ECONOMIC ANALYSIS OF ALTERNATIVE SOURCES OF ENERGY FOR TOBACCO CURING IN TABORA URBAN DISTRICT, TABORA REGION.

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A DISSERTATION SUBMITTED IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTER OF SCIENCE IN MANAGEMENT OF NATURAL RESOURCES FOR SUSTAINABLE AGRICULTURE OF SOKOINE UNIVERSITY OF AGRICULTURE. MOROGORO, TANZANIA.

2019

ABSTRACT

The growth of tobacco production in Tanzania has become a threat to the woodlands due to the amount of firewood used for curing the crop. The overall objective of the research was to assess the economic feasibility of substituting firewood with sawdust and/or rice husks in curing tobacco. The specific objectives were to: (1) determine calorific values of sawdust briquettes, rice husk briquettes and firewood, (2) examine quality of tobacco cured by sawdust briquettes, rice husk briquettes and firewood, (3) compare curing costs for the three biomass. A Bomb Calorimeter was used to determine the calorific values of all energy sources. The grade indices were determined by dividing the value of tobacco in each harvest/reaping per hectare to the weight of dry tobacco per hectare. The grade indices produced by each biomass was compared by using t-test to see if they were statistically different. The curing costs were compared by using t-test to see if they were statistically different. The results indicated that there was no significant difference at $p>0.05$ between the quality of tobacco cured by sawdust briquettes and that which was cured by firewood. There was significant difference in curing costs at $p<0.05$. The study therefore concludes that the heat content within the sawdust briquette was able to remove the amount of water in green tobacco leaf, the quality of tobacco cured by sawdust briquettes was the same as the quality of tobacco cured by firewood and the difference in curing cost was brought about by the differences in amount of biomass required to cure tobacco, the differences in distance where these biomass were collected and the differences in labour days required in curing tobacco. The study recommended the adoption of the use of sawdust briquettes in curing tobacco in order to reduce deforestation rate.

DECLARATION

I, **ELIMBOTO MUNA,** do hereby declare to the Senate of Sokoine University of Agriculture that this dissertation is my own original work done within the period of registration and that it has neither been submitted nor being concurrently submitted in any other institution.

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ACKNOWLEDGEMENT

First and foremost, my special thanks to the ALMIGHTY GOD who made completion of this work possible. May his name be glorified forever and ever, AMEN.

The completion of this study has been possible through contributions made by various individuals, and institutions. I hereby wish to acknowledge all the institutions, and individuals who made the completion of this study possible.

First, I wish to express my profound gratitude and sincere appreciation to my supervisors Prof. Jumanne M. Abdallah, Prof. Gerald C. Monela and Prof. Romanus C. Ishengoma for their tireless, guidance and encouragement from the initial stage to the production of this dissertation.

I would like to express my sincere appreciation to the Management of Tobacco Research Institute of Tanzania (TORITA) and TORITA'S Board of Directors for sponsoring my studies, and for granting me a study leave. Special thanks should also go to Tanzania Industrial Research and Development Organization (TIRDO) for enhancing analysis of calorific values of sawdust and firewood. I also thank MHM Advent Co. Ltd for manufacturing a low pressure briquetting machine which was used in briquetting sawdust

The field work would not have been successful without the cooperation of skilled laborers from TORITA and the provision of secondary data from Tanzania Tobacco Board (TTB). I also thank the Management of Jiemel Industries Limited for providing me with waste paper as binding materials and Tabora Saw Mills workshop for providing me with sawdust.

Special thanks are due to my lovely wife Donatha whom I shall always remain greatly indebted for her moral support, love and advice in my education. I would like to convey my gratitude to my lovely daughters Elizabeth, Evelyn and Emilia and my son Gideon for their love and support.

Finally my sincere appreciation goes to my sisters Martha, Sarah, Joyce, Mary and Upendo and my brother Godfrey for their moral support. May God bless them.

DEDICATION

This work is dedicated to my late Father Mr. Ibrahim Muna and my lovely Mother Elizabeth Yohana who built the foundation for my education. May the soul of my Father rest in eternal peace, Amen.

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LIST OF ACRONYMS AND ABBREVIATIONS

ATTT	Association of Tanzania Tobacco Traders
BAT	British American Tobacco
BOT	Bank of Tanzania
CHP	Combined Heat and Power
FAO	Food and Agriculture Organization of United Nations
FCT	Fire Cured Tobacco
FCV	Flue Cured Virginia
HRID	Hestian Rural Innovation Development
NCT	Naturally Cured Tobacco
PMI	Philip Morris International
ProBEC	Programme for Biomass Energy Conservation
SHI	Sao Hill Industries
TANESCO	Tanzania Electric Supply Company
TIRDO	Tanzania Industrial Research and Development Organization
TLC	Total Land Care
TLTC	Tanzania Leaf Tobacco Company
TORITA	Tobacco Research Institute of Tanzania
TTB	Tanzania Tobacco Board
TZS	Tanzanian Shillings
URT	United Republic of Tanzania
USD	United States of America Dollar

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background Information

1.1.1 Tobacco production world wide

Tobacco is a cash crop grown widely in various countries in the world. It is consumed worldwide and has been cultivated in Africa since end of 16th century, but commercial cultivation began around 19th century (Kibwage *et al.*, 2009). According to Jaffee (2003), eleven countries (including Tanzania, Zimbabwe and Malawi) account for about 80% of global tobacco production. China alone accounts for about 40%, followed by India, Brazil and United States of America, which collectively account for about 25%.

1.1.2 Tobacco production in Tanzania

In Africa, Tanzania is the third largest producer of tobacco after Zimbabwe and Malawi. It is one of the major cash crops benefiting the majority of farmers and other stakeholders. Recently, according to the BOT (2015) Monthly Economic Review Report of November 2015, tobacco was ranked as the first foreign exchange earner among the exported cash crops in Tanzania. Tobacco is increasingly becoming imperative both socio-economically and as a competitive export crop in Tanzania (Abdallah, 2006). In Tanzania, Tobacco Regions are Singida (Manyoni), Katavi (Mpanda), Tabora (Uyui, Urambo, Sikonge and Tabora urban), Shinyanga (Kahama and Bukombe), Kigoma (Kasulu and Kibondo), Kagera (Biharamulo), Ruvuma (Namtumbo, and Songea), Iringa and Mbeya (Chunya). Tobacco production in Tanzania has steadily expanded annually from 46 728 tonnes in 2006 to 87 231 tonnes in 2015 (TTB, 2015).

1.1.3 Tobacco production and deforestation

The growth of tobacco production is leading to new and severe threats to woodlands. Ecological functions of the woodlands are particularly threatened by the production of flue-cured tobacco which accounts for 99% of the crop's total production in Tanzania (TTB, 2015). The threat impact comes from the large quantities of wood harvested from miombo woodlands for curing the crop. According to Scott (2006) small scale farmers consume approximately 43 m^3 of firewood (15 000 kg per year) and produce an average of 1400 kg of cured tobacco. Clay (2004) shows that 19.9 m^3 of wood is used to cure one metric tonne of tobacco. Also Siddiqui and Rajabu (1996) in their experimental research on firewood consumption for flue cured tobacco estimated that 14 kg of firewood is required to cure a kilogram of tobacco. These variations in wood consumption can be linked to a number of factors including the types of barns used, state and wood species and the knowledge of famers on the importance of improving tobacco curing efficiency.

This firewood consumption in flue cured tobacco is accompanied by forest woodland clearance. According to (FAO, 2010; Musoni *et al*., 2013) more than 300 000 ha of indigenous forests in Zimbabwe are destroyed annually by new small-scale tobacco farmers. Chenje and Johnson (1994) conducted a study to find the area of land needed to be cleared annually for tobacco curing and found that 140 000 ha of Miombo woodlands need to be cleared annually and this accounts for 4–26% of the Miombo deforestation. Hence the need for alternative energy source in tobacco curing is crucial.

1.1.4 Tobacco curing

According to Reed *et al*. (2012), curing is the process in which tobacco leaf moisture is removed without affecting its aroma, colour and taste. During curing, tobacco drives off moisture in the leaf, preparing the crop for further manufacturing. According to North

Carolina State University (2013), the initial moisture content of tobacco is 80 to 85% and this moisture is completely removed to approximately 0% at the end of curing.

