DEVELOPMENT OF AERATED PITS FOR SHEA BUTTER WASTEWATER TREATMENT

BY

SULAIMAN, Hassan Danlami
MEng/SEET/2017/7057

DEPARTMENT OF AGRICULTURAL AND BIORESOURCES ENGINEERING
SCHOOL OF INFRASTRUCTURE, PROCESS ENGINEERING AND TECHNOLOGY
FEDERAL UNIVERSITY OF TECHNOLOGY
MINNA

JANUARY, 2022

ABSTRACT

Waste disposal is a big challenge in shea butter industry in the presence of tannin, an environmental pollutant which is toxic to soil microbes, makes the waste recalcitrant to biodegradation and unacceptable to animals as feed. Wastes generated during Shea butter processing are indiscriminately disposed thereby becoming menace to the environment. Local method of shea butter production generates more waste than mechanical and chemical methods. This study evaluates the treatment of shea butter wastewater after processing. Shea butter waste, which includes shea butter wastewater were collected from the study site (Kakapangi shea butter processing mill). Thirty (30) litres of the shea wastewater was taken and carefully introduced into the polyethene bags for each of the dug pit. Thereafter, vulcanizing machine with a capacity of 120 HP was used to aerate each of the pit. After every 15 minutes aeration time, sample were collected, from each of the tagged pit and labelled. Subsequent samples were also collected after 3 days, 6 days, 9 days, and 12 days. Atomic absorption spectrometer was used to determine the concentration of lead, cadmium and ammonia while multiple fermentation tube techniques was used for the determination of total coliform in the shea butter waste water. The result revealed that the higher the aeration time, the lower the heavy metals, cyanogenic glycosides and total coliform bacterial concentration in shea butter wastewater. Conclusively, the aeration technique was found or observed to be effective for treating shea butter wastewater. This study is recommended that the aeration technique can be used to lower the level of heavy metals, cyanogenic glycosides and coliform bacterial accumulation. The wastewater from shea butter processing plant should be properly disposed to avoid contamination of water.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATES

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background to the Study

Until the late 1970's when hydrocarbon was discovered in commercial quantity in Oloibiri, present day Bayelsa State, Agriculture remained the mainstay of the economy contributing over 90% of the Gross Domestic Product (GDP) of the country as against the less than 40% it now contributes. Crop production account for an estimated 85%, livestock 10% and the balance made up by fisheries and forestry (Foraminfera Market Research Limited, 2015).

Apart from hydrocarbon, Nigeria has a comparatives Agricultural sector where a variety of products are produced due to the favorable climatic condition, good soil condition and the fact that over 70% of the entire land mass of the country is arable (Foraminfera Market Research Limited, 2015). Nigeria has an edge in the cultivation, processing and export of crude Shea butter in Africa over her counterparts due to the large arable land available for production and the favourable climatic condition. Presently Nigeria is the leading exporter of Shea nuts and butter in the world with a total trade value estimated at $400,000 (Foraminfera Market Research Limited, 2015). As stated earlier, as farming practices are continually devised to intensify farming activities, so the amounts of agricultural wastes continue to increase.

Agriculture is the source of a considerable sum of hard currency that is needed for the control of balance of payment in the country's budget, as well as it is the major source of raw materials for local industry (Foraminfera Market Research Limited, 2015).

Expanding agricultural production has naturally resulted in increased quantities of livestock waste, agricultural crop residues and agro-industrial by-products. There is likely to be a significant increase in agricultural wastes globally if developing countries continue to intensify farming systems. It is estimated that about 998 million tonnes of agricultural waste is produced yearly (Agamuthu, 2009).

Agricultural wastes are defined as the residues from the growing and processing of raw agricultural products such as fruits, vegetables, meat, poultry, dairy products, and crops (Obi *et al.*, 2016). Agricultural wastes are non-product outputs of production and processing of agricultural products that may contain material that can benefit man but whose economic values are less than the cost of collection, transportation, and processing for beneficial use (Obi *et al.*, 2016). Agro-waste as agricultural wastes are also referred to as any form of liquids, slurries, or solids. The content of agro- wastes depends on the type and system of agricultural activities.

The first goal of any waste management system is to maximise the economic benefit from the waste resource and maintain acceptable environmental standards. To be practical, the system must also be affordable and suitable to the operation. If wastes are not properly handle they can pollute surface and groundwater and contribute to air pollution.

Household farms in rural communities generate solid organic wastes such as manure, tree trimmings, grass clippings, and crop residues such as shea butter waste water, shea nut cake, Shea nut residue (kernel residue), rice husk, rice straws, maize stalk, maize husk, maize cobs, cassava peels and stalk, groundnut shells and straws, soyabeans pods, sugarcane bagasse and leaves, and cotton stalk. Organic wastes can amount up to 80 percent of the total solid wastes generated in any farm household. Also, livestock generate large amounts of wastes. Manure production can amount up to 5.27

kg/day/1000 kg live weight, on a wet weight basis (Mbam & Nwibo, 2013; Olorunfemi *et al.*, 2017).

