DEVELOPMENT OF FUEL BRIQUETTES FOR KNOCKDOWN OF MOSQUITOES USING NATURAL PRODUCTS

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Development of Fuel Briquettes for Knockdown of Mosquitoes Using Natural Products

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DECLARATION

This thesis is my original work and has not been presented for a degree in any other University.

Signature……………………. ……………...   Date……………………

Loise Nyakeru Thuku

This thesis has been submitted for examination with my approval as a University supervisor.

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DEDICATION

This work is dedicated to my husband Benson and our daughter Joy whose unending support has remained very instrumental throughout the entire course.

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LIST OF ABBREVIATIONS AND ACRONYMS

Mt	Million tones
WHO	World Health Organization
KD	Knockdown
JKUAT	Jomo Kenyatta University of Agriculture and Technology
ITNs	Insecticide Treated Nets
Btu	British thermal units
DFID	Department for International Development
FAO	Food and Agriculture Organization
Cpm	Cycles per minute
DDT	Dichlorodiphenyltrichloroethane

ABSTRACT

Although there has been fruitful effort in managing most of the diseases that affect humankind, some of them like malaria are still a major death cause in many parts of the World. This necessitates the development of alternative ways of curbing the problem. On the other hand, energy plays a vital role in facilitating and sustaining development in the World over, a fact that has led to great increase in demand for energy. This has in turn resulted into practices such as rampant deforestation, which affect the environment adversely. Previous studies have recorded great energy supply shortages and high cost and therefore a need to diversify these sources. This study focused on development of dual purpose fuel briquettes that provide heat energy when burnt and also knockdown (KD) mosquitoes in the course of burning.

The briquettes were developed using jatropha seed husks (source of energy), cow dung (binder) and pyrethrin (insecticide). The jatropha seed husks were collected, ground into fine powder, carbonated and then mixed with cow dung. Varying amounts of pyrethrin was added to the mixture and then hand-pressed to form briquettes.The briquettes were then tested for their ability to knockdown mosquitoes at Kenya Pyrethrum Board laboratory. Using a bomb calorimeter, their calorific value was determined and the results were analysed using the ANOVA.

This research showed that a hand pressed mixture of jatropha seed husks, pyrethrin and cow dung (binder) in the ratio of 3 g: 0.5 ml: 2 g respectively can cause a 100% mosquito knockdown within 10 min. and mortality of 97.50% within 24 hr when burnt indoors. The calorific value of such a briquette was found to be 19.70 J/g and this energy can be utilized as fuel. The percentage mosquito knockdown, percentage mortality rate and calorific value were found to vary significantly with the amount of pyrethrin used. It is expected that the findings of this study will generate new knowledge on briquette development. The research findings will also contribute towards reducing the death rate resulting from malaria as well as energy shortage by providing briquettes capable to knockdown mosquitoes when used as fuel.

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background

In Kenya, malaria is the leading cause of mortality and morbidity particularly among pregnant women and children under 5 years (DFID, 2005). Studies suggest that between 20 - 25% of all deaths can be attributed to malaria, with up to twenty eight million Kenyans (70% of the population) being at risk and at any one time, 1.5 million pregnant women are susceptible (DFID, 2005). Effective treatment of malaria is inaccessible or costly for vulnerable groups. In many places, health services are of poor quality, with long waiting times, inaccurate diagnosis, inappropriate prescription and advice, frequent drug stock-outs, and high levels of resistance to the drugs provided. Patients often resort to unregulated private commercial sector, where treatment may be inappropriate, although access costs may be lower. The coverage of effective prevention is very limited, especially in areas with the highest transmission. Most households rely on personal protection measures of limited effectiveness, such as burning mosquito coils or leaves (Ejezie, 1990). This situation persists despite the wide range of effective malaria control measures available.

On the other hand, energy is a vital input for the enhancement of the living standards of people in any given society but there is still a shortage of all types of fuels. Moreover, the prices of these fuels are high and even beyond the reach of many people. According to Energy Information Administration (2010), the World marketed energy consumption grows by 49% from 2001 to 2035. Total World energy use rises from 495 quadrillion British thermal units (Btu) in 2001 to 590 quadrillion Btu in 2020 and to 739 quadrillion Btu in 2035 (Energy Information Administration, 2010).

The growing dependency on traditional sources of energy like fossil fuels and wood fuel has led to problems such as scarcity of wood, deforestation and competitive land uses. It is therefore, necessary to take stock of energy sources which are underutilized, conserve them and consider the possibility of harvesting other sources which are not utilized at present (Sehgal, 1988).

1.2 Energy Requirement in Kenya

Petroleum and electricity are the drivers of modern sector of the Kenyan economy while wood fuel provides energy needs of the traditional sector including rural and poor urban households. According to Wegulo (2002), fuel wood is the largest form of primary energy consumed in Kenya, accounting for about 68% followed by Petroleum and then electricity accounting for 22% and 9% respectively. Other sources of energy include solar, wind, biogas and bagasse together accounting for the remaining 1%. Renewable energy resources include biomass, solar energy, windmills, power alcohol and biogas.

Petroleum fuels are the most important source of commercial energy in Kenya, and are mainly used in the transport, commercial and industrial sectors. The country relies entirely on imported petroleum products. Imports of petroleum accounted for 16% of the total import bill in 2002 and consumed 31% of the country's foreign exchange earnings from merchandise exports (Ministry of Energy, 2004). Consumption of petroleum products was 2.4 Mt with per capita consumption at 76.2 Kg and the projected growth in this demand, with Kenya's anticipated economic recovery, is 2% per annum (Ministry of Energy, 2004).

Wood fuel has remained the most important source of energy in Kenya, meeting over 70 % of the country's total energy consumption needs, where 80% of the population depends on it (Kituyi, 2002). It provides 90% of rural households' energy requirement and 85% in urban areas (Kituyi, 2002). This state of affairs has major implications on sustainable development, such as unsustainable tree harvesting given the lack of efforts in reforestation and on-farm planting of wood lots, has often led to soil degradation, deforestation and associated diseases. About 47% of the Kenyan households use charcoal.

Charcoal continues to be harvested from trust lands and gazetted forests, an annual business worth KSh 17 billion (Ministry of Energy, 2004). Studies in Western and Central Kenya found that all households regardless of socio-economic status used woody or high quality crop residues (like maize cobs) before changing to other forms of biomass energy for cooking. In Western Kenya, the population used maize cobs before turning to wood or maize stalks, while in Central Kenya the coffee prunings, tea prunings and maize cobs were used before the population turned to wood or other lower forms of residues (Mugo, 1997; 1999). It was noted that, in rural households of a given area, the types of fuels used for cooking were nearly uniform among all income groups. However, as scarcity increased, the better-off switched to using wood while the poorer groups of society turned to lower forms of crop residues. In Bungoma, it was found that all households preferred wood fuel for cooking, Maize cobs were the next favourite followed by kerosene, gas, electricity and charcoal (Mugo, 1997).