The amount of moisture driven off through the curing is dependent on several factors, namely the strand of tobacco, leaf position, and handling of the leaf (Reed *et al.*, 2012). For example, leaves positioned lower on the stalk have higher moisture content and therefore need a higher energy input to drive the moisture off. The necessary changes in the leaf during the process of curing are achieved by controlled but varying temperatures and relative humidity during the various stages of curing

1.1.5 Types of tobacco curing

In order to cure tobacco, there must be an energy input. This energy input can be from natural sources, such as the sun or wind. Sun and air cured tobacco are categorized as Naturally Cured Tobacco (NCT). Geist (1998), estimated that in 1993 NCT comprised 38% of the global production. According to Schmid (2010), 30% of the global tobacco production is cured through natural means and remaining 70 to 62% of the global tobacco production is cured through unnatural means. Unnatural means of cured tobacco are of two types fire-cured tobacco (FCT) and flue-cured tobacco referred to as Flue-Cured Virginia (FCV).

1.1.6 Flue cured tobacco

According to TTB (2015), about 99% of tobacco produced in Tanzania is FCV. It is cured in simple, homemade barns using firewood placed in a small furnace at one end of the barn. When the firewood is lit, heat is simply drawn up through the barn to dry tobacco hanging from poles that are stacked from the bottom to the top of the barn. This is referred to as flue-cured tobacco (CAMCO, 2014).

1.1.7 Alternative energy sources in tobacco curing

Due to large amount of firewood used for curing which results to deforestation, the use of alternative energy sources in tobacco curing could be of great importance in combating defforestation (Nayak, 2013). An example of alternative energy source which is practical for tobacco curing is through use of sawdust and rice husk biomass. Biomass is fuel that is developed from organic material, a renewable and sustainable source of energy (www.eai.gov/energyexplained/). Use of biomass residues and wastes for energy production has been increasingly proposed as a substitute for fossil fuels. Biomass residues can also offer an immediate solution for the reduction of the CO_2 content in the atmosphere (Hood, 2010). Due to their heterogeneous nature, biomass residues materials possess inherently low bulk densities, and thus, it is difficult to efficiently handle large quantities of most residues. In order to increase the efficiency of handling bulk biomass, densification is often required. The process of compaction of residues into a product of higher bulk density than the original raw material is known as densification or briquetting (Hood, 2010).

Briquettes can be produced with a density of 1.2 g/cm^3 from loose biomass of bulk density 0.1 to 0.2 g /cm^3. These can be burnt clean and therefore are eco-friendly arid also those advantages that are associated with the use of biomass are present in the briquettes.

Basing on compaction, the briquetting technologies can be divided into:

i. High pressure compaction
ii. Medium pressure compaction with a heating device
iii. Low pressure compaction with a binder (Grover and Mishra, 1996)

In this study low pressure compaction with a binder was used for production of briquettes where by the biomass materials was sawdust and waste paper was used as a binder because papers are known to contain proteinaceous materials that tend to have an excellent adhesive property, making it useful as partial binder material (Njenga *et al.*, 2009)

1.2 Problem statement and justification of the study

Tobacco farming in Tanzania relies heavily on shifting cultivation and use of firewood for curing. High deforestation of miombo woodlands has also been one of the attribute in tobacco growing areas. On average, a farmer cultivates 1.3 ha of tobacco each growing season. Over 61 000 ha of land are cleared annually for tobacco growing at Urambo district. A conservative average crop harvest stood at 1000 kg (cured leaf) per ha which consume 23 m^3 of wood for curing (Mangora, 2012). The high demands of firewood for the tobacco industry can as well no longer be sustained under the implicated pace of woodland deforestation. For small scale tobacco farming households, these are inevitable consequences of tobacco farming for livelihood and survival. Continuing deforestation however, has contributed to the Tabora Region experiencing increasingly acute water shortages in recent years as rainfall dwindles (Makoye, 2012). Despite concerns regarding firewood use in tobacco curing, few studies to date are focusing on the feasibility of alternative energy sources to firewood for tobacco curing. This study aims at analyzing the economic profitability of substituting firewood for sawdust and/or rice husks in curing tobacco in Tabora urban district, Tanzania.

1.3 Objectives

1.3.1 Overall objective

To assess the economic feasibility of substituting firewood with sawdust and/or rice husks in curing tobacco.

1.3.2 Specific objectives

The specific objectives of the study were to:

i. determine calorific values of sawdust briquettes, rice husk briquettes and firewood.
ii. examine quality of tobacco cured by sawdust briquettes, rice husk briquettes and firewood.
iii. compare the tobacco curing costs when tobacco is cured by sawdust briquettes, rice husk briquettes and firewood.

1.4 Research questions

The study strive to answer the following questions

i. What are the calorific values of sawdust briquettes, rice husk briquettes and firewood?
ii. What are the qualities of tobacco cured by sawdust briquettes, rice husk briquettes and firewood?
iii. What are the tobacco curing costs when tobacco is cured by sawdust briquettes, rice husk briquettes and firewood?

1.5 Hypotheses

H_{01}: There is no difference in the quality of tobacco when sawdust briquettes, rice husk briquettes and firewood are used as source of heat energy in curing tobacco.

H_{02}: There is no difference in curing costs when sawdust briquettes, rice husk briquettes and firewood are used as source of heat energy in curing tobacco.

1.6 Organization of the dissertation

This dissertation is organized into five chapters. Chapter one presents the background information of the study; problem statement; objectives of the study; research questions and hypotheses. Chapter two present literature review.

Chapter three presents the methodology used in the study, it explain the study area, the research design used, the methodology used in data collection and the method used in data analysis. Chapter four present results of the study and the discussion. Chapter five present conclusion and recommendations emanating from the major findings of the study.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Tobacco production and its impact on deforestation

Deforestation is the removal of trees from a forested site and the conversion of land to another use, most often agriculture (Van Kooten and Bulte 2000). Flue and fire cured tobacco has a great impact on the indigenous forests. This impact is due to the use of firewood for tobacco curing. Curing is the process of killing chlorophyll and converting starch into sugar, remove the moisture and give the tobacco leaves a lemon or orange appearance (Sauer and Abdallah, 2005). These impacts are serious in less developed countries that heavily depend on natural forest as a source of firewood for tobacco curing. Most of the smallholder farmers use firewood sourced from the natural forest as the cheapest method of curing their tobacco leaves.

2.2 Initiatives towards reducing deforestation rate

Tobacco is being grown by various countries in the world. Every country has programs for minimizing tobacco curing related problems. For example, British American Tobacco (BAT) encourages farmers to use non-wood fuels and sponsors forestry programs, as well as using packaging materials from suppliers who use sustainable sources (www.bat.com). Philip Morris International (PMI) has developed 'Good Agricultural Practices' guidelines, which include avoidance of deforestation and establishment of reforestation (www.pmi.com).

In Zimbabwe the tobacco industry has put in place some initiatives to produce tobacco in a sustainable way in order to protect biodiversity and foster the development and maintenance of healthy ecosystems. These ongoing initiatives include; Sustainable

Afforestation programs such as funding the afforestation programme through levies raised from tobacco revenue, and funding research into the use of alternative energies for curing tobacco and also researches for the development of appropriate technologies for curing (www.timbco.zw). One of the appropriate technologies is the introduction of Rocket barn. A Rocket barn decreases wood use while improving the amount and quality of tobacco cured. It is 50 percent more efficient than the conventional barn, thus creating benefits both to the producer and to the environment.

In Malawi flue-cured and fire-cured tobacco place high demands on firewood. Various methods have been introduced to decrease this problem. These include a combination of new tree planting, the adoption of energy efficient stoves and tobacco curing furnaces, and sustainable management of existing trees (Bunderson *et al.,* 2001).

2.3 The use of alternative energy sources in tobacco curing

Despite concerns regarding firewood use for tobacco curing some few studies done by; Nayak (2013), Xinfeng *et al.* (2015), Tippayawong *et al.* (2006), and Nyer (2011) have studied the feasibility of alternative energy sources to firewood for tobacco curing, though there is evidence that proper use of biomass residues results in less air pollution than firewood. Nayak (2013) conducted a research on using coffee husks as an alternative to firewood in curing tobacco and found that barn owners could save as much as 35% of their energy cost.

Xinfeng *et al.* (2015), conducted a research by using tobacco stems briquetting (TSB) and honeycomb briquette (HB) in curing tobacco and found that the temperature of TSB was higher than that of HB, the efficiency of bio-fuel system with TSB was from 43.5% to 54%, while the efficiency of traditional fuel system was 51.5% and the cost of tobacco flue-curing per hectare with TSB and HB was 750.0 USD and 1 282.5 USD, respectively.

It is proved that TSB is an alternative choice using for the industry of tobacco flue-curing, and the improvement in the structure of fire furnace could optimize the process of tobacco flue-curing.