For hundreds of years, shea trees have grown across Africa within a semi-arid zone known as the Sahel-Savannah. During this period, people have used shea nuts to make shea butter, an edible fat that is a part of daily life for millions of Africans and, today, for billions around the world (Lovett & Philips, 2018). The tree is considered a valuable asset in many parts of Africa where it can be found because of its high yielding edible oil for domestic use and products for cosmetic and pharmaceutical uses. It is important for the livelihoods of the rural population as it has been for over centuries (Lovett & Haq, 2013). Almost every part of the tree has its use, for example: the fruit is eaten and the leaves are used as fodder and serve as an ingredient for making alkaline and paint (Lovett & Haq, 2013). When the leaves are put in water, it forms a frothy opalescent liquid, which is used to bath a patient. The shea tree grows well in 19 countries across the African continent, namely: Nigeria, Benin, Burkina Faso, Cameroon, Central African Republic, Chad, Ethiopia, Ghana, Guinea Bissau, Côte d'Ivoire, Mali, Niger, Senegal, Sierra Leone, Sudan, Togo, Uganda, Democratic Republic of Congo and Guinea. Seven West African countries, Nigeria, Ghana, Burkina Faso, Benin, Cote D'Ivoire, Mali and Togo, produce about 500,000 tons of shea nuts, of which an estimated 270,000 tons are exported as raw nuts (Addaquay, 2004). Despite the nutritional and economic benefits of Shea, its processing causes a major environmental issue which has become a major public health and environmental concern. Wastes generated during Shea butter processing are indiscriminately disposed thereby becoming a menace to the environment.

Man has continually sought to improve the quality of life, transforming nature to provide more food, better living conditions and long life. Agricultural mechanization and technology has helped to accomplish this transformation and to achieve many of man's goals (Adeoye *et al*., 2013). The Shea tree belongs to the Sapotaceae family indigenous to Africa. The West African variety of the Shea tree is the *Vitellaria paradoxa.* The tree grows naturally in the wild Savannah belt of West Africa and in over 19 countries across Africa. The Shea fruit consists of a thin, tart, nutritious pulp that surrounds a relatively large, oil-rich nut from which Shea butter is extracted. Africa produces about 1,760,000 ton of raw Shea nuts annually from its wild trees (Mohammed *et al.*, 2013).

It is traditionally processed and locally used as cooking oil or as butter for the skin and hair. Almost every part of the fruit and seed is useful for one purpose or the other. With all the economic importance this tree has, the process of extracting butter from the raw Shea nuts still remains rudimentary and very laborious, in often very dangerous environments ranging from the risks involved in the collecting stage coupled with the ignorance in the management of waste generated from shea processing. Jibreel *et al.* (2013) clearly stated that wastes generated during Shea butter processing are mainly waste brown water, waste black sludge, seed husks and seed shells.

Abagale *et al.* (2012) on the other hand identified shea waste-slurry as another waste extracted from shea processing. Shea waste-slurry is said to be the concentration of solids and the water as well as the fats that remains after the extraction of the oil from the Shea nut and it is used in so many ways; the residue serves as a potential source of fuel for domestic heating.

As urbanization continues to take place, management of solid and liquid waste especially Shea waste-slurry is becoming a major public health and environmental concern in urban areas of developing countries. Considerable quantities of Shea waste-slurry are disposed of on farmlands used for crop production such as cereals and vegetables.

1.2 Statement of the Research Problem

Most of the rural dwellers especially women in Niger State depend on agriculture and petty trading for food and income to take care of family needs and even send their children to schools. Production of Shea butter is one of the main vocations for the rural women in almost all communities in Niger State where shea butter is being produced. Notwithstanding the nutritional and economic benefits of Shea, its processing causes a major environmental issue which has become a major public health and environmental concern.

Wastes generated during Shea butter processing, mainly waste brown water, waste black sludge, seed husks and seed shells are indiscriminately disposed thereby becoming menace to the environment and health threats to dwellers (Jibreel *et al.,* 2013). In Niger State, the predominant system employed by rural women in Shea butter extraction is the traditional manual system. Ajayi (2004) observed that the inefficiency of this method of extraction gives lower yields per unit input of raw materials resulting in most of the raw materials being discarded as waste. These discarded wastes are not properly managed and accumulate causing serious environmental pollution.

These wastes are rich in phenol compounds which can combine with enzymes and other proteins to form polymers of high molecular weight compounds which are not biodegradable and have toxic effects on aquatic organisms and microorganisms

(Sarkodie *et al.*, 2016). These organic wastes have some dramatic effect on soil physical properties as well. Also, hot water which is used for the extraction of shea butter produces heat and wastewater which is oily in nature. This oily wastewater flows freely into the immediate bare land and ceases motion making the place muddy and non-supportive of crop and animal survival. The decomposing organic waste and idle waste water give off unpleasant odour, while also providing conducive atmosphere for flies, mosquitoes and maggots which are threatening to the health of the close dwellers.

