commercially of interest under existing conditions and only one plant is operating presently in India and on a small scale (Paturau, 1989).

Press mud can serve as a good source of organic manure (Bokhtiar et al., 2001) an alternate source of crop nutrients and soil ameliorates (Razzaq, 2001). Filter cake increases cation exchange capacity for thirty months after its application (Rodella et al., 1990) and its residual effect remains after four years (Viator et al., 2002).

2.5.3 Molasses

Molasses is the final effluent obtained in the preparation of sugar by repeated crystallization; it is the residual syrup from which no crystalline sucrose can be obtained by simple means. The yield of molasses is approximately 3.0 percent per tonne of cane but it is influenced by a number of factors and may vary within a wide range (2.2 to 3.7 percent). The specific gravity varies between 1.39 and 1.49, with 1.43 as indicative average.

Table 1: The composition of molasses

Water	20%	Other carbohydrates	4%
Sucrose	35%	Nitrogenous compounds	4.5%
Fructose	9%	Non-nitrogenous acids	5%
Glucose	7%	Ash	12%
Other reducing sugars	3%	Others	5%

Source: Paturau, 1989

A very large number of products can be derived from molasses. The main products of molasses fermentation that are of economic importance are namely rum, ethyl alcohol, acetic acid, butanol/acetone, citric acid, yeast and monosodium glutamate.

2.6 Overview of the Sugar Industry in Kenya

Kenya is well suited for sugarcane development particularly in the lowlands around Lake Victoria in the western part of the country as well as in the coastal area on the south eastern part of Kenya. The western part of the country is comprised of 3 sugarcane growing sub-regions, namely: Nyando Sugar Belt, Western Sugar Belt and South Nyanza Sugar Belt (KSB, 2009).

Bagasse-based cogeneration is not a new technology in the Kenyan sugar industry. By design, all sugar factories have an in-built cogeneration plant. However, historically, due to age of the equipment, poor maintenance, inefficient sugar production processes and waste management systems and lack of a ready market for available electricity, sugar factories in Kenya have operated relatively inefficient boilers to limit the amount of excess bagasse in their backyards. Over the past 10 years, bagasse production in the country has increased by nearly 30% (KSB, 2009). In 2008, the sugar factories in the country crushed over 5 million tons of sugarcane thereby producing just above 2 million tons of bagasse. The following figure shows trends in bagasse production over the past 10 years.

Table 2: Bagasse production trends over the past 10 years

Sugar Factory	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
Chemelil	218,125	256,959	196,028	270,674	197,192	243,005	193,186	270,920	279,266	253,209
Muhoroni	157,334	67,295	6,027	180,477	171,174	142,100	144,377	161,431	177,076	190,857
Mumias	879,962	725,116	729,625	799,166	785,173	877,433	888,604	842,989	898,871	839,129
Nzoia	211,799	160,289	122,850	234,046	207,682	247,182	241,898	222,705	267,523	217,310
South Nyanza	257,415	185,297	179,945	205,546	196,321	256,318	268,533	223,445	244,406	191,865
Miwani[3]	68,583	57,803	4,229	N.A	N.A	N.A	N.A	N.A	N.A	N.A
Ramisi[4]	N.A	N.A	N.A	N.A	N.A	N.A	N.A	N.A	N.A	N.A
West Kenya	77,508	45,776	55,273	85,099	85,830	86,111	114,239	156,663	119,379	201,821
Kibos[5]	N.A	N.A	N.A	N.A	N.A	N.A	N.A	N.A	N.A	137,104
Soin[6]	N.A	N.A	N.A	N.A	N.A	N.A	N.A	N.A	N.A	N.A
Total[7]	**1,870,726**	**1,498,535**	**1,293,997**	**1,775,008**	**1,643,372**	**1,852,149**	**1,850,837**	**1,878,153**	**1,986,521**	**2,031,295**

Source: KSB, 2009

Key:

3. Miwani Sugar Factory closed indefinitely in February 2001.
4. Ramisi Sugar Factory collapsed in 1988. It is, however, in the process of revival and anticipated to start sugar production in 2011/12.
5. Kibos Sugar Factory started operations in December 2007.
6.Soin Sugar Factory is a small sugar mill which started operations in mid-2006. However, no data is available on its bagasse production.
7. There could differences in the totals in other sources due to errors in aggregation.

2.6.1 Kenya’s utilization of bagasse-Case Study of Mumias Sugar Company

Mumias Sugar Company (MSC) is the largest sugar factory in Kenya and has the most advanced cogeneration development experience in the sugar industry (Karekezi, 2009). The company started operations in 1973.The the original cogeneration plant at Mumias sugar factory was deliberately designed to be inefficient by burning as much bagasse as possible to avoid accumulating an excess of the by-product. However, MSC’s interest in exporting excess cogenerated electricity dates back in the 1990s. The national electricity utility, however, was not interested in offering attractive tariffs to the sugar factory. For several years, in spite of having the potential to export 5.5 MW to the national grid, Mumias supplied only about 2 MW on an intermittent basis (Mumias, 2010).

In May 2009, Mumias Sugar Company commissioned its 38 MW cogeneration plant – making it the sugar factory with the largest and most efficient cogeneration plant. With the new cogeneration plant, Mumias increased its electricity generation capacity nearly three-fold. Currently, the sugar factory exports about 26 megawatts to the national grid. While the company has successfully developed an advanced cogeneration plant, its implementation has met a several challenges including about a 6 months' delay in commissioning of the plant (MSC, 2009). However, the most significant challenge has been Kenya Power Company's failure to provide the cogeneration plant at Mumias Sugar Factory priority dispatch as stipulated in the Feed-in Tariff Policy. The resolution of this issue is critical to the future development of cogeneration in Kenya as all other sugar is looking up to Mumias Sugar Factory as the benchmark on which to develop their own cogeneration plants.

Given that no other sugar mill in Kenya has had the ability to utilize all the bagasse produced, then there is need to harness cheap efficient technologies that will convert the sugar mill wastes into environmentally and economically sound products.

2.7 Biomass Densification

Densification of loose biomass (agricultural and agro-industrial wastes) is called biomass briquetting. It facilitates easy transportation, better handling and storage besides being efficient in use as an alternative fuel to coal and firewood. The high temperature developed during the high-pressure densification process assists the inherent lignin present in the biomass to bind the biomass and form a densified fuel called briquettes. Utilization of biomass residues and wastes is often difficult due to their uneven and troublesome characteristics. This drawback can be overcome by means of densification, which is compaction of the residues into products of high density and regular shape.

Briquetting involves collecting combustible materials that are not usable due to a lack of density, and compressing them into a solid fuel of a convenient shape that can be burned like wood or charcoal. Materials such as sawdust, wood bark, rice husks, and straw have been successfully briquetted.

Depending on the type of equipment used, densified biomass can be categorized into two main types: briquettes and pellets. Briquettes are of relatively large size (typically 5-6 cm in diameter and 30-40 cm in length) while pellets are small in size (about 1 cm in diameter and 2-4 cm in length). Densified biomass produced in developing countries is mostly in the form of briquettes, which are used directly to substitute fuelwood or for carbonizing to produce briquetted charcoal; use of pellets so far appears to be insignificant. Because of small and uniform size, pellets are particularly suitable for automatic auger-fed combustion systems; densified biomass used in developed countries is mostly in the form of pellets.

2.7.1 Densification technologies

Two common types of briquetting presses employed in developing countries are heated-die screw press and piston press. The piston press technology is the dominant technology in India, Brazil and Africa.

Compared to piston-press machines, heated-die screw press machines have smaller capacity but produce stronger and denser briquettes. Screw press technology is therefore more suitable if the briquettes are to be carbonized to obtain briquetted charcoal (UNFAO, 1995).

Conventional binder less briquetting, low-pressure cold briquetting using binder has also been tried in some places. Most noteworthy among these is the carbonization-briquetting process, in which biomass is first carbonized and the resulting charcoal is briquetted using a suitable binder. Another low-pressure binder less briquetting process involves mixing pulverized chopped and decomposed biomass with water into a pulp. The pulp is pressed inside a perforated pipe to get 4-inch diameter cakes, which are sun-dried to get briquettes (Stanley, 2002). The briquettes, called coal-biomass briquettes are produced by using a roll-press. It is claimed that the use of the desulfurizing agent (slaked lime) and biomass results in cleaner combustion of the briquettes in stoves and less of ash compared with coal or coal briquettes (Kobayashi, 2002). Briquetting using piston-and-die type of briquetting technology has been extensively studied by Ndiema *et al*., 2002; Husain *et al*., 2002). The findings show that characteristics of briquettes are influenced by process and material parameters such as die pressure and moisture content.

2.8 Operating Principles

Compaction can be accomplished with or without a binder. One must have something to make the material stick together during compression. Otherwise, when the briquette is removed from the mold, it will crumble to pieces. This fastening agent is known as a binder. In some cases, most commonly under high temperature and/or pressure, a material can act as its own binder. Wood, for example, becomes plastic and can be briquetted without a binder under such conditions. Fillers delay heat release of burning briquettes. Additives are also used to enhance ignition characteristics, prevent fermentation or accelerate chemical processes as well as give flame some decorative colors (Emrich, 1984).

The chemical composition of biomass residues used for briquettes influence the quality of briquettes. Raw materials with high lignin and extractive content produce charcoal with higher gross calorific value. Lignin promotes char formation while holocellulose (cellulose and hemicellulose) promotes the release of volatile matter during pyrolysis. Sudradjat (1983) reported that briquettes bonded with starch are lower in density, compressive strength, ash content and volatile matter, but higher in moisture content, fixed carbon and calorific value than briquettes bonded with molasses.

In most cases, the process of briquetting will consist of a series of steps, namely:

1. Collecting material to be densified.
2. Preparing material.
3. Compacting.
4. Removing, drying or cooling, and storing.

2.9 Collection of materials

Materials collected for densification are those that can burn, but are not in a convenient size, shape, or form to be readily usable as fuel. Such materials are good candidates for briquetting and they include and are not limited agriculture wastes, and forest-based industry wastes. It is also advisable to make briquettes of more than one material, which according to Emrich, (1984) the combination enhances, energy recovery efficiency.

2.10 Preparation of Feed Stock

The method of mixing the raw material with the binder to produce a feed stock can vary widely. The correct proportion of raw material to binder must be determined before starting full-scale production. This is best accomplished by a trial and error method of making several briquettes with different mixtures of binder material, then testing each for mechanical strength and burning properties.

The cost of the binding material can be critical to the economic success of the project, so the smallest amount of binder necessary for an acceptable briquette should be used. Although a combustible binder is desirable, it is possible to use a noncombustible binder with good results. Alternative uses of the binder must be weighed against the value of the final product as an energy source. Non-combustible binders include clay, cement, tar, lime and other adhesive minerals. Combustible binders include: slime, natural or synthetic resins, animal manure, dewatered sewage sludge, fish waste, algae, and starch.

2.10.1 Carbonization

A biomass material is heated to very high temperatures but is not given enough oxygen for the material to burn, to allow their decomposition into (1) charcoal fine (2) ash (3) tarry substance (4) liquid and gaseous products and (5) non-condensable gases (UNFAO, 1995). The briquetting process can be used with carbonization to produce briquettes made wholly or partially of charcoal. The briquettes can be made using charcoal fines or ash as part of the feed stock, or the briquettes can be compacted with any of the raw materials listed above and then carbonized. The first method most probably produces a more consistent product. The second method may result in briquettes that are too fragile to handle without creating excessive dust.