According to Ministry of Energy (2004), the demand for biomass fuels (including residues) is expected to reach 53.4 Mt in 2020 and without any policy intervention, the wood fuel deficit of 20 Mt reported for 2004 will grow to 33 Mt by 2020. Availability and access to firewood on communal land is expected to diminish in most parts of the country, leading to lower consumption levels. A downward trend in firewood consumption to 11.8 Mt in 2030 is therefore expected (Kituyi, 2002).

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Current Status of Malaria Prevention Interventions

There is currently no effective malaria vaccine. The preventive interventions that are available can be classified into:

2.1.1 Methods that Inhibit Breeding of Mosquitoes

This can be done by environmental management to reduce breeding sources or by the destruction of mosquito larvae, which has proved successful in some areas. Environmental management involves removal of mosquitoes' habitat by elimination of standing water, emptying and change of water in rain gutters, old tyres etc and ensuring that swimming pool water is treated and circulating. If habitat modification is not feasible, biological control using fish may be possible.

Chemical larvicides with selective action and moderate residual activity are also applied to the aquatic habitats. Larvicides target larvae in the breeding habitat before they can mature into adult mosquitoes and disperse (WHO, 1982). Since the Anopheles mosquitoes can fly long distances, effective control in rural areas requires elimination of virtually all the breeding sites within 2 or 3 Km of a settlement. This approach therefore, tends to be successful only where breeding sites are well defined. However, these methods are generally less effective in areas where breeding sites are small, numerous and scattered (Ault, 1994; Curtis, 1989; Rozendaal, 1997; Sharma, 1986 ;).

2.1.2 Methods Aimed Against Adult Mosquitoes

These methods focus on the use of natural and chemical insecticides and repellents. Prevention of exposure to mosquitoes through use of mosquito repellents when necessary, use of head nets, long sleeves and long pants when venturing into areas with high mosquito populations, ensuring that windows and door screens are "bug tight" and replacement of outdoor lights with yellow "bug" lights which tend to attract less mosquitoes than ordinary lights although yellow lights are not repellents (Mills 1998).

Residual house spraying can also be done. It involves treating of interior walls and ceilings using a handheld compression sprayer and is effective against mosquitoes that favor indoor resting before or after feeding. A variety of insecticides have been used for spraying, including organochlorine compounds such as dichlorodiphenyltrichloroethane (DDT), organophosphates such as malathion and most recently pyrethroids such as deltamethrin. The first house spraying campaigns, just after World War II, showed the capacity of this intervention to produce profound reductions in malaria transmission in a wide variety of circumstances (Mills, 1998). This was mainly due to the reduction in vector longevity, which greatly reduced the fraction of female mosquitoes surviving long enough to transmit malaria. However, many countries have curtailed their spraying activities, primarily because of financial and logistical constraints and also because of insecticide resistance, disillusionment over the failure to achieve eradication and concerns over the safety and environmental impact of some insecticides.

Two further challenges are resistance of the mosquitoes and resistance by the affected population. The main impact of resistance in the vector is to decrease efficacy (if the same compound is used despite resistance) or to increase the cost (if there is a switch to a more expensive compound). Vector resistance to DDT and to other residual insecticides is a major problem in South Asia, Southeast Asia and some parts of Latin America (World Health Organization, 1992).

Houses spraying is however, widely used in countries such as Ethiopia, South Africa Madagascar and in the North and South of the continent. Growing concern about possible health and environmental hazards has sparked a debate on whether DDT should be completely banned for use in malaria control (Curtis and Lines, 2000). As a result, many countries have switched to the use of more expensive but more biodegradable compounds for house spraying.

2.1.3 Methods for Isolating Humans from Mosquito Biting

They include insecticide treated materials and domestic insecticides such as sprays, coils and repellents. In the case of insecticide treated nets (ITNs), the net is dipped in a solution of pyrethroid insecticide that repels and kills mosquitoes. While nets normally last for several years, the efficacy of the insecticide gradually wears off over time, so it is necessary to retreat the nets regularly. The efficacy of ITNs in reducing mortality has been demonstrated by several large-scale African trials, which found reduction in all-cause mortality in children aged less than five years ranging from 14% to 63% (Lengeler, 1998).

Households also prevent malaria and avoid nuisance insect biting through the extensive use of insect repellents and domestic insecticides such as aerosol sprays, repellent coils and mats and traditional herbs, all of which are privately provided. There is growing recognition of the potential importance of these household practices in some countries, given that much more money is spent on household-based methods of personal protection than on publicly organized vector control. The global retail market for coils, sprays and mats is estimated to be worth 2 billion US$ (World Health Organization, 1998). High-income households have access to other private options for mosquito control including screening on windows and doors and air conditioning.

2.1.4 Methods of Preventing Malaria Infection in Humans

This can be prevented through the provision of chemoprophylaxis using anti-malarial drugs. Mass chemoprophylaxis can lead to a rapid increase in drug resistance and is therefore not recommended (Draper, 1985; Greenwood, 1988). Instead it is recommended that prophylaxis be targeted to vulnerable groups, such as non-immune travelers, young children and pregnant women (Mujinja *et al.*, 1999). The most commonly used regimen is weekly prophylactic doses of chloroquine, but more recently an intermittent treatment regimen with sulfadoxine-pyrimethamine (SP) has been advocated (Steketee *et al.*, 1996). Prophylaxis is generally recommended by WHO as a component of ante-natal care for all pregnant women but this is rarely achieved in practice. For example, in a survey of four African countries only 1 - 18% of women reported taking adequate weekly doses (Steketee *et al.*, 1996). Where it is provided, effectiveness is often compromised by both high levels of resistance to chloroquine and low compliance with the weekly chloroquine regimen.

In summary, ranges of effective preventive interventions exist, although they need to be carefully targeted to meet local epidemiological conditions. However, coverage remains woefully low, and the services provided suffer from technical inefficiency and low quality.

2.2 Biomass

Biomass can be defined as renewable organic materials that contain energy in a chemical form that can be converted to fuel (Hossain, 1995). It includes the residues from agricultural operations, food processing, forest residues, municipal solid wastes and energy plantations. It has recently attracted much attention as a future energy source in many parts of the World (Hossain, 1995). Despite being a conventional energy source, there has been a considerable controversy as to the prospects for its wider use. Some say its use for energy purposes should not be expanded due to the large water needs for energy crops and competing uses of biomass for food, animal feedstuffs and industry while others advocate for its wider use for fuel purposes (Charter and Palz, 1980). According to Hossain (1995), all photosynthetic residues represent a huge energy reserve that should be well utilized. Biomass convertible to energy feedstock arise from agricultural materials and wild plants such as yellow oleander, jatropha, nuts, cereals, fodder, animal manure, straw, green vegetables, fruit matter and woody wastes, some of which can developed into fuel briquettes.