Another study was done by Tippayawong *et al.* (2006) on the use of rice husk and corn cob as renewable energy sources for tobacco-curing and found that rice-husk and corn-cob can be used successfully to meet the requirement of thermal output for tobacco-curing at low emissions. These agricultural residues show great potential to replace wholly or partially traditional fuels for tobacco-curing.

According to a study conducted by Nyer, (2011) on the use of biomass in high efficiency tobacco curing, the study found that fuel efficiency index was improved by 22.6% and 21.6% for sesbania and rice straw respectively also the buying price was 0.13 USD higher per kg for rice straw and 0.01 USD lower for sesbania.

2.4 Tobacco curing technologies in Tanzania

Tanzania Leaf Tobacco Company (TLTC) over many years have introduced various energy technologies for tobacco curing through Association of Tanzania Tobacco Traders (ATTT) to minimize wood consumption in curing tobacco by training farmers and converting traditional barns to improved ones, while making sure that newly built barns conform to modern improved standards. Barn designs that reduce firewood use were experimented by TLTC at Seed Farm in Urambo, and introduced or disseminated to farmers. The barns include: Improved Barns, Stadard barns, Rocket barns and Brazilian barns. Comperatively, traditional barns consumes more energy than the others. In terms of energy saving, Rocket Barn is the most efficient compared to the rest. It has exhaust chimney made of iron sheet. The main concern regarding Rocket Barn is that its construction cost is relatively high at an average of TZS 400 000 per unit and this affect its adoption. There is a very high potential to lower wood use in tobacco sector if the adoption of the energy serving technologies are increased (Abdallah and Ishengoma, 2015).

2.5 Tobacco curing

According to Reed *et al*. (2012), curing is the process in which tobacco leaf moisture is removed without affecting its aroma, colour and taste. FCV is cured by controlling the heat and relative humidity in the barn through combustion and ventilation respectively. To monitor the temperature and humidity, operators typically use dry and wet-bulb thermometers. However, the wet-bulb thermometer is often omitted and the appearance and feel of the leaf is used to approximate the humidity in the barn. Although the specific curing cycle varies considerably based on factors such as the leaf position, strand of tobacco, environmental conditions, and even the company, there are three steps that are always included: yellowing, leaf drying, and stem drying (NCSU, 2013).

During yellowing, sometimes called coloring, biological processes take place inside the leaf where starches are turned into sugars, thus changing the color of the leaf from green, to the desired color of the final product, which is usually yellow but varies depending on the strand of tobacco and the market demand. Maintain a dry bulb temperature of 100°F until all leaves are yellow. Provide enough ventilation so that when the leaves become yellow, those on the bottom tier will be completely wilted. Generally, a difference of 2 to 3°F between the wet and dry-bulb reading should be maintained.

The leaf drying, or lamina drying phase kills the stomata cells preventing gases to be exchanged between the leaf and air, thus halting the biological processes occurring in the leaf. This stops the color from progressing to brown, which is undesirable. When leaves are yellow and sufficiently wilted, the dry-bulb temperature should be advanced 2°F per hour to 130°F. Increase ventilation enough so that the wet bulb does not exceed 105°F. Toward the end of the leaf drying period it will usually be possible to reduce the amount of ventilation without exceeding 105°F on the wet bulb. A 130°F dry-bulb temperature should be maintained until all of the leaves on the lower two tiers are dry.

The last phase of the curing cycle is drying of the stem. Again the temperature is raised and the relative humidity is decreased. Now that the indoor environment and leaves are relatively dry, the temperature can easily be increased by closing the ventilators and heating the indoor environment by adjusting the feeding rate of fuel into the furnace. The temperature is held at approximately 160^{o}F until the stem of every leaf is dry. The end product is a leaf that is essentially 0% water.

2.6 Availability of sawdust in tobacco growing regions

According to a study conducted by Abdallah and Ishengoma (2015), study revealed that in the saw milling process of Sao Hill Industries (SHI) in Mufindi-Iringa the proportional of products produced are: lumber (45%), slabs and edgings (27%), sawdust (14%), trimmings (5%) and barks (9%). That means about 99 000 m^3 of waste are generated annually of which 48 600 m^3 are edgings; 25 200 m^3 are inform of saw dust; 9000 m^3 are trimmings and about 16 200 m^3 is bark. Other sources of wood wastes are small-scale sawmilling machines operating in the Sao-Hill Forest Plantations and other outside the plantation. It is estimated that there are about 300 small scale sawmilling machines currently operating in Sao-Hill Forest Plantation. Others are located in urban centres e.g. more than 15 in Iringa town. SHI have a plan to construct a 15 MW and a 7 MW Combined Heat and Power (CHP) system within Sao Hill Forest Plantations. The plan is intended to enable utilization of the lowest-quality wood generated from forest activities, and materials that are currently being generated as residuals. The proposed new 15 MW CHP biomass-fired power plant intends to ensure reliability of power supply both to the sawmill and to local consumers, who frequently have erratic electric supply. The plant intends to utilize sawmill wood waste to generate electricity and steam. The steam will be used for thermal processes such as dry kilns and a portion of the electricity generated will be used to operate the sawmill. The fuel for this will be waste from own production as well as waste from small scale saw mills in the region. Excess electricity is intended to be sold to Tanzania Electric Supply Company (TANESCO) or to local industries nearby. In case this plan materializes most of the wood residuals from SHI will not be available for tobacco curing. Based on the above findings the consultant was reluctant to recommend this as a source of energy for tobacco curing.

2.7 Density of sawdust briquettes

A briquette (or briquette) is a compressed block of coal dust or other combustible biomass material such as charcoal, sawdust, wood chips, peat, or paper used for fuel and kindling to start a fire. The term comes from the French language and is related to brick. Biomass briquettes are made from agricultural waste and are a replacement for fossil fuels such as oil or coal (www.wikipedia.com). Wood briquettes are characterized by high density of compression, which leads to a perfect burning and high thermal efficiency (www.biowood.eu).

Briquettes produced from agro-residues are fairly good substitute for coal, lignite and firewood. Briquettes from saw dust have high specific density of 1400 kg/m^3 compared to bulk density of 210 kg/m^3 (approx.) of loose saw dust. Loading/unloading, transportation and storage costs of agro-residues are drastically reduced if they are converted in the form of briquettes. Formation of briquettes at the very site of its production stops air pollution to a large extent. Hence briquetting of saw dust produces renewable and environment friendly source of energy (Pushpa and Yadav, 2012).

Briquette quality, as a final output of the densification process, is evaluated mainly by its density, and is influenced by many different variables. According to Križan *et al*. (2009) suggests that these variables can be divided into the following three groups: - raw material parameters; - technological parameters and structural parameters. Križan *et al*. (2009) in their study of Behavior of Beech Sawdust during Densification into a Solid Biofuel found that increased compression pressure, compression temperature, and reduced particle size, increase the density of beech briquettes. Pushpa and Yadav (2012) found that briquette density remains constant around the value 1.4 gm/cm^3 for the composition of binder in the range of 12-20%.

Mitchual *et al*. (2013) found that briquettes made from hydraulic piston press are usually less than 1000 kg/m^3 and are usually between 300 and 600 kg/m^3 in density. Furthermore the results suggest that the relaxed density of the briquettes produced increases with increasing compacting pressure level and that briquettes produced from sawdust of tropical hardwoods species with smaller particle size are likely to have higher relaxed density than those with larger particle size.

Bulk density plays vital role in transportation and storage efficiency. In addition, bulk density influences the engineering design of transport equipment, storages, and conversion process (Woodcock and Mason, 1987). Karunanithy *et al*. (2012) found that bulk density of the feed stocks (sawdust, pigeon pea, cotton stalk, corn stover and switch grass) ranged between 66 to 191 kg/m^3, whereas the briquettes bulk density varied between 285–964 kg/m^3. Among the feed stocks, corn stover had the lowest and sawdust had the highest bulk density.