Carbonization is the most critical step that determines the amount of calorific value of the fuel. Unless it is carried out as efficiently as possible, it puts the whole operation of charcoal production at risk since low yields in carbonization reflect back through the whole chain of production as increased costs and waste of resources.

Bagasse consists of three main components: cellulose, lignin and water. The cellulose and lignin and some other materials are tightly bound together. The water is adsorbed or held as molecules of water on the cellulose/lignin structure. Air dry or "seasoned" the briquette still contains 12-18% of adsorbed water.

The water in the bagasse has to be driven off as vapor before carbonization can take place. To evaporate water requires a lot of energy so that using the sun to pre-dry as much as possible before carbonization greatly improves efficiency. The water remaining in the bagasse to be carbonized, must be evaporated in the kiln and this energy must be provided by burning some of the bagasse itself which otherwise would be converted into useful charcoal.

The first step in carbonization in the kiln is drying out of the bagasse at 100°C or below to zero moisture content. The energy for these steps comes from partial combustion of some of the bagasse charged to the kiln or pit and it is an energy absorbing or endothermic reaction.

When the bagasse is dry and further heated, it begins to spontaneously break down to produce charcoal plus water vapor, methanol, acetic acid and more complex chemicals, chiefly in the form of tars and non-condensable gas consisting mainly of hydrogen, carbon monoxide and carbon dioxide. Air is admitted to the carbonizing kiln or pit to allow some bagasse to be burned and the nitrogen from this air will also be present in the gas. The oxygen of the air is used up in burning part of the bagasse charged.

The spontaneous breakdown or carbonization of the bagasse at higher temperatures liberates energy and hence this reaction is said to be exothermic. This process of spontaneous breakdown or carbonization continues until only the carbonized residue called charcoal remains. Unless further external heat is provided, the process stops. This now carbonized bagasse, however, will still contain appreciable amounts of tarry residue, together with the ash of the original bagasse.

In the study conducted by Forest Department on Simple technologies for charcoal making (UNFAO, 1987) from wood, the findings were as follows, in wood, the ash content of the charcoal was about 3-5%; the tarry residue was to about 30% by weight and the balance is fixed carbon about 65-70%. Further heating increased the fixed carbon content by driving off and decomposing more of the tars. When carbonizing wood, a temperature of 500°C gives a typical fixed carbon content of about 85% and a volatile content of about 10%. The yield of charcoal at this temperature is about 33% of the weight of the oven dry wood carbonised - not counting the wood, which was burnt to carbonize the remainder. Thus, the theoretical yield of charcoal varies with temperature of carbonization due to the change in its content of volatile tarry material. The following table showed the effect of final carbonization temperature on the yield and composition of the charcoal.

Table 3: Effect of carbonization temperature on yield and composition of charcoal

Carbonization temperature °C	Chemical analysis of charcoal		Charcoal Yield based on oven dry wood (0% moisture)
	% of fixed charcoal	% volatile material	
300	68	31	42
500	86	13	33
700	92	7	30

Source UNFAO, 1987

Low carbonization temperatures give a higher yield of charcoal but this charcoal is low grade, is corrosive due to its content of acidic tars, and does not burn with a clean smoke-free flame. Good commercial charcoal should have a fixed carbon content of about 75% and this call for a final carbonizing temperature of around 500°C.

The yield of charcoal also shows some variation with the kind of wood. There is evidence that the lignin content of the wood has a positive effect on charcoal yield. High lignin content gives a high yield of charcoal. Therefore, mature wood in sound condition is preferred for charcoal production. Dense wood also tends to give a dense, strong charcoal, which is also desirable. However, very dense woods sometimes produce a friable charcoal because the wood tends to shatter during carbonization. The friability of charcoal increases as carbonization temperature increases and the fixed carbon content increases as the volatile matter content falls. A temperature of 450 to 500°C gives an optimum balance between friability and the desire for high fixed carbon content (UNFAO, 1987).

The many variables possible in carbonization make it difficult to specify an optimum procedure - generally, the best results will be obtained by using sound hardwood of medium to high density. Just like wood, the bagasse should be as dry as possible. Bagasse, which will be burnt up to start the carbonization process, can be of inferior quality. Its sole function is to produce heat to dry out and heat up the remainder to carbonizing temperature.

In carbonizing bagasse, there have been no studies to suggest optimum temperatures for optimum carbonizing temperatures for optimum carbon content. During carbonization in this study, carbonization was difficult since the air circulation, cooling effects were irregular, and cold spots occur. These produce "brands" of uncarbonized bagasse resulted in burning part of the charcoal to ashes, while leaving other parts of the charge only partly carbonized. Hence, the importance of using well designed kilns properly operated for an efficient charcoal operation.

2.10.2 Compaction

In general, a supply of prepared feed stock is loaded into a chamber, the chamber is covered with a close-fitting top, and pressure is applied to compress the feed stock. The pressure applied can be anywhere from 0.5 to 2,000 bars, attaining densities of 200kg/m^3 to 1200kg/m^3 or higher depending on the process employed. In some cases, the feed stock is heated to aid in the binding.

Compaction can be accomplished by some of the more sophisticated briquetting machines. Heating the feed stock may be done, then extrude it. Extrusion is a process whereby the feed stock is forced through a small opening at high pressure.

The result is a continuous log that can be cut to any length. The advantage of extrusion is that it is a continuous process that can produce briquettes in many shapes and sizes.

2.11 Comparing the Alternatives

Briquetting or densification is only one of several technologies that should be considered for the use of agricultural and biomass waste. Alternatives include (Cosgrove-Davies 1985):

i. Fertilizer or Soil Conditioner
ii. Livestock Feed
iii. Bacterial Fermentation for Alcohol Production.
iv. Anaerobic Digestion for Methane Production
v. Gasification.
vi. Pyrolysis
vii. Suspension Burners
viii. Fluidized Bed Combustors
ix. Appropriate in light industrial settings.

2.11 Choosing the Right Technology

Before embarking on a briquetting program investigate the potential market to determine the viability of the project.

Cost of final energy from biomass energy systems depends on costs associated with the fuel, e.g. plantation, harvesting, transportation etc. and costs associated with the energy systems, that is capital and maintenance costs.

Small-scale energy systems-Cost of energy for traditional thermal applications, for example cooking, varies quite widely. In most cases in rural areas, people collect their own biomass fuel and build their own stoves. Energy from biomass in such cases is practically free (if we neglect the value of the time for fuel collection and stove building).However, in situations where biomass fuels are purchased and utilized with low efficiency (say, about 10per cent), the cost of useful energy delivered to the cooking pot may be substantial and even exceed cost of energy from LPG or kerosene, particularly if the fossil fuels are subsidized.

Social, environmental, political, and economic factors should be researched along with technical matters. For example, although in some cases the raw materials required for briquetting will be very low in cost, the market for briquettes itself will increase the value of the raw materials. This could have negative effects on the distribution of income.

In addition, some briquetting materials have competing uses. Dung, for example, is also used as a fertilizer. Thus the value of the fuel for its various uses must be weighed before any decision is made.

In general, the final briquetted product should have a heating value comparable to wood. It may, however, burn in a different manner than traditional fuels and thus the stove (or the briquette) may have to be modified to be compatible. This issue should be taken quite seriously by the briquette manufacturer who plans to sell the product on the open market appropriate in light industrial settings.

When analyzing the feasibility of a briquetting project and the market appeal of the product, some preliminary research is essential before proceeding with technical design. The most effective way of achieving success is to assess the situation from several viewpoints farmers' cooperatives, women's associations, contractors, technicians, etc. These groups are a good source of information about the availability of combustible waste of all kinds, the social climate, the attitudes of local people to innovations, and economic and other relevant factors (Cosgrove-Davies 1985)

Environmental questions should also be taken into consideration, because using biomass waste as fuel eliminates an important element in the ecological chain. Normally, biomass waste is returned to the soil. If this balance is broken, the consequences may decrease productivity of the soil and, in extreme conditions, even lead to desertification. The briquetting of biomass waste that would otherwise be unavailable as fuel can be an effective, low-cost method of increasing the fuel supply. In addition, by providing an alternative to wood burning, briquetting can help slow the process of deforestation (Cosgrove-Davies 1985). A wide range of technologies makes briquetting accessible to nearly everyone.

2.12 Barriers

The major barriers to biomass energy in developed countries appear to include:

1. Information - since there is a lack of understanding of using biomass for energy in many countries
2. Risk - mainly those associated with unproven fuel supply and conversion technologies
3. Financial - since the cost of energy from biomass is normally higher compared with fossil fuels;
4. Market characteristics - mainly arising out the network involving farming/forestry communities and power producers; and

5. Insufficient policy support for energy crops.

2.13 Benefits of Bagasse briquette Development

Bagasse-based briquettes are a clean source of energy compared to fossil fuels and, it is “carbon-neutral”. It utilizes waste material, which, if not well disposed off, becomes a fire hazard as well as an environmental concern - decomposition of bagasse releases to the atmosphere methane which is a more potent greenhouse gas than carbon dioxide. Thus its use for heat energy generation delivers significant local environmental as well as climate benefits.

Another important consideration for bioenergy development is the potential conflict between food production and energy generation. Bioenergy development has been criticized for impacting negatively on food production due to changes in land use. This is not the case with bagasse utilization.

Bagasse briquetting does not affect existing settlements and therefore does not lead to displacement of communities unlike other forms of energy development example coal mining and crude oil extraction.

Briquetting when adopted enhances job creation opportunities in sugarcane growing zones. Expansion of cogeneration development invariably leads to increased sugarcane production, which, in turn, requires additional labour – thereby increasing job opportunities.

Aided by cogeneration development, the survival of sugar factories in Kenya is crucial for the social welfare of rural communities residing in the sugar belt of Kenya.

2.14 Carbon sequestration versus carbon sinks

The 1997 Kyoto Protocol, article 3.3 and 3.4 recognize the potential of biomass as a carbon sink and as a substitute for fossil fuels. The Intergovernmental Panel on Climate Change (IPCC) has estimated that between 60-87 billion tons of carbon would be stored in forests between the years 1990-2050. Some of the strategies proposed for tackling greenhouses gases emission are:

1 Sustainable production of energy resources that result in neutral CO_2 production

2 Sequestration of CO_2which creates carbon sinks e.g. forest mitigating global CO_2-induced greenhouse effect by sequestrating carbon in their standing biomass

3 Direct substitution of fossil fuels with greater environmental and ecological benefits

Displacing fossil fuels with biomass grown sustainably and converted into useful energy by modern conversion technologies is more effective in decreasing atmospheric CO_2 than in sequestrating carbon in trees (Hall et al., 1993).

2.15 Millennium Development Goals

The international community has pledged to reduce poverty by 2015 through the Millennium Development Goals (MDGs). The MDGs have set targets for a reduction in poverty, improvements in health and education, and protection of the environment, and are commonly accepted as a framework for measuring progress towards poverty alleviation.