2.3 Fuel Briquettes

Briquetting is the densification of loose biomass material. Many waste products, such as wood residues and sawdust from the timber industry, municipal waste, bagasse from sugar cane processing, or charcoal dust are briquetted to increase compactness and transportability (Karekezi and Ranja, 1997). The process increases the net calorific value of the material per unit volume. The end product is easy to transport and store.

Generally, briquettes require a binder to be mixed with the main briquetting material and a press to form the mixture into a cake, which is then passed through a drying oven to cure or set it by drying out water. This makes the briquette strong enough to be used in the same burning apparatus as normal lump charcoal. The binder should preferably be combustible and include such materials as starch, plastic clays, cow dung and tar. Non-combustible binders that are effective at low concentrations can also be used (Matsuo, 1977).

In the 1950s, several economic methods were developed to make briquettes without a binder where multitude of factories throughout the World produced literally tens of millions of tons of usable and economic material that met the household and industrial energy needs (Lardinois and Klundert, 1993). During the two World Wars, households in many European countries made their own briquettes from soaked waste paper and other combustible domestic waste using simple lever-operated presses. Today's industrial briquetting machines, although much larger and more complex, operate on the same principle (Lardinois and Klundert, 1993). According to FAO, (1990) briquetting can be classified into five main types depending on the types of equipment used;

2.3.1 Piston Presses

There are of two types; the die and punch technology and the hydraulic press (FAO, 1990). In the die technology which is also known as ram and die technology, biomass is punched into a die by a reciprocating ram with a very high pressure thereby compressing the mass to obtain a compacted product. The standard size of the briquette produced using this machine is 60 mm, diameter. The power required by a machine of capacity 700 Kg/hr is 25 KW and the ram moves approximately 270 times per minute in this process (FAO, 1990). The hydraulic press process consists of first compacting the biomass in the vertical direction and then again in the horizontal direction. The standard briquette weight is 5 Kg and its dimensions are: 450 mm x 160 mm x 80 mm. The power required is 37 KW for 1800 Kg/h of briquetting. The process of oil hydraulics allows a speed of 7 cycles/minute (cpm) against 270 cpm for the die and punch process (FAO, 1990).

2.3.2 Screw Presses

The biomass is extruded continuously by one or more screws through a taper die which is heated externally to reduce the friction (FAO, 1990). Due to the application of high pressures, the temperature rises fluidizing the lignin present in the biomass which acts as a binder. The outer surface of the briquettes obtained through this process is carbonized and has a hole in the centre which promotes better combustion. Standard size of the briquette is 60 mm diameter. The screw press is usually sized in the range 75 - 250 Kg/h (FAO, 1990).

2.3.3 Roller Press

In a briquetting roller press, the feedstock falls in between two rollers rotating in opposite directions and is compacted into pillow-shaped briquettes (FAO, 1990). Briquetting biomass usually requires a binder. Very often this type of machine is used for briquetting carbonized biomass to produce charcoal briquettes (FAO, 1990).

2.3.4 Pelletizing

It is closely related to briquetting except that it uses smaller dies (approximately 30 mm) so that the smaller products are called pellets (FAO, 1990). The pelletizer has a number of dies arranged as holes bored on a thick steel disk or ring and the material is forced into the dies by means of two or three rollers. Typically pelletizers can produce up to 1000 Kg of pellets per hour (FAO, 1990).

2.3.5 Manual Presses and Low Pressure Briquetting

There are different types of manual presses used for briquetting biomass feedstocks (FAO, 1990). They are specifically designed for other purpose or adapted from existing implements used for other purposes like manual clay brick making presses. They are used for both raw biomass feedstock and charcoal. The use of a binder is imperative. The common inherent characteristics of manual presses are: very cheap implements/equipment; low production capacity; demand intensive labour and use of binders. Wet feedstock is shaped under low pressure in simple block presses or extrusion presses (FAO, 1990).

Densified biomass is acquiring increasing importance because of the growing domestic and industrial, applications for heating, combined heat and power (CHP), and electricity generation in many countries. In countries such as Austria, Denmark, the Netherlands and Sweden, for example, it is becoming a major industry with pellets traded internationally. In Europe this potential has been estimated at around 200 Mt/year and is increasing continuously because advances in technology allow the densification of biomass to be more competitive, driven by high demand. The demand is for both domestic (space heating) and industrial units in many developed countries but also in many developing countries particularly China. Thus, it is expected that this market will expand rapidly and become an internationally widely traded commodity despite the growing importance of wood chips due to their lower price (Hood, 2010).

Briquetting technology has also been reported to be of great importance in countries such as; Japan, Korea, India, China, Vietnam, Thailand, Malaysia, Philippines, and Bangladesh (Hood, 2010). There has been briquetting projects in many African countries such as; Zimbabwe, Tanzania, Uganda, Kenya, Sudan, Rwanda, Niger, Gambia, Ethiopia and Senegal, though not all of these are still functional (Hood, 2010). The raw materials most commonly briquetted in Africa are coffee husks and groundnut shells while sawdust and cotton stalks are also used to a limited extent (Hood, 2010).

2.4 Reasons for their Failure

The history of residue briquetting in Africa is largely one of single projects in various countries which have usually not been successful (FAO, 1990). A survey carried by FAO, (1990) showed that many briquetting plants in East Africa have been faced by outright failures while others have had their operations marred by problems. According to this survey, it was difficult to find a single agency-funded briquetting project which had been commissioned and was operating fully satisfactorily. The reasons that seemed to explain this failure included; inappropriate or mis-specified ordering of briquetting machinery, non-availability and high cost of the briquetting machines' spare parts, poor projects' planning and implementation where free supply of raw materials was assumed, low local prices of firewood and charcoal which inhibited the marketing of briquettes and unacceptability of briquettes in the household sector due to their ignition difficulties and smoke generation which caused indoor pollution, little involvement of the private sector and early withdrawal of donor as well as lack of government financial support. The main generalization that can be made about briquetting in Africa is that it has often proved difficult to sell briquettes against the competitive price of wood or charcoal and the very high capital cost of the briquetting plants.

According to Eriksson and Prior (1990), several biomass briquetting projects have been implemented in Kenya. The main raw material has been coffee husks and both direct briquetting and carbonization/briquetting were tried on a commercial basis but due to the high cost of biomass briquettes compared with cheap firewood, none of the plants was able to continue production. However, in the recent years, Chardust established a carbonization/briquetting plant based on bagasse. It seems Chardust is successful in marketing its charcoal briquettes but their main market is within the services sector and not households. In order to produce cheap biomass briquettes for the household sector, the general trend nowadays in Africa is towards low pressure or manual briquetting. The Legacy Foundation is taking the lead in promoting the technology in Africa. Production is mainly based on women's groups to produce their family needs and excess briquettes could be sold to generate income (Eriksson and Prior, 1990).

