UNIVERSITY OF EDUCATION, WINNEBA

COLLEGE OF TECHNOLOGY EDUCATION, KUMASI

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DECEMBER, 2016

DECLARATION

STUDENT'S DECLARATION

I, CHARLOTTE CAITOE, hereby declare that this dissertation with the exception of specified sources which have been identified and acknowledged is my own original work and that no part of it has been presented for another degree in the university or elsewhere.

SIGNATURE..

DATE..

SUPERVISOR'S DECLARATION

I hereby declare that this work is the result of the student"s own effort, and I supervised in accordance with the guidelines and supervision of thesis laid down by the University of Education, Winneba.

SUPERVISOR"S NAME: **DR. ELLEN OLU**

SIGNATURE..

DATE..

DEDICATION

This work is a special dedication to my children, Akosua Gyamfua, Kweku Asamoah and Akosua Birago

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This work would not have come to a successful completion without the many people who encouraged, inspired and assisted me, and the sheer grace of God.

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ABSTRACT

This dissertation reports the findings on the effects of six briquette species on thesensory characteristics of smoked mackerel. Experimental design was assigned as the research design for this study. The population for the research were panellists from the UEW. Purposive sampling method was used to select 15 respondents for the study. Tables and figures were used to present the results of the study. Briquettes from six timber species, *Triplochiton scleroxylon* (Wawa), *Ceiba pentandra* (ceiba), *Aningeria robusta* (Asafina), *Terminalia superba* (Ofram), *Celtis mildbreadii* (celtis), *Piptadenia africana* (Dahoma) and firewood, were selected for the smoking of the fish. The findings revealed that all the respondents preferred the colour of the Asafena briquette smoked fish to Celtis, Dahoma, Ceiba, Ofram, and Wawa briquette smoked fish and firewood smoked fish. Majority of the respondents preferred the taste of Ceiba and Wawa briquette smoked fish compared to Celtis, Dahoma, Asafena, Ofram briquette smoked fish and firewood smoked fish. In terms of flavour, majority of the respondents preferred the flavour of the Ceiba, Asafena and Wawa briquette smoked fish compared to Celtis, Dahoma, Asafena, Ofram briquette smoked fish and the firewood smoked fish. To add more, majority of the respondents preferred the texture of the Asafena, Ofram and Wawa briquette smoked fish compared to Celtis, Dahoma, Ceiba and disliked the texture of the firewood smoked fish. The study recommended that the CSIR through the Food and Drugs Authority (FDA) should organise periodic workshops and training programmes to educate fish mongers regarding the use of briquettes to smoke fish.

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background

Many fish mongers in Ghana preserve fish by smoking when refrigeration is not available. Smoking fish makes it edible for longer, enhances the flavour and preserves it which improves the keeping quality. Over the years, various smoking techniques and different woods have been used in smoking fish, with these woods imparting different flavours and colours. Smoke, according to Nerquaye-Tetteh, Dassah and Quashie-Sam (2002), does not only impart colour and flavour but also has anti – oxidative and bactericidal properties. Studies on fish consumption patterns in Ghana shows that, fish mostly consumed are in the smoked form (Plahar 1995; Nti and Steiner; 1996; Asiedu 1997).

Fish is high in nutrients and it is valued particularly the protein it contains which is of high quality compared to those of meat and egg (Ojutiku, Kolo and Mmhammed, 2009). It has high quality protein, amino acids and absorbable dietary minerals (Bruhiyan, Ratnayake and Aukman, 1993).

Different species of fish are smoked, depending on availability. In Ghana, fish mostly smoked include mackerel, tuna, red fish, herrings and mud fish. Different techniques are used in processing fish which include smoking, freezing, salting, chilling, drying and fermentation in many countries. However, in Ghana, smoking is the most common and affordable processing technique employed by fish processors. According to Nerquaye-Tetteh *et al.* (2002), 80 percent of fish that is processed is smoked.Wood has been the main source of fuel for smoking fish. Even though, many types of wood may be used as fuel for fish smoking, choice of wood type depends on availability in the locality. Fish smoker‟s preference of wood fuel is also related to the physical characteristics of the wood and how they affect the smoked product (Kordylas *et al*., 1982; Nerquaye-Tetteh, 1985; Lartey, Asiedu and Okeke, 1994). Materials such as palm nuts, coconut shell, fish scales, sugar cane fibre and sawdust are currently used either separately or in combination with firewood as alternative sources of fuel. These alternative fuels may affect the quality and the sensory characteristics of the smoked fish differently.

Smoking demands great quantities of firewood, and the demand grows when the movement of fresh fish becomes more difficult because of poor access roads, an increase in the amount of fish landing, and need for disposal to market outlets (Ssali, Reynolds and Ward, 1992). Akande, Ajayi, Ogunweno and Ash (2001) report that „„localised shortage of fuel wood are known to be due in whole or part to the activities of fish processors.

In Ghana, firewood and charcoal accounts for 64 percent of primary source of energy and 95 percent of rural energy consumption (Duku, Gu and Hagan, 2011).An estimation of 3 percent annually is the rate at which Ghana‟s forest reserve is depleting as result of over reliance on it for firewood, charcoal production and furniture making (Akowuah, Kemausour and Mitchual, 2012). Increasing pressure on forest resources for energy has led to what is termed „„Other Energy Crisis of Wood‟‟‟‟ (Akinbami, 2001). This has contributed to environmental degradation, deforestation and misuse of forests. The uncontrollable levels of cutting wood for firewood for fish smoking and other domestic and industrial uses are a serious problem in Ghana.

Sustaining the forest has over the past years been a vital issue that is gaining more attention and concern. A study in South West Province, Cameroon, reported how the use of mangrove wood for fish smoking by the local people is in conflict with the conservation and sustainability of mangrove ecosystem (Feka and Manzano, 2008). Feka and Manzano (2008) further explained that „„the exploitation of mangroves for fuel wood, charcoal production, construction and other uses have been identified as an important pervasive and intrusive threat to the ecosystem"". The need for alternative energy sources that are renewable and sustainable are growing because of rapid depletion of the non renewable fossil energy resources and the negative impacts fossil fuel shortage, fuel increasing price, global warming and other environmental problems. With regards to these problems, biomass is becoming of great interest because of its many advantages such as its availability, low price and carbon free neutral features (Davies, Davies, and Mohammed, 2013).

Plant residues, sawdust and wood shavings are gradually becoming popular as choice of fuel for cooking and producing heat due to their availability in larger quantities as waste. Sawdust is an abundant waste material at sawmills. Compressing this wood residue into briquette blocks suitable for cooking and smoking fish can help reduce waste as well as reducing the demand for non – renewable fuel sources. Briquettes can be made from materials that cost little or no money to obtain, which include sawdust, and agricultural residues. Briquette can be used as fuel instead of charcoal or firewood and may cost less. Therefore, the use of briquette for smoking fish and other domestic purposes should be encouraged in order to reduce the pressure on forest for firewood.

1.2 Statement of the Problem

Sawdust is produced abundantly after lumbering of woods. In most cases, these sawdust and other wood shavings are left to burn in the open field causing environmental pollution. Compressing these wood residues into briquette can be used in generating alternative fuel which is cost effective and environmental friendly. Briquettes are easy to store, transport, and generate higher energy and less wood fuel for smoking fish and other food items. Using firewood in smoking fish, though, a traditional energy resource is an increase environmental concern. Wood logs used in smoking contributes to the depletion of the forest. The exploitation of wood mostly for commercial purpose – selling for use in fish smoking could be reduced if focus is shifted to the use of briquette for cooking and smoking fish. Wood is sometimes scarce and expensive; and increase in price erodes the profit of the processors who purchase it very often. The situation is known to be critical in fishing villages and urban centres where smoking takes place on daily basis. Fish smoking has been practiced over the years in Africa and the fuels used are well documented. However, the use of briquette for smoking fish has not been documented. Also, little information is available concerning the effect of fuel type on the sensory characteristics of fish. This study was therefore conducted to assess the effect of briquettes as fuel wood on sensory characteristics of fish.

1.3 Purpose of the Study

As a result of firewood being an age long fuel for smoking fish, most fish smokers feel reluctant to look for other fuel alternatives which could even give better sensory characteristics than what firewood could offer. Since wood cutting contributes to deforestation, there is the need to look for other sources of fuel that will put less pressure on our forest in order to sustain it. Therefore, the purpose of this study was to determine how the use of six briquette species affect the sensory characteristics of smoked *Scomber scombrus.*

1.4 Research Objectives

The specific objectives were to;

- Assess the chemical composition of fish smoked with briquettes
- Evaluate the sensory characteristics of the smoked fish.
- Determine the effect of the briquettes on the shelf life of the smoked fish.

1.5 Research Question

The following research questions will guide the study;

- What is the chemical composition offish?
- To what extent would the briquettes type affect the sensory characteristics of the smoked fish?
- How would the briquette affect shelf life the smoked fish?

1.6 Significance of the Study

The significance of this study among others are:

- It will help document the chemical and sensory characteristics of fish smoked using six different types of briquette.
- It will actually be of great benefit to fish smokers‟health as firewood could be substituted with biomass briquette which is carbon neutral.
- Pressure on the forest for use of firewood would be reduced since briquette can replace firewood for smoking fish.

- Findings from this study would also be recommended to fish smokers which will impact on their understanding and knowledge in the use of briquette for smoking fish.
- Lastly in the energy security of Ghana, briquette would help improve the diverse sources of fuel energy for the smoking of fish

1.7 Organization of the Study

Chapter one will focus on introduction which will include the background, which gives a general overview of the study; statement of the problem, which is the exact gap in knowledge, for which reason this study is been conducted. It will also be focussed on the objectives and research questions, which forms basis for data collection; purpose of the study, and significance of the study. Other items in the same chapter will be delimitation and limitation, definition of terms as well as organization of the study. Chapter two of this research work will emphasise on review of related literature on topics such as smoking as a method of preserving fish, the physical and chemical composition, briquetting, sensory evaluation, just to mention a few.

Chapter three will spell out the researchdesign, data collection instrument and procedure for analysing the data. Chapter four will deal with the analysis and discussion of the data collected. Chapter five will also look at the summary of the major findings, conclusions and recommendations.

CHAPTER TWO

LITERATURE REVIEW

2.0 Introduction

2.1 Historical Background of Briquetting Process

Briquetting is the process of converting low density biomass into high density and energy concentrated fuel briquettes (Suguman and Seshardri, 2010). A briquette is a block of compressed material suitable for burning. Fuel briquettes emerged as a significant enterprise in the 20th century. 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 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 waste soaked papers and other combustible domestic waste using simple lever- operated presses (Lardinois and Klundert, 1993).

Commercial production of sawdust briquette also started in 1984 (Akowuah, *et al*., 2012). According to them, the production could not be sustained due to operational, marketing and standardization challenges, though the briquettes had high prospects as an alternative to firewood and charcoal.

2.2 Theoretical Framework on Forest Resource Conservation

The theoretical underpinnings for sustaining the environment are rooted in national and global agreements/conventions. The prime focus is sustaining the environment through the adoption of appropriate approaches in charcoal production and other human activities that affect the natural environment. This thinking is reinforced by the MDG 7 (Ensuring Environmental Sustainability). Thus, in the development agenda, environment is seen as a sensitive cross cutting issue and must therefore be integrated in the principles and policies of national programmes/projects. The basic aim is to reverse the loss of forest resources (Arnold, 2006).

2.2.1The Concept of the Tragedy of the Commons

The concept of the Tragedy of the Commons is extremely important for understanding the degradation of our environment. The tragedy of the commons is a dilemma arising from the situation in which multiple individuals, acting independently and rationally consulting their own self-interest, will ultimately deplete a shared limited resource, even when it is clear that it is not in anyone's long-term interest for this to happen. This dilemma was first described in an influential article titled "The Tragedy of the Commons," written by ecologist Garrett Hardinin in 1968 (Arnold, 2006).

Hardin's Commons Theory is frequently cited to support the notion of sustainable development, meshing economic growth and environmental protection, and has had an effect on numerous current issues, including the debate over global warming. The basic idea espoused by the theorist is that if a resource is held in common for use by all, then ultimately that resource will be destroyed. "Freedom in a common brings ruin to all." To avoid the ultimate destruction, the human values and ideas of morality must be changed. This theory assumed that each human exploiter of the common (shared resources) was guided by self-interest. At the point when the carrying capacity of the commons was fully reached, an exploiter might ask himself, “Should I continue my actions?” Because the gain of so doing would come solely to him, but the loss from his actions would be "commonized" he will not give up his action. Because the privatized gain would exceed his share of the communized loss, a self-seeking exploiter would not change his behaviour. Others reasoning in the same way, would follow suit. Ultimately, the common property would be ruined (Arnold, 2006). Even when exploiters understand the long-run consequences of their actions, they generally are powerless to prevent such damage without some coercive means of controlling the actions of each individual. Idealists may appeal to individuals caught in such a system, asking them to let the long-term effects govern their actions. But each individual must first survive in the short run. If all decision makers were unselfish and idealistic calculators, a distribution governed by the rule "to each according to his needs" might work.