Density is a very important parameter in briquetting as it indicates the amount of mass per unit volume. It has a significant role in compressive strength of any material. According to a study conducted by Wachira *et al*. (2015), the density was found to have a high dependence on the type of machine, amount and type of binder. Various press machines behaved under different binders and ratios. The compressed density of the samples varied from one machine to the other. In all the pressing machine hand dual was noted to have briquettes with the highest density in all the ratios and the density of the briquettes ranged from 0.387-0.69, 0.355-0.794, 0.373-0.831 g/cm^3 for paper, loam and clay soil briquettes respectively

2.8 Calorific value of sawdust briquettes

According to the Collins English Dictionary the calorific value is the quantity of heat produced by the complete combustion of a given mass of a fuel, usually expressed in joules per kilogram. According to a study conducted by Rajaseenivasan *et al*. (2016) on the performance of sawdust, neem power and its blend briquettes. The result illustrates that the neem powder has higher strength, handling and water resistance properties and lower calorific value than the sawdust briquettes. Thus the neem powder is added as a blending material with sawdust to increase the handling and water resistance properties of the briquettes. The tests with various blend ratio show that increasing the neem content in briquette enhances the strength of the briquettes. Pushpa and Yadav (2012), found that calorific values of sawdust briquettes increase with increase in the percentage of binder from 12 to 16%. But beyond binder percentage of 16% the calorific values of sawdust briquettes remain constant.

According to Thabuot *et al*. (2015) on their study on Effect of Applied Pressure and Binder Proportion on the Fuel Properties of Holey Bio-Briquettes, found that briquette production from bamboo sawdust obtained the briquette having the high calorific heating value reached to 21.26 MJ/kg. Burning rate of produced briquette decreased with the increasing of applied pressure, and the use of 20% molasses and 70 kg/cm^2 gave the briquettes having low value of burning rate. Also this condition showed briquette obtained from rubber wood residue has the slowest burning rate of 2.01 g/min. The study results presented showed that briquettes with high density, high heating value and slow burning rate can be produced depending on the material variables and process factors.

Brožek *et al*. (2012) found that the gross calorific value of sawdust briquette was 18.9 MJ/kg with ash content and moisture content of 0.29 and 6.8% respectively. The briquettes fulfilled the demands of relevant directives for combustion heat, total moisture and ash amount.

Heat value or calorific value determines the energy content of a fuel. It is the property of biomass fuel that depends on its chemical composition and moisture content. The most important fuel property is its calorific or heat value. According to Aina *et al*. (2009), briquettes made from *Albizia zygia* had a higher heat value than the solid wood of the same species. The briquettes generate more energy or heat per gram compared to the same amount of solid wood. The calorific value of sawdust briquette was 4 723.02 kcal/kg while that of solid wood was 4 014.80 kcal/kg.

2.9 Tree species used for tobacco curing

According to Njana *et al*. (2013) in their study are Miombo Woodlands Vital to Livelihoods of Rural Households? Evidence from Urumwa and surrounding communities, Tabora, Tanzania, tree species which were mostly preferred by farmers for firewood were: *Brachystegia boehmii, Brachystegia spicifomis, Brachystegia microphylla, Combretum molle, Combretum obovatum, Julbernadia globiflora, Dalbergia melanoxylon, Flacourtia indica, Kigelia africana, Sterculia quinqueloba and Ziziphus mucronata*.

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Location of the study area

The study was conducted at the district of Tabora urban in Tabora region. Tabora region is found between latitude 4^0 and 7^0 South of Equator and longitude 31^0 to 34^0. The region is in the central-western part of the country. It is bordered to the north by Shinyanga Region, to the east by Singida Region, to the south by Mbeya Region, to the southwest by Katavi Region, to the west by Kigoma Region, and to the northwest by Geita Region. It has size of 76 151 square kilometers. According to the region socio-economic profile, Tabora region is divided into seven districts which are Nzega, Igunga, Uyui, Tabora urban, Urambo, Sikonge and Kaliua (URT, 2014).

3.2 The study district

3.2.1 Location

Tabora urban is one of the seven districts of Tabora Region. It is located -5.02^0 latitude and 32.83^0 longitude and it is situated at elevation 1191 meters above sea level. The District covers the area of 1092.26 square kilometers and with a population of about 226 999 (URT, 2012). Tabora urban is 800 km West of Dar es Salaam, 320 km east of Kigoma port on the shores of Lake Tanganyika, and 360 km South of Mwanza city.

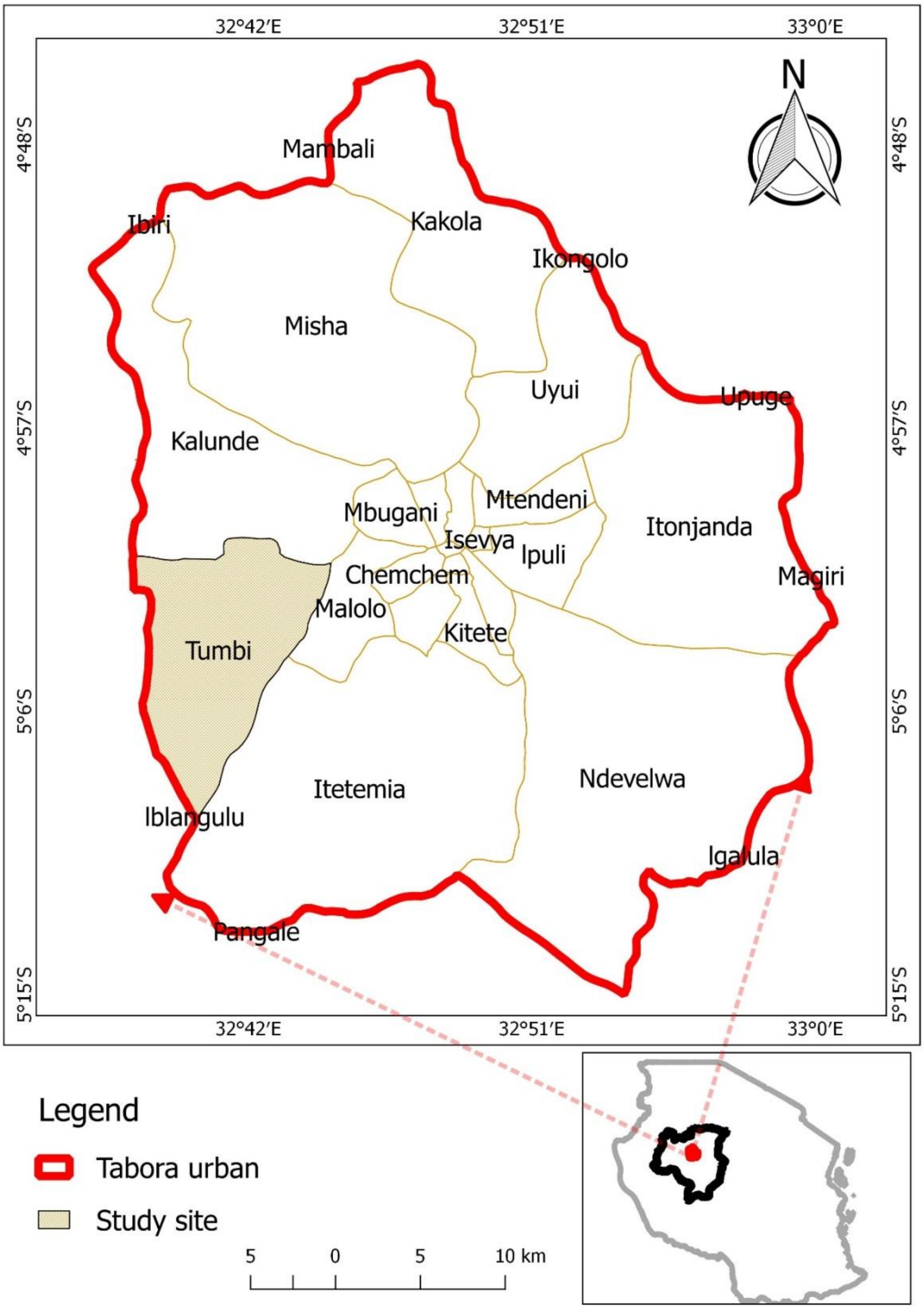


Figure 1: Map of Tabora urban district showing study site

3.2.2 Climatic condition and topography

The climate of the district is generally hot (20 to 32^{o}C), with relative humidity ranging from 25 to 65% and the rain fall ranges from 650 to 850 mm per year. This is tropical characteristics of the semi-arid areas.

3.2.3 Economic activities

Agriculture is the main economic activity, focusing on maize, rice, groundnuts, beans, cowpeas, cassava, sweet potatoes and tobacco. Tabora is also famous for beekeeping (honey and beeswax) and forest timbering activities. Livestock farming is also an important economic activity in the region.

Much of the arable land in Tabora urban has been degraded due to poor irrigation practices and an increasing demand for land for agriculture, grazing and firewood. The industrial sector employs about 8929 people, 13.5% of which are in the formal sector (URT, 2014).