Reducing the level of indoor air pollution is included in MDG7, ensuring environmental sustainability, as an indicator to monitor the proportion of people using solid fuels. Measuring the proportion of people relying on solid fuel may turn out to be a very blunt instrument for monitoring indoor air pollution. Though cooking with a cleaner fuel is by far the least polluting option, switching to higher quality fuel is out of reach for the vast majority of people at risk. Poverty will continue to condemn many households to cook on traditional fuel. In the short to medium term, the most feasible option for these homes is to get smoke safely out of the house.

Nevertheless reducing levels of indoor air pollution could contribute to the achievement of most of the MDGs. Most significantly, MDG 4 has a target to reduce by two-thirds the under-five mortality rate between 1990 and 2015. At the World Summit on Sustainable Development (WSSD) in Johannesburg in 2002 there was acknowledgement that the vicious cycle of energy poverty needs to be broken in order to achieve the Millennium Development Goals for reducing world poverty. A lack of access to clean and affordable energy can, and should, be considered a core dimension of poverty.

2.16 Quality of briquettes

The quality of briquettes is generally influenced by various physico-chemical properties; the most important being calorific value, density, moisture content, volatile matter, fixed carbon content, ash content, heavy metals, sulfur and cadmium concentrations.

2.16.1 Calorific value

Calorific value of a substance, usually a fuel or food, is the amount of heat released during the combustion of a specified amount of it. The energy value is a characteristic for each substance. It is measured in units of energy per unit of the substance, usually mass, such as kJ/kg, kJ/mol, kcal/kg; Btu/lb. heating value is commonly determined by use of a bomb calorimeter (NIST Chemistry WebBook).

A bomb calorimeter consists of a small cup to contain the sample, oxygen, a stainless steel bomb, water, a stirrer, a thermometer, the dewar (to prevent heat flow from the calorimeter to the surroundings) and ignition circuit connected to the bomb.

2.16.2 Moisture content

Two forms of moisture content are of interest in biomass:

1. Intrinsic moisture: the moisture content of the material without the influence of weather effects,
2. Extrinsic moisture: the influence of prevailing weather conditions during harvesting on the overall biomass moisture content.

In practical terms, it is the extrinsic moisture content that is of concern, as the intrinsic moisture content is usually only achieved, or applicable, under laboratory conditions. Briquettes exposed to ambient atmosphere absorbs moisture to between 5-10% increasing its hygroscopicity upto 15% moisture content when not properly burnt or where pyroligneous acids and tars are washed back onto the charcoal. Higher moisture content lowers calorific or heating value of the briquettes. Quality of specification for charcoal limit content is between 5-15% of gross weight.

2.16.3 Proportions of fixed carbon and volatile matter

The fixed carbon content is the amount of "pure" carbon contained in charcoal. This should not be confused with the overall carbon content, which also include carbon contain in volatile substances. These variations depend essentially on the carbonization temperature and the species of biomass used.

Fuel analysis has been developed based on solid fuels, such as coal, which consists of chemical energy stored in two forms, fixed carbon and volatiles:

- The volatiles content, or volatile matter (VM) of a solid fuel, is that portion driven-off as a gas (including moisture) by heating (to 950 °Cfor 7 min)
- The fixed carbon content (FC), is the mass remaining after the releases of volatiles, excluding the ash and moisture contents.

Laboratory tests are used to determine the VM and FC contents of the biomass fuel. Fuel analysis based upon the VM content, ash and moisture, with the FC determined by difference, is termed the proximate analysis of a fuel. Elemental analysis of a fuel, presented as C, N, H, O and S together with the ash content, is termed the ultimate analysis of a fuel. Good commercial charcoal should have a net volatile matter of about 30%

2.16.4 Ash/residue content

When heat energy is produced by combustion in air, this solid residue is called `ash' and forms a standard measurement parameter for solid and liquid fuels. The ash content of biomass affects both the handling and processing costs of the overall, biomass energy conversion cost. Of importance in respect of the prevailing weather conditions at the time of harvesting, is the potential contamination of the harvested biomass by soil and other detritus, which can in turn have a significant deleterious impact on other `material' properties during subsequent treatment or processing. The parameters of interest that are affected by such contamination are the ash and alkali metal content of the material.

Other factors, which play a significant role on briquette quality, are acids that are recovered during carbonization e.g. pyroligneous acids, acetic, methanol, acetone and tar (UNFAO, 1995).Specifications of lump charcoal and briquettes based on ash content, moisture content, carbon, volatile matter, binder and calorific values is given in Table 4.

Table 4: Export specification for lump charcoal and briquettes

Parameter	**Lump charcoal %**	**Lump charcoal %**	
		Without energy extender	**Without energy extender**
Ashes	3-4	Max. 8	Max. 25
Moisture	<5	5	5
Carbon	80-82	70-75	60-65
Volatiles	10-15	10-15	10-15
Binder	-	Max. 8	Max. 8
Calorific value	6,800-7,200 kcal/kg	6,000 kcal/kg	5,200 kcal/kg

Source: Emrich (1985)

The following are permissible specifications of various parameters on quality of charcoal briquettes quality specified by SANS (1399:2008, Edition 2.3).

- Moisture content: ≤10%
- Volatile matter content: ≤20%
- Ash content: ≤5%
- Fixed carbon content: ≥55%
- Sieve analysis permissible specification for charcoal briquettes- the amount passing through test sieve of aperture 9.5mm shall not exceed 5% (by mass).

2.17 Determination of Elemental Composition of Ash

Ashing in analytical chemistry is defined as the heating of a substance to leave only noncombustible ash, which is analyzed for its elemental composition. Ash is the inorganic residue remaining after the water and organic matter have been removed by heating in the presence of oxidizing agents, which provides a measure of the total amount of minerals within a food. Analytical techniques for providing information about the total mineral content are based on the fact that the minerals (the analyte) can be distinguished from all the other components (the matrix) in some measurable way. The most widely used methods are based on the fact that minerals are not destroyed by heating, and that they have a low volatility compared to other food components. The three main types of analytical procedure used to determine the ash content of foods are based on this principle: dry ashing, wet ashing and low temperature plasma dry ashing. The method chosen for a particular analysis depends on the reason for carrying out the analysis, the type of substance analyzed and the equipment available. Ashing may also be used as the first step in preparing samples for analysis of specific minerals, by atomic spectroscopy or the various other methods.

Sample Preparation

Typically, samples of 1-10g are used in the analysis of ash content. Solids are finely ground and then carefully mixed to facilitate the choice of a representative sample. Before carrying out an ash analysis, samples that are high in moisture are often dried to prevent spattering during ashing. High fat samples are usually defatted by solvent extraction, as this facilitates the release of the moisture and prevents spattering. Other possible problems include contamination of samples by minerals in grinders, glassware or crucibles which come into contact with the sample during the analysis. For the same reason, it is recommended to use deionized water when preparing samples.

Dry Ashing

Dry ashing procedures use a high temperature muffle furnace capable of maintaining temperatures of between 500 and 600 ^{o}C. Water and other volatile materials are vaporized and organic substances are burned in the presence of the oxygen in air to CO_2, H_2O and N_2. Most minerals are converted to oxides, sulfates, phosphates, chlorides or silicates. Although most minerals have fairly low volatility at these high temperatures, some are volatile and may be partially lost, *e.g.*, iron, lead and mercury. If an analysis is being carried out to determine the concentration of one of these substances then it is advisable to use an alternative ashing method that uses lower temperatures.

The food sample is weighed before and after ashing to determine the concentration of ash present. The ash content can be expressed on either a *dry* or *wet* basis:

$$\%\ \text{Ash (dry basis)} = \frac{M_{ASH}}{M_{DRY}} \times 100$$

$$\% \text{ Ash (wet basis)} = \frac{M_{ASH}}{M_{WET}} \times 100$$

Where M_{ASH} refers to the mass of the ashed sample, and M_{DRY} and M_{ASH} refer to the original masses of the dried and wet samples.

There are a number of different types of crucible available for ashing food samples, including quartz, Pyrex, porcelain, steel and platinum. Selection of an appropriate crucible depends on the sample being analyzed and the furnace temperature used. The most widely used crucibles are made from porcelain because it is relatively inexpensive to purchase, can be used up to high temperatures (< 1200^{o}C) and are easy to clean. Porcelain crucibles are resistant to acids but can be corroded by alkaline samples, and therefore different types of crucible should be used to analyze this type of sample. In addition, porcelain crucibles are prone to cracking if they experience rapid temperature changes. A number of dry ashing methods have been officially recognized for the determination of the ash content of various foods (AOAC Official Methods of Analysis). Typically, a sample is held at 500-600 ° C for 24 hours.

- Advantages*:* Safe, few reagents are required, many samples can be analyzed simultaneously, not labor intensive, and ash can be analyzed for specific mineral content.
- Disadvantages*:* Long time required (12-24 hours), muffle furnaces are quite costly to run due to electrical costs, loss of volatile minerals at high temperatures, *e.g.*, Cu, Fe, Pb, Hg, Ni, Zn.

Wet Ashing

Wet ashing is primarily used in the preparation of samples for subsequent analysis of specific minerals (see later).It breaks down and removes the organic matrix surrounding the minerals so that they are left in an aqueous solution. A dried ground food sample is usually weighed into a flask containing strong acids and oxidizing agents (*e.g.*, nitric, perchloric and/or sulfuric acids) and then heated. Heating is continued until the organic matter is completely digested, leaving only the mineral oxides in solution. The temperature and time used depends on the type of acids and oxidizing agents used. Typically, a digestion takes from 10 minutes to a few hours at temperatures of about 350 °C. The resulting solution can then be analyzed for specific minerals.

- *Advantages:* Little loss of volatile minerals occurs because of the lower temperatures used, more rapid than dry ashing.
- *Disadvantages* Labor intensive, requires a special fume-cupboard if perchloric acid is used because of its hazardous nature, low sample throughput.

Low Temperature Plasma Ashing

A sample is placed into a glass chamber which is evacuated using a vacuum pump. A small amount of oxygen is pumped into the chamber and broken down to nascent oxygen (O_2:$2O^{\cdot}$) by application of an electromagnetic radio frequency field. The organic matter in the sample is rapidly oxidized by the nascent oxygen and the moisture is evaporated because of the elevated temperatures. The relatively cool temperatures (< 150^{o}C) used in low-temperature plasma ashing cause less loss of volatile minerals than other methods.

- *Advantages:* Less chance of losing trace elements by volatilization
- *Disadvantages:* Relatively expensive equipment and small sample throughput.

2.17.2. Determination of Specific Mineral Content

The major physicochemical characteristics of minerals that are used to distinguish them from the surrounding matrix are their low volatility; their ability to react with specific chemical reagents to give measurable changes; and their unique electromagnetic spectra. The most effective means of determining the type and concentration of specific minerals in foods is to use atomic absorption or emission spectroscopy. Instruments based on this principle can be used to quantify the entire range of minerals in foods, often to concentrations as low as a few parts per million (ppm). The following methods are used.

Gravimetric Analysis

All Gravimetric analyses rely on some final determination of weight as a means of quantifying an analyte. Since weight can be measured with greater accuracy than almost any other fundamental property, gravimetric analysis is potentially one of the most accurate classes of analytical methods available. These methods are among the oldest of analytical techniques, and they may be lengthy and tedious.

Colorimetric methods

Colorimetric analysis is a method of determining the concentration of a chemical element or chemical compound in a solution with the aid of a color reagent. It is applicable to both organic compounds and inorganic compounds and may be used with or without an enzymatic stage. The method is widely used in medical laboratories and for industrial purposes, e.g. the analysis of water samples in connection with industrial water treatment.