2.5 Pyrethrin

Pyrethrin is a highly effective insecticide used for centuries against all types of insect pests. The active component of pyrethrin is natural plant oil that occurs in the pyrethrum daisy, *Tanacetum cinerariaefolium*, and a member of the chrysanthemum family. The oil is found mainly in tiny oil-containing glands on the surface of the seed case inside the tightly packed flower head. This oil is the plant's own insecticide. It is made up of six complex chemical esters, known as pyrethrins, which work in combination to repel and kill insects (Lengeler, 1998).

In mammals, pyrethrins are quickly broken down into inactive forms, and pass from the body quickly. Another benefit is that pyrethrins break down quickly in sunlight, and are non-persistent in the environment. Because pyrethrins are such complex and non-persistent chemicals, insect resistance is less likely to occur.

Mainly, pyrethrin act as contact poisons, which affect the central nervous systems of all types of flying and crawling insects. The chemical blocks nerve junctions so that the insect's nervous impulses fail, causing them to die. In low concentrations, pyrethrin affects insects' behaviour resulting in a so-called 'avoidance reaction' that causes the insect to flee the source of the chemicals. Pyrethrin inhibits normal biting behaviour in female mosquitoes, making them unable to seek their usual blood meals ((Lengeler, 1998). At slightly greater concentrations, pyrethrin makes insects alter their normal behavioral patterns. This means they abandon their hiding places and come out into the open, bringing them into contact with larger quantities of pyrethrins, which will quickly knock them from the air and kill them (WHO, 1982).

According to Kenya Standard Specification for mosquito coils (2000), the accepted biological efficacy of mosquito coils is a knock down of 50% within 20 min. and a kill of 90% within 24 hr.

2.6 Jatropha Curcas Seed Husks

Freshly harvested *Jatropha curcas* dried fruit contains about 35 - 40% shell and 60 - 65% seed by weight (Singh *et al.,* 2008). There are about 400 - 425 fruits per Kg, 1580 to 1600 seeds per Kg and the Weight of 100 seeds is about 63 g (Singh *et al.*, 2008). Jatropha shells are available after de-shelling of the Jatropha fruit while Jatropha seed husks are available after decortications of Jatropha seed for oil extraction. The seed contain about 40 to 42% husk/hull and 58 to 60% kernels, which have about 50% oil (Singh *et al.*, 2008). If the oil is extracted by solvent method, the oil recovery is more than 95% but in mechanical expeller the oil recovery is about 85% only (Singh *et al.*, 2008). If 100 Kg of seed is expelled by an expeller, it will give about 28 - 30 Kg oil (Singh *et al.*, 2008). While lot of emphasis is being given on use of bio-diesel, which is only about 17 - 18% of the dry fruit, not much attention is being given to utilize other components of fruit for energy purposes (Singh *et al.*, 2008).

2.7 Cow Dung

Cow dung refers to the undigested residue of plant matter that is passed through a cow's gut, which is rich in minerals and fibre. According to Kumar and Shende, (2006), the typical ultimate analysis of cow dung is 31.6 % carbon, 5.18 % hydrogen, 37.8 % oxygen, 6.12 % nitrogen and 19.3 % ash.

Previous studies have indicated that cow dung is used as an agricultural fertilizer, as a fuel when dried, in production of biogas to generate electricity and heat, as a pest repellent when mixed with cow urine, in lining of walls of rustic houses as a cheap thermal insulator, as an ingredient in the manufacture of mud bricks and as a binder in manufacture of some fuel briquettes (Kumar and Shende, 2006; Matsuo,1977). In this research cow dung was used in the briquettes as a binder.

2.8 Rationale and Justification

Control strategies for African malaria mosquitoes largely involve methods that kill or deter adult mosquitoes. These strategies include promoting the use of insecticide-treated bed nets and indoor residual spraying. These tools, when properly applied, have great impact on malaria morbidity and all-cause mortality. But like every known malaria control measure, they have their drawbacks, as illustrated by the emergence of insecticide resistance and difficulties in attaining adequate population coverage due to their cost. Additional methods for reducing transmission of malaria are sorely needed for.

On the other hand, energy plays a vital role in facilitating and sustaining development World over, a fact that has led to great increase in demand for energy. This has in turn resulted in practices such as rampant deforestation, which affect the environment adversely. Previous studies have recorded great energy supply shortages and high cost and therefore, a need to diversify these sources. This project is intended to provide method of controlling mosquitoes as well as an alternative domestic fuel.

2.9 Statement of the Research Problem

Malaria is one of the major death- causing diseases to date despite the many preventive and curative measures employed to fight it. This calls for more diversified measures in order to reduce its morbidity and consequently, the malaria related deaths. In addition studies have recorded great energy demand which has led to practices that adversely affect the environment, hence the need to diversify sources of energy.

2.10 Null Hypothesis

Natural products such as *Jatropha curcas* seed husks, cow dung and pyrethrin cannot be developed into fuel briquettes for mosquitoes' knockdown.

2.11 Objectives

2.11.1 Main Objective

To develop energy briquettes capable of knocking down mosquitoes when burned as fuel.

2.11.2 Specific Objectives

- **i.** To develop pyrethrin enriched fuel briquettes from cow dung and *Jatropha curcas*.
- **ii.** To determine the extent to which pyrethrin enriched briquettes can knockdown mosquitoes and kill them when burnt.
- **iii.** To determine the calorific value of the pyrethrin enriched briquettes.

2.12 Significance of the Study

It is expected that the findings will generate new knowledge on briquettes' development, contribute towards reducing malaria-associated deaths as well as energy shortage by providing briquettes that are able to cause mosquitoes' knockdown when used as fuel.

2.13 Scope and Limitations of the study

Due to time and financial constrains, this study focused on development of dual purpose fuel briquettes that can knockdown mosquitoes and kill them while providing heat energy in the course of burning.

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Research Design

Experimental design was used in this research, where the briquettes were developed and laboratory experiments carried out to determine their ability to knockdown and kill mosquitoes as well as determination of the briquettes' calorific values.

3.2 Raw Materials

The raw materials used included the following;

i. 25% Pyrethrin oil obtained from Kenya Pyrethrum Board, Nakuru,

ii. *Jatropha curcas* seed husks obtained from Jomo Kenyatta University of Agriculture and technology (JKUAT),

iii. Fresh cow dung from Kiangari Secondary School, Muranga,

These materials were obtained from the mentioned places due to their availability and nearness to the places where the various experiments were being carried.