The spoilage process comes in two stages. First, the non-angel gains from his "competitive advantage" (pursuing his own interest at the expense of others) over the angels. Then, as the once noble angels realize that they are losing out, some of them renounce their angelic behaviour. They try to get their share out of the commons before competitors do. In other words, every workable distribution system must meet the challenge of human self-interest. An unmanaged commons in a world of limited material wealth and unlimited desires inevitably ends in ruin. Inevitability justifies the epithet "tragedy," which Hardin introduced in 1968. This theory underpins the activity of charcoal producers. Fuel wood exploitation for charcoal burning results in forest destruction which charcoal producers is aware of but continues because of the selfish economic gains which however have general ramifications. The long term impacts thus do not matter to them (Lazarus, Diallo and Sokona, 1999).

2.3 Briquette as a Source of Fuel

Biomass briquetting can use a wide range of waste biomass such as agricultural residues, agro-industrial residue and forest waste (Singh, 2013). For industrial production of compacted biomass from sawdust, adequate process controls focused on risk management are required as this material is a forestry residue with one of the largest environmental impact, being a contaminant agent of soil and water. In addition, when in the open, it is harmful to human health and a safety risk with regard to fire and spontaneous combustion (Lelitikanges, 2001; Vinterback, 2004; Stahl, Granstorm, Berghel, and Renstorm, 2004).

However, the basic process of making sawdust briquettes (figure 2.1) is not demanding on the particle size, which reduces production costs compared to the process of pellets production. At the industrial level, drying is one of the most important stages as the combustion of wet wood waste reduces energy efficiency and increases hydrocarbon emissions and other unwanted particles, besides generating further problems in the compacting stage and causing crack problems in the briquettes (Stahl, *et al*., 2004). Biomass briquettes are a form of solid fuel that can be burned for energy. They are created by compacting loose biomass residue into solid blocks that can replace fossil fuels, charcoal and natural firewood for domestic and institutional cooking and industrial heating processes (Suguman and Seshadri 2010). In the briquetting process, particles of solid materials are pressed to form blocks with defined shape and dimension. Briquettes produced from agricultural waste at low cost are an excellent source to produce cheap energy, which is environmentally friendly and in many cases replace fossil fuel in use today (Yamaji, 2010).

Woodfuels, consisting of firewood and charcoal, constitute the most important energy forms in Ghana. It contributes about 60 percent of total energy consumption in the country (Energy Commission, 2010). While woodfuels will continue to provide the bulk of Ghana‟s energy supply in the foreseeable future there is the need to put in place measures to deal with the negative impacts, such as deforestation and its associated impact on people‟s health and the environment. In Ghana numerous studies and draft policies are being conducted on fuel wood and charcoal harvesting but with limited targeted interventions and actual implementation in the country. This makes it practically difficult to regulate activities within the industry, hence the incidence of severe pressure on both the natural environment and the biodiversity (Energy Commission, 2010).

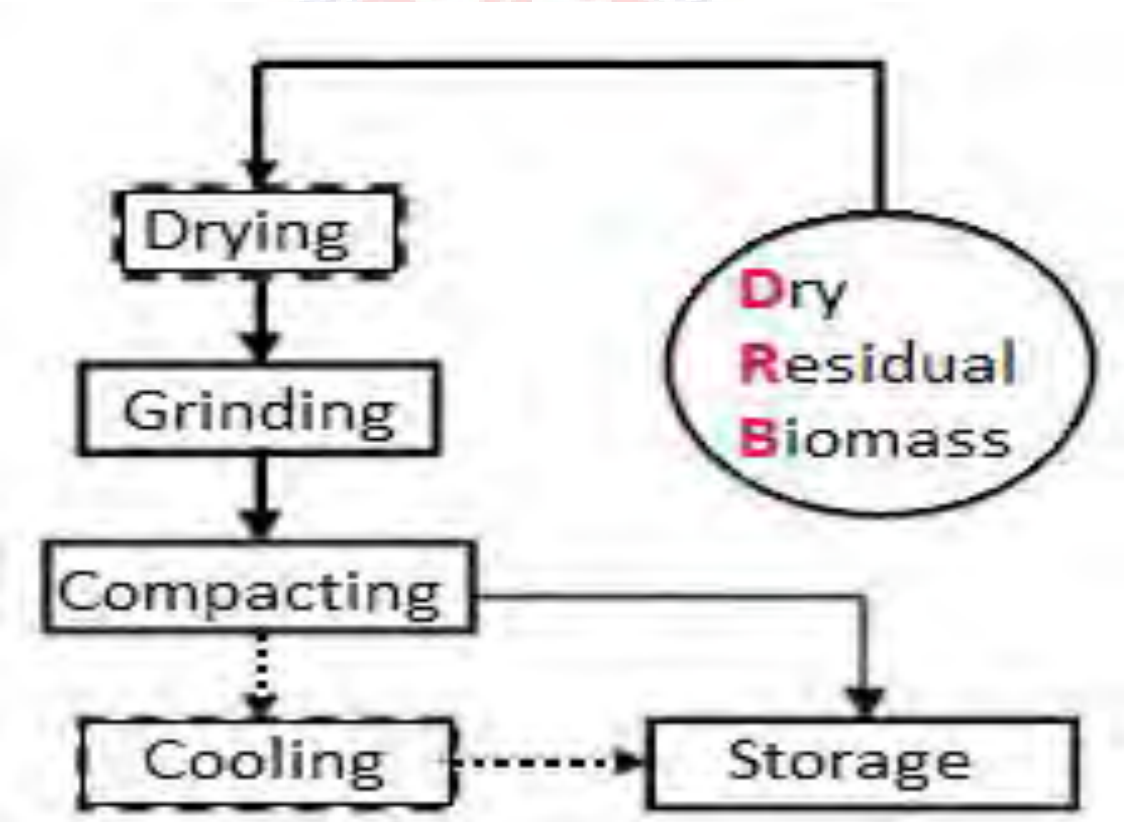

Figure 2.1 Diagram of Compaction of Residual Biomass

Source: Sanchez, IAENG, Pasache, and Garcia, (2014)

Table 1: Consumption of wood fuel and charcoal in Ghana for 2004 – 2008

Year	Wood fuel (m^3)	Wood Charcoal (t)
2004	20,678,000	752,000
2005	20,678,000	752,000
2006	33,039,530	1,358,977
2007	31,477,900	1,4183,000
2008	35,363,400	1,477,700
Total	**141,236,830**	**5,758,977**

Source: Duku et al., (2011)

2.4 The Potentials of Briquetting

Fuel wood being the dominant energy source both in the home and in many industries in Ghana is increasingly putting pressure on wood land resulting in deforestation. Sparse forest as a result of deforestation then put pressure on rural dwellers that depend on firewood as their principal cooking fuel. The collectors, usually women and children then have the daily pressure of long journey for its collection. On the national level, as the Ghanaian economy expands, there will be immense pressure on fuel wood supplies, resulting in further serious deforestation. With regards to these issues, it is undoubtedly clear that alternative fuel sources need to be identified for the use of smoking fish, cooking, heating both at home and industries for sustainable economic growth.

Researchers are studying (for example, a detailed study by Mitchual, Mensah and Darkwa, 2014, looked at the evaluation of fuel properties of six tropical hardwood timber species for briquettes) and are bringing to bare the large quantities of underutilized waste biomass residues in Ghana which can be made useful by compressing them into briquettes which can be a complete fuel substitution to fuel wood and charcoal. Briquetting involves the collection of biomass material that are not normally considered useful as fuel, due to their low density, and compressing them into a solid fuel of convenient size and shape that can be burned in the same way as wood or charcoal (Chaney, 2010). Briquetting increase the bulk density of biomass material, increasing its energy density, which in turn reduces transportation cost and makes it much easier for the end user to handle. Agricultural residues in their raw state are often bulky and difficult to handle and in combustion often burn fast and are smoky (Wamukonya and Jenkins, 1995). Densification of material results in marked improvement in combustion characteristics compared with loose bio waste. Thus, this simple technology might provide a practical means of upgrading the loose residues and providing a wood substitute that could potentially be used in existing stoves.

Comparatively, briquetting do not impose significant changes in the way people cook their food as other type of technology such as biogas digesters and gasification (Chaney, 2010). They are very low- tech and provide a low-cost method which can be made at a village level to upgrade fuel, even using a hand operated press. Briquette production can be on different scales, from small village producers making briquettes for themselves and other families, to larger scale briquette manufacturers, producing sufficient quantities for local industries and commercial businesses. Briquetting eliminates problems associated with large quantities of waste agro-residues disposed and provide an alternative to wool fuel, thereby reducing the impact on forests. This technology being simple and assessable, with the benefits it could bring to people„s lives, give it huge potential as a alternative energy source for developing nations (Chaney, 2010).

2.5 Biomass Energy

Biomass is the term used to describe all the organic matter produced by photosynthesis that exists on earth‟s surface (Practical Action, 2011).Until the middle of 19th century, biomass dominated the global energy supply with a 70% share (Grubler and Nakicenovic, 1988). Wood fuels are the most prominent among the biomass energy sources. With rapid increase in fossil fuel use, the share of biomass in total energy declined steadily through substitution by coal in the 19th century and later by refined oil and gas during the 20th century (Shekhar, 2010).

Biomass energy currently plays a major role in meeting the present energy needs of developing countries. A number of authors (Mitchual, *et al*., 2014; Sanchez *et al*., 2014; Adekunle, Olorunfemi, Aina and Adegbite, 2010) have also expressed the view that, biomass has the potential to meet the additional energy demands of urban and industrial sectors, thereby making a significant contribution to the economic advancement of developing countries. Biomass can also offer an immediate solution for the reduction of carbon dioxide content in the atmosphere (Shakhar, 2011), and it is increasingly becoming important globally as a clean reliable source of energy to fossil fuel (Duku, *et al*., 2011).Among the many advantages of biomass, its availability and produced locally; and the fact that it can be used essentially without damage to the environment, in addition to its positive global effect by comparing with other sources of energy, among others, presents no risk of major accidents as nuclear and oil energy do.

2.6 Benefits of Using Briquettes for Cooking and Smoking Fish

Smoking fish with briquettes has the potential to reduce Ghana"s dependence on wood fuel to smoke fish. Using briquettes for smoking addresses the issue of deforestation, in that, there would be a sustainable alternative for the long term future of the country so that it is not reliant on firewood. The use of briquette for smoking fish however will help to reduce the need for rural folks who are forced to walk long distance to collect firewood for smoking fish and cooking will be at minimal. Many women who process fish by smoking spend huge amount of money in buying timber logs for firewood and would have to hire someone to split them up for easier burning. All these add up to the cost of fish sold and may end up reducing the profit margin earned by these processors. The technology of briquetting is one effective way of converting woody residues and other crop residue to a more attractive fuel (Chaney, 2010).

2.7 Advantages of Using Briquettes in Comparison with other Solid Fuels

- Briquettes are cheaper than coal.
- Sulphur is not found in briquettes, and thus, do not pollute the environment
- Do not pollute the environment.
- Once cool, oil or lignite are used, they cannot be replaced
- Biomass briquettes have higher practical thermal value.
- Briquettes have much lower ash content (2-10% as compared to 20-40% in coal)
- Combustion is more uniform compared to coal.
- Briquettes production centres are usually nearer to the consumption centres and supplies do not depend on erratic transport from long distance (Sharma, Prinyank and Sharma, 2015)

2.8 Quality Characteristic of a Good Briquette

Two main qualities of briquettes that need to be considered are that: (1) it shall remain solid until it has served its function and (2) it shall perform well as a fuel. The first aspect which implies that the product be intact when handled or stored, is mainly a function of the quality of the densification process for a given raw material. The second aspect is mainly related to the properties of the raw material, the shape and density of the individual briquette (FAO, 1990). A briquette of good quality should be stable enough to withstand handling and long term storage (Krauss and Szymanski, 2006).

2.9 The effect of Deforestation on Energy Supply

Ghana depends heavily on forest wood for its energy supply but other countries depend on coal and gas. Wood fuel is the largest source of energy consumed in Ghana (Energy Commission of Ghana, 2005).With the increases in population, growing commercial activities, resource utilization has been reported to be beyond a critical point where the current levels are now exceeding the natural regeneration capacity of the forest (Energy Commission of Ghana, 2005). An estimation of about 1.5 million hectares of forest remained in Ghana in 1992, of which 22, 000 hectares was lost annually to deforestation. Timber logging for fuel wood and timber export is an important factor constituting to deforestation (Japan International Cooperation, 1999). Regulations and restriction on tree- felling, though are in place, most people do not adhere to them and those who cut the trees and shrubs do not replace them (Siaw, 2001).