Titrations

This is a laboratory method of quantitative chemical analysis that is used to determine the unknown concentration of an identified analyte. Because volume measurements play a key role in titration, it is also known as volumetric analysis. A reagent, called the titrant or titrator is prepared as a standard solution. A known concentration and volume of titrant reacts with a solution of analyte or titrant to determine concentration.

Ion-Selective Electrodes

An ion-selective electrode (ISE), also known as a specific ion electrode (SIE), is a transducer (or sensor) that converts the activity of a specific ion dissolved in a solution into an electrical potential, which can be measured by a voltmeter or pH meter. The voltage is theoretically dependent on the logarithm of the ionic activity, according to the Nernst equation. The sensing part of the electrode is usually made as an ion-specific membrane, along with a reference electrode. Ion-selective electrodes are used in biochemical and biophysical research, where measurements of ionic concentration in an aqueous solution are required, usually on a real time basis.

Atomic Spectroscopy

Atomic Spectroscopy is the determination of elemental composition by its electromagnetic or mass spectrum. It investigates the interaction of electromagnetic radiation (such as X-rays, ultra-violet and visible light) with atoms, usually by means of absorption or emission. This is usually done by associating the amount of energy absorbed or emitted by an atom or atom cloud to the quantity of atoms in a given sample (or, indirectly, to the concentration of the element in that sample). The most usual techniques associated to atomic spectroscopy are atomic absorption spectrometry, optical (or atomic) emission spectrometry and X-ray fluorescence spectrometry.

Crop nutrition and Fertilizer requirements

To achieve the higher crop productivity needed to meet current and future demand, healthy soil consideration is essential. The over-use of inorganic fertilizer in agricultural production has carried significant costs to the environment, including the acidification of soil, the contamination of water, and increased emissions of potent greenhouse gases. More targeted and sparing use of fertilizer would save farmers money and help to ensure that nutrients reach crops and do not pollute air, soil and waterways.

Experience indicates that higher and more sustainable yields are achieved when crop nutrients come from a mix of inorganic fertilizer and organic sources, such as animal manure and trees and shrubs which, in dryer climates, can pump up from the subsoil nutrients that would otherwise never reach crops. The use of soil tests can help to determine the status of plant available nutrients to develop fertilizer recommendations to achieve optimum crop production

2.18.1 Types of fertilizers

2.18.1.1 Organic fertilizers

Organic fertilizers can be either synthetic organic fertilizers or natural organic fertilizers. Synthetic fertilizers are organic compounds produced artificially and natural fertilizers are those formed and produced by nature alone. Natural fertilizers are those of green manures, seaweed manures, fish emulsion manures and all the others being used to provide high nutrients for their plants. One great thing about organic fertilizers is that they can maintain the growth and development of good bacteria’s in to the soil to keep plants healthy and strong all the time.

2.18.1.2 Inorganic fertilizers

They are chemical based fertilizer that use man made substances to yield positive gardening effects. They can provide quick and convenient benefits on plants by letting the soil absorb fertilizers more rapidly and swiftly without the need to further break them out through cultivating of the soil. The downside of chemical based fertilizers is that they kill mostly good bacteria’s into the soil making plants more at risk for harmful bacteria’s that may damage them in the long run.

Presence of macro and micronutrients in the resultant ash after briquette combustion can be a great source of the much need inorganic fertilizers, useful for crop nutrition.

2.19 Optimization

Optimization is about finding the "best" way to do a task, subject to any restrictions. Research in optimization includes model development, analysis, numerical techniques and applications. It also refers to the selection of a best element from some set of available alternatives. (Danztig 1991)

An optimization problem consists of maximizing or minimizing a real function by systematically choosing input values from within an allowed set and computing the value of the function. The generalization of optimization theory and techniques to other formulations comprises a large area of applied mathematics. More generally, optimization includes finding "best available" values of some objective function given a defined domain, including a variety of different types of objective functions and different types of domains.

An optimization problem can be represented in the following way

> *Given:* a function $f: A \longrightarrow \mathbf{R}$ from some set A to the real numbers
>
> *Sought:* an element x_0 in A such that $f(x_0) \leq f(x)$ for all x in A ("minimization") or such that $f(x_0) \geq f(x)$ for all x in A ("maximization").

Typically, A is some subset of the Euclidean space $\mathbf{R}^n$, often specified by a set of *constraints*, equalities or inequalities that the members of A have to satisfy. The domain A of f is called the *search space* or the *choice set*, while the elements of A are called *candidate solutions* or *feasible solutions*.

The function f is called, variously, an objective function, cost function (minimization), utility function (maximization), or, in certain fields, energy function, or energy functional. A feasible solution that minimizes (or maximizes, if that is the goal) the objective function is called an *optimal solution*.

By convention, the standard form of an optimization problem is stated in terms of minimization. Generally, unless both the objective function and the feasible region are convex in a minimization problem, there may be several local minima, where a *local minimum* x^* is defined as a point for which there exists some $\delta > 0$ so that for all x such that

$$\|\mathbf{x} - \mathbf{x}^*\| \leq \delta;$$

the expression

$$f(\mathbf{x}^*) \leq f(\mathbf{x})$$

holds; that is to say, on some region around x^* all of the function values are greater than or equal to the value at that point. Local maxima are defined similarly.

2.19.1 Multi-objective optimization

This is applicable to situations where the objectives conflict. For example, to optimize a structural design, one would want a design that is both light and rigid, but these two objectives conflict, a trade-off exists. There will be one lightest design, one stiffest design, and an infinite number of designs that are some compromise of weight and stiffness. The set of trade-off designs that cannot be improved upon according to one criterion without hurting another criterion is known as the Pareto set. The curve created plotting weight against stiffness of the best designs is known as the Pareto frontier.

A design is judged to be "Pareto optimal" (equivalently, "Pareto efficient" or in the Pareto set) if it is not dominated by any other design: If it is worse than another design in some respects and no better in any respect, then it is dominated and is not Pareto optimal.

In defining the problem as multi objective optimization, some information is missing that is the desirable objectives are given but not their detailed combination. In some cases, the missing information can be derived by interactive sessions with the decision maker.

2.19.2Multi-modal optimization

Optimization problems are often multi-modal; that is they possess multiple good solutions. They could all be globally good (same cost function value) or there could be a mix of globally good and locally good solutions. Obtaining all (or at least some of) the multiple solutions is the goal of a multi-modal optimizer. Classical optimization techniques due to their iterative approach do not perform satisfactorily when they are used to obtain multiple solutions, since it is not guaranteed that different solutions will be obtained even with different starting points in multiple runs of the algorithm. Evolutionary Algorithms are however a very popular approach to obtain multiple solutions in a multi-modal optimization task.

2.19.3 Classification of critical points and extrema

Feasibility problem

The satisfiability problem, also called the feasibility problem, is just the problem of finding any feasible solution at all without regard to objective value. This can be regarded as the special case of mathematical optimization where the objective value is the same for every solution, and thus any solution is optimal. Many optimization algorithms need to start from a feasible point. One way to obtain such a point is to relax the feasibility conditions using a slack variable, (a variable that is added to an inequality constraint to transform it to equality. Introducing a slack variable replaces an inequality constraint with an equality constraint and a non-negativity constraint (Boyd & Vandenberghe 2004) with enough slack, any starting point is feasible. Then, minimize that slack variable until slack is null or negative.

Existence

The extreme value theorem of Karl Weierstrass states that a continuous real-valued function on a compact set attains its maximum and minimum value, Keisler, H. Jerome (1986). More generally, a lower semi-continuous function on a compact set attains its minimum; an upper semi-continuous function on a compact set attains its maximum.

Necessary conditions for optimality

One of Fermat's theorems states that optima of unconstrained problems are found at stationary points, where the first derivative or the gradient of the objective function is zero. More generally, they may be found at critical points, where the first derivative or gradient of the objective function is zero or is undefined, or on the boundary of the choice set. An equation (or set of equations) stating that the first derivative(s) equal(s) zero at an interior optimum is called a 'first-order condition' or a set of first-order conditions. Optima of inequality-constrained problems are instead found by the Lagrange multiplier method. This method calculates a system of inequalities called the 'Karush–Kuhn–Tucker conditions' or 'complementary slackness conditions', which may then be used to calculate the optimum,(Vapnyarskii, I.B. (2001).

Sufficient conditions for optimality

While the first derivative test identifies points that might be extreme, this test does not distinguish a point that is a minimum from one that is a maximum or one that is neither. When the objective function is twice differentiable, these cases can be distinguished by checking the second derivative or the matrix of second derivatives (called the Hessian matrix) in unconstrained problems, or the matrix of second derivatives of the objective function and the constraints called the bordered Hessian in constrained problems. The conditions that distinguish maxima, or minima, from other stationary points are called 'second-order conditions'. If a candidate solution satisfies the first-order conditions, then satisfaction of the second-order conditions as well is sufficient to establish at least local optimality.

Sensitivity and continuity of optima

The envelope theorem describes how the value of an optimal solution changes when an underlying parameter changes. The process of computing this change is called comparative statics. The maximum theorem of Claude Berge (1963) describes the continuity of an optimal solution as a function of underlying parameters.

CHAPTER THREE

MATERIALS AND METHODS

3.1 Introduction

This chapter presents a detailed description of the experimental research design that was adopted to carry out the study. It describes what was to be done and how it was done.

Research Design

This study was a quantitative research strategy that took the form of an experimental research design, and was concerned with systematic manipulation of percentages of bagasse, press mud and molasses in formulating bagasse briquettes. For the purposes of this study, physico-chemical analysis of the best formulation and the ash nutrient values was determined.

3.2.2 Study area

This study was conducted in Chemelil Sugar Company, located along the Awasi-Nandi Hills road in Nyando District of Nyanza province, approximately 50 kms from Kisumu City, located at the latitude and longitude coordinates of -.083333 and 35.083333. It was established in 1965 as a private limited company and later became a parastatal in 1974. The climate is hot and humid with alternating dry spells. The mean temperatures are 20-30^{0}C, with low altitude flat land with mean rainfall distributes at 1500mm annually, the soils vary from light sandy to heavy alluvial soils. The main varieties of cane grown are CO421, N14, CO 945 and CO 617. (Awilly (1997)

3.2.1 Sample collection and Processing

The samples consisted of fresh bagasse and press mud heaps from randomly selected points at the disposal site. Molasses was obtained from the processing line. Samples consisting of about 200 kg of bagasse, 5 kg press mud and molasses were collected. Bagasse and press mud were collected in polyethylene bags, while molasses was collected 20 L plastic containers. Press mud and bagasse was dried under direct sunlight to reduce moisture content from about 50 % to less than 18 % thereafter bagasse was carbonized on site to reduce the bulk during transportation and increase the carbon content.

Carbonization was achieved by placing loosely bagasse inside a 70l steel drum kiln that had 5mm holes in the bottom. The drum was placed on stones to allow for oxygen circulation from the bottom upwards. A chimney was attached to the top of the inverted funnel through which white smoke was ejected. The process of semi burning of biomass was done layer by layer until the drum was filled two-third. The chimney was then taken out and drum was completely covered to completely extinguish the fire. Once the fire was extinguished and contents cooled down, and the now carbonized bagasse was taken out.