3.3 Research materials and design

A plot size of 3 780 m^2 was cultivated in Tumbi Tabora using K 326 variety at a spacing of 1.2m by 0.5m and all principles of good agricultural practices was followed. Tobacco harvested from this plot was loaded into two rocket barns whereby in one barn sawdust briquettes was used and another one firewood was used as source of energy for curing tobacco. Rocket barn was used to assess the efficiency of sawdust briquettes and firewood for tobacco curing. Rocket barn is the energy efficient curing barn that use less amount of firewood for tobacco curing as compared to local barns (Munanga *et al*., 2014).

A manually operated or low pressure briquetting machine was used to briquette the sawdust using waste paper as binding material.

3.3.1 Rocket barn

The Rocket Barn is an energy efficient curing barn that was invented in Malawi in 2006 by biomass energy consultant Peter Scott in collaboration with Hestian Rural Innovation Development (HRID), Total Land Care (TLC), and the Programme for Biomass Energy Conservation (ProBEC), Plate 1. This type of barn consumes less amount of firewood as compared to local barns (Munanga *et al*., 2014).

Plate 1: Rocket barn

3.3.2 Fuels

Sawdust and firewood were used as source of energy for curing tobacco. Sawdust was collected from Tabora Saw mills which is located in Tabora town and was transported to trial site which is about 23.5 km from where they were collected. Firewood was collected from the natural forest which was about 2 km from the trial site (Plate 2).

Plate 2: Firewood for curing tobacco

Plate 3: Sawdust briquettes for curing tobacco

3.3.3 Briquetting machine

A low pressure or manually operated briquetting machine which was constructed by MHM Advent Company Limited was used in briquetting sawdust (Plate 4). This is a company located in Tabora urban which deals with dissemination of efficient energy serving devices for institutions and households.

Plate 4: Low pressure briquetting machine

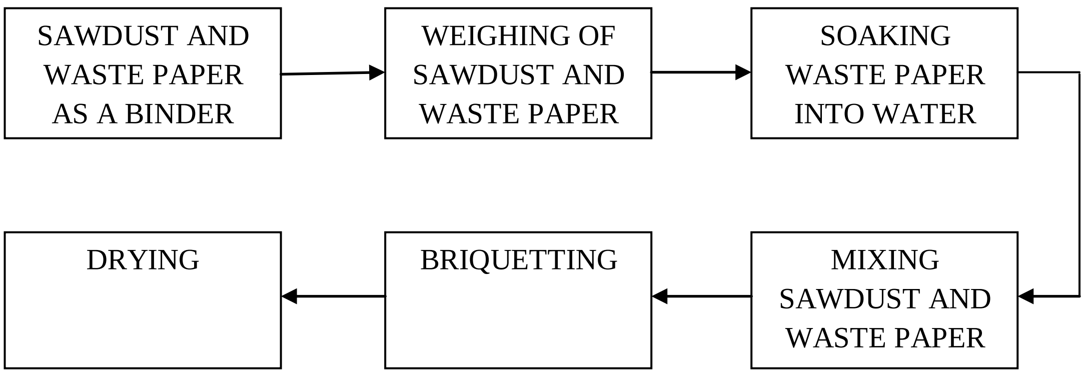
3.3.4 Binding materials

Waste paper from Jiemel Industries Limited was used as binding materials (Plate 5), this is because paper is known to contain proteinaceous materials that tend to have an excellent adhesive property, making it useful as partial binder material (Njenga *et al.*, 2009). Jiemel Industries Limited is a box manufacturing industry which is located at Chang'ombe, Temeke Dar es Salaam. Waste paper was transported from Dar es Salaam to Tumbi, Tabora where the trial was located. This industry produces about 1.5 tonnes of waste paper per day.

Plate 5: Waste paper as a binding materials

3.3.5 How briquettes were made and size of the briquette

Waste paper which weigh 4 kg was soaked into 80 litres of water for 24 hours. Sawdust which weigh 42 kg was mixed thoroughly with 4 kg of waste paper which was soaked into water then the process of briquetting started. Manually operated or low pressure briquetting machine was used. One bag of sawdust which weigh 42 kg together with waste paper 4 kg which was used as binding materials produced 95 briquettes with weight of 49.40 kg. The briquettes were sun dried before they were used for tobacco curing as shown in Plate 3 above. For the period of 8 hours using four laborers a total of 780 briquettes with weight of 405.60 kg were produced. 4 kg of waste paper mixed with 42 kg of sawdust produced 49.40 kg of briquettes. In a period of 8 hours 4 labourers produced a total of 405.60 kg of briquettes.



Source: Own construction

Figure 2: Briquette manufacturing process

The briquette produced was of 0.50 to 0.52 kg, 18.5 cm long, diameter of 9.8 cm with a hole of 2.6 cm wide for supporting combustion. By using low pressure briquetting machine it was not possible to briquette rice husks by using waste paper, cow dung and cassava flour as binding materials as shown in Plate 6 and 7.

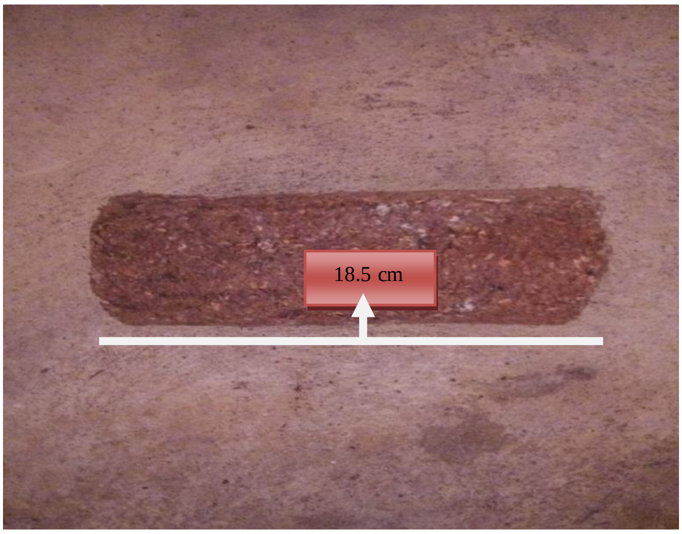


Plate 6: Longitudinal section of sawdust briquette

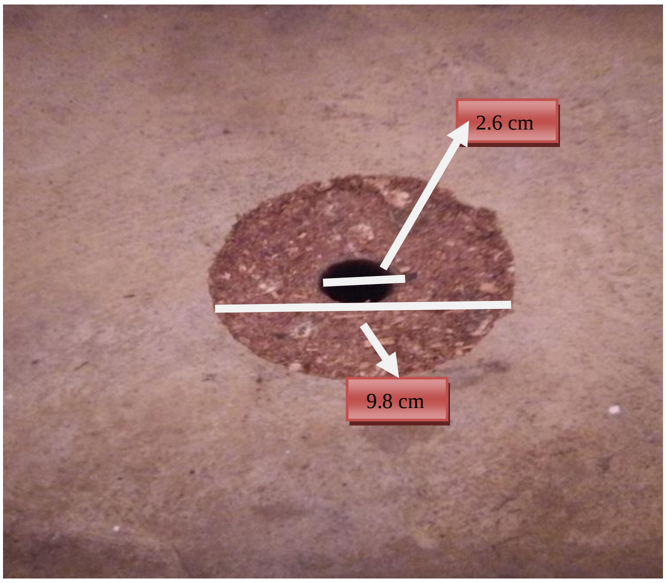


Plate 7 :Cross-section of sawdust briquette

3.3.6 Barn loading

Tobacco was reaped the day of loading and brought to each barn. It was loaded into each barn on the same day. The quality and maturity of tobacco was kept as even as possible during tying and loading. The overripe tobacco was placed on the top of the barn.

3.3.7 Weighing

The tobacco was weighed before and after each cure with a 300 kg digital scale (Plate 8). Before the cure the total weight of green leaves were recorded before tying them in sticks. After leaf curing, the tobacco from each barn was off loaded, untied and conditioned. Then the dry weight of tobacco was recorded for each harvest.

Plate 8: 300 kg digital weighing scale

3.3.8 Leaf curing

After tobacco was reaped from the field, it was loaded into the barn and the process of curing started. The process of leaf curing was monitored by skilled laborers from TORITA under the supervision of the author. The total hours required to accomplish one cure was recorded for each barn. The total weight of sawdust briquettes required to accomplish one cure and the weight of firewood required in one curing were also recorded.

Plate 9: Burning of sawdust briquettes

3.3.9 Tobacco grading and classification

Successful grading depends largely on good organization of stored tobacco. Tobacco leaves were graded by skilled laborers according to plant position, type, texture, color and size. The process of grading was done by considering tobacco from each harvest.