This unsustainable forest management has detrimental effects both on biodiversity and environment as well as the producers themselves who have to travel increasingly longer distance in search of wood (Energy Commission of Ghana, 2005). Among the consequences of deforestation is how it significantly affects the livelihoods of people, especially those who directly depend on wood as a source of fuel. Some women and children spend long hours walking over distance to fetch firewood for cooking and heating needs of the household. Even though these people would not spend money in the collection of the firewood, it denies the women the opportunity to be involved in any paid job, which on the hand would have raised the family"s income. It also denies the children from going to school and some could even fall prey to snake bites and all forms of accidents.

2.10 Briquette End-Use

Several of the early projects aimed at introducing briquettes as a household fuel met with difficulties, or even failed completely, because of the lack of combustion know-how. The users complained that briquettes generated excessive smoke, were very difficult to ignite and many more. This led to the fairly common belief that special briquettes stoves had to be developed and introduced, which would have been a rather complicated task.

Later studies, in laboratories as well as in practical field tests, have shown that briquettes use is not so difficult. What is needed is patience on the part of the user, who has to learn to burn the briquettes in his or her specific stove through trial-and-error. In most cases, it is possible to achieve acceptable combustion even with unsophisticated equipment. An interesting illustration of this ""ease-of-use"" is the study of Nicaragua of 50 families using cotton-stalk piston briquettes. Basically, all the families were pleased with the briquettes, without specific training or modification of the stoves in use. Individually, or in contact with their neighbours, they came up with different methods of igniting briquettes; either by using liquid fuel or by mixing the briquettes with wood, or a combination of both.

It is not fully clear why end-use created so many initial problems. One reason could be that many projects were not really „market driven, that is there was not a sufficient need for wood fuel substitutes for the users to get involved with a new seemly difficult product ".They simply preferred to continue to burn wood or charcoal than to mess around with briquettes. In other projects, where either physical scarcity or a high marked price for wood fuel made briquettes work and generally succeeded.Another explanation could be that screw-pressed briquettes, because they are very compact, are not easy to break by hand into pieces, nor do they break up during combustion. They are in fact slightly more difficult to ignite than the piston briquettes. In some cases, they may have been too large a step from wood fuel to make a spontaneous learning process possible (Svenningson, 1990).

2.11 Chemical Composition of Fish

Chemical composition can vary widely from fish to fish even of the same species. The composition is important to the processor as it enables him or her know the raw material before any techniques such as smoking can be applied correctly. The nutritionist want s to know what contribution fish can make to the diet and to health, and the cook must know for example, whether a fish is normally lean or fatty in order to prepare it for the table (Murray and Burt, 2001).

2.11.1 The Structure of Fish Muscle

The blocks of muscle, which form the individual flakes in the cooked fish, are separated by their sheets of what is known as connective tissue, these are curved within the fillet and run from the backbone to the skin. In fresh fish the muscles blocks are firmly attached to the connective tissue, and the surface of a cut fillet is smooth and continuous. There are also tiny blood vessels running through the muscle. The connective tissue accounts for only a small percentage of the total weight of the muscle, smaller than for example in beef muscle; this is one reason why fish is generally less though to eat than meat.

Fish muscle is of two kinds, light muscle and dark muscle. In white fish muscle such as cod and haddock there is a small strip of dark or red, muscle just under the skin on both sides of the body, running beneath the lateral line. In fatty fish such as herring and mackerel, the strips of dark muscle are much larger in proportion and contain higher concentrations of fat and certain vitamins (Murray and Burt, 2001).

2.11.2 The Principal Composition of Fish Muscle

2.11.2.1 Water

The main constituent of fish flesh is water which usually accounts for about 80% of weight of fresh white fish. Whereas the average water content of the flesh of fatty fish is about 70 percent. The water in fresh fish muscle is tightly bound to the proteins in the structure in such a way that it cannot readily be expelled even under high pressure. After prolonged chilled or frozen storage, however, the proteins are less able to retain all the water and some of it containing dissolved substances, is lost as drip.

Frozen fish that are stored at too high a temperature, for example, will produce a large amount of drip and consequently quality will suffer. In the living fish, the water usually increases and the protein content decreases as spawning time approaches, thus it is possible, with cod for example, to estimate the condition of the fish by measuring the water content of the muscle (Murray and Burt, 2001). In cod the water content of the muscle is slightly higher at the tail than at the head; this slight but consistent increase from head to tail is balanced by a slight reduction in protein content.

2.11.2.2 Protein

The amount of protein in fish muscle is usually somewhere between 15 and 20 percent, but values lower than 15 percent or as high 28 percent are occasionally met within some species.All proteins including those from fish are chains of chemical unit linked together to make on long molecule. These units of which there are about twenty types called amino acids, and some of them are essential in the human diet for maintenance of good health. Two essential amino acids called lysine and methionine are generally found in high concentrations in fish proteins. Fish proteins provide a good contamination of amino acids which is highly suited to men‟s nutrition requirements and compares favourably with that provided by meat, milk and egg (Murray and Burt, 2001).

2.11.2.3 Fat

Taking all species into accounts, the fat content of fish can vary very much more widely than the water, protein or mineral content. Whilst the ratio of the highest to the lowest volume of protein or water content encountered is not more than three to one, the ratio between highest and lowest fat values is more than 300 to one.There is usually considerable seasonal variation in the fat content of fatty fish, for example a starved mackerel may have as little as 1/2 percent fat whereas one that has been feeding heavily to replenish tissue may have a fat content of over 20 percent. As the fat content rises, so the water content falls, and vice versa, the sum of water and fat in a fatty tissue is fairly constant at about 80 percent (Murray and Burt, 2001).

The fat is not always uniformly distributed throughout the flesh of a fatty fish. For example in pacific salmon there may be nearly twice as much fat as there is in the tail muscle.

In the white fish of the cod family, the fat content is noticeable mainly in the liver, where the bulk of the fat is stored.

2.11.3 The Minor Components of Fish Muscle

2.11.3.1 Carbohydrate

The amount of carbohydrate in white fish muscle is generally too small to be of significance in the diet. In white fish the amount is usually less than 1 percent, but in the dark muscle of some fatty species it may occasionally be up to 2 percent. Some molluscs, however, contain up to 5 percent of the carbohydrate glycogen (Murray and Burt, 2001).

2.11.3.2 Minerals and Vitamins

These include a range of substances widely different in character that must be present in the diet, even if only in minute quantities, not only to promote good health but also to maintain life itself. Although fish is very unlikely to be the only source of an essential mineral in the diet, fish does provide a well-balanced supply of minerals in a readily usable form. The vitamin content of individual fish of the same species, and even of different parts of the same fish, can also vary considerably. Often the parts of a fish not normally eaten, such as the liver and the gut, contain much greater quantities of oil. Soluble vitamins than the flesh; the livers of cod and halibut for example contain almost all of the vitamins A and D present in those species. In contrast, the same two vitamins in eels, for example are present mainly in the flesh.

Water soluble vitamins in fish are, although present in the skin, the liver and gut, are more uniformly distributed, and the flesh usually contains more than half the total amount present in the fish. The roe, when present, is also a good source of these vitamins.In general, the vitamin content of white fish muscle is similar to that of lean meat and, with the exception of vitamin C, can usually make a significant contribution to the total vitamin intake of man and domestic animals. The minerals and vitamin content of fish is not markedly affected by careful processing or by preservation, provided storage is not very prolonged (Murray and Burt, 2001).

2.11.3.3 Extractives

These substances are so called because they can easily be extracted from fish flesh by water or water-based solutions. Unlike the proteins, substances in this group have comparatively small molecules; the most important extractives in fish include sugars, free amino acids, that are free in the sense that they are not bound in the protein structure, and nitrogenous bases, which are substances chemically related to ammonia. While many of these extractives contribute generally to the flavour of fish, some of them, known as volatiles, contribute directly to the flavours and odours characteristic of particular species; as the name suggests, volatiles are given off from the fish as vapours. Most of the extractives are present at very low concentrations but, because of their marked flavour of odour, are nonetheless important to the consumer.

When fish is stored after capture, the amount of some of the extractive present will change with time, thus measurement of the amount can often indicate the storage time and hence indirectly the quality. Extractive compounds whose concentration in fish varies directly with time of storage have long been studied since they may provide indicators of the quality of fish (Murray and Burt, 2001).

2.12 Factors Affecting the Composition of Fish

The composition of a particular species often appears to vary from one fishing ground to another, and from season to season, but the basic causes of change in composition are usually variation in the amount and quality of food that the fish eats and the amount of movements it makes. For example, fish usually stops feeding before they spawn, and draw on their reserves of fat and protein. Again, when fish are overcrowded, there may not be enough food to go around; intake will be low and composition will change accordingly. Reduction in basic food resource, plankton for example can affect the whole food chain. An example of how abundance of food supply can markedly change the composition of a specie is shown by the sheepshead, an American freshwater fish: when taken from certain small lakes that were overstocked, the sheepshead had an average fat content of 1 percent, compared with 6-10 percent for these taken from rivers or lakes where food was plentiful (Murray and Burt, 2001).

2.12.1 Fish for Human Consumption

Fish can form a very nutritious part of man‟s diet; it is rich in most of the vitamins he requires, it contains a good selection of minerals, and the proteins contain all the essential amino acids in the right proportions. Although the amount of protein in fish varies a little from species to species and, on occasions, within a species, the protein content for meat and for fish is roughly comparable.

The extreme variability of composition of different species of fish accounts to some extent for the large variety of dishes than can be made from them; unfortunately fish are all too often lumped together in one category while pork, beef, lamb and mutton are invariably regarded as being quite distinct kinds of meat. In fact there is a much greater difference in composition, flavour and texture between, say, herring, haddock, halibut and salmon than there is in butcher meats and this range is even wider when shell fish are included (Murray and Burt,2001). Fish contain unsaturated fatty acids, which, when substituted for saturated fatty acids such as those in meat, may lower your cholesterol. But the main beneficial nutrient appears to be omega-3 fatty in fatty fish. Omega -3 fatty acids are a type of unsaturated fatty acid that may reduce inflammation in the body can damage your blood vessels and lead to heart disease (Loren, 2015).

2.13 Atlantic Mackerel (*Scomber scombrus*)

The Atlantic mackerel is classified as a fat fish species that belong to the Scombridae family of fish. Atlantic mackerel is distributed on both sides of the North Atlantic Ocean, including the Baltic Sea. Atlantic mackerel is found in cold and temperate waters. They are typically a surface –living species and swim in schools (NOAA, 2014).

Mackerel is a valuable pelagic fish and most of the catch is for human consumption (Icelandic Ministry of Fisheries, 2014). The mackerel is a fatty fish, and the fat and water content vary with season. The fat content is about 6-23%, water content is 56-

74% and protein content is 18-20 % throughout the year (FAO, 2014). It is considered one of the more healthy fish because it is rich in omega-3 fatty acids and an excellent source of selenium, niacin, and vitamins B6 and B12 (NOAA, 2014).

Figure 2.2: Atlantic mackerel (*Scomber scombrus*)

2.14 Fish Smoking Process

From an engineering point of view, there is no such process as fish smoking. Smoke is used as a condiment and claimed as a preservative but smoke alone does not give us the so- called smoke products. The basic food process called drying, combined with the effects of salt and smoke particulates result in such a product. Since fishery product smoking began, the general procedure has remained almost unchanged. The method used still depend largely upon opinions and prejudice of the operator resulting in each individual having different ideas about the kind of wood, time, temperature of smoking and so on.

Although smoking cannot be used to significantly extend shelf life, it does have some preservation effect on the product through the combined effects of drying and of bacteria-killing chemicals in the smoke. However, the 2% -3%salt content in most products have only slight effect on the bacteria that spoil smoked fish. Smoking is a combination of drying and adding the chemicals from the smoke to the fish, through preserving and adding desired flavour (Piggot, 1988).

2.14.1 Product Preparation

Each person has his/her own special treatment for the fish preparatory to smoking, but the general steps of the smoking process include the following:

2.14.2 Splitting and Cleaning

The smoke fish are gutted, the gut cavity scrapped and all blood removed. These fishes are usually beheaded and fillet, although the long bones are often left on the fillet to give the finished product a better appearance.