Press mud and bagasse was then stored in zip lock polythene bags and transported to Kenya Forest Research institute (KEFRI) headquarters for briquetting and calorific value analysis. Physical chemical and nutrient analysis was done at KEFRI-Muguga research centre. A set of three samples of each of the ten briquette formulation was obtained.

3.2.2 Briquette Formulation

Bagasse and press mud were separately pulverized or ground in a manual hammer mill, to increase surface area for bonding. The hammer mill consisted of hardened steel balls placed inside a manually driven drum. The ground bagasse and press mud were sieved to achieve 6-8 mm particle size. It is generally agreed that biomass material of 6-8 mm size with 10-20% powdery component (< 4 mesh) gives the best results.The presence of different size particles improves the packing dynamics and also contributes to high static strength(Ludwig 1994).

Blending of bagasse, press mud and molasses was achieved in a rotating drum mixer, whereby the hardened steel balls were removed from the hammer mill to substitute for the blender. Blending provided extra retention time to guarantee complete mixing with binders. Both charred bagasse and press mud was pounded, separately. Briquettes were formed by blending bagasse, press mud and molasses using predetermined ratios. The well-mixed briquette was compressed and extruded in a screw manual press to cylindrical briquettes of 40mm diameter radius and 80mm length. The formulation was achieved by mixing ten (10) different ratios of bagasse, press mud and molasses as predetermined by the researcher.

The moulds were made from mild steels by drilling to the required diameters and properly polished to achieve smooth internal surfaces. Holes were drilled on the moulds to about one third of the height, so that water could drain easily during briquetting process as recommended by Dahlam *et al*. (2001).

The briquette was then dried for 2-3 days under direct sunlight. While drying, briquettes were kept on plane and hard surface and covered with plastic during the night to protect from rain and wind. Once the briquette was dried and made hard, it was ready for burning in the briquette stove and further testing.

Testing and Burning Properties

3.3.1 Calorific Value

Procedure

The procedure from Nelkon and Parker (1995) was adopted. Calorific value was determined using adiabatic bomb calorimeter model 1013-B having a working power of 100 V. The test samples were ground and weighed to 1 g in triplicate and wrapped with tissue paper of a known calorific value and weight. It was then tied with an ignition wire (platinum) of known calorific value. Both ends of the wire are connected to the bomb calorimeter electrodes (+,-) and placed in a bomb and firmly closed. The bomb calorimeter was calibrated with benzoic acid of a known calorific value.

The firing circuit test plug was inserted and the bomb test switch depressed. The lamp in the switch lights lit up signifying correct fitting of the firing wire. Filling the bomb was achieved by connecting the filling tube to the bomb, tightening the union by hand and filling the bomb slowly with oxygen without displacing the original air content by using pressure of 30 bars. The calorimeter was adjusted by adding water to calorimeter till total weight of 3 Kg was reached (This corresponds to about 10.5kJ/K)

The bomb was placed on three supports in the calorimeter vessel and checked that the bomb did not leak gas. The calorimeter vessel was placed in the water jacket and turned on. The cover of the water jacket was lowered complete with thermometer and thermistors. Measurement of the temperature rise was achieved by checking that initial balance was set to the correct reading and waited until the temperatures of the jackets and calorimeter stabilized. The thermometer reader was used to read initial calorimeter temperature to 0.001^{0}C and the sample was ignited, left for 8-10 minutes to obtain its final equilibrium temperature, to 0.001^{0}C.

The following formula was used to calculate the calorific value of the test samples:

$$\textbf{CV (Cal/g)} = \frac{\{[\text{water equivalent (g)} + \text{Water quantity of inner cylinder (g)}] \times \text{rise in temperature (°C)} - \text{Correction Value}\}}{\text{Quantity of sample (g)}}$$

Where, CV = calorific value.

The correction value is the sum of the calorific values for the tissue paper and the ignition wire.

The water equivalent was computed as follows:

$$\textbf{Water equivalent} = \frac{\{[\text{CV of benzoic acid (cal/g)} \times \text{weight of benzoic acid (g)}] - \text{Water quantity of inner cylinder (g)}\}}{\text{Rise in temperature (°C)}}$$

3.3.2 Moisture content

The trial briquettes produced were kept in stationery drying chambers and dried on direct sunlight to about 18% moisture content. The moisture content was necessary so that we could understand whether there were intrinsic moisture properties example hygroscopic attributed to the different formulation ratios that could in turn contribute to the overall calorific value. They were tested in accordance with South African National Standards (SABS (1399:2008, Edition2.3)) using a muffle furnace, Yamato

FP-41. These standards were preferred to apply charcoal briquettes for domestic use. The British and American standards use coal as the basic material to determine the permissible limits for charcoal. The parameters on quality of briquettes are:

- Moisture content-Not exceeding 10%
- Volatile matter content-Not exceeding 20%
- Fixed carbon content-at least 55%
- Sieve analysis- the amount passing through test sieves of aperture 9.5mm shall not exceed 5 % (by mass).

a) Moisture content (MC)

The test specimen was heated to constant mass in an air oven at temperatures of 105^0C, and the moisture content determined from loss in mass of the test specimen.

$$MC\% = \frac{(m_2 - m_3)}{(m_2 - m_1)} * 100$$

Where:

m_1-Mass of empty tray (g)

m_2- Initial mass of tray +sample (g)

m_3-Mass of tray +sample after heating (g)

3.3.3 Ash Content (A)

The sample without moisture content was further heated in air at $710^0C \pm 10^0C$ and maintained at this temperature till constant mass. The percentage ash content from mass of the residue was calculated after incineration. The apparatus used are analytical balance whose accuracy was within 0.1g, muffle furnace, porcelain dish, insulating plate, desiccant and desiccators.

The results are calculated as

$$A\% = \frac{(m_3 - m_1)}{(m_2 - m_1)} * 100$$

Where:

m_1-Mass of dish (g)

m_2- Mass of dish +sample dried at 105^0C for 1 hour (g)

m_3-Mass of dish + ash after incineration (g)

3.3.4 Volatile matter (V)

The sample was further heated for 7 minutes at 900^0C in the muffle furnace, and the percentage volatile matter was calculated from the loss of mass of the sample.

Percent volatile matter was calculated as

$$V\% = \frac{(m_2 - m_3)}{(m_2 - m_1)} * 100$$

Where:

m_1-Mass of empty clean crucible+ lid (g)

m_2- Mass of crucible +lid+ sample dried at 105^0C for 1 hour (g)

m_3-Mass of crucible+ lid+ residue after heating at 900^0C for exactly 7 minutes (g)

3.3.5 Fixed carbon content (FC)

This was determined after removal of volatile matter content and ash content. The fixed carbon content is expressed as:

$$FC\% = 100 - (A + V)$$

Where:

A-Ash content in %

V-Volatile matter content in %

Elemental Analysis for macro and micro nutrient

The American Society for Testing and Materials method (ASTM) D3174 (3), (ASTM, 1984*)* was used. Reference this method was made to Javier and Dalmacio, (1990).

Air-dried ash samples were ground to pass a number 60 (250 µm) sieve and were ashed at 750° C to remove carbonaceous material. Up to 0.5 g of ash was placed in an open Teflon capsule (40 mm diameter, 40 mm height), then 10 ml of hydrofluoric acid (d=1.13, 40% w/ w) was added and the mixture was heated until near dryness. Then, 20 ml of sulfuric acid (d=1.84, 96% w/ w) and 20 ml of nitric acid (d=1.42, 69.8% w/ w) were added to the capsule in order to ensure complete oxidation of organic matter, and the sample was allowed to evaporate to dryness. A volume of 25 ml of hydrochloric acid (d=1.19, 37.9% w/w) and 10 ml of hydrogen peroxide (33%) were then added, and the sample was again heated until complete dissolution of the residue. Then it was cooled and transferred quantitatively to 100-ml volumetric flasks; just prior to analysis it was adjusted to volume with 15% v/v HCl solution. The time required for a complete analysis was about 4 - 5 h.

Aliquots were prepared by the ASTM fusion method and the proposed dissolution procedure and were analyzed by atomic absorption spectrometry. In the ASTM fusion method, 0.1 g portions of ash were fused with 1 g of a 1 / 1 mixture of lithium tetraborate and lithium methaborate in platinum crucibles over an air-boosted Meker burner at 1000° C. The ash was fused for 15 min; the melt was then permitted to cool and then was dissolved in 50 ml of 10% HN03. When dissolving is complete, the sample is diluted to a final volume of 500 ml. The proposed dissolving method used 0.5 g of ash diluted to a final volume of 100 ml. The sampling of 0.5 g of ash was enough to obtain a representative sample. The calibration standard and blank were prepared in the appropriate matrix for both the fusion and dissolving techniques.

The resulting solution was analyzed using spectrophotometer. Optimized operating conditions example lamp current, wavelength and slit width, sensitivity and flame type as specified in the manual were used for analysis of a particular element. Mercks-AAS standards were used for standardization and calibration of AAS. Three standards and a blank of the concerned elements were used to cover the range of 0.1-0.8 Abs. the calibration was performed using the blank solution to zero the instruments. The standards were then analyzed with the lowest concentration first and blank run between standards to ensure baseline (zero point) has not changed. Samples were then analyzed and their absorbance recorded. Calibration was performed in the concentration mode in which the concentration of samples was recorded.

Data Analysis and Interpretation

MS-Excel statistical package was used to give measures of central tendency and graphically represent correlation of parameters. Linearity was checked by simple linear regression and the study adopted one way analysis of Variance (One Way ANOVA) to analyze to determine suitability of the formulation models and conclusions were made by comparing the 5% error to the P-Value. If P-Value was greater than (>5%) I accepted the null hypothesis. In one of the scenarios, the Predictors were percentage Carbon Content (CC), percentage Ash content (AC), percentage Moisture Content (MC) and percentage Volatile Matter (VM) regressed against dependent variable, calorific energy (kCal/g).

The one sample T-Test was used to determine whether the variable obtained met the

SABS (2008) criteria. The test value was moisture content=10, volatile matter=27, ash content=13 and carbon content=60, all tested at 95%confidence level.

All data was analyzed at a level of significance of 95%. Graphs, charts and description were used to present findings of the study. The scatter plots showed the relationship between the dependent variable and each of the independent variable. A line of best fit has been fitted to show the degree of linear relationship. If the scatter dots varied so much above and below the line there is almost no linear relationship.
The R squared showed how much of the variations in the dependent variable are explained by the linear model. If the scatter pots very small it means that, a linear model does not suit the data. The maximum value of R squared is one (100%).

3.5.1 Optimization of the results obtained

This was achieved by using MATLAB® whereby calorific energy values were selected and the optimization problem defined. Optimization options were set, inspected and their default values for the selected solver, and then the problems were run. Intermediate and final results were visualized. Problem definitions were imported, and algorithm options selected. The resultant equation defining various values of bagasse, press mud and molasseswere exported between the MATLAB® workspace and the Optimization Tool, MATLAB code was automatically generated to capture work and automate tasks.

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 Introduction

This chapter analyses the results obtained from the experimental trials by simplifying in form of graphs and narratives. The first part describes the findings from the graph. The second part looks into predictability of the results obtained by use of regression equation. A section of this chapter compares nutrient component of the press mud ash and compares threshold nutrient levels for selected crops as researched by Mannitoba University.