3.3 Mosquito Species Used

Female *Aedes aegypti* mosquitoes were used in this research due to their availability at Kenya Pyrethrum Board, Nakuru where knockdown tests were carried out and the fact that the anopheles mosquitoes would place the researcher at a risk of being infected with malaria. However, their methods of control are the same as those of the Anopheles mosquitoes. They were obtained from Kenya Pyrethrum Board Entomology laboratory at Nakuru, Kenya.

3.4 Equipment

The following equipment were used; analytical weighing balance, pestle and mortar, bomb calorimeter (Auto bomb-Automatic Adiabatic Bomb Calorimeter), pelletizing machine, burner, crucibles, beakers, measuring cylinder and spatulas.

3.5 Development of Briquettes

Jatropha seed husks were collected from JKUAT and ground using a mortar and a pestle. They were then carbonated by burning them in limited amount of oxygen using a metallic drum for 12 hr. Three grams of carbonated jatropha was mixed with two grams of fresh cow dung in a beaker for each one briquette and different volumes (cm^3) of 25% pyrethrin were added. The proportion of jatropha and cow dung was kept constant while that of pyrethrin was varied as shown in Table 3.1

Table 3.1 Ratio of Jatropha to Cow Dung to Pyrethrin in the Samples

Sample	Jatropha husks (g)	Cow dung (g)	Pyrethrin oil (ml)
A (control)	3.0	2.0	0
B	3.0	2.0	0.1
C	3.0	2.0	0.2
D	3.0	2.0	0.3
E	3.0	2.0	0.4
F	3.0	2.0	0.5

The components of each sample were thoroughly mixed in a beaker using a spatula and then hand-compacted to form briquettes. The briquettes were then dried under shade for one month in readiness for the tests.

3.6 Briquettes' Utility Tests

This involved briquettes' calorific value tests and knockdown efficacy tests.

3.6.1 Determination of Briquettes' Calorific Value Using Bomb Calorimeter

The following procedure adopted from Sanyo (1997) was used to determine the calorific values:

Preparation of test specimens involved development of 5 pellets for each of the six samples by crushing the briquettes using a mortar and a pestle and then compacting 1 g of the ground mixture together with 90 mm long cotton thread using a palletizing machine (Sanyo, 1977). Each of the above pellets was placed in a crucible. The bomb cap was placed on the stand provided with the outfit. The ring support was swung to one side and the crucible containing the sample was inserted. A piece of platinum firing wire was stretched between the electrodes of the bomb and the single strand of cotton 90 mm. long thread from the pellet was tied to it. The length of firing wire and strand of cotton was kept constant from test to test in order to facilitate the calculation of the calorific value. The crucible was swung into position, the ring was clamped and the ends of cotton were arranged so that they were in contact with the pellet and 1 ml. of water was added to the bomb.

The bomb closure ring was tightened manually and after assembling the bomb, it was put on top of the apparatus. The firing circuit test plug was inserted and the bomb test switched on. The filling tube was connected to the bomb, the union tightened by hand and the bomb was slowly filled with oxygen without displacing the original air content. After filling the bomb, it was put on top of the apparatus, and the firing circuit was tested again to ensure that assembling and filling the bomb did not have disturb the firing wire. Exactly 2.1 l of water was added to the calorimeter can to sub-merge the bomb completely. This quantity of water was kept constant for all tests to facilitate calculations. The calorimeter can containing the bomb was then placed on the three supports in the calorimeter vessel and checked to ensure that the bomb did not show any sign of leakage. The calorimeter vessel was placed in the water jacket. The cover of the water jacket with thermometers and thermositors were lowered completely. The bomb-firing plug was pressed to ensure that it engaged the socket on the bomb correctly by pressing the 'TEST' switch. The water flow was set through the cooling coil to counteract the heating effect of the pump.

The calorimeter lid was lowered to the fully closed position to operate a micro-switch, which activated the balance control. The jacket temperature was adjusted using control knob until the mean jacket temperature was close to that of the calorimeter. The temperature was allowed to stabilize and the initial calorimeter temperature read using the thermometer reader. The 'FIRE' switch was switched on for 2 sec. to ignite the pellet. The apparatus was left for 10 min. to obtain its final equilibrium temperature. At the end of this time the final temperature of the calorimeter was recorded and the calorific values calculated.

3.6.2 Knockdown Efficacy Test Against Adult Mosquitoes

The following procedure adopted from Kenya Bureau of Standards was used;

3.6.2.1 Testing Room

The briquettes were tested for their knock down activity against adult, *Aedes aegypt*i mosquitoes in a test room 40 m^3 in size. This room was provided with closable vents in the wall and ceiling and a powerful extractor fan system. It was illuminated by a number of daylight florescent tubes installed behind a translucent fibreglass ceiling to give uniform illumination. Mosquitoes were exposed in a test room having a relative humidity and temperature of 70 - 80% and 28 -30^{o}C respectively.

3.6.2.2 Test Procedure

Two to three days old *Aedes Aegypt* female mosquitoes were pre-tested to guard against including damaged specimens in the actual test. For this purpose, the holding lamp glasses were set upright for at least one hr. At the end of this period, the damaged mosquitoes were identified visually, removed and replaced.

Ten female mosquitoes were placed in each of the four 10 cm × 10 cm lamp glasses provided with muslin gauze at the viable end. Four retort rings were placed 60 cm above base. A wire gauze was placed on each of the retort and the lamp glasses containing mosquitoes were placed with their open end on the gauze of the retort rings. However, some mosquitoes could get crushed or escapes during the time of placement, which made some jars have less than ten mosquitoes initially before the knock down test. An electric fan was placed on its back in the centre of the room and a hardboard disc of similar diameter supported above it on three 8 cm pillars. The fan was switched on to a minimum in order to distribute the smoke from the briquettes more easily around the room and ensure that the air steam would not pass directly through the briquette. The burning rate was not being affected. The briquettes were weighed in grammes to three decimal places and placed on lighted jiko and allowed to burn for 30 min. The number of mosquitoes knocked down in each lamp glass was noted and recorded at 5 min. intervals. The knocked down mosquitoes from the 4 lamp glasses were then transferred in a clear lamp glass containing a freshly cut orange (mosquitoes' feed) and placed in the mosquito post recovery room. They were examined after 24 hr. for mortality by counting the number of dead and the surviving mosquitoes. Between tests, the wire gauzes were washed in acetone and replaced on the rings. The vents were opened and the extractor system was used to ventilate the room for 25 min. Fresh lamp glasses were used for each test. Four replications were done for each of the six briquettes.