2.14.3 Salting

This is almost always done by soaking the fish in strong brine. One of the permitted dyes is added if colour is desired. The duration of the brine dip depends on the brine strength and on the size and fitness of the fish.70 to 80% saturated brine are usually employed for all the common type of smoked fish. During salting the fish picks up 2 to 3 percent salt. Brine becomes weaker during use. Water on the surface of fish dilutes the brine and the fish also absorbs the salt. Brine strength is usually maintained by adding solid salt or by using large volume of brine. Normally brining procedures do not produce uniform salt content even in fish of uniform size.Better results are obtained if brine is stirred during the dip. A mechanical process would improve matters as well as allowing continuous control of brine strength (Piggot, 1988).

2.14.4 Hanging (Removal of Excess surface water)

Brined fish is conventionally hung or laid on racks to drip and partly drying after brining. If fish are smoked while too moist, the smoke does not absorb evenly, and a „„streaky"" product results. If the surface is too dry the smoke is not adequately absorbed. Also, during the hanging, protein dissolved in brine dry on the cut and produces the familiar glossy skin, which is one of the commercial criteria for quality.

2.14.5 Smoking

Smoking is carried out by using one of the following two processes:

- Cold smoking: The temperature of the smoke does not rise above about 85°F, or the fish will begin to cook.
- Hot smoking: In this process the intention is to cook the fish as well as smoke it. The smoke reaches 250°F or so and the centre of the fish may be 140°F or more. Most of the smoked product available at the market is hot smoked. However, the temperature of the fish during and at the end of the process, vary tremendously among processes.

The desirable effects of smoking on foods are flavouring, preservation and colouring. Undesirable effects are contamination with toxic compounds of smoke and some destruction of essential amino acids of food proteins which are attributed to certain classes of components of smoke and smoke liquid. The typical aroma of smoked foods seems to be due to the effect of certain phenols, carbonyls and acids. These compounds also cause, at least in part different flavours in smoked fish (Barylko-Pikielema, 1977).

2.14.6 The Nutritional Quality of Smoked Fish

The desirable effects of smoking are flavouring, preservation and colouring. However, excessively heating proteins may destroy certain amino acids or render them unavailable for digestion. One of the most important changes which results from heating is the interaction of certain amino acids residues of the protein with reducing sugars as glucose. Lysine is mostly frequently involved. Trytophan, arginine and histidine may also enter into reaction with reducing sugars. In the early stages, melanoid in condensation, a bond is formed between the sugars and the amino group which interferes with the action of protulytic enzymes but which may be broken by boiling with acid. In later stages browning and subsequent loss of the amino acids occurs.

Moisture content plays a very important part in the browning reaction. Moisture content of 30% is most favourable for the reaction and hence the browning reaction is peculiar to dehydrated fish products. The moisture of these fish is reduced usually by passing through the range conductive to protein damage. Low moisture type of fish products fall into this very low moisture category. During smoking, fish products go through heating and drying. Non-enzymatic browning reactions definitely go on in smoked products. These reactions form the desired colour of the finished product. The availability of the lysine is lost during smoking due to non-enzymatic browning (Chen and Denberg, 2012). The extent of the reduction depends on the length and temperature of the heating process and the extent of the fish dehydration. Loss of lysine increases with an increase in both of these parameters (Piggot, 1988).

2.15 Effects of Smoking on Microorganisms in Fish

2.15.1 Hot Smoking

Although the fat composition of fish can influence how it reacts to temperature (Ben Embrek, 2014), fish protein starts to rapidly denature (i.e. starts to effectively cook) at temperatures above 60^{o}C. Thus by definition, hot smoking temperatures typically exceed 60^{o}C in order to cook fish as it smokes. Consequently, Jemmi and Keusch

(2012) inoculated trout with *L. monocytogenes* at a concentration of 10^6cfu g^{-1} and determined the fate of the bacteria after exposure to hot smoking conditions at 65°C. Complete kill of the *L. monocytogenes* was observed after 20 minutes. Similar findings were reported by Ben Embrek (2014) for fish inoculated with *L. monocytogenes* at 100 cfu g^{-1} who reported that no *L. monocytogenes* was recovered after hot-smoking at 65°C for 15 minutes.

Although Poysky, (2007) summarises a number of reports of thermal inactivation of *L. monocytogenes* as „temperatures approaching 70°C are required for effective bacterial kill‟, mild hot smoking of Atlantic mackerel at 60°C resulted in an approximate a two log unit reduction in total mesophilic aerobe numbers (Kolodziejska, Niecikowska, Januszewska and Sikorski, 2002).

Taken in combination, these publications provide strong evidence that the temperatures and exposure duration typically experienced by fish during hot smoking are sufficient to completely kill any *L. monocytogenes* present on the surface of the fish. Consequently, hot smoking is a critical control point for *L. monocytogenes* and any contamination issues with hot smoked product are highly likely to be caused by recontamination of the fish after the smoking stage.

2.15.2 Chemical Smoking

Chemical smoking uses wood smoke which has been cooled to condense it into a liquid. The smoke condensate is used to flavour fish either by direct application to the fish flesh (e.g. by dipping the fish in a solution of condensate), or by heating the condensate so that it returns to a gaseous state and using that in a more traditional manner.

The literature has some conflicting reports regarding role of chemical smoking in controlling *L. monocytogenes*. For example, a minimum temperature of 67.2°C was required during hot (mechanical) smoking to completely inactivate *L. monocytogenes* on salmon fillets if the temperature was applied in combination with smoke (Poysky *et al*., 2007). When an increased quantity of liquid smoke was applied by dipping fillets in a solution of smoke condensate, inactivation was achieved at the lower temperature of 58.9°C (Poysky *et al*., 2007) suggesting that the smoke condensate was anti listerial. If no smoke was applied, a temperature of 82.8°C for at least three hours was required for complete inactivation of *L. monocytogenes*. 82.8°C is towards the high end of the temperatures achieved by a traditional wood-burning hot smoke process and thus there exists the possibility the fish that are on the periphery of a wood burning process may still harbour *L. monocytogenes* after smoking. To ensure even heating and smoking it is recommend repositioning of fish during hot smoking.

A French study (Thurette, Membre, Ching, Tailliez and Catteau, 2008) used predictive modelling validated with experimental data to determine growth rates of *Listeria* during the smoking of salmon. The study determined, using liquid smoke, that phenol concentrations as high as 20 ppm and temperatures as low as 4°C could limit the growth rate of *L. monocytogenes* during smoking. Thus the French study also provides evidence that chemical smoke can be anti-listerial and at much lower temperatures than those reported by Poysky *et al.* (2007).

A study, which was similar in design to the Thurette study, was undertaken by Sabanadesan, Lammerding and Griffiths (2000). Looking at the inactivation of *Listeria innocua* on salmon fillets during mechanical cold smoking, it was found that under industrial conditions, temperatures of 18-30°C did not affect the inactivation of *L. innocua*, but that smoking time had a significant effect, with a 3 log reduction observed for the longest time assessed (12 h; Sabanadesan *et al*., (2000).

Vitt, Himelbloom and Crapo (2001) investigated the inhibitory effect of 5 liquid smokes. The two that had greatest effect were the „Charsol" and „Supreme" brands with optimum inhibition on *L. monocytogenes* growth shown to be after a five minute marinade. However, sensory acceptability of the smoked product reduced rapidly after 2 minutes immersion in the smoke condensate.

In contrast to the four previous studies showing a role for smoke in reducing *L. monocytogenes* numbers. Neunlist *et al*. (2005) observed no differences in the numbers of *L. monocytogenes* before and after exposure to smoke condensate at cold smoking temperatures under laboratory conditions. Furthermore, an earlier study by Sunen, Fernadez- Galian and Aristimuno (2001) evaluated the antimicrobial activity of one dried and three liquid smoke extracts. In contrast to the indications initially suggested by Thurette *et al*. (2008). Sunen and colleagues found there was no relation between the antimicrobial activity and the concentration of phenols in the smoked products. Confoundingly, two of the liquid smoked products Sunen et al. (2006) tested reduced the populations of *L. monocytogenes*, whereas the other products studied did not.

More recently, in the most comprehensive study identified, Sunen *et al*. (2003) have revisited the antimicrobial consequences of exposing *L. monocytogenes* inoculated onto the surface of rainbow trout before exposure to one of four commercial smoke wood condensate preparations. The fish were smoked under cold smoking conditions before vacuum packing and stored at 4°C for 21 days (Sunen *et al*., 2003). In agreement with their previous findings, only two of the four smoke extracts effectively controlled the numbers of *L. monocytogenes* keeping them below the detection limit for the quantitative enumeration test method used. However, *L. monocytogenes* was still detectable by enrichment after treatment with any of the four condensates examined. In contrast to their earlier findings (Sunen *et al*., 2001), the two smoke wood condensates that had significant anti-*Listerial* activity were the two containing the highest quantities of phenolic compounds (Sunen *et al*., 2003).

It is apparent that some smoke condensates appear to be able to cause reductions to some *L. monocytogenes* strains inoculated onto fish. There is also evidence that these anti-listeria effects are influenced by exposure time and smoking temperature. The later findings of Sunen and colleagues broadly support the initial speculations of Vitt *et al* (2001) who were the first to suggest a linkage between phenolic compound concentrations and antimicrobial activity. However later work, which modelled the cold fish smoking process using smoke condensates indicated that the antimicrobial effect cannot be determined solely on the level of phenolic compounds (Cornu *et al*., 2006). Furthermore, based on the output from a model built from laboratory-generated data, Hwang (2009) believes that the concentrations of phenol required to *reliably* prevent the growth of *L. monocytogenes* may be too high to be attained practically in smoke condensates (Hwang *et al*., 2009). Although of little practical use for cold smoking, the conclusions of Hwang (2009) broadly agree with those of

Poysky *et al*. (1997) and both suggest that smoking at the highest temperature possible is the best strategy for the inactivation of *L. monocytogenes.*

Although it is somewhat removed from commercial processing conditions, Guilbaud *et al*. (2008) observed decreases in *L. monocytogenes*numbers when liquid smoke was added to laboratory broth cultures at 37°C. However, there was no attempt to match the experimental conditions to those found in commercial smoking plants. The Guilbaud work is mentioned in this report only because the authors report that smoke condensate addition triggered changes in *L. monocytogenes* gene expression, suggesting there are potential adaptation mechanisms in *L. monocytogenes* to smoke. If that is the case, then any adaptations may well be strain specific because Porsby, Vogel, Mohr and Gram 2008 found that plant environment persistent strains of *L. monocytogenes* were no more resistant to the salmon smoking process than other strains. They also found that combining a drying step after brining and liquid smoking reduced significantly the levels of *L. monocytogenes* over a 24 h period. In contrast to the findings of Guilbaud et al (2008) a second lab-based study by Neunlist *et al*. (2005) observed no differences in the numbers of *L. monocytogenes* before and after exposure to smoke condensate at cold smoking temperatures under laboratory conditions.

2.16 Sensory Evaluation

Senses are one of the most important goals of food industry in determining how food products affect consumers. It is a primary concern for food developers who develop food products in order to produce healthier recipes that will be acceptable by consumers. Because our five senses act as the gatekeepers of our bodies, the benefits of healthy food will be reaped only if our senses accept it. Therefore, consumer reaction, as perceived by the five senses, is considered a vital measure of food development.

Today"s consumers are discerning, demanding and more knowledgeable about food, and expect products which are safe, good value and of high sensory quality. Therefore, knowing consumers" preferences and perceptions of the sensory characteristics of food products is very important to manufacturers of food (Hashmi, 2007).

Sensory evaluation as defined by Sidel and Stone (1993) is „„a scientific discipline used to evoke measure, analyse and interpret those responses to products as perceived through the senses of sight, smell, touch, taste and hearing"". Product developers make use of many „„tools"" in the development of a product. These „"tools"" include for example, chemical tests, microbiological procedures and the use of equipment to determine elasticity, hardness, viscosity, colour, intensity and more. It is unfortunately possible for food products to select similar measurement or result when these tools applied individually, yet still result in different perceptions, acceptability or preferences on consumption of the product (Singh, Ackbardi and Maharaj, 2014).

Sensory analysis can be considered to be an interdisciplinary science that uses human panellist sensory response. Experimental design is used to measure the sensory characteristics and the acceptability of food products as well as many other materials.Since there is no instrument that can replicate or replace the human psychological and emotional response, the sensory evaluation component of any food study is essential and the importance of good experimental design cannot be overemphasised in sensory experiment (Singh *et al*., 2014).

For all sensory assessment methods, human are the measuring instrument. In order for sensory assessment to provide reliable and valid results, the sensory panel must be treated as scientific instrument; that is members of the panel must be screened, calibrated and validated (Meilgaard, Carr and Civille, 2007).