During carbonization of bagasse, it was found that 5 bags of raw bagasse were used to produce 1 bag of charred bagasse. This implied that if one ton of charcoal briquettes are produced, five tones of raw bagasse have to be used. The main criterion used for selection of the optimum ration was based on the ratio's ability to consume most of the bagasse as it was in most abundance and significantly high calorific value content. With Kenya generating about 2.0 million tons (KSB, 2009) of bagasse annually, this means that about 400,000 tones of charcoal briquettes could be produced annually based on a ratio of 5: 1 raw bagasse to carbonized bagasse and assuming that 90% was utilized annually.

Although the recorded value do not meet the SABS2008 standards, availability of a optimal working kiln during carbonization could have yielded higher percentages of fixed carbon content and lower percentages values for volatile matter, ash content. This could in turn have yielded higher values for calorific energy.

4.2 Different ratios of Bagasse, Press mud and Molasses and their respective physicochemical characteristics

Table 4.1 gives the average values of physico-chemical properties of different formulation ratios of press mud bound briquettes. The specific properties analyzed are moisture content (MC), volatile matter (VM), ash content (AC), and calorific value (CV) against the respective percentage composition of bagasse.

Table 5: Average physico-chemical properties of various briquette formulations

Ratios	**%Bagasse**	**%Pressmud**	**%molasses**	**% MC**	**% VM**	**% AC**	**% FCC**	**CV (kCal/g)**
Ratio 1	20.00	40.00	40.00	9.54	37.72	21.43	31.32	4.49
Ratio 2	25.00	50.00	25.00	7.93	34.16	27.09	30.82	3.85
Ratio 3	25.00	25.00	50.00	11.12	37.51	23.93	27.44	3.50
Ratio 4	33.30	33.30	33.33	8.01	39.77	22.27	29.95	4.50
Ratio 5	40.00	20.00	40.00	10.46	30.92	26.53	32.08	4.22
Ratio 6	50.00	25.00	25.00	6.97	34.18	28.01	31.85	3.76
Ratio 7	52.60	26.30	21.05	7.00	31.43	28.25	33.32	3.75
Ratio 8	52.60	21.10	26.32	7.57	32.40	23.74	36.08	4.21
Ratio 9	55.60	22.20	22.22	7.80	32.54	27.61	32.05	3.94
Ratio 10	66.70	0.00	33.33	8.87	40.20	22.24	28.70	4.05

Source: Author (2013)

M.C - Moisture content; **A.C** - Ash content; **V.M**. – Volatile matter; **F.C.C**. – Fixed carbon content

4.2.1 Moisture content

The moisture content in all the formulations is below 18%, and at this state, a material does not contain *free water* but water that is chemically bonded with a material, *bound* water (Onchieku et.al, 2012). This means that so long as a material contains moisture content of less than 18 %, most of its physico-chemical properties would not be influenced by moisture content. The SABS (2008) recommends charcoal briquettes for household to be analyzed for these properties at moisture content not exceeding 10 %. Formulations 3 with 25% bagasse, 25% Press mud and 50% molasses has 11.12% M.C and ratio 5 with 40%bagasse, 20 % Press mud and 40% molasses has 10.46%. This could be attributed to high amounts of molasses, which tend to be hygroscopic. Molasses contains an invert sugar and is not 99% sucrose as granulated sugar is, highly hygroscopic thus it attracts moisture from the atmosphere. In that respect less of molasses should be used as a binder to minimize reabsorption of atmospheric moisture by the briquette.

4.2.2 Volatile matter

Volatile matter in all the samples exceeded the 27% maximum standard (SABS, 2008). However, as UNFAO (1995) notes good commercial charcoal can have a net volatile matter content - (moisture free) of about 30%. The formulation ration 5 briquettes, with Volatile matter 30.92% were closest to both standards for recommended standard volatile matter. Notably ratio 7 with relatively high bagasse content of 52.6%, and low molasses content of 21.05% recorded 31.43% volatile matter, although the press mud ratio increased from ratio 5 to ratio 7 by 6.3%. The main contributing factor in the percentage of volatile matter is higher temperatures and prolonged carbonization times. While the carbonized bagasse was uniform for all formulations, the highest volatile matter at 40.2% was recorded in 66.7% of bagasse. Clay is known to contain insignificant quantity of organic matter but predominantly inorganic particles (Onchieku, 2012) High proportion of volatile matter could also be attributed to the high proportion of organic matter in the individual briquette components. Optimum parameters for carbonization of bagasse when studied could be the key to achieving the best percentages of the volatile matter.

4.2.3 Fixed carbon content (FCC)

All the test formulation ratios were below the recommended standard SANS 2008 ratio of at least 60%. Although molasses binder had better gluing effect of adjacent particles resulting in stronger bonds, the ratio of molasses and press mud binder had significant effects on the density and overall strength of the briquette. Strong bonds were generated by better gluing effects resulting in minimal expansion of briquettes after withdrawn from the mould. However as UNFAO (1995) denotes that carbon content is the most important constituent in metallurgy since it is the fixed carbon which is responsible for reducing the iron oxides of the iron ore to produce metal. There must be a balance between the friable nature of high fixed carbon charcoal and the greater strength of charcoal with a lower fixed carbon and higher volatile matter content to obtain optimum blast furnace operation. The highest FCC is for ratio 8 with 52.6%bagasse, 21.1%pressmud and 26.32% molasses, followed by ratio 7 with 52.6% bagasse, 26.32% press mud and 21.1% molasses. Notably ratio 1 has equal FCC as ratio 7 but the molasses content is 40% but corresponding higher moisture content. Ratio1 is ruled out as a viable waste management option in this case because competing uses of bagasse in the food industry, so that the overall cost of the briquette from ratio 1 will be higher. Ratio 1 takes in the least amount of bagasse in all the formulations, but the sole aim of this briquetting option is to use as much bagasse as possible, so as to eliminate this environmental hazard.

4.2.4 Ash content

Ash content in ratio 1 is lowest at 21.43% with a corresponding high calorific value of 4.49% kCal/g, and highest at 28.25% with 3.75kCal/g. Depending on the magnitude of the ash content, the available energy of the fuel is reduced proportionately. It is mineral matter, such as clay, silica and calcium and magnesium oxides, etc. The ash reacts to form a `slag', a liquid phase formed at elevated temper and this reduced the amount of heat released. The higher ash content could be attributed to a higher combined percentage of bagasse and molasses in ratio 7, compared to that of ratio1. The presence of incombustibles matter could have further slowed down the calorific energy since it has lower thermal conductivity.

4.2.5 Calorific value

The highest calorific value was 4.5kcal/g for the briquette formulation ratio 4 with 33.3% bagasse 33.3% press mud, 33.3% molasses, but a moisture content of 8.01%, while the lowest calorific value is formulation 3, with 3.5kcal/g, at the highest moisture content of 11.12%, and 50% molasses ,25 bagasse and 25 % molasses. This further supports that molasses could be attracting moisture back to the briquette, because if any moisture is present, this reduces the calorific value proportional to the moisture content (McKendry, 2002).

4.2.6 Summary of physico-chemical characterization of pressmud bound briquettes

The contribution of each of physico chemical properties to the different formulation ratios is summarized below.

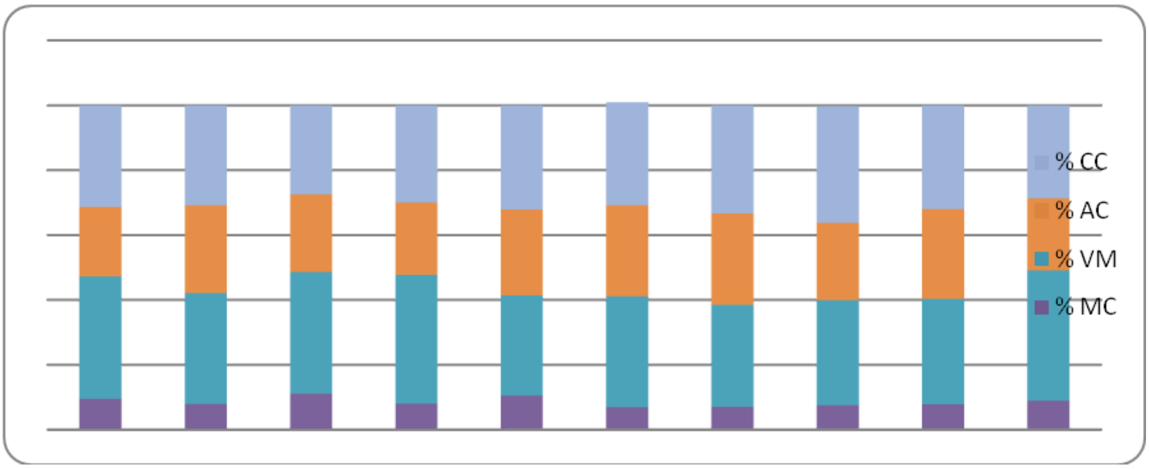


Fig 1: Proportion of combination of physicochemical properties against various formulation ratios.

Where: CC=Carboncontent AC=Ash content, VM=Volatile matter,

MC=MoistureContent

The sample (ratio 4) with equal proportions of 33.3% press mud, 33.3% bagasse and 33.3% molasses had the highest calorific value of 4.5 Kcal/g. This was followed by formulation (ratio 1) with 40% molasses, 20% bagasse and 40% press mud had calorific value of 4.49 Kcal/g. The next composition (ration 5) close in calorific value 4.22Kcal/g had 40% molasses, 20%pressmud, 40% bagasse.

The next best formulation (ratio 8) had 52.6% bagasse, 21.1% press mud and 26.32% molasses that had a calorific value of 4.21Kcal/g, carbon content of 36.08%. This implies that these briquettes will not smoke; the moisture content is within the requirement thus it will take less time to ignite, and that significant amounts of the briquette will combust better.

The aim of this research was to identify ways of efficient utilization of bagasse since it is the waste that is most abundant yet unutilized in the sugar industry. The negative environmental consequences in terms of fire hazards and contamination by storm water runoff necessitate a means to utilize it as soon as it is generated. It is for the above reasons that the researcher chooses the formulation that takes in most of the bagasse and press mud but least molasses. Chirchir et.al. (2013) in a study of comparing crow dung ,molasses and clay as binders, concluded that briquettes made using molasses had the best ignition, density and calorific values of the three variables. It is thus important to incorporate molasses in the briquette. However as noted in the discussion on desirable moisture content, volatile matter ash content and carbon content, the best ratio that gave a mould that did not crumble and burnt with least smoke was ratio7. However although ratio 7 was chosen as the best in this research**,** it did not meet the SABS, 2008 standards for household fuel. Further research needs to be conducted on deduce the optimal carbonization parameters to given higher fixed carbon content.

4.3 Linearity and suitability of the models

Bagasse, press mud and molasses were the predictors and were regressed against the dependent variable volatile matter, ash content, carbon content and moisture content.

The regression equations were as follows:

a)Volatile matter

From the linear regression equations the volatile matter proportions were inversely proportional to changes in bagasse, press mud and molasses as follows:

VM=52.622-0.497B-0.0334P-0.16M……………………………………… (1)

R2=0.72

Where B=Bagasse P=Press mud, M=Molasses

The P-Value of Bagasse (0.09) and Press mud (0.025) are all lesser than 0.0 meaning that they both influence volatile matter, unlike the P-value of 0.883.