After tobacco grading the process of tobacco classification followed. This was done by tobacco classifier from TTB. Tobacco classification is the judgment of tobacco by putting grade marks according to grade descriptions/specifications. A classification grade or grade mark is made up of symbols in sequence to describe a lot of tobacco by group, quality, colour, extra factors and special factors (TTB, 2016).

6.2 Data collection and analysis

Objective 1: To determine the calorific values of sawdust briquettes and firewood.

The samples of sawdust briquettes and firewood was collected and sent to Tanzania Industrial Research and Development Organization (TIRDO) laboratory. A Bomb

Calorimeter was used to determine the calorific values of all energy sources. The calorific values obtained was compared and described.

Objective 2: To examine the quality of tobacco cured by sawdust briquettes and firewood.

Both primary and secondary data was used. Secondary data was on minimum indicative flue cured grade prices for 2016/17 crop season which were obtained from Tanzania Tobacco Board (TTB). Primary data collected include, weight of dry tobacco for each harvest, the tobacco grades for each harvest, weight of each grade in each harvest and the grade index for each harvest. Grade index was taken as the ratio between the values of tobacco produced by sawdust briquettes and firewood in each harvest/reaping per hectare to the dry weight of tobacco produced in one hectare. The dry weight of tobacco leaves was measured by using a 300 kilogram digital scale after curing and grading. Tobacco grades were assigned by the classifier from TTB after the tobacco has been cured and graded.

The grade indices produced by each biomass was compared by using two sample independent t-test to see if they were statistically different. Data collection form in Appendix 1 was used to collect data for this objective. Data was analyzed by using Microsoft excel.

Objective 3: To compare the tobacco curing cost when tobacco is cured by sawdust briquettes and firewood.

Data collected included cost of transporting, loading and offloading sawdust and binding materials, labor cost for briquetting sawdust, cost of the low pressure briquetting machine, labor cost for tobacco curing using sawdust briquettes, man days of preparing cubic meter of firewood, cost of transporting, loading and offloading firewood and man days of curing by using firewood. The curing costs were compared by using two sample independent t-test to see if they were statistically different. Data collection form in Appendix 2 was used to collect data for this objective. Data was analyzed by using Microsoft excel computer program.

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

4.1 Calorific values of sawdust and firewood

The laboratory results indicated that the calorific value of sawdust briquette was 3 133.10 Cal/g while that of firewood was 4 218.11 Cal/g. According to the Collins English Dictionary the calorific value is the quantity of heat produced by the complete combustion of a given mass of a fuel, usually expressed in joules per kilogram. The higher the calorific value the less amount of biomass is required during curing hence less cost. According to the laboratory results firewood had higher calorific value than the sawdust hence less cost was incurred when using firewood as the source of heat energy during curing tobacco.

Gross calorific value (GCV) is a significant indicator of biomass quality that depends on elemental composition, moisture content and ash content (Montes *et al*., 2011). According to Erakhrumen (2009), the GCV of different types of biomass is ranging from 14-23 MJ/Kg (dry basis). The differences are mainly due to different carbon content (main energy source) and different ash content (not combustible material).

4.2 Quality of Tobacco Cured by Sawdust Briquettes and Firewood

Results in Table 1 indicates that the mean of grade index when tobacco was cured by sawdust briquettes and firewood was 1.756 and 2.257 respectively. Plate 10 indicates one of top grade obtained after curing by using sawdust briquettes.

Table 1: Grade index analysis of tobacco cured by sawdust briquettes and firewood per hectare with six harvests

	Sawdust briquettes	Firewood
Mean	1.756	2.257
Variance	0.125	0.3050
Observations	6	6
Pooled Variance	0.215	
Hypothesized Mean Difference	0	
df	10	
t Stat	-1.869	
P(T<=t) two-tail	0.091	

Since p value 0.091 is greater than the level of significance which was 0.05, the null hypothesis is not rejected, hence there is no significant difference between the quality of tobacco cured by sawdust briquettes and that which was cured by firewood.

Plate 10: Top grade obtained after curing with sawdust briquettes

4.3 Cost of tobacco curing when sawdust briquettes were used as source of heat energy

4.3.1 Cost of purchasing, transporting, loading and offloading sawdust used in tobacco curing per hectare

Sawdust was collected from Tabora Saw Mills free of charge and they were transported by using Fuso which had a capacity of carrying 10 tonnes. The distance from Tabora Saw Mills workshop to Tumbi where the research was conducted was about 23.5 km. In order to cure tobacco of one hectare which was 2 029.05 kg/ha (see Table 5) an amount of 61.16 tonnes of sawdust is needed. The transport cost per trip was 36.74 USD and the cost of loading and offloading was 18.37 USD per trip. The transport cost, loading and offloading of sawdust per hectare are presented in Table 2 below.

Table 2: Cost of purchasing, transporting, loading and offloading sawdust used in tobacco curing per hectare

Item	No of trips	Cost/trip (USD)	Total cost (USD)
Purchasing price	6.12	Free	Free
Transport cost	6.12	36.74	224.848
Loading and offloading	6.12	18.37	112.424
Total			**337.272**

Exchange rate was taken as 1 USD=2 177.6331 TZS

4.3.2 Cost of purchasing, transporting loading and offloading binding materials (waste paper)

Waste paper was transported from Dar es Salaam to Tabora at a cost of 0.046 USD per kg. They were provided free of charge from Jiemel industry. Total amount of waste paper required to cure one hectare was 5 827.96 kg. Hence the total cost of transporting 5 827.96 kg was 268.086 USD. The total cost of loading and offloading was 51.01 USD.

Hence the total cost of transporting, loading and offloading waste paper was 319.096 USD.

4.3.3 Cost of manually operated or low pressure briquetting machine

The cost of all materials used in manufacturing of low pressure briquetting machine together with labor cost are indicated in Table 3.

Table 3: Cost of manually operated or low pressure briquetting machine

S/N	Material	Specification	Quantity	Cost/quantity (USD)	Total cost (USD)
1	Timber	(2"x6"x5ft)	6	1.56	9.37
2	Timber	(2"x6"x4ft)	6	1.56	9.37
3	Timber	(2"x6"x2ft)	5	1.56	7.81
4	GS Pipe	3/4"	0.25	16.07	4.02
5	Bolt	8"	5	1.15	5.74
6	Bolt	6"	5	0.92	4.59
7	Angle Line	7"	0.25	11.02	2.76
8	Nails	2"	0.5	1.61	0.80
9	Nails	3"	0.4	1.61	0.64
10	PVC pipe	4"	0.125	13.78	1.72
11	Alluminium Shell	4"diameter	0.2	9.18	1.84
12	Stand	8"x8"	1	5.53	5.53
13	Colour	Brown	0.5	11.02	5.51
14	Labor charges	Currency	1	55.11	55.11
	Grand total				**114.80**

Exchange rate was taken as 1 USD=2 177.6331 TZS

4.3.4 Man days of briquetting sawdust briquettes per hectare

For a period of 8 hours using 4 laborers a total of 405.60 kg of briquettes were produced. In order to cure one hectare you need about 71 953.44 kg of briquettes (see Table 5) which will take about 1 419.20 hours, dividing by 8 you get 177 man days. For this item total cost was taken by multiplying 177 by 1.77 USD which was minimum labor wage rate per day in agricultural sector with exchange rate taken as 1USD = 2 177.63 TZS (see Appendix 4). Hence the total labor cost for briquetting sawdust per hectare was 313.29 USD.

4.3.5 Man days of curing by using sawdust briquettes as source of energy

The total number of hours required to accomplish one curing was recorded per harvest. One man-day is equivalent to 8 hours. The results in Table 4 indicates that for the first and second harvest the hours and man days was the same, that is it took about four days to complete one curing. Furthermore for the third, fourth, fifth and sixth harvest the total number of hours and man days was higher compared to the first and second harvest. This was due to the fact that the weight of tobacco for the third, fourth, fifth and sixth harvest was higher than those of the first and second harvest. Total cost for this item was taken by multiplying total man days 81 by 1.77 USD which was minimum labor wage rate per day in agricultural sector (see Appendix 4). Hence total cost was 143.37 USD per hectare

Table 4: Man days of curing by using sawdust briquettes as source of heat energy

Harvest	Hours	Man days
1	102	12.75
2	102	12.75
3	105	13.13
4	108	13.50
5	114	14.25
6	118	14.75
Total		**81**

4.3.6 Weight of tobacco and sawdust briquettes used in each reaping/harvest

Field results showed that a mixture of 4 kg of waste paper with 42 kg of sawdust produced 49.40 kg of briquettes. Also results in Table 4 shows curing 20.5kg of dry tobacco a total of 726.96 kg of briquettes were required. 4kg of waste paper mixed with 42kg of sawdust produced 49.40 kg of briquettes. From Table 4 If 726.96 kg of briquettes can cure 20.5kg of dry tobacco, then 1kg of dry tobacco needs 726.96*1kg/20.5kg of dry tobacco.