Studies have shown that to have a sensory evaluation panel as a precise tool, the judges have to be carefully selected, the proper physical facilities must be available and statistical analysis must be used (Larmond, 2007). According to the same study the testing environment may influence the results. Thus, it is generally recommended that a special room, in which as many variables as possible is controlled, be used. This room should be noise and odour free and equipped with individual booths to minimise distraction. For difference testing, it is important to select a cooking method which best permit detection of a difference, and to avoid preparations which may add flavour to the samples.

According to Larmond (2007) studies have shown that training reduced differences in scoring levels between judges. Kramer (2012) recommended that judges should be selected based on how well they can detect differences, how consistent they are and how they compare with the panel average.

Sensory methods can be either subjective or objective. The subjective methods are based on the panellist"s preference for a product and bias among panellists is high. Subjective methods are often applied in market research, consumer tests or product development. Objective methods, on the other hand are used in quality inspection. Sensory methods used in inspection of freshness quality of raw fish usually involve grading of the fish quality parameters. The methods must be precise, technically correct and objective rather than subjective (Huss, 2001; Lutenn and Martinsdontir, 2007).

2.17 The Human Senses

The characteristics of food are perceived by the five senses: sight, smell, taste, sound and touch.

2.17.1 Sight

The eyes perceive the initial quality of food, receiving such information as colour, size, shape, texture, consistency and opacity. Colour may accurately indicate ripeness, strength of dilution and the degree to which the food has been heated. Colour is used to evaluate a food"s desirability and acceptability. Burnt fish or meat, greenish banana and dark brown avocado send visual signals that can change a person"s choices. Colour often triggers certain expectations in the mind. For example, the glossy, oily, shiny look of smoked salmon evokes an expectation of quality and good taste. But colour can be deceiving. The quality of food can be masked by changes in colour. For example, if brown colouring is added to the smoked fish to improve its colour, the quality of the fish will be improved. Colour changes alone can increase a food"s acceptability considerably.

Even small visual details such as adjacent or background colours and the relative sizes of areas of contrasting colour can affect a consumer‟s perception. Parameters of sizes and shapes, such as width, length, thickness, particle size, geometric shape and distribution of pieces also provide information on food quality. The shininess, smoothness or roughness of a surface and the clarity of liquids evoke preconceptions about food (Choi, 2013).

2.17.2 Smell

Our sense of smell or olfactory sense, also contributes to our evaluation of food quality. The volatility of odour is related to temperature. Because only volatile molecules, in the form of gas carry odour, it is much easier to smell hot foods than cold ones. For example, hot smoked fish is much easier to detect than cold one, and the odour of a baked item is more intense than that of ice cream.

Lighter molecules that can become volatile are detected by the olfactory epithelium in the nasal cavity through one of the two pathways: (1) directly through the nose or (2) after entering the mouth and flowing retro-nasally, or towards the back of the throat and up into the nasal cavity (Brown, 2008).Human subjects have varying sensitivities to odours, depending on hunger, satiety, mood, concentration, presence or absence of respiratory infections and gender (e.g. Women who are menstruating or are pregnant may perceive odours differently (Maruniak, 1988). Because different people perceive a given odorant differently, identifying a new odour from a food product requires as large a panel as possible to get valid results.

2.17.3 Taste

Taste, or the perception of gustatory input, is the most influential factor in a person‟s selection of a particular food. For a substance to be tasted, it should be dissolved in water, oil or saliva. Taste is perceived by the taste buds, which are primarily on the surface on the tongue, by the mucosa of the palate, and in areas of the throat. In the middle of each taste bud lies a pore, where saliva collects. When food enters the mouth, bits of it are dissolved in the saliva pools and come into contact with cilia, small hair like projections, from the gustatory cells (Brown, 2008). The gustatory cells send signals to the brain through cranial nerves. The brain, in turn, translates the nervous electrical impulses into sensations that people recognize as taste (Brown, 2008).

2.17.3.1 Basic Components of Taste

For many years, four basic tastes were recognised: sweet, salty, sour and bitter. A fifth, umami was added more recently. These tastes can be characterised as follows;

Sweet: Substances that produce sweet taste include sugars, glycols, alcohols, aldehydes and alternative sweeteners (Godshall, 1997).

- **Salty**: The salty taste comes from ionised salts, such as the ions in sodium chloride (NaCl) or other salts found naturally in some foods.
- **Sour**: The sour taste comes from the acid found in foods. It is related to the concentration of hydrogen ions (H^+) that are found in the natural acids of fruits, vinegar, and certain vegetables.
- **Bitter**: Bitterness is imparted by compound such as caffeine (tea, coffee) the bromine (chocolate), and phenolic compounds (grapefruit) (Brown, 2008). Many bitter substances are alkaloids that often are found in poisonous plants.

- **Umami:** This is the most recently defined component of taste, which was identified from a study of seaweed broth (McWilliams, 2008). Umami is a Japanese word meaning „„delicious"" - it is evoked by glutamate compounds, which are commonly found in meats, mushrooms, soy sauce, fish sauce and cheese. Some taste experts do not recognise umami as a taste at this time.

2.17.4 Flavour

Whereas taste relies on the sensation produced through the stimulation of taste buds, flavour is a broader concept. Flavour is the combined senses of taste, aroma and mouth feel. Mouth feel encompasses textural and chemical sensations such as astringency, spice heat, cooling and metallic flavour.

Among the flavour components, aroma is especially important; it provides approximately 75% of the impression of flavour (De Roos, 1997). To get an idea of how the ability of smell affects the perception of flavour, pinch your nose and begin to eat a certain flavour of jelly bean. Then, as you are chewing, unpinch your nose. You will clearly see the difference between when the nose is pinched and unpinched.

2.17.5 Sound

Sound is another sense used in evaluating quality. Sounds such as sizzling, crunching, popping, bubbling, squeaking, dripping, exploding and cracking can communicate much about food. Most of these sounds are affected by water content; thus, their characteristics indicate a food"s freshness and ripeness (Brown, 2008).Sound is detected as vibrations in the local medium, usually air. The vibrations are transmitted via the small bones in the middle ear to create hydraulic motion in the fluid of the inner ear, the cochlea. The cochlea is a spiral canal covered in cilia that, when agitated, sends neural impulses to the brain (Meilgaard, *et al.,* 2007).

2.17.6 Touch

The sense of touch delivers impression of a food‟s texture to us through oral sensations or the skin. Texture is a very complex perception: the first input is visual; second comes touch, either directly through the fingers or indirectly via eating utensils; the third is the feeling in the mouth (mouth feel), as detected by the teeth and tactile nerve cells on the tongue and palate. Texture is the sensory manifestation of the structure or inner makeup of products in terms of their reaction to stress, which are measured as mechanical properties (such as hardness/firmness, adhesiveness, cohesiveness, gumminess, springiness/resilience and viscosity) by the kinaesthetic sense in the muscles of the hands, fingers, tongue, jaws or lips (Meilgaard *et al*., 2007). Texture also includes tactile feel properties, which are measured as geometric properties (that is, grainy, gritty, crystalline, flaky) or moisture properties (that is, wetness, oiliness, moistness, dryness) by the tactile nerves in the surface of the skin or the hands, lips or tongue (Meilgaard *et al*., 2007). The greater surface sensitivity of the lips, tongue, face and hands makes easy detection of small differences in particle size and thermal and chemical properties possible among food products.

2.18 Selection of Panel Members

Sensory evaluation involves evaluation of products or materials by people (respondents/panels/members/panellists) with/without the assistance of technology. Thus it is important that these persons be:

- Screened to eliminate for example personal prejudice, preference and acceptability to ensure an objective evaluation and differentiation between and description of product characteristics.
- Be trained to perform analytical (laboratory) sensory evaluation procedures repeatedly and are audited and evaluated to ensure that their determinations are consistent.
- Selected to be representative of (target market) consumers (respondents).

2.18.1 Shelf Life of Smoked Fish

The shelf life of food is defined as the maximum length of time a given product is fit for human consumption. For fish, it is the time from when the fish is caught until it is no longer fit to eat (Huss *et al*, 2005). Most fish are caught in nets, or with lines with baited hooks. Hence it is difficult to control the initial quality of the raw material with any degree of repeatability. The stress and mechanical damage caused during capture, the structure and composition of the fish, pH and storage temperature prior to landing all influence the spoilage rate of the fish (Church, 2008).

It cannot be overemphasized that most smoked fish products, unless canned and sterilized by retorting have little more shelf life than fresh fish. This implies that smoked fish should be handled, packaged and stored almost like fresh fish, not a highly preserved product. A dried-salt fish containing more than 10% salt and perhaps 25% water or ""jerky"" type smoked fish containing some salt and perhaps 2% water has a fairly long shelf life due to the low water activity. However, most smoked fish demanded by today"s markets are low salt, high water content items that are ideal substrates for growth of microorganism.

Fish, like meat, spoil because of bacterial growth. These factors all influence the sensory quality of fish during storage time. At the end of the shelf life, odour, flavour, texture, and appearance have become unpleasant (Church, 2008).

2.18.2. Sensory Changes

The first sensory changes that occur in fish during storage are concerned with the appearance and texture. The characteristic flavour of fish normally develops in the first couple of days of storage (Church, 2008). It has been estimated that the characteristic sensory changes in fish vary considerably depending on species and storage method (Huss, 2005; Church 2008). Fish spoilage can be divided into four distinct phases, according to Huss (2005) and Church (2008):

- Phase 1: Very fresh, sweet, seaweed and delicate taste
- Phase 2: Loss of characteristic odour and taste, flesh neutral (no off-flavours), texture pleasant
- Phase 3: There is a sign of spoilage and a range of volatile, unpleasant-smelling substances are produced depending on the fish species and type of spoilage (aerobic, anaerobic). One of the volatile compounds may be trim ethylamine (TMA) derived from the bacterial reduction of trimethylaminoxide (TMAO). There is a very characteristic “fish” smell. Production of volatile unpleasant smelling odours/flavours starting with slightly sour, fruity and bitter off-flavours. During later stages sickly sweet, cabbage like, ammonia, sulphurous and rancid smells develop. The texture becomes either soft and watery or dry and tough
- Phase 4: The fish is spoiled and putrid

In phases 1 and 2 the major changes are due to autolytic reactions, but in phases 3 and 4 the major changes are due to bacterial activity.

2.18.3 Autolytical and chemical changes

pH fall

The glycogen levels of fish muscles are lower than those of mammalian muscles, mainly due to the stress of capture. As a result, the pH of fish muscle remains high after death (>6.0) favouring microbial growth and enzymatic activity (Church 2008: Gram and Huss, 2006).

2.18.4 Autolytic changes

Autolysis or "self-destruction" of fish is due to enzyme activity. Depending on the type of enzymes and the substrate where it actuates, the changes that can be encountered are for instance, belly-bursting, gapping of fillets, softening and loss of fresh fish flavour.

2.18.5 Oxidation

Consumers perceive rancidity as an unacceptable taste: Typically soapy, stale and linseed oil flavours are detected. There are two types of rancidity, hydrolytic and oxidative. In the case of hydrolytic rancidity, the off-flavour is caused by free amino acids and is generally caused by a combination of micro-organisms and moisture. Oxidative rancidity is a much more common problem than hydrolytic rancidity. Oxygen attacks unsaturated fatty acids giving hydro peroxides which degrade into off-flavour compounds (Church, 2008).

2.18.6 Bacteriological Changes

The first stage of fish spoilage is dominated by endogenous enzymes, whilst the bacterial flora of the gut cavity, gills and skin adapt to the changing environmental conditions (Church, 2008).

The wide range of fish species, the vastly different environments from which they are harvested and the variety of the microbiological sampling techniques used, has resulted in widely ranging reports in numbers of organisms on fish. The bacterial flora of cold water fish is dominated by the psychrotropic Gram negative genera. Organisms involved belong to the genera *Acinetobacter, Flavobacterium, Moraxella, Shewanella* and *Pseudomonas*. Members of the *Vibrionaceae* (*Vibrio* and *Phosphobacterium*) and the *Aeromonadaceae* (*Aeromonas spp*.) are also common aquatic bacteria, whilst Gram-positive organisms such as *Bacillus, Micrococcus, Clostridium* and *Lactobacillus* can also be found in varying proportions (Huss, 2005). Shewan (2002) concluded that the gram-positive *Bacillus* and *Micrococcus* dominate in fish from tropical waters. However, others have found that the micro flora on tropical fish is very similar to that on temperate species but with a slightly higher load of Gram-positive and enteric bacteria (Huss, 2005). Many of the organisms present on spoiled fish play no active role in spoilage (Huss, 2005).

A clear distinction should always be made between “spoilage flora” and “spoilage bacteria”. Spoilage flora refers to the bacteria present on the fish when considered spoiled, whereas spoilage bacteria are the bacteria responsible for producing the off odours and off-flavours in the spoiled fish (Church, 2008).