The model's R squared is 0.72, meaning that there's a strong relation between the dependent and the predictor variables.

b) Ash Content

The regression equation for ash content showed proportional increase in amount of ash content as bagasse and press mud increased but an inverse proportion in molasses as depicted in the following equation.

AC=17.095+0.272B+0.205P-0.94M ……………………………………………… (2)

Where B=Bagasse P=Press mud, M=Molasses

R^2=0.513, meaning that the relationship between ash content and the predictors was not very strong. The corresponding P Values are Bagasse0.88, Press mud=0.12, Molasses=0.416. All the P-values were greater than 0.05, meaning that they have insignificant contribution towards ash content

c) Carbon content (CC)

The regression equation for carbon content showed proportional increase in amount of carbon content as bagasse, molasses and press mud increased, defined as follows.

CC=22.25+0.292B+0.21P-0.65M,…………………………………………………(3)

Where B=Bagasse P=Press mud, M=Molasses

R^2=0.628, thus there exists a strong relation of bagasse, press mud and molasses in relation to carbon content. The corresponding P-Values are Bagasse=0.033, Press mud=0.061 and molasses =0.471. This relation is true about earlier studies, for example UNFAO 1985.

d) Moisture content (MC)

The regression equation for moisture content showed proportional increase in moisture content as amount of molasses increased but an inverse proportion as bagasse and press mud increased.

$MC=7.705-0.05B-0.071P+0.171M$ ……………………………………………….....(4)

Where B=Bagasse P=Press mud, M=Molasses

The corresponding P-Values are Bagasse=0.12, Press mud=0.003 and molasses =0.000.According to the P-value, only bagasse does not significantly influence the moisture content in the briquette, but is highly influenced by increasing amounts of molasses

All the above regression equations concur with theories regarding factors that quality of briquettes as discussed by McKendry, (2002).

The above models were used to test the null hypothesis that moisture content, ash content, volatile matter and carbon content do not significantly enhance calorific value of briquettes, tested against the alternate hypothesis that moisture content, ash content, volatile matter and carbon content significantly enhance calorific value. From the findings, we can confidently accept the alternate hypothesis.

4.4 Optimization for determination of the best briquette ratio

4.4.1 Data for model development of optimization

Results from the formulation ratio and calorific value of the briquettes equation 5 was obtained, and thereafter imported to MATLAB solver, and 3-D graphs were as follows in fig.2 and fig.3.

Let: X_1 represent Bagasse, X_2 represent Press mud and X_3 represent molasses as shown Table 9 below.

Table 6: Percentage ratios of different formulations

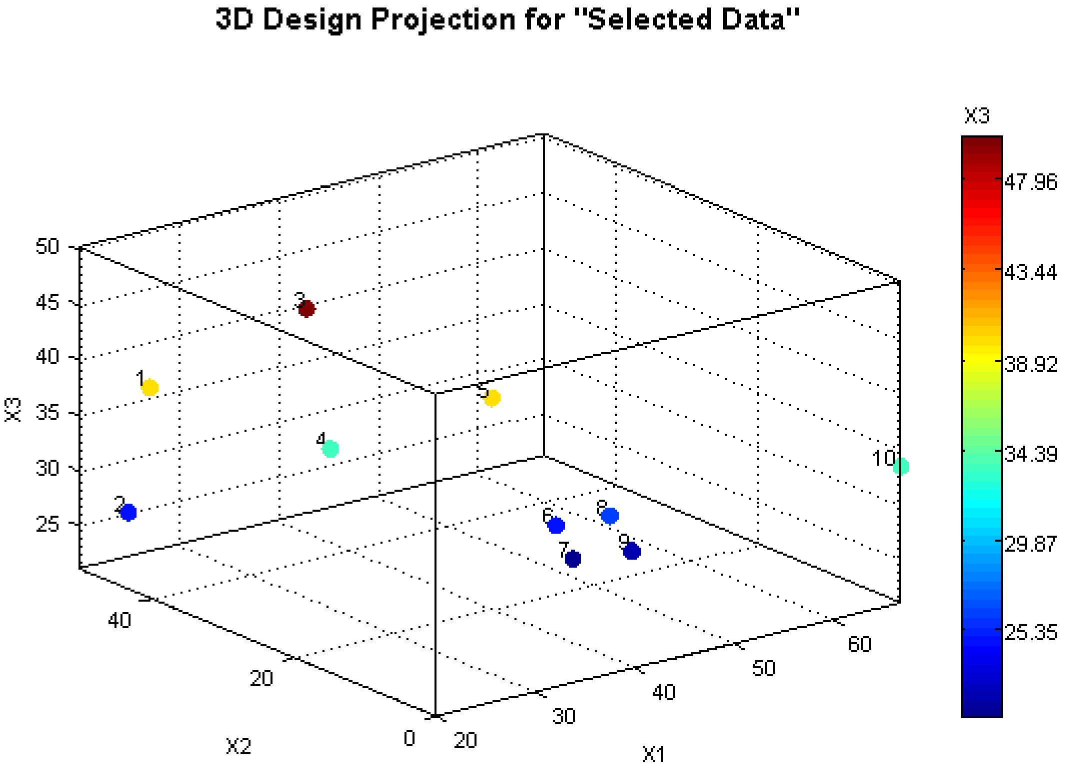
Ratios	%Bagasse (X_1)	%Press mud (X_2)	%molasses (X_3)	CV (kCal/g)
Ratio 1	20.00	40.00	40.00	4.49
Ratio 2	25.00	50.00	25.00	3.85
Ratio 3	25.00	25.00	50.00	3.50
Ratio 4	33.30	33.3	33.33	4.50
Ratio 5	40.00	20.00	40.00	4.22
Ratio 6	50.00	25.00	25.00	3.76
Ratio 7	52.60	26.30	21.05	3.75
Ratio 8	52.60	21.10	26.32	4.21
Ratio 9	55.60	22.20	22.22	3.94
Ratio 10	66.70	0.00	33.33	4.05

Source: Author, (2013)

The resultant model is;

$$y = 1 + 2x_1 + 12x_2 + 18x_3 + 3x_1^2 + 7x_1x_2 + 10x_1x_3 + 13x_2^2 + 16x_2x_3 + 19x_3^2 + 4x_1^3 + 5x_1^2x_2 + 6x_1^2x_3 + 8x_1x_2^2 + 9x_1x_2x_3 + 11x_1x_3^2 + 14x_2^3 + 15x_2^2x_3 + 17x_2x_3^2 + 20x_3^3 \ldots\ldots(5)$$

Fig. 2: Representation of maximization results for different formulation ratios

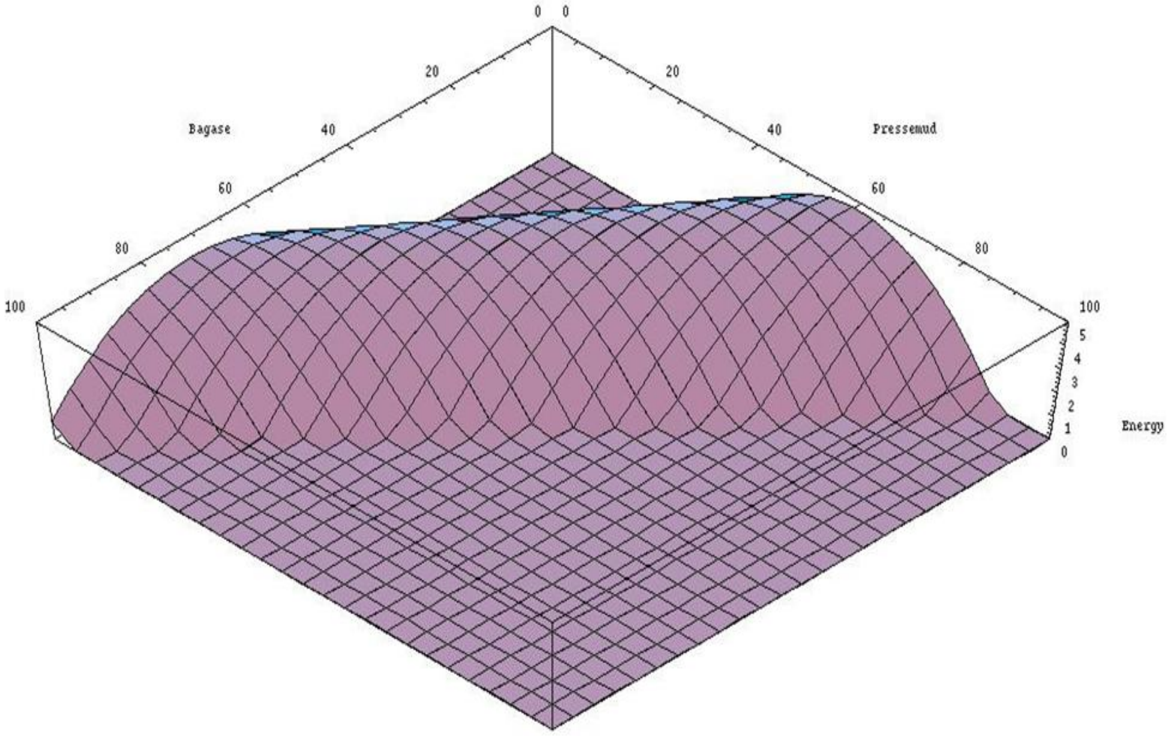


Source: Author, (2013)

Where: X1=bagasse,X2=Press mud,X3= molasses

From the above graphical representation, point 2 has very low percentages of bagasse, followed by point 1. We are interested in consuming the highest possible amount of baggase, Altough point 10 has the highest concentration of, we rule it out uses no press mud, which is also a consideration of cane waste management. We therefore have to decide among ratios in the range of point 6,7,8 and 9.

Fig. 3: 3-Dimension plenary representation of maximization results for different formulation ratios



Source: Author, (2013)

From the above results, the optimal range of formulation is ratio 6, 7, 8 and 9, and are seen at the peak of the trough. In other words it maximizes our objective function as seen from the 3-D surface with minimum value of f(x) as compared to the rest. Then substituting the ratio values (of the 3-D surface formed) to the objective function, y, and ratio 7 gives the minimum value and thus gives the best fitting results. Additionally, we want to maximize the use of bagasse, while use the least possible amount of molasses due to abundance. From the obtained results, ratio 7 appears to be the ratio containing the least content of molasses and relatively high content of bagasse, hence satisfying our objective.

4.5 Quality of the briquette in relation to SANS 2008

The one sample T-Test showed whether the variable obtained meets the SABS (2008) criteria. A tabulation of individual results was as follows:

Table 7: One-Sample Test for moisture content

	Test Value = 10					
	t	df	P-Value. (2-tailed)	Mean Difference	95% Confidence Interval of the Difference	
					Lower	Upper
Moisture Content in %	-3.255	9.000	.010	-1.473	-2.497	-.449

Here the test value is 10 and the hypothesis is i) the mean for MC=10 versus ii) the mean is not 10. Since the P-Value<0.05 therefore we accept the alternative hypothesis that MC does not meet SANS, 2008 standards.

For all the other variables the SANS 2008 standards are not met with 95% confidence. The test values were: Volatile matter=27, Ash content=13 and carbon content=60. For all the above the P-Value (2-tailed) was 0.000.