3.7 Data Analysis

The major objective of this study was to develop energy briquettes capable of knocking down mosquitoes when burnt as fuel. After pyrethrin-enriched fuel briquettes were developed, various data analysis procedures were employed to determine the amount of pyrethrin required to obtain the briquettes which met the optimum biological efficacy of mosquito coils in relation to knock down and mortality as specified by Kenya Standard Specification for Mosquito Coils (2000). Descriptive statistics (frequencies, percentages, and the mean) were used to record knockdown and mortality over given time intervals (in minutes). Line graphs were used to plot variations in knockdown, mortality and calorific value of briquettes containing different amounts of pyrethrin. Analysis of Variance (ANOVA) test was used to determine whether there were significant differences between amount of pyrethrin in briquettes and the mean knockdown, mortality and calorific value of the briquettes. These statistical analyses were conducted at the 0.05 level of significance.

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

4.1 Introduction

The knockdown, mortality and calorific value tests for each of the six samples were undertaken after which the percentage mean knock down, percentage mortality and calorific values were calculated and analysed.

4.2 Sample A Knockdown Test Results

Sample A contained 2 g of cow dung and 3 g of jatropha (wet weight) and had no pyrethrin hence was the control sample. This briquette was not able to knock down the mosquitoes when burnt since it had no pyrethrin. This indicates that the jatropha and cow dung present in the burning briquette cannot knock down mosquitoes. The percentage mortality (3.2%) was far much below the accepted standards and the calorific value obtained was 16 J/g. The average results obtained for the four replications are presented in Table 4.1.

Table 4.1 Results for Sample A Mosquitoes' Mean Knockdown and % Mortality

	Number of knocked down mosquitoes					
Time (min.)	Jar 1	Jar 2	Jar 3	Jar 4	Total	Mean KD
0	0	0	0	0	0	0
5	0	0	0	0	0	0
10	0	0	0	0	0	0
15	0	0	0	0	0	0
20	0	0	0	0	0	0
25	0	0	0	0	0	0
30	0	0	0	0	0	0
Initial total No. of insects	39	38	40	39	156	_
No. of dead insects after 24 hr.			5			
% mortality after 24 hr.			3.2			
Volume of Pyrethrin (ml)			0			

The percentage mean knockdown of mosquitoes in each time interval for each of the six samples was calculated using the formula indicated below;

% mean KD = (Total number of mosquitoes knocked in the four gas jars in a given time interval ÷ Initial total number of insects in the four gas jars) × 100

The percentage mortality of mosquitoes for each of the six samples was calculated using the formula indicated below;

% mortality = (Total no. of dead insects after 24 hr ÷ Initial total no. of insects in the four gas jars) × 100

4.2 Sample B Knockdown Test Results

Sample B contained 2 g of cow dung and 3 g of jatropha (wet weight) and 0.1 ml pyrethrin. The briquette produced a knockdown of 98.7% within 20 min. and a mortality of 27.2% within 24 hr. This indicates that the 0.1 ml of 25% pyrethrin present in the briquette was not adequate to produce the recommended mortality. The calorific value obtained was 16.9 J/g. The average results obtained for the four replications are presented in Table 4.2.

Table 4.2 Results for Sample B Mosquitoes' Mean Knockdown and % Mortality

	Number of knocked down mosquitoes					
Time (min.)	Jar 1	Jar 2	Jar 3	Jar 4	Total	Mean KD
0	0	0	0	0	0	0
5	2	0	0	0	2	1.26
10	18	9	14	12	53	33.45
15	31	27	28	34	120	76.45
20	39	38	40	39	156	98.68
25	40	38	40	40	158	100.00
30	40	38	40	40	158	100.00
Initial total No. of insects	40	38	40	40	158	-

No. of dead insects after 24hr.	43
% mortality after 24 hr.	27.2
Volume of pyrethrin (ml)	0.1

4.3 Sample C Knockdown Test Results

Sample C contained 2 g of cow dung and 3 g of jatropha (wet weight) and had 0.2 ml pyrethrin. The briquette produced a knockdown of 100% within 20 min. and a mortality of 77.4% within 24 hr. This indicates that the 0.2 ml of 25% pyrethrin present in the briquette was not adequate to produce the recommended mortality. The calorific value obtained was 17.6 J/g).The average results obtained for the four replications are presented in Table 4.3.

Table 4.3 Results for Sample C Mosquitoes' Mean Knockdown and % Mortality

	Number of knocked down mosquitoes

Time (min.)	Jar 1	Jar 2	Jar 3	Jar 4	Total	Mean KD
0	0	0	0	0	0	0
5	0	0	0	0	0	0
10	5	3	5	8	21	14.34
15	23	24	27	22	96	66.01
20	35	36	37	38	146	100.00
25	35	36	37	38	146	100.00
30	35	36	37	38	146	100.00
Initial total No. of insects	35	36	37	38	146	_
No. of dead insects after24 hr.	113					
% mortality after 24hr.	77.4					
Volume of pyrethrum (ml)	0.2					

4.4 Sample D Knockdown Test Results

Sample D contained 2 g of cow dung and 3 g of jatropha (wet mass) and 0.3 ml pyrethrin. The briquette produced a knockdown of 100% within 20 min. and a mortality of 84.6% within 24 hr. This indicates that the 0.3 ml of 25 % pyrethrin present in the briquette was not adequate to produce the recommended mortality. The calorific value obtained was 18.7 J/g.The average results obtained for the four replications are presented in table 4.4.

Table 4.4 Results for Sample D Mosquitoes' Mean Knockdown and % Mortality

	Number of knocked down mosquitoes					
Time (min.)	Jar 1	Jar 2	Jar 3	Jar 4	Total	Mean KD
0	0	0	0	0	0	0
5	10	18	31	25	84	54.19
10	37	36	38	38	149	96.13
15	39	40	38	38	155	100.00
20	39	40	38	38	155	100.00
25	39	40	38	38	155	100.00
30	39	40	38	38	155	100.00
Initial total No. of insects	39	40	38	38	155	_
No. of dead insects after 24 hr.	131					
% mortality after 24	84.6					

hr.	
Volume of pyrethrin (ml)	0.3

4.5 Sample E Knockdown Test Results

Sample E contained 2 g of cow dung and 3 g of jatropha and 0.4 ml pyrethrin. The briquette produced a knockdown of 100% within 20 min. and a mortality of 87.9% within 24 hr. This indicates that the 0.4 ml of 25% pyrethrin present in each of the briquette was not adequate to produce the recommended kill. The calorific value obtained was 19.2 J/g. The average results obtained for the four replications are presented in Table 4.5.

Table 4.5 Results for Sample E Mosquitoes' Mean Knockdown and % Mortality

	Number of knocked down mosquitoes					
Time (min.)	Jar 1	jar 2	Jar 3	Jar 4	Total	Mean KD
0	0	0	0	0	0	0
5	6	1	2	3	12	7.73
10	33	28	23	17	101	65.17
15	39	37	36	36	148	94.82
20	40	40	39	36	155	100.00
25	40	40	39	36	155	100.00
30	40	40	39	36	155	100.00
Initial total No. of insects	40	40	39	36	155	_
No. of dead insects after 24 hr.						