2.19 The Fish Smoking Process in the Shelf Life of the Fish

Fish smoking is undertaken in either one of three different ways: cold, hot or chemically smoked. Traditionally, fish are either hot or cold smoked using the smoke from burning or smouldering hardwood (commonly oak) logs or chips. The amount of exposure that the fish get to the heat generated by the burning wood determines whether the fish protein denatures (cooks). The temperature and the exposure time to smoke are the primary differences between hot and cold smoking (Arvanitoyannis, Palaiokostas and Panagiotaki, 2009).

More recently, chemical smoking using wood smoke condensate has become available. Referred to anecdotally as mechanical smoking, fish are loaded into a sealed vessel (which can be heated or not). Smoky air is blown across the fish to flavour the flesh. The smoky air is generated either by using condensate-derived smoke (solid or liquid) or by burning hardwood in a separate compartment which is external to the kiln holding the fish. Mechanical smoking attempts to mimic the temperature ranges found inside traditional hot and cold smokers. The primary advantage of mechanical smoking is that it can provide a more consistently reproducible product as a consequence of electronic control over kiln temperature and air flow/smoke application (if smoke condensate is used). For mechanical smoking, the key factor for reproducibility is not to vary the smoke condensate source and composition, since condensate change influences the sensory attributes and shelf-life of the finished product (Martinez, Salmeron, Guillen and Casas, 2007).

2.19.1 Chilled Storage and Freezing

Large quantities of seafood are harvested from cold water, therefore the microflora associated with fish tends to predisposed to low temperature survival and growth may not be inhibited as effectively by refrigeration as the microflora associated with other foods (Nickelson, Finne and Vanderzant, 2010). Adequate refrigeration for seafood is consequently more important for controlling both spoilage organisms and those of public health concern compared with other animal-derived foodstuffs.

There is little evidence that prolonged frozen storage, either of the raw fish or packed product results in significant reductions to *L. monocytogenes* numbers. Furthermore, sub-zero temperatures do not cause sufficient injury to *L. monocytogenes* cells to affect their subsequent regrowth at chill temperatures after thawing fish (Gram, 2001; El-Kest, Yousef and Marth, 2011). Gram (2001) hypothesised that the high lipid concentrations found in fish flesh may protect bacteria against sub-zero temperatures and ice formation damage. As might be expected, given the observation that long-term frozen storage does not significantly affect *L. monocytogenes* viability, unpublished preliminary work undertaken at the Danish Institute for Fisheries Research (cited by Gram, 2001) determined that the growth of *L. monocytogenes*in cold-smoked salmon was not significantly affected by the ice formation at the point of freezing.

There appears to be little in the published literature relating to the common practice of freezing raw fish prior to smoking, and any consequences to *L. monocytogenes* numbers after smoking. However, there is limited information in related areas. For example, 250 samples of frozen sushi from supermarkets and fresh sushi from sushi bars in Northern Germany were surveyed for *L. monocytogenes* contamination. Only three samples were found to contain *L. monocytogenes* (Atanassova, Reich and Klein, 2008) and all three isolates were from fresh sushi. Generally, when other hygiene indicators such as *Escherichia coli* were determined; the fresh sushi was of a poorer microbiological quality than frozen sushi. Evidence of this type however is at best considered anecdotal because although sushi is raw fish, the foodstuff is minimally processed before consumption. Thus, it may not be appropriate to interpret differences between fresh and frozen fish used for sushi as a relevant indication of the status of fresh or frozen raw fish destined for smoking. Atanassova (2008) and colleagues concluded that the sushi processing stages may influence the microbiological quality of the sushi and that the final product status was dependant on the skills and habits of the cooks preparing it.

In conclusion there is quite a strong body of evidence that shows *L. monocytogenes* on fish flesh is largely unaffected by freezing, even for extended periods of time.

CHAPTER THREE

METHODOLOGY

3.0 Introduction

Chapter three constitutes the methodology used in conducting the research work. It looks at the research design, selection and collection of the research materials, material preparation, and experimental procedures and the data analysis.

3.1 Research Design

Experimental design was assigned as the research design for this study. Experimental design was chosen because this work involved the study of cause-effect relationship resulting from manipulation of research factors; six briquettes from sawdust of six timber species and maize cobs, frozen mackerel, firewood and sensory evaluation.

The study also assessed the sensory characteristics of the fish smoked with the six species of briquettes and the shelf life of the smoked fish. Factorial experiment in complete randomized design was employed for the study. Trochim (2016) reported that randomized experiment generally is the most appropriate research design when the interest of the researcher is in establishing a cause –effect relationship.

3.2 Population

The targeted group for the research includes consumers of smoked fish selected from the UEW-K campus. The population for the study was fifteen (15).

3.3 Sampling Procedures and Sample Size

Purposive random sampling method was used to select 15 respondents for the study. The researcher used the purposive sampling method because the researcher had specific respondent in mind (fish consumers) who were trained for the sensory evaluation.

3.4 Instruments for Data Collection

The main instruments used to gather primary data was questionnaire and sensory evaluation form. The questionnaire was structured to consist of closed ended and open ended type of questions in order to elicit feedback from respondents.

3.5 Materials and Methods

3.5.1 Source of Materials

Briquettes from six timber species, *Triplochiton scleroxylon* (Wawa), *Ceiba pentandra* (ceiba), *Aningeria robusta* (Asafina), *Terminalia superb* (Ofram), *Celtis mildbreadii* (celtis), *Piptadenia africana* (Dahoma), were selected for the smoking of the fish. These briquette species were collected from the Wood Department of University of Education, Winneba-Kumasi. Firewood was bought from Tanaso Kumasi.

Frozen mackerel was obtained from a cold store at Asafo Market. Mackerel was chosen because it is one the most consumed fishes in Ghana. The smoker (drum type) was also obtained from Asafo fish smoking centre. Selection of smoker type was based on its availability in the region and it"s mostly used by fish smokers in Ashanti Region.

3.5.2 Methods

3.5.2.1 Pre – Study Method

Before the main experiment was carried out, pre- trial was done to determine the suitability of the briquettes species as a source of for fuel for smoking fish and its effects on the sensory characteristics of the fish smoked. The results of the pre-trial were good but fell short of time and fuel consistency and were therefore considered during the main experiment.

3.6 Sample Preparation

3.6.1 Flow Chart for smoking fish

Flow chart of the experiment is presented below:

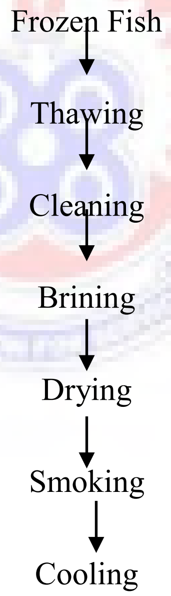

Figure 3.1: Flow chart for smoking fish

Source: Authors construct (2016)

3.7 Product Preparation

3.7.1. Frozen Fish

Frozen Atlantic mackerel (*Scomber scombrus*) was obtained from Asafo and was transported to the food laboratory of the University of Education Winneba, Kumasi.

3.7.2 Thawing

The frozen fish were thawed in the air at a temperature of 32°C for four hours. The thawing process allowed the fish to change from a frozen state to a soft one, and thus the stiffness of the fish was lost for the fish to be used easily.

3.7.3 Cleaning

The fishes were washed under running water to remove any dirt on the fish and to reduce the microbial load the fish. Head and fins of the fishes were not removed. They were left on the fish.

3.7.4 Brining

The fishes were soaked in a salt solution for 1 hour.Enough time was allowed to ensure salt is present throughout entire fish. Two teaspoon of salt to one litre of water was used to salt every three pounds of fish. Brine was stirred from to time to allow the fish to pick up the salt and was removed after the 1hour.

3.7.5 Drying

Brined fishes were laid on a rack for water to drain and to partially dry the fish after brining. The fishes were left to dry in the air for one hour.

3.7.6 Smoking

The smoker (barrel type) was prepared to be used for the smoking. It was cleaned, and a little oil was used to smear on the rack to prevent the fish from sticking on to it. Six briquettes species: Wawa, Ofram, Asafina, Celtis,Dahoma and Ceiba were used as the source of fuel for smoking the fish. The fish were smoked in batches; and with each batch of fish smoked, 600g of briquettes of each specie was measuredand used for smoking the fish.Briquettes were measured with the Camry Dial Spring (Made in China) weighing scale.

Between 4-6 fishes depending on their sizes (body weight between 200-300g and body length between 25-30cm) were arranged on the smoker rack. The fish were smoked dried starting with smothering smoke. Smoking lasted for two hours with each batch of the fish smoked with each briquette specie. The fish were hot smoked at 60- 82°C, thus, fish was cooked and smoked at the same time. The temperature during smoking was recorded with 20 minutes interval. The temperature in the centre of the fish was measured during smoking by an Eisco Red Spirit -10 to 110 1 C, Grad (P K/ 20) thermometer.

Firewood was also used to smoke the mackerel. About 25kg of firewood was used to smoke the fish and fish smoked with firewood also lasted for two hours.Firewood smoked was used as control.

3.7.7 Cooling

The smoked fish products were cooled to temperature of 30°C and were labelled for sensory analysis.

3.8 Sensory Analysis

3.8.1 Sensory Panel

Fifteen panellists of University of Education, Winneba, Kumasi students participated in the sensory evaluation of the smoked fish. They were selected ahead of time by a procedure as described by Meilgaard, *et al*, (1991). The members of the panel were previously trained especially in quantitative descriptive analysis for colour, texture, flavour and taste attributes of the smoked fish.

3.8.1.2 Sensory Evaluation Procedure

Seven different samples were evaluated by each panellist. Each panellist was seated in a separate booth under normal light in the sensory evaluation room and used the sensory evaluation form. The smoked fish were cut into smaller sizes and each portion was put on a side plate and placed before each panellist. One after the other the panellist assessed the sensorial characteristics of the fish smoked with all the briquettes species, and the firewood which served as control. Sample 1 contained fish smoked with Celtis briquette. Sample 2 contained fish smoked with Dahoma briquette. Sample 3 contained fish smoked with Asanfena. Sample 4 contained smoked with Ceiba briquette. Sample 5 contained fish smoked with Ofram briquette. Sample 6 contains fish smoked with Wawa briquette while sample 7 contained fish smoked with firewood. The samples were stored in a food warmer prior to the sensory evaluation. The fish was served in disposable plates for the selected panellists. The panellists were given sensory evaluation form based on colour, taste, flavour and texture. Panellists were provided with water to rinse their mouths after scoring each sample of the fish smoked with the briquettes. The scores ranged between 1 to 5, where;

1. Like very much
2. Like moderately
3. Neither like nor dislike
4. Dislike moderately
5. Dislike very much

3.9 Data Analysis

The data analysis involved reducing the raw data into a manageable size, developing summaries and applying statistical inferences. The following steps were be taken to analyze the data for the study. The data collected was edited to detect and correct, possible errors and omissions that occurred to ensure consistency across respondents. Raw data obtained from a study is useless unless it is transformed into information for the purpose of decision making (Emery and Couper, 2003).

The SPSS version 16 was used to analyse the primary data. Data was presented in tabular form, graphical and narrative forms. In analyzing the data, descriptive statistical tools such as frequencies, percentages, tables and charts will be used to present the results of the study.

3.10 Ethical Consideration

The consideration of some ethical issues is vital for the completion of research project as well as to make a credible research report. Saunders et al. (2009) have described that to ensure the validity, reliability and quality of the research report, the researcher must follow and maintain relevant ethical issues during the completion of research project. The researcher has to follow and maintain relevant ethical issues. All ethical issues were followed and maintained by the researcher include- honesty, integrity, acknowledgment, confidentiality, objectivity and fairness. The researcher has acknowledged all previous works that have been used in this research report. In similar ways, the researcher followed and maintained other relevant ethical during the collection of primary and secondary data and information from the parties involved in this study

CHAPTER FOUR

PRESENTATION, ANALYSIS AND DISCUSSION OF RESULTS

4.0 Introduction

4.1 Demographic Information of the Respondents

This section contains Tables that show the demographic information of the respondents including the respondent‟s gender, age range and occupation.

Table 4.1: Gender of Respondents

Gender of Respondents	Frequency	Percent
Male	6	40.0
Female	9	60.0
Total	15	100.0

Source: Field survey, (2016)

Table 4.1 shows that 60% of the respondents were females while 40% were males.

Table 4.2: Age Range of the Respondents

Age range of Respondents	Frequency	Percent
20-25 years	2	13.3
26-30 years	3	20.0
31-35 years	4	26.7
36-40 years	4	26.7
41 and above	2	13.3
Total	15	100.0

Source: Field survey, (2016)

Table 4.2 indicates that 26.7% of the respondents were between the age range 31-35 and 36-40 years respectively, 20% were between the age range 26-30 years while 13.3% were between the age range 20-25 years and above 41 years old.