This means in curing 1 kg of dry tobacco 35.46 kg of briquettes were required, and this required 2.856 kg of waste paper and 30.056 kg of sawdust because 4kg of waste paper and 42kg of sawdust produced 49.40 kg of briquettes. Hence 1 kg of briquette needs 4/49.40 kg of waste paper =0.081 kg and 42/49.40 kg of saw dust= 0.850 kg 35.46 kg of briquettes needs 0.081 kg*35.46= 2.872 kg of waste paper and 0.850 kg*35.46 = 30.056 kg of Sawdust.

Results in Table 4 shows that one hectare yield 2 029.05 kg of tobacco. This will need: 35.46 kg of briquettes *2 029.05 = 71 950.11 kg of briquettes. 71 950.11 kg of briquettes require = (71950.11*0.081) kg of waste paper =5827.96 kg of waste paper and (71 950*0.850) kg of sawdust= 61 157.50 kg of sawdust. Hence in order to cure one hectare of tobacco (2 029.05 kg) you need 5.83 tonnes of waste paper and 61.16 tonnes of sawdust.

Table 5: Weight of tobacco and sawdust briquettes used in each reaping/harvest

Harvest	Green weight ($kg/1890m^2$)	Green weight (kg/ha)	Dry weight ($kg/1890m^2$)	Dry weight (kg/ha)	Weight of sawdust briquettes ($kg/1890m^2$	Weight of sawdust briquettes (kg/ha)
1	175.00	1 409.64	20.5	165.13	726.96	5 855.72
2	312.25	2 011.58	36.09	232.49	1 279.72	8 244.60
3	325.17	2 090.77	37.57	241.57	1 332.24	8 566.48
4	530.67	3 412.09	74.45	479.02	2 640.04	16 986.84
5	512.16	3 293.08	71.85	461.98	2 547.48	16 382.60
6	497.58	3 199.33	69.81	448.86	2 475.75	15 917.20
Total	**2 352.83**	**15 416.49**	**310.27**	**2 029.05**	**11 002.16**	**71 953.44**

4.4 Cost of tobacco curing when firewood was used as source of heat energy

4.4.1 Man days of preparing cubic meter of firewood

Four hours was used to harvest and prepare one m^3 of firewood. Since one hectare require 23 m^3, total man days for preparing total m^3 for one hectare was 23*4=92 hours. To get man days total hours were divided by eight to get 12 man days. For this item total cost was obtained by multiplying 12 by 1.77 USD which was minimum labor wage rate per day in agricultural sector with exchange rate taken as 1 USD = 2 177.63 TZS(see Appendix 4). Hence the total labor cost for preparing total number of cubic meter of firewood per hectare was 21.24 USD.

4.4.2 Cost of transporting, loading and offloading firewood

Firewood was collected from the natural forest which was near the trial site about 2 km. A truck with a capacity of ten tonnes was used for transporting. Table 6 indicates the cost of transporting, loading and offloading firewood per hectare

Table 6: Cost of transporting, loading and offloading firewood

Item	No of trips	Cost/trip (USD)	Total cost (USD)
Purchasing price	2	Free	Free
Transport cost	2	31.62	63.24
Loading and offloading	2	13.78	27.56
Total			**90.80**

4.4.3 Man days of curing by using firewood as source of energy

For each harvest total number of hours required to accomplish one curing was recorded. In order to get man days for each harvest total number of hours recorded in each harvest was divided by eight. The results in Table 7 indicates that for the first, second and third harvest the hours and man days was the same, that is it took about four days to complete one curing. Furthermore for the fourth, fifth and sixth harvest the total number of hours and man days was higher compared to the first, second and third harvest. This was due to the differences in weight of tobacco for each harvest. Total cost for this item was taken by multiplying total man days 77 by 1.77 USD which was minimum labor wage rate per day in agricultural sector (see appendix 4). Hence total cost was 136.29 USD per hectare.

Table 7: Man days of curing by using firewood as source of heat energy

Harvest	Hours	Man days
1	98	12.25
2	98	12.25
3	102	12.75
4	103	12.86
5	105	13.13
6	107	13.38
Total		**77**

4.4.4 Weight of tobacco and weight of firewood used in curing each reaping/harvest

The weight of one cubic meter of firewood was determined by taking the average weight of four cubic meters. A 300 kg digital weighing scale was used. The average weight of one cubic meter of firewood was 464.75 kg. Table 8 shows the results of the weight of tobacco harvested in each harvest and the weight of firewood used in curing. In order to get the number of cubic meter required to cure one hectare 11.50 was multiplied by two because in one hectare you need four curing barns, one harvest/reaping is loaded into two curing barns with the consumption of firewood per reaping shown in Table 8.

Table 8: Weight of tobacco and Firewood Used in Curing Each Reaping/Harvest

Harvest	Green weight (kg/1890m²)	Green weight (kg/ha)	Dry weight (kg/1890m²)	Dry weight (kg/ha)	Weight of firewood (kg/1890m²)	Number of cubic meter/1890m²
1	117.00	1 446.53	18.00	222.54	697.13	1.5
2	328.15	2 102.63	40.78	261.30	697.13	1.5
3	335.37	2 148.90	51.90	332.55	929.50	2.0
4	534.28	3 423.42	74.96	480.31	1 161.88	2.50
5	515.41	3 302.51	72.31	463.33	929.50	2.0
6	499.06	3 197.74	70.02	448.66	929.50	2.0
Total	**2 329.27**	**15 621.73**	**327.97**	**2 208.69**	**5 344.64**	**11.50**

4.4.5 Comparing curing costs when tobacco was cured by sawdust briquettes and firewood

The costs which were compared included transport cost, cost of loading and offloading, cost of briquetting sawdust, cost of preparing cubic meter of firewood and the labor cost for curing.

The results in Table 9 indicates that the p value (0.04) is less than the level of significance which was 0.05, hence the null hypothesis is rejected. There is significant difference between cost of curing tobacco by using firewood and sawdust briquettes. When tobacco was cured by sawdust briquettes the curing costs were significantly higher than when tobacco was cured by firewood. This difference is brought about first by the difference in amount of biomass required for curing, in order to cure one hectare of tobacco (2 029.05 kg/ha see Table 5) you need 61.16 tones of sawdust but with the same amount of tobacco you will need 10.69 tonnes of firewood that is 23 cubic meter with an average of 464.75 kg per cubic meter.

Secondly, the difference in curing cost was brought about by the distance where the biomass was collected. Firewood was collected about 2 km from the trial site while sawdust was collected about 23.5 km from the trial site.

Thirdly, the differences in curing costs was also brought about by the labor days required to cure tobacco per hectare. In order to cure tobacco by sawdust briquettes you need about 81 man days (see Table 4) while curing tobacco by firewood require 77 man days (see Table 7).

Table 9: Curing cost analysis when tobacco was cured by sawdust briquettes and firewood

	Sawdust briquettes	**Firewood**
Mean	198.66	62.08
Variance	8 160.42	2 789.34
Observations	4	4
Pooled Variance	5 474.88	
Hypothesized Mean Difference	0	
df	6	
t Stat	2.61	
P(T<=t) two-tail	0.04	

CHAPTER FIVE

5.0 CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

The main objective of the study was to assess the economic feasibility of substituting firewood with sawdust and/ or rice husks in curing tobacco. In achieving this objective the following specific objectives were undertaken; to determine the calorific values of sawdust briquettes and firewood, to examine the quality of tobacco cured by sawdust briquettes and firewood and lastly was to compare the tobacco curing costs when tobacco is cured by sawdust briquettes and firewood.