	136
% mortality after 24 hr.	87.9
Volume of pyrethrin (ml)	0.4

4.6 Sample F Knockdown Test Results

Sample F contained 2 g of cow dung, 3 g of jatropha (wet mass) and 0.5 ml of pyrethrin. The F briquettes caused 100% mosquitoes' knockdown within 10 min. and a kill of 97.5% within 24 hr. They can therefore be used to knock down mosquitoes, since they meet the acceptable Kenya Standards Specifications for biological efficacy of mosquito coils which are a knock down of 50% within 20 min. and a kill of 90% within 24 hr. This briquette was developed by mixing 2 g of cow dung, 3 g of jatropha and 0.5 ml. of 25% pyrethrin**.** It produced the highest calorific value (19.7 J/g) when completely burnt and therefore, can be used to knock down mosquitoes and at the same time to provide energy. The average results obtained for the four replications are presented in Table 4.6.

Table 4.6 Results for Sample F Mosquitoes' Mean Knockdown and % Mortality

	Number of knocked down mosquitoes

Time (min.)	jar 1	jar 2	jar 3	jar 4	total	mean KD
0	0	0	0	0	0	0
5	10	10	0	23	53	33.54
10	40	39	39	40	158	100.00
15	40	39	39	40	158	100.00
20	40	39	39	40	158	100.00
25	40	39	39	40	158	100.00
30	40	39	39	40	158	100.00
Initial total No. of insects	40	39	39	40	158	_
No. of dead insects after 24 hr.	154					
% mortality after 24 hr.	97.5					
Volume of pyrethrin (ml)	0.5					

Fig. 4.1 shows the change in mosquitoes' % mortality as the amount amount of pyrethrin was varied.

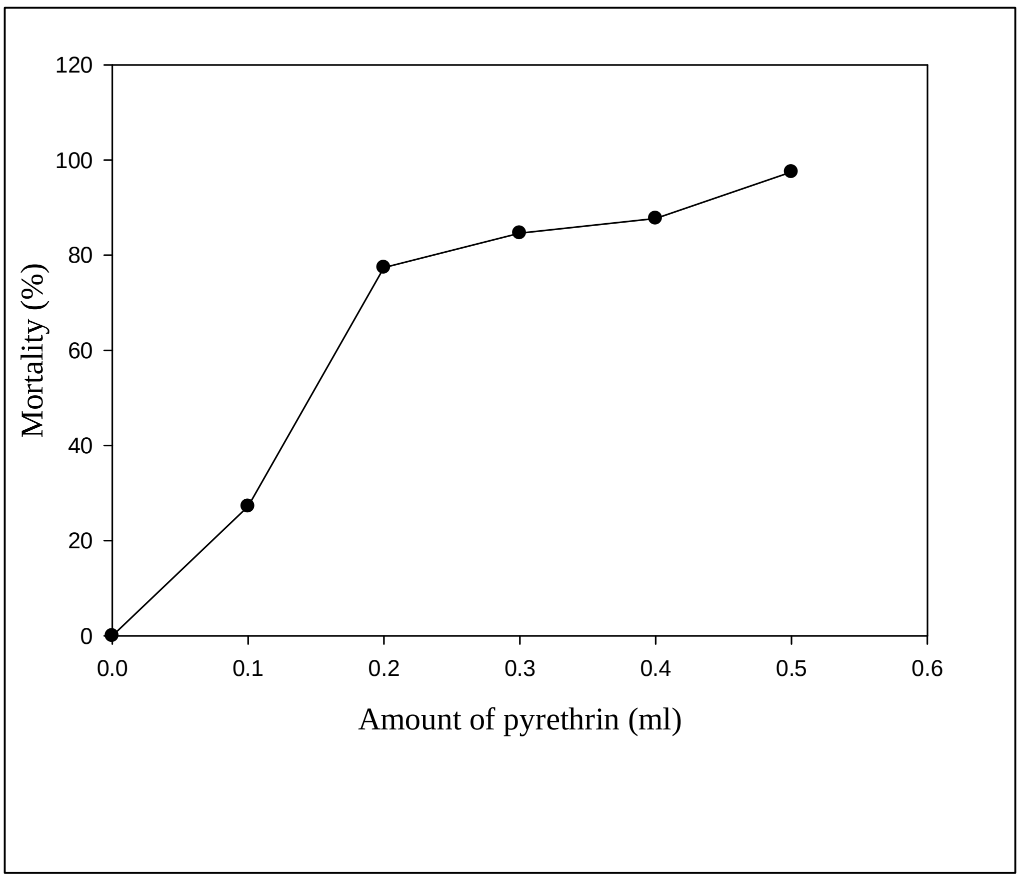

Figure 4.1 Graphical Relationship Between Amount of Pyrethrin and % Mortality of Mosquitoes

The graph showed that mortality increased with amount of pyrethrin (insecticide) in the briquettes. When 0.5ml of pyrethrin was used, the percentage mortality of mosquitoes obtained within 24 hr. was 97.5% while it was 87.9% when 0.4ml of pyrethrin was used. Since the acceptable Kenya Standards Specifications for biological efficacy of mosquito coils is a mortality of 90% within 24 hr., the optimum amount of pyrethrin is therefore 0.5ml.

Table 4.7 shows the variation of the mosquitoes' % mortality and mean knockdown as the amount of pyrethrin (ml) used was increased. Four replications were done for each of the six samples.

Table 4.7 Descriptive Statistics for Mosquitoes' % Mortality and Mean Knockdown

Variable	Amount of pyrethrin (Ml)	**N**	Mean	Std. Deviation	Std. Error
% Mortality	0.0 ml	4	0.00	0.00	0.00
	0.1 ml	4	27.20	2.13	1.06
	0.2 ml	4	77.40	5.47	2.73

	0.3 ml	4	84.63	5.28	2.64
	0.4 ml	4	87.73	2.65	1.32
	0.5 ml	4	97.50	2.89	1.44
Mean knock down after 20 min.	0.0 ml	4	0.00	0.00	0.00
	0.1 ml	4	98.68	2.65	1.33
	0.2 ml	4	100.00	0.00	0.00
	0.3 ml	4	100.00	0.00	0.00
	0.4 ml	4	100.00	0.00	0.00
	0.5 ml	4	100.00	0.00	0.00

These results show that both % mortality and knock down increased with the amount of pyrethrin which was used as an insecticide.

Table 4.8 indicates the significance of varying the amount of pyrethrin to the mosquitoes' % mortality and mean knockdown.

Table 4.8 ANOVA Results for % Mosquitoes' Mortality and Mean knockdown

Variable	Sum of Squares	Df	Mean square	F	Sig.