Table 4.3: Occupation of the Respondents

Occupation of the Respondents	Frequency	Percent
Unemployed	3	20.0
Student	3	20.0
public service	4	26.7
Private	2	13.3
self employed	3	20.0
Total	15	100.0

Source: Field survey, (2016)

Table 4.3 depicts that 26.7% of the respondents were public servants, 20% were unemployed, self-employed and students respectively while 13.3% were private workers.

4.2 Sensory Characteristics of the Celtis Briquette smoked fish

Table 4.4 shows the sensory characteristics of the Celtis briquette smoked fish

Table 4.4: Sensory Characteristics of the Celtis Briquette smoked fish

Sample 1: Celtis Briquette smoked fish	1 Freq. (%)	2 Freq. (%)	3 Freq. (%)	4 Freq. (%)	5 Freq. (%)	Total Freq. (%)
Colour	3 (20%)	5 (33.3%)	4 (26.7%)	2 (13.3%)	1 (6.7%)	15 (100%)
Taste	6 (40%)	2 (13.3%)	3 (20%)	2 (13.4%)	2 (13.3%)	15 (100%)
Flavour	3 (20%)	3 (20%)	2 (13.3%)	4 (26.7%)	3 (20%)	15 (100%)
Texture	4 (26.7%)	2 (20%)	1 (6.7%)	5 (33.3%)	3 (20%)	15 (100%)

1- Like very much, 2- Like moderately, 3- Neither like nor dislike, 4- Dislike moderately 5-Dislike very much

Source: Field survey, (2016)

Table 4.4 shows that 53.3% of the respondents liked the colour of the Celtis briquette smoked fish, 26.7% of the respondents were neutral while 20% of the respondents disliked the colour of the Celtis briquette smoked fish. The study indicates that 53.3% of the respondents liked the taste of the Celtis briquette smoked fish, 26.7% of the respondents disliked the taste while 20% were neutral. The study depicts that 46.7% of the respondents disliked the flavour of the Celtis briquette smoked fish, 40% of the respondents liked the flavour while 13.3% were neutral. The study shows that 53.3% of the respondents disliked the texture of the Celtis briquette smoked fish, 46.7% liked the texture while 6.7% were neutral.

Figure 4.1 shows the samples of the Celtis briquettes used for the smoking of the fish.

Figure 4.1: Sample of the Celtis briquettes used for the smoking of the fish

Source: Field survey, (2016)

Figure 4.2 shows the visual display of the characteristics of the Celtic briquettes smoked fish

Figure 4.2: Celtis briquettes smoked fish

Source: Field survey, (2016)

4.3 Sensory Characteristics of the Dahoma Briquette smoked fish

Table 4.5 indicates the sensory characteristics of the Dahoma Briquette smoked fish

Table 4.5: Sensory Characteristics of the Dahoma Briquette smoked fish

Sample 2: Dahoma Briquette smoked fish	1 Freq. (%)	2 Freq. (%)	3 Freq. (%)	4 Freq. (%)	5 Freq. (%)	Total Freq. (%)
Colour	2(13.3%)	4(26.7%)	3(20%)	6(40%)	-	15(100%)
Taste	5 (33.3%)	3 (20%)	3(20%)	3(20%)	1 (6.7%)	15(100%)
Flavour	3 (20%)	4(26.7%)	1(6.7%)	4(26.7%)	3 (20%)	15(100%)
Texture	5 (33.3%)	3(20%)	-	5(33.3%)	2(13.3%)	15(100%)

Key: 1- Like very much, 2- Like moderately, 3- Neither like nor dislike, 4- Dislike moderately, 5-Dislike very much

Source: Field survey, (2016)

Table 4.5 indicates that 40% of the respondents liked the colour of the Dahoma briquette smoked fish, 40% disliked the colour while 20% were neutral. Moreover, 53.3% of the respondents liked the taste of the Dahoma briquette smoked fish, 26.7%

disliked the taste while 20% were neutral. The study further shows that 46.7% of the respondents liked the flavour of the Dahoma briquette smoked fish, 46.7% of the respondents disliked the flavour while 6.7% were neutral. Furthermore, 53.3% of the respondents liked the texture of the Dahoma briquette smoked fish while 46.6% disliked the texture. Texture is the sensory manifestation of the structure or inner makeup of products in terms of their reaction to stress, which are measured as mechanical properties (such as hardness/firmness, adhesiveness, cohesiveness, gumminess, springiness/resilience and viscosity) by the kinaesthetic sense in the muscles of the hands, fingers, tongue, jaws or lips (Meilgaard, 2007).

Figure 4.3 shows the samples of the Dahoma briquettes used for smoking the fish

Figure 4.3: Sample of Dahoma briquette used for smoking the fish

Source: Field survey, (2016)

Figure 4.4 demonstrated the features of the Dahoma briquettes smoked fish

Figure 4.4: Dahoma briquette smoked fish

Source: Field survey, (2016)

4.4 Sensory Characteristics of the Asanfena Briquette smoked fish

Table 4.6 shows the sensory characteristics of the Asanfena Briquette smoked fish

Table 4.6: Sensory Characteristics of the Asanfena Briquette smoked fish

Sample 3: Asanfena Briquette smoked fish	1 Freq. (%)	2 Freq. (%)	3 Freq. (%)	4 Freq. (%)	5 Freq. (%)	Total Freq. (%)
Colour	8 (53.3%)	7(46.7%)	-	-	-	15(100%)
Taste	6(40%)	5(33.3%)	2(13.3%)	2(13.4%)	-	15(100%)
Flavour	5(33.3%)	5(33.3%)	3(20%)	2(13.3%)	-	15(100%)
Texture	9(60%)	3(20%)	2(13.3%)	1(6.7%)	-	15(100%)

Key: 1- Like very much, 2- Like moderately, 3- Neither like nor dislike, 4- Dislike moderately, 5-Dislike very much

Source: Field survey, (2016)

Table 4.6 depicts that all the 100% respondents liked the colour of the Asafena briquette smoked fish. Moreover, 73.3% of the respondents liked the taste of the Asafena briquette smoked fish, 13.4% disliked the taste while 13.3% were neutral. Furthermore, 66.6% of the respondents liked the flavour, 20% were neutral while 13.3% disliked the flavour. Also, 80% of the respondents liked the texture, 13.3% were neutral while 6.7% disliked the texture.

Figure 4.5 shows the samples of the Asanfena briquettes used for smoking the fish

Figure 4.5: Asafena briquettes used for smoking the fish

Figure 4.5: the features of the Asanfena briquettes smoked fish

Source: Field survey, (2016)

Figure 4.6: Asafena briquette smoked fish

Source: Field survey, (2016)

4.5 Sensory Characteristics of the Ceiba Briquette smoked fish

Table 4.7 shows the sensory characteristics of the Ceiba Briquette smoked fish

Table 4.7: Sensory Characteristics of the Ceiba Briquette smoked fish

Sample 4: Ceiba Briquette smoked fish	1 Freq. (%)	2 Freq. (%)	3 Freq. (%)	4 Freq. (%)	5 Freq. (%)	Total Freq. (%)
Colour	9(60%)	4(26.7%)	2 (13.3%)	-	-	15(100%)
Taste	7(46.7%)	5(33.3%)	3(20%)	-	-	15(100%)
Flavour	8(53.3%)	5(33.3%)	2(13.3%)	-	-	15(100%)
Texture	2(13.3%)	3 (20%)	2 (13.3%)	5(33.3%)	3(20%)	15(100%)

Key: 1- Like very much, 2- Like moderately, 3- Neither like nor dislike, 4- Dislike moderately, 5-Dislike very much

Source: Field survey, (2016)

Table 4.7 shows that 86.7% of the respondents liked the colour of the Ceiba briquette smoked fish while 13.3% of the respondents were neutral. Also, 80% of the respondents liked the taste of the Ceiba briquette smoked fish while 20% were neutral. Moreover, 86.6% of the respondents liked the flavour while 13.3% were neutral. Furthermore, 53.3% of the respondents disliked the texture of the Ceiba briquette smoked fish, 33.3% of the respondents liked the texture while 13.3% were neutral.

Figure 4.7 shows the sample of the Ceiba briquettes used for smoking the fish

Figure 4.7: Ceiba briquettes used for smoking the fish

Source: Field survey, (2016)

Figure 4.8 shows the features of the Ceiba briquettes smoked fish

Figure 4.8: Ceiba briquette smoked fish

Source: Field survey, (2016)

4.6 Sensory Characteristics of the Ofram Briquette smoked fish

Table 4.8 shows the sensory characteristics of the Ofram Briquette smoked fish

Table 4.8: Sensory Characteristics of the Ofram Briquette smoked fish

Sample 5: Ofram Briquette smoked fish	1 Freq. (%)	2 Freq. (%)	3 Freq. (%)	4 Freq. (%)	5 Freq. (%)	Total Freq. (%)
Colour	3(20%)	7(46.7%)	5(33.3%)	-	-	15(100%)
Taste	5(33.3%)	3(20%)	2(13.3%)	3(20%)	2 13.3%)	15(100%)
Flavour	4(26.7%)	3(20%)	2(13.3%)	6(40%)	-	15(100%)
Texture	7(46.7%)	5(33.3%)	3(20%)	-	-	15(100%)

Key: 1- Like very much, 2- Like moderately, 3- Neither like nor dislike, 4- Dislike moderately, 5-Dislike very much

Source: Field survey, (2016)

Table 4.8 indicates that 66.7% of the respondents liked the colour of the Ofram briquette smoked fish while 33.3% were neutral. Moreover, 53.3% of the respondents liked the taste, 33.3% disliked the taste while 13.3% were neutral. Furthermore, 46.7% of the respondents liked the flavour of the Ofram briquette smoked fish, 40% disliked the flavour while 13.3% were neutral. 80% of the respondents liked the texture of the Ofram briquette smoked fish while 20% were neutral.

Figure 4.9 shows the Ofram briquettes used for smoking the fish

Figure 4.9: Ofram briquettes used for smoking the fish

Source: Field survey, (2016)

Figure 4.10 displayed the features of the Ofram briquettes smoked fish

Figure 4.10: Ofram briquette smoked fish

Source: Field survey, (2016)

4.7 Sensory Characteristics of the Wawa Briquette smoked fish

Table 4.9 shows the sensory characteristics of the Wawa Briquette smoked fish

Table 4.9: Sensory Characteristics of the Wawa Briquette smoked fish

Sample 6: Wawa Briquette smoked fish	1 Freq. (%)	2 Freq. (%)	3 Freq. (%)	4 Freq. (%)	5 Freq. (%)	Total Freq. (%)
Colour	10(66.7%)	3(20%)	2(13.3%)	-	-	15(100%)
Taste	9(60%)	3(20%)	1(6.7%)	2(13.3%)	-	15(100%)
Flavour	7(46.7%)	3(20%)	2(13.3%)	3(20%)	-	15(100%)
Texture	8(53.3%)	4(26.7%)	3(20%)	-	-	15(100%)

Key: 1- Like very much, 2- Like moderately, 3- Neither like nor dislike, 4- Dislike moderately, 5-Dislike very much

Source: Field survey, (2016)

Table 4.9 shows that 86.7% of the respondents liked the colour of the Wawa briquette smoked fish while 13.3% were neutral. Moreover, 80% of the respondents liked the taste, 13.3% disliked the taste while 6.7% were neutral. The study indicates that 66.7% of the respondents liked the flavour of the Wawa briquette smoked fish, 20% disliked the flavour while 13.3% were neutral. Furthermore, 80% of the respondents liked the texture of the Wawa briquette smoked fish while 20% were neutral.

Figure 4.11 shows the sample of the Wawa briquette used for the study

Figure 4.11: Sample of the Wawa briquette used for the study

Source: Field survey, (2016)

Figure 4.12 displayed the characteristics of the Wawa briquette smoked fish

Figure 4.12: Wawa briquette smoked fish

Source: Field survey, (2016)

4.8 Sensory Characteristics of the Firewood Smoked Fish

Table 4.10 shows the sensory characteristics of the firewood smoked fish

Table 4.10: Sensory Characteristics of the firewood smoked fish

Sample 7: Firewood smoked fish	1 Freq. (%)	2 Freq. (%)	3 Freq. (%)	4 Freq. (%)	5 Freq. (%)	Total Freq. (%)
Colour	3 (20%)	2(13.3%)	2(13.3%)	2(13.3%)	6(40%)	15(100%)
Taste	6 (40%)	2(13.3%)	3 (20%)	2(13.4%)	2(13.3%)	15(100%)
Flavour	3 (20%)	3 (20%)	2(13.3%)	4(26.7%)	3 (20%)	15(100%)
Texture	4(26.7%)	2 (20%)	1(6.7%)	5(33.3%)	3(20%)	15(100%)

Key: 1- Like very much, 2- Like moderately, 3- Neither like nor dislike, 4- Dislike moderately, 5-Dislike very much

Source: Field survey, (2016)

Table 4.10 indicates that 53.3% of the respondents disliked the colour of the firewood smoked fish, 33.3% liked the colour while 13.3% were neutral. To add more, 53.3% liked the taste, 20% were neutral while 26.7% disliked the taste. Furthermore, 46.7% of the respondents disliked the flavour, 40% liked the flavour while 13.3% were neutral. Also, 53.3% of the respondents disliked the texture, 46.7% liked the texture while 6.7% were neutral.