Based on the objectives of this study, the conclusions were as follows;

i. The calorific value of sawdust briquette was lower than that of firewood. Despite of the low calorific value of sawdust briquette but the heat content within the sawdust briquette was able to remove the amount of water present in green tobacco leaf which is about 80 to 85% and hence obtaining the quality of tobacco which was the same to that obtained when tobacco was cured by firewood.

ii. There was no significant difference between the mean of the grade indices of tobacco cured by sawdust briquettes and the mean of the grade indices of tobacco cured by firewood at $p>0.05$.

iii. There was significant difference in curing costs when tobacco was cured by sawdust briquettes and firewood at $p<0.05$. This difference in curing cost was brought about by the differences in amount of biomass required to cure tobacco, the differences in distance where these biomass were collected and the differences in labour days required in curing tobacco.

iv. By using a low pressure briquetting machine it was not possible to briquette rice husks using waste paper, cow dung and cassava flour as binding materials.

v. Based on literature review on availability of sawdust in tobacco growing regions, it was revealed that the amount of sawdust present in tobacco growing regions is not enough to substitute firewood in curing tobacco. However sawdust when briquetted can be used as an alternative source of energy for tobacco curing.

5.2 Recommendations

The following are the recommendations drawn from the conclusion

i. Since the heat content within the sawdust briquette was able to remove the amount of water present in green tobacco leaf and hence obtaining the quality of tobacco which was the same as when tobacco was cured by firewood, sawdust briquettes have demonstrated its ability to be used as an alternative source of energy to firewood for tobacco curing.

ii. Even though the curing costs was higher when sawdust briquettes were used as source of heat energy than when firewood was used during curing, when this technology is adopted by tobacco farmers it can help to reduce pressure in the natural forests and hence reduce deforestation rate. The government of Tanzania in collaboration with tobacco stakeholders should promote the adoption of this technology to tobacco farmers.

5.3 Areas for further research

Based on the findings the study also recommends on the following areas for further research.

i. Research should done to investigate on the appropriate binding materials for rice husks when briquetted by using low pressure briquetting machine.

ii. More research is needed to assess the availability of sawdust in tobacco growing regions in Tanzania and to investigate on other alternative sources of energy for tobacco curing.

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APPENDICES

Appendix 1: Assessment of qualities of tobacco cured by firewood and sawdust briquettes

1. Tobacco grades produced by each biomass

Source of energy	Grades of harvest one (examples)	Weight of grades (kg)	Value in Usd (weight of grade*price of garde)	Grade index
Firewood	X5L			
	L2OF			
	LOV			
	L3O			
Sawdust briquettes				
	LLK			
	LLG			
	C4O			
	C3L			

This procedure was done for all six harvests

Appendix 2: Cost of tobacco curing when sawdust briquettes were used as source of heat energy

1. Weight of dry tobacco produced in each harvest (reaping)

Tobacco harvests	1	2	3	4	5	6	Total weight in kg
Weight in kg							

2. Man days of curing

No of harvests	Hours	Man days
1		
2		
3		
4		
5		
6		
Total		

3. Cost of transporting, loading and offloading sawdust

Item	No of trips	Cost/trip	Total cost
Purchasing price			
Transport cost			
Loading and offloading			
Total			

3. Cost of transporting, loading and offloading waste paper

Item	No of kg	Cost/kg	Total cost
Purchasing price			
Transport cost			
Loading and offloading			
Total			

4. Man days of briquetting sawdust

Number of briquettes	Hours used to briquette	Man days

5. Quantity of sawdust and binding materials used during briquetting

Type of material	Weight in kg
Sawdust	
Waste paper	

Appendix 3: Cost of tobacco curing when firewood was used as source of heat energy

1.Man days of preparing cubic meter of firewood.

Activity	Hours	Man days
Cutting and preparing one cubic meter		

2. Cost of transporting, loading and offloading firewood

Item	**No of trips**	**Cost/trip (USD)**	**Total cost (USD)**
Purchasing price			
Transport cost			
Loading and offloading			
Total			

3. Ma days of curing by using firewood.

No of harvests	Hours	Man days
1		
2		
3		
4		
5		
6		
Total		

Appendix 4: Minimum Wages in Tanzania with effect from 01-07-2013

Sector	Area	Minimum Wage per Hour	Minimum Wage per Day	Minimum Wage per Week	Minimum Wage per Fortnight	Minimum Wage per Month
Health Services		677.00	5,077.33	30,463.90	60,927.76	
Agricultural Services		512.85	3,846.50	23,078.70	46,157.40	100,000.00
Trade, Industries and Commercial Services	Trade, Industry and Commerce	589.80	4,423.40	26,540.50	53,081.00	115,000.00
	Financial Institutions	2,051.45	15,385.50	92,314.80	184,629.60	400,000.00
Communication Services	Telecommunication Services	2,051.45	15,385.80	92,314.80	184,629.60	400,000.00
Communication services	Broadcasting and Mass Media, Postal and Courier Services	769.30	5,769.70	34,618.05	69,236.10	150,000.00
Mining	Mining and prospecting licenses	2,051.45	15,385.80	92,314.40	184,629.60	400,000.00
	Primary Mining Licences	1,025.80	7,692.90	46,157.40	91,314.80	200,000.00
	Dealers licenses	2,367.10	11,539.35	69,236.10	138,472.20	
	Brokers licenses	1,025.80	7,692.90	46,157.40	92,314.80	200,000.

Source: www.wageindicator.org/main/salary/minimum-wage/tanzania

Appendix 5: Grades of tobacco cured by firewood and their indicative prices in USD

S/n	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Grade	XN2L	XN1L	X5L	XN2O	X3L	XN1O	X2L	XNK	X1L	X2O	X4L	X4O	X5O	LLG	C3L	LOG	L2O
Price in USD	0.450	0.680	0.918	0.462	1.577	0.690	1.990	0.075	2.230	2.041	1.349	1.402	0.983	0.040	1.740	0.050	2.940
S/n	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34
Grade	C4O	L1L	LLV	C2L	L2L	L4O	C4L	L4L	C3O	L2OF	L4OF	L1O	L2O	L3O	L3L	L5L	N1L
Price in USD	1.454	3.015	1.200	2.270	2.850	2.120	1.423	2.060	1.790	2.960	2.140	3.060	2.940	2.590	2.490	1.610	0.950

Appendix 6: Grades of tobacco cured by sawdust briquettes and their indicative prices in USD

S/n	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Grade	X5L	XN2O	X3L	XN1O	XNK	X1L	X1O	X2O	X3O	X4O	X5O	LOG	L2L	L4O	C4L	L3OF	N1O
Price in USD	0.918	0.462	1.577	0.690	0.075	2.230	2.265	2.041	1.678	1.402	0.983	0.050	2.850	2.120	1.423	2.670	0.970
S/n	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	
Grade	L5O	L4L	L2O	C3O	LOV	L3O	LOK	LLK	C1L	L3L	L2OF	L1O	L1L	N2L	LLV	LLG	
Price in USD	1.700	2.060	2.940	1.790	1.270	2.590	0.150	0.070	2.465	2.490	2.960	3.060	3.015	0.848	1.200	0.040	

Appendix 7: Minimum indicative flue cured grade prices for 2016/17 crop season

MINIMUM INDICATIVE FLUE CURED GRADE PRICES FOR 2016/17 SEASON IN US-DOLLARS

S/No	GRADE	PRICE Per KG
1	X1O	2.265
2	X1L	2.230
3	X2O	2.041
4	X2L	1.990
5	X3O	1.678
6	X3L	1.577
7	X4O	1.402
8	X4L	1.349
9	X5O	0.983
10	X5L	0.918
11	XOV	0.661
12	XLV	0.610
13	XOJ	0.362
14	XLJ	0.300
15	XOK	0.080
16	XLK	0.072
17	XN1O	0.690
18	XN1L	0.680
19	XN2O	0.462
20	XN2L	0.450
21	XNK	0.075
22	C1O	2.565
23	C1L	2.465
24	C2O	2.300
25	C2L	2.270
26	C3O	1.790
27	C3L	1.740
28	C4O	1.454
29	C4L	1.423
30	BO	0.366
31	BL	0.348

S/No	GRADE	PRICE Per K
32	L1OF	3.140
33	L2OF	2.960
34	L3OF	2.670
35	L4OF	2.140
36	L5OF	1.737
37	L1O	3.060
38	L1L	3.015
39	L2O	2.940
40	L2L	2.850
41	L3O	2.590
42	L3L	2.490
43	L4O	2.120
44	L4L	2.060
45	L5O	1.700
46	L5L	1.610
47	LR	1.640
48	LOV	1.270
49	LLV	1.200
50	LOJ	0.527
51	LLJ	0.507
52	LOK	0.150
53	LLK	0.070
54	N1O	0.970
55	N1L	0.950
56	N2O	0.840
57	N2L	0.848
58	NK	0.045
59	LOKD	0.065
60	LLKD	0.062
61	LOG	0.050
62	LLG	0.040

SECOND PAYMENTS $ 0.0220

Source: TTB, 2016