4.6 Characterization of briquette ash in terms of nutrient content

This section was a minor subject in the research and sought to give insight as to whether there exist significant quantities of macro and micro nutrients in the resultant ash after complete combustion of the bagasse briquettes. The briquettes after combustion were digested with acid mixtures of Nitric and Hydrochloric acid and analyzed for presence of macro and micro nutrients. The nutrient quantities of the press mud briquettes are summarized in Table 4.7. These values were compared with the various crop nutrient sufficiency values in Table 4.8, obtained from a study by Manitoba Agriculture, Food and Rural Initiatives (1991c)

The results show that the briquettes ashes have significant amounts of nutrients that can enhance crop growth. Three crop varieties that could be grown in the area were identified as corn, peas/beans and soybean. Comparison these three crops nutrient requirement with studied briquettes nutrient levels showed briquettes formulation ratio 8 was the best in terms of nutrients In particular, nitrogen, phosphorous, potassium, calcium and iron percentages are all higher than the threshold levels and therefore under ideal soil condition the ashes resulting from this briquettes ration can be used to enhance crop production in kitchen gardens thereby reducing dependence and cost of application of synthetic fertilizers. However, the integration of calorific value, waste management (bagasse) and maximizing nutrient recovery ration 7 is the next best alternative. Notably before adopting the ash as inorganic fertilizer, it is important to establish bioavailability of the nutrients to the plants. This study is in line with by Hind et.al, 2012, where in his study on ‘Land application of rice husk ash, bagasse ash and coal fly ash: Effects on crop productivity and nutrient uptake in rice–wheat system on an alkaline loamy sand’ noted that indeed there is positive influence in crop nutrition on application of different ashes.

Table 8: Nutrient availability in press mud briquette ash

Formulation Ratio	**% N**	**% P**	**% K**	**% Na**	**% Ca**	**% Mg**	**Mn ppm**	**Fe ppm**	**Znppm**
1	12.74±0.07	20.08±0.34	4.35±0.00	2.25±0.03	0.31±0.00	0.28±0.00	1.67±0.02	0.13±0.00	0.06±0.00
2	16.62±0.07	21.73±0.37	3.39±0.00	1.88±0.03	0.29±0.00	0.28±0.00	1.69±0.02	0.11±0.00	0.06±0.00
3	11.54±0.05	38.02±0.65	4.86±0.01	1.99±0.03	0.31±0.00	0.26±0.00	1.62±0.02	0.14±0.00	0.07±0.00
4	12.20±0.040	10.69±0.18	3.87±0.01	1.36±0.02	0.24±0.00	0.220±0.00	1.50±0.01	0.12±0.00	0.05±0.00
5	15.96±0.08	14.01±0.23	4.83±0.01	1.66±0.03	0.28±0.00	0.23±0.00	1.53±0.02	0.12±0.00	0.06±0.00
6	13.76±0.05	7,76±0.12	3.91±0.01	1.16±0.02	0.22±0.00	0.21±0.00	1.19±0.01	0.12±0.00	0.08±0.00
7	12.09±0.08	6.08±0.09	36±0.01	1.18±0.02	0.22±0.00	0.22±0.00	1.50±0.01	0.11±0.00	0.06±0.00
8	10.55±0.11	5.78±0.09	4.16±0.01	1.3±0.02	0.23±0.00	0.22±0.00	1.53±0.01	0.11±0.00	0.06±0.00
9	15.2±0.09	0.68±0.00	2.26±0.02	1.16±0.02	0.24±0.00	0.21±0.00	1.48±0.01	0.11±0.00	0.04±0.00
10	15.97±0.08	23.66±0.4	3.19±0.01	1.68±0.03	0.28±0.00	0.25±0.00	1.38±0.02	0.10±0.00	0.07±0.00

Source: Manitoba Agriculture, Food and Rural Initiatives (1991c)

Table 9: Nutrient sufficiency levels for different plants

Crop	**Plant part/ Growth stage**	**%N**	**%P**	**%K**	**%Ca**	**%Mg**	**Fe ppm**	**Mn ppm**	**Zn ppm**
Corn	Ear leaf/Tasseling	2.5-3.5	0.25-0.5	1.7-2.25	0.2-1.0	0.2-0.6	20-250	20-150	20-70
Peas/beans		3.0-5.5	0.25-0.5	1.5-3.0	0.2-1.5	0.2-0.4	20-250	20-100	15-70
Soybeans	Upper trifoliate leaf/prior to flowering	4.25-5.5	0.25-0.5	1.7-2.5	0.35-2.0	0.2-1.5	50-350	20-100	20-50

Source: Manitoba Agriculture, Food and Rural Initiatives (1991c)

4.7 Influence of physico-chemical of the briquette characteristics on quality

Descriptive statistics gave the mean and the standard deviation of the observed data as follows:

Table 10: Descriptive statistics of physic-chemical characteristics

Descriptive Statistics

	Mean	Std. Deviation	Frequency
Calorific Value (kCal/g)	4.0270	.32897	10
Moisture Content in %	8.5270	1.43093	10
Volatile Matter in %	35.0830	3.44808	10
Ash content in %	25.1100	2.65771	10
Carbon Content in %	31.3610	2.40550	10

The R^2 for the model was 0.568; meaning 56.8% of variations in calorific value can be explained by the model.

The ANOVA gave the statistical tests on the suitability of the model. All the tests have been done with 95% confidence giving an error merging of 5%. To make conclusion we compare the 5% error to the P-Value if P-Value>5% I accepted the null hypotheses. In this case the null hypothesis is i) the model is not significant versus ii) the model is significant

Since .297>5%=0.05 we accept the null hypothesis with 95% confidence.

Table 11: ANOVA[b]

Model		Sum of Squares	df	Mean Square	F	P-Value.
1	Regression	.553	4	.138	1.645	.297[a]
	Residual	.421	5	.084		
	Total	.974	9			

a. Predictors: (Constant), Carbon Content in %, Ash content in %, Moisture Content in %, Volatile Matter in %

b. Dependent Variable: Calorific Value (kCal/g)

The coefficients in all the tables give the values of the coefficients of independent herein referred to as the predictors. The constant gave the value of the dependent variable when all the coefficients of the predictors are zeros. The P-Value again determined whether the hypothesis is to be accepted or not. The hypothesis in this case is i)the coefficient for the predictor variable in question is not significant versus ii) the coefficient is significant

We accept the i) hypothesis if P-value>0.05. In this case all the coefficients are greater than 0.05 hence all are not significant.

With significant coefficients the regression equation would be;

Calorific value=2.651+0.009*MC+0.018VM-0.078AC+0.083CC

On the basis of the above discussions in the literature review, although we reject the hypothesis that physical-chemical do not affect the calorific value, the intrinsic properties of the bagasse, press mud and molasses have factors that directly affect physic-chemical properties. However the quality of bagasse, press mud and molasses greatly influence the overall properties of the briquettes.

We also conclude that there is no ratio to give optimum calorific value but the ratio are within a range, in which, we obtain calorific values high enough to provide heat energy.

The nutrient content in the resultant briquette ash has been shown to compare with known threshold nutrient parameters for specific crops, and thus we accept the null hypothesis formulated

CHAPTER FIVE

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

Conclusions

Based on the results it can be concluded that:

Formulation ratio of 52.6% bagasse, 26.3% press mud and 21.1% molasses can produce press mud briquettes with relatively high calorific values of 3.75kcal/g, high volatile matter and less smoke. The ratios take high amounts of bagasse, which is an integrated waste management strategy in sugarcane processing factories. It was found out that the rations of bagasse, press mud and molasses was enough to optimize the calorific value in briquettes.

KSB, 2009 reported that there still exists excess and unutilized bagasse in local industries due to inefficiency of boilers, and the fact that most companies have not adopted cogeneration of electricity for sale. This means that bagasse needs to be disposed in environmentally sound manner. One way to achieve this is adoption of briquetting technology by communities, especially living near the sugar industry due to lower cost benefits of transportation. The briquettes could substitute use of trees and charcoal and thus avert deforestation. When adopted, where briquettes are in surplus, they could be sold to increase the income margins of household, and in a way reduce poverty.

Briquettes ashes have significant amounts of nutrients that can enhance crop growth. Briquettes nutrient levels showed briquettes formulation was the best in terms of nutrients in particular, nitrogen (10.55±0.11), phosphorous (5.78±0.09), potassium (4.16±0.01), calcium (1.3±0.02) and iron (0.11±0.00) percentages are all higher than the threshold levels and therefore under ideal soil condition the ashes resulting from briquettes can be used to enhance crop production. Ashes from the briquettes contain sufficient available nutrients that can be utilized to grow crops. Surplus produce can be sold to supplement for additional income.

Source of clean energy: In principle, bagasse-briquetting is not only a clean source of energy compared to fossil fuels, it is also “carbon-neutral”. This is because the carbon dioxide emitted during combustion is less or equal to the CO_2 absorbed by the sugarcane as it grows. In addition, as the sugarcane grows, it absorbs an amount of carbon dioxide that is either equal or greater than the amount released during combustion. This technology can therefore benefit from carbon credits.

Bagasse-based briquetting is a solution to environmental hazards as it utilizes waste material which is otherwise a nuisance for sugar factories – unutilized bagasse is a fire hazard as well as an environmental concern

Recommendations

1. Optimal carbonization temperatures should be determined so as to have highest fixed carbon content, a key factor in calorific value obtained.
2. Studies should be carried out when considering applicability of resultant ash from briquettes in crop nutrition, to determine the nutrient bioavailability
3. Cost analysis studies should be carried out to compare their cost with other bio-fuels.
4. Determine the type of soil and suitability of specific crops for the specific nutrients in briquette ash.

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APPENDICES

Appendix I: Types of fertilizers and their Sources

Fertilizers used as primary source of Potassium		
Potassium chloride(potash)	0-0-60 0-0-62	Mostly commonly used potassium fertilizer in Manitoba. Can be mixed with other fertilizers. Contains chloride which is a nutrient and may help to reduce the incidence of some plant diseases

Fertilizers used as primary source of sulphur		
Ammonia sulfate	21-0-0-24	Applied prior to seeding. Contains sulphur in the sulphate readily available form. A highly acidifying fertilizer, which should not be used continuously or at high rates on acidic soils
Combination or blended fertilizers: Note: when blending fertilizers, it is important to use fertilizers sources with evenly matched particles sizes. Using inconsistently sized sources will result in segregation of different fertilizers and may result in lost productivity and crop damage.		
Ammonium thiosulfate	12-0-0-26	Non-corrosive. Contains sulfur in readily available forms

	15-0-0-20	
Elemental sulphur	0-0-0-90	Must be oxidized to sulphate before the plant can use it. Apply one year in advance of crop use
Ammonium thiosulfate		
Urea and monoammonium phosphate		Suitable for nitrogen and phosphorous deficient soils. Nitrogen component can cause germination damage to seed above recommended rates.
Microessentials S15		Offer some improved safety when placed with seed compared to ammonium sulpahte blends.
Monoammonium phosphate and ammonium sulphate		Suitable for sulfur-deficient soils. Phosphorous availability same as mono ammonium phosphate. Suitable for size blending.

Source: Manitoba Agriculture, Food and Rural Initiatives (1990c)