Figure 4.13: Sample firewood for smoking of fish

Source: Field survey, (2016)

Figure 4.14: Firewood smoked fish

Source: Field survey, (2016)

Shelf Life of the Smoked Fish with all the Species of the Briquettes

Samples of the fish smoked with each briquette specie: Wawa, Asafina, Ceiba, Dahoma, Ceitis and Ofram were studied for their shelf life under room temperature. The fishes were wrapped in transparent polythene and kept on a shelve in a room with the minimum temperature of 24°C and highest temperature of 34°C for the eight days that the fishes were observed for changes in their sensorial characteristics.

On the first and second day that the fishes were kept, it was observed that colour, texture, flavour and taste remained unchanged. On the third day, flavour, taste and texture begun to change, however, the colour of the fishes was without any remarkable change. From the fourth to the fifth day, off flavour was detected and the taste was unacceptable.

On the sixth day of the shelf life, colour begun to change to a darker one and fish developed an unpleasant smelling odour. Texture of fish became soft and watery. On the seventh and eighth days, which were the later stages of the shelf life of the fish, the fish developed a sulphurous and rancid smell, after which fish became spoilt and putrid. At the end of the shelf life, colour, flavour, texture, and taste all became unpleasant. All the fish smoked with the six species of the briquettes exhibited almost similar changes in the sensorial characteristic of the smoked mackerel.

CHAPTER FIVE

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

5.1 Summary

The purpose of the study was to investigate the effects of six briquette species on smoke fish. Experimental design was assigned as the research design for this study. The population for the research includes consumers of smoked fish selected from the UEW-K campus. The population for the study was fifteen (15). Purposive sampling method was used to select 15 respondents for the study. The main instruments used to gather primary data was sensory evaluation report. The data gathered was analysed statistically using Statistical Package for Social Sciences (SPSS) software version 16. Tables and figures were used to present the results of the study. Briquettes from six timber species, *Triplochitonscleroxylon* (Wawa), *Ceibapentandra* (ceiba), *Aningeriarobusta* (Asafina), *Terminalia superb* (Ofram), *Celtismildbreadii* (celtis), *Piptadeniaafricana* (Dahoma), were selected for the smoking of the fish. These briquette species were collected from the Wood Department of University of Education, Winneba-Kumasi. Frozen mackerel was obtained from a cold store at Asafo Market. The sample of the mackerel (*Thunnusthynnus*) (body weight between 200-300g and body length between 25-30cm) bought was transferred to the food laboratory of University of Education, Winneba. The fish samples were divided into seven batches and prepared separately for smoking. They seven samples were served in side for the selected panelists. In analyzing the quantitative data, descriptive statistical tools such as frequencies, percentages, tables and charts were used to present the results of the study.

5.2 Major Findings

5.2.1 Sensory Characteristics of the Celtis Briquette Smoked Fish

The study shows that 53.3% of the respondents liked the colour of the Celtis briquette smoked fish,53.3% of the respondents liked the taste of the Celtis briquette smoked fish, 46.7% of the respondents disliked the flavour of the Celtis briquette smoked fish, while 53.3% of the respondents disliked the texture of the Celtis briquette smoked fish.

5.2.2 Sensory Characteristics of the Dahoma Briquette Smoked Fish

The study indicates that 40% of the respondents liked the colour of the Dahoma briquette smoked fish while 40% disliked the colour. Moreover, 53.3% of the respondents liked the taste of the Dahoma briquette smoked fish, 46.7% of the respondents liked the flavour of the Dahoma briquette smoked fish while 46.7% of the respondents disliked the flavour, 53.3% of the respondents liked the texture of the Dahoma briquette smoked fish.

5.2.3 Sensory Characteristics of the Asanfena Briquette Smoked Fish

The study depicts that all the 100% respondents liked the colour of the Asafena briquette smoked fish. Moreover, 73.3% of the respondents liked the taste of the Asafena briquette smoked fish, 66.6% of the respondents liked the flavour, 80% of the respondents liked the texture.

5.2.4 Sensory Characteristics of the Ceiba Briquette Smoked Fish

The study shows that 86.7% of the respondents liked the colour of the Ceiba briquette smoked fish, 80% of the respondents liked the taste of the Ceiba briquette smoked fish, 86.6% of the respondents liked the flavour, while 53.3% of the respondents disliked the texture of the Ceiba briquette smoked fish.

5.2.5 Sensory Characteristics of the Ofram Briquette Smoked Fish

The study indicates that 66.7% of the respondents liked the colour of the Ofram briquette smoked fish, 53.3% of the respondents liked the taste, 46.7% of the respondents liked the flavour of the Ofram briquette smoked fish, while 80% of the respondents liked the texture of the Ofram briquette smoked fish.

5.2.6 Sensory Characteristics of the Wawa Briquette Smoked Fish

The study shows that 86.7% of the respondents liked the colour of the Wawa briquette smoked fish, 80% of the respondents liked the taste, 66.7% of the respondents liked the flavour of the Wawa briquette smoked fish, while 80% of the respondents liked the texture of the Wawa briquette smoked fish.

5.2.7 Sensory Characteristics of the firewood Smoked Fish

The study indicates that 53.3% of the respondents disliked the colour of the firewood smoked fish, 53.3% liked the taste, 46.7% of the respondents disliked the flavour, while 53.3% of the respondents disliked the texture.

5.3 Shelf Life of Briquettes Smoked Fish

The study indicated that the smoke preserved the fish for a short period of time. The fish were kept for close to three days without any remarkable change in the sensorial characteristics. From the fourth to the fifth day changes begun to occur in the flavour and the taste of the fish. Colour of fish started changing on the sixth day and an unpleasant smell developed in fish.

On the eighth day, the fish developed a sulphurous rancid smell after which fish became spoilt and putrid.

5.3 Conclusions

The study concluded that briquettes types from Celtis, Dahoma, Ceiba, Ofram, Wawa and Asafena could be used as an alternative fuel to smoke fish and they imparted on the sensorial characteristics of the smoked mackerel. The study revealed that all the respondents preferred the colour of the Asafena briquette smoked fish to Celtis, Dahoma, Ceiba, Ofram, Wawa briquette smoked fish and firewood smoked fish.

Moreover, majority of the respondents preferred the taste of Ceiba and Wawa briquette smoked compared to Celtis, Dahoma, Asafena, Ofram briquette smoked fish and firewood smoked fish.

Furthermore, majority of the respondents preferred the flavour of the Ceiba, Asafena and Wawa briquette smoked fish compared to Celtis, Dahoma, Asafena, Ofram briquette smoked fish and the firewood smoked fish.

To add more, majority of the respondents preferred the texture of the Asafena, Ofram and Wawa briquette smoked fish compared to Celtis, Dahoma, Ceiba and disliked the texture of the firewood smoked fish.

Also, the study revealed that shelf life of the smoked mackerel lasted for two days at room temperature. After the third day, changes begun to occur in the sensorial characteristics of the smoked fish and at the end of the shelf life colour, texture, taste and flavour were all unpleasant.

5.4 Recommendations

According to the major findings and conclusions of the study, the following recommendations were made,

1. The CSIR through the Food and Drugs Authority (FDA) should organise periodic workshops and training programmes to educate fish mongers regarding the use of varieties of wood briquettes to smoke fish and improve the flavour, taste, texture and colour of the smoked fish for commercial and home use.
2. The CSIR and the Food and Drugs Authority should conduct thorough research into the chemical constituents of the wood briquettes in order to ensure consumer safety.
3. The Bank of Ghana through the micro finance institutions should provide soft loans to fish mongers so that they can purchase storage facilities to store fish on commercial bases.
4. Based on the findings of the sensory characteristics of the fish smoked with the six briquette species, Asafena briquette is recommended mostly for the smoking of fish.

5.5 Suggestions for Further Research

Based on the recommendations of the study, the researcher suggested that a similar study should be conducted to investigate the effects of the chemical components of wood briquettes on consumer"s health. Moreover, the researcher suggested that a study should be conducted to assess the use of briquettes to heat traditional oven for the baking of bread.

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APPENDIX I

UNIVERSITY OF EDUCATION, WINNEBA

COLLEGE OF TECHNOLOGY EDUCATION, KUMASI

DEPARTMENT OF HOSPITALITY AND TOURISM

SENSORY EVALUATION FORM.

This experiment is designed to assess the sensorial characteristics of fish smoked with six briquette species. The success of this experiment depends on how you respond to the sensory evaluation objectively.

Please read and tick [√] the appropriate option (tick one option only for each question asked).

Demographic Data

1. Gender

   Male [ ] Female [ ]

2. Age

   20 – 25 [ ] 26 – 30 [ ] 31 – 35 [ ] 36 – 40 [ ] 41 and above [ ]

3. Occupation

   Unemployed [ ] Student [ ] Public Service [ ]

   Private [ ] Self-employed [ ]

Kindly assess the product based on sensory characteristics presented below using the 1 – 5 scale:

1 – Like very much 2 – Like moderately 3 – Neither like nor dislike 4 – Dislike moderately 5 – Dislike very much

Species	Colour	Taste	Flavour	Texture
Celtis				
Dahoma				
Asanfena				
Ceiba				
Ofram				
Wawa				
Firewood				

Comment

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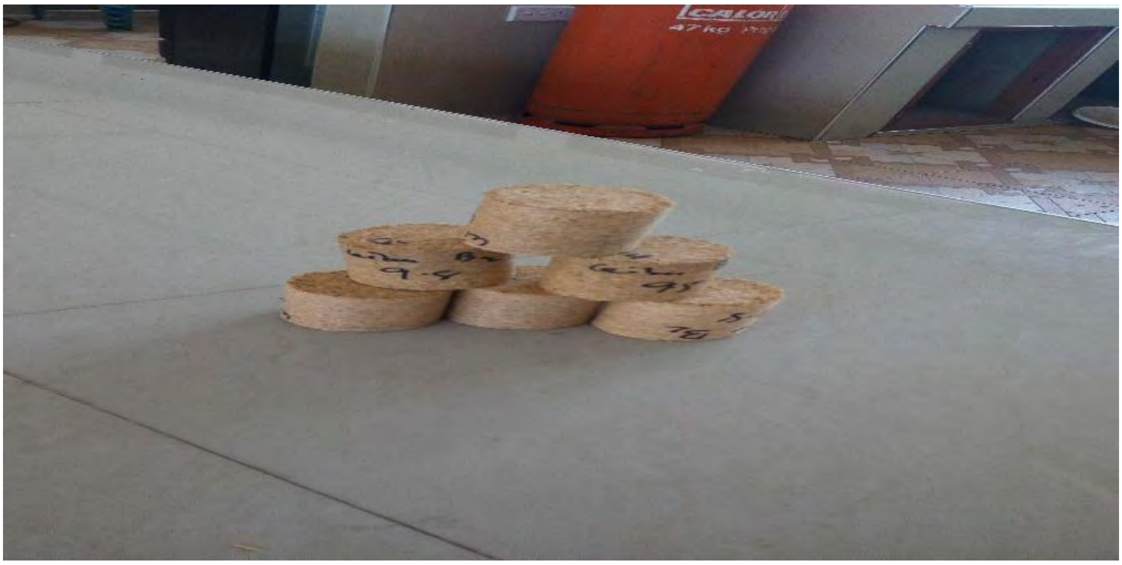
Thank you.

APPENDIX II

Sample of the Celtis briquettes used for the smoking of the fish

Celtis briquettes smoked fish



Sample of Dahoma briquette used for smoking the fish

Dahoma briquette smoked fish

Shows the features of the Asanfena briquettes smoked fish

Asafena briquette smoked fish

Ceiba briquettes used for smoking the fish

Ceiba briquette smoked fish

Ofram briquettes used for smoking the fish

Ofram briquette smoked fish

Sample of the Wawa briquette used for the study

Wawa briquette smoked fish

Sample firewood for smoking of fish

Firewood smoked fish