% Mortality	Between Groups	30900.46	5	6180.09	477.48	0.00
	Within Groups	232.98	18	12.94		
	Total	31133.44	23			
Mean knock down after 20 min.	Between Groups	33162.52	5	6632.50	5666.79	0.00
	Within Groups	21.08	18	1.17		
	Total	33183.59	23			

*p > 0.05

One way ANOVA showed that percentage mortality rate differed across the amount of pyrethrin, F = 477.5, p = 0.05. Specifically, results showed that mortality increased with increase in the amount of pyrethrin in the briquettes.

From Table 4.8 also, it can be seen that the amount of pyrethrin in the briquettes had an effect on knockdown after 20 min., F = 5666.78, p = 0.05. The mean knockdown increased with increase in the amount of pyrethrin in the briquettes.

Fig. 4.2 shows the variation of calorific value of the briquettes as the amount of the pyrethrin was increased.

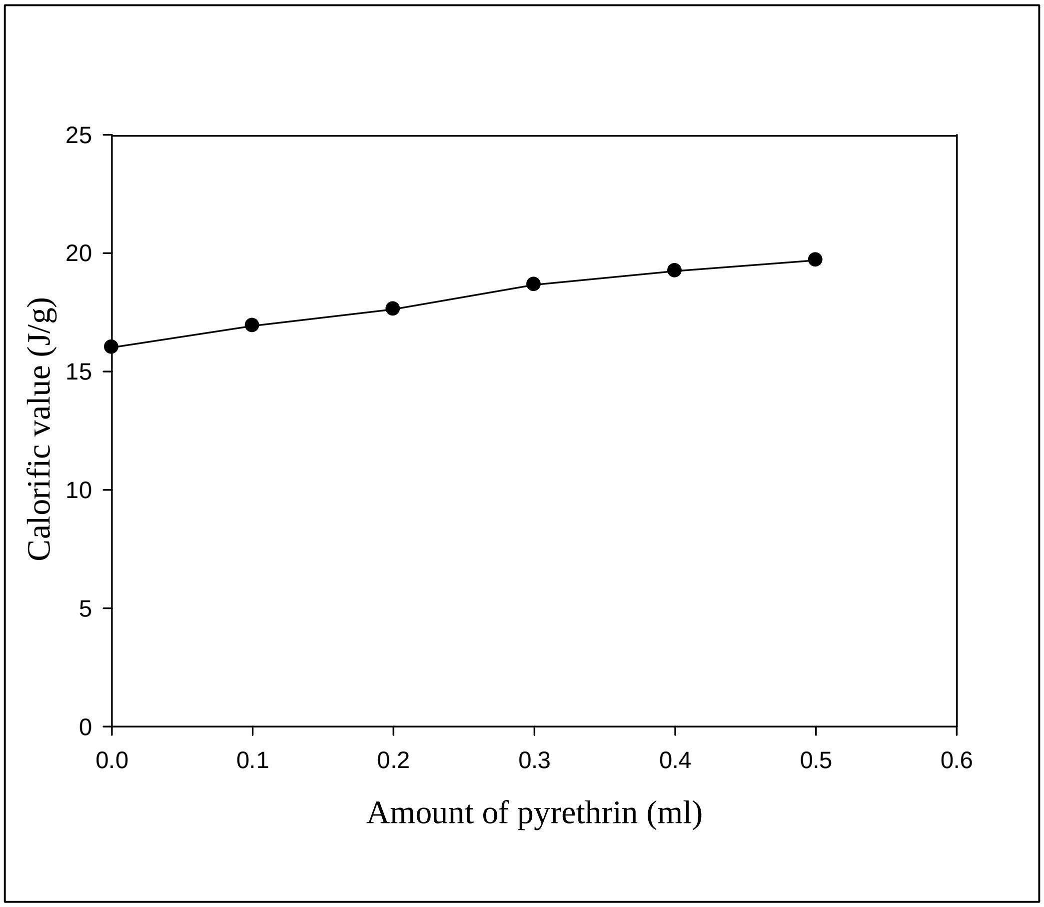

Figure 4.2 Graphical Relationship Between the Amount of Pyrethrin and the Briquettes' Calorific Value

The calorific value increased with amount of pyrethrin in the briquettes.

Table 4.9 Descriptive Statistics for Amount of Pyrethrin and the Briquettes' Calorific value

Table 4.9 shows the variation of the calorific value as the amount of pyrethrin was increased. Five replications were done for each of the six samples.

Amount of pyrethrin (ml)	N	Mean	Std. Deviation	Std. Error
0.0 ml	5	16.00	0.82	0.37
0.1 ml	5	16.93	0.08	0.04
0.2 ml	5	17.62	0.18	0.08
0.3 ml	5	18.66	0.08	0.04
0.4 ml	5	19.24	0.08	0.04
0.5 ml	5	19.70	0.16	0.07

The calorific value increased with amount of pyrethrin in the briquettes.

Table 4.10 shows the level of significance of change of amount of pyrethrin to the briquettes' calorific value.

Table 4.10 ANOVA Statistics for the Briquettes' Calorific Value

	Sum of Squares	Df	Mean Square	F	Sig.
Between Groups	50.57	5	10.11	81.31	0.00
Within Groups	2.99	24	0.124		
Total	53.56	29			

*p>.05

Analysis of variance from Table 4.10 revealed that percentage calorific value of the briquettes differed across the amount of pyrethrin, $F = 81.1$, $p = 0.05$, whereby calorific value increased with the amount of pyrethrin in the briquettes.

CHAPTER FIVE

5.0 CONCLUSIONS AND RECOMMEDATIONS

5.1 Conclusions

i. The first objective in this study was to develop pyrethrin enriched fuel briquettes. This research has shown that a mixture of jatropha seed husks and pyrethrin can be hand- pressed together with cow dung as a binder in the ratio of 3 g: 0.5 ml: 2 g respectively to produce fuel briquettes. The null hypothesis is therefore rejected.

ii. The second objective was to determine the extent to which Pyrethhrin enriched briquettes can knock down mosquitoes. The results of this study show that briquettes can be burnt indoors to knock down mosquitoes since they are able to cause 100% mosquito knockdown within 10 min and a kill of 97.6% within 24 hr. when burnt. This is in line with the Kenya Standard Specification for mosquito coils (2000), which states that the accepted biological efficacy of mosquito coils is a knock down of 50% within 20 min. and can cause a mortality of 90% within 24 hr.

iii. The third objective was to determine the calorific value of the pyrethrin enriched briquettes. 1 g of such a briquette was found to have a calorific value of 19.7 J/g and this energy can be utilized as a source of energy.

5.2. Recommendations

It is recommended that further research should be conducted to;

i. Determine the levels of sulphur and other contaminants which may be in the briquettes.

ii. Assess the possibility of producing such briquettes on large scale.

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