1.3 Aim and Objectives of the Study

The aim of this study is to develop cottage aerated pits for shea wastewater treatment and to carry out its performance evaluation. The specific objectives are to:

i. Design and construct aerated pits

ii. Carry out performance evaluation of the constructed pits

iii. Evaluate the effect of aeration, inoculum addition and activated sludge process on aerobic treatment of shea wastewater.

iv. To optimise the process of shea wastewater treatment using inoculum and activated sludge

1.4 Justification of the Study

It has been observed that rural farmers have little knowledge about wastes utilisation and are not well informed about modern economically viable waste utilisation innovation. Farm waste depending on utilisation could either be assets in improving the living standards of farmers, if their benefits are maximised or potential hazards to the environment where they are generated.

A large market exists for shea butter world-wide, particularly as it is organically produced. There is a growing interest in butter from Africa for use as ingredients in the cosmetics, pharmaceutical and confectionary industries. Generation and management of shea butter waste after harvest is of great concern.

The method used in utilising and disposing of these wastes should be put into account. As waste dumped into drainage channels, creeks, rivers, ponds, lagoons and other water bodies create a serious environmental challenge which has adverse effect on air, water and soil conditions, and may constitute a nuisance to those who dwell nearby because our dependence on ground-water, the delicate balance of our water bodies and the economic importance of tourism each provide adequate reason to use the best management practices to handle waste.

1.5 Significance of the Study

This study will provide information and insight for extension agencies and policy makers in ensuring that better waste utilization strategies are extended to farmers especially shea butter processors.

For owners and managers of shea processing plants, this research work will give them a hint on the effects of their shea processing effluents on the environment especially water impoundments in the immediate environment and the need to properly manage these wastes. Finally, some of the unanswered questions of this research will instigate more Researchers and Academicians in the area of waste generation and management until the impact of the malady is ultimately exterminated.

1.6 Scope of the Study

This research work covered only Kakakpangi community shea butter processing centre of Katcha Local Government Area (LGA), Niger State. Also, Shea butter wastewater was the only waste collected and analysed.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Biological Description of Shea Butter Tree

Vitellaria paradoxa, or commonly known as Shea Butter Tree is a deciduous tree with a spreading crown and grows about 25m in height. It is indigenous to Africa and is the sole species in the *Vitellaria* genus. Its bark is corky. The leaves are oblong and clustered at the ends of branches. The flowers are white and clustered at the ends of shoots. The fruits are flat and round containing up to four shiny brown seeds. Fruiting commences 10-15 years after planting but full production occurs at 20-30 years. It then produces nuts for up to 200 years (Ken, 2019). The fruit resembles large plums and takes 4 to 6 months to ripen.

Plate I: Shea tree

Plate II: Shea fruit

2.2 Etymology of Shea Butter Tree

Shea butter tree is known by different names. In South west Nigeria, the butter is known as 'Ori' and the tree is named 'Kade' or 'Kadanya' in Northern Nigeria. In South east Nigeria, the butter is referred to as 'òkwùma'. The common name is *'shiyiri'* or '*shisu'* in the Bambara language of Mali. The tree is called *'ghatiri'* in the Wolof language of Senegal, which is the origin of the French name of the tree and the butter, '*karite'.*

2.3 Shea Butter Tree

The Shea popularly called karité tree, meaning 'tree of life', has many unique properties (Goeja, 2004). Shea trees (*Vitellaria paradoxa*) grow in parklands, dry savannahs and forests on a strip of about 5,000 km that crosses West Africa (IPGRI, 2006), more precisely in Nigeria, Benin, Burkina Faso, Cameroon, Congo, Côte d'Ivoire, Democratic Republic of Congo, Ghana, Guinea, Mali, Niger, Senegal, Sudan, Togo and Uganda (Bup *et al.,* 2014). The Shea tree is usually not planted but selected, saved and protected by farmers in their fields (Rousseau *et al.,* 2015). *Vitellaria paradoxa* is considered a genetically diverse species. Shea is not a wild, but a semi-domesticated crop resulting from long-term anthropogenic selection by indigenous farming communities for specific desirable attributes (vigour, fruit productivity and characteristics, combining ability with crops) through cultivation and fallow cycles (Maranz & Wiesman, 2003, Teklehaimanot, 2004). The Shea tree is well adapted to poor shallow soils and dry environments and has a life span of between 200 and 300 years (Boffa, 1995). It produces its first fruit when it is about 20 years old and reaches its full production by its 45th year (Höfer, 2009).

2.4 Uses and Application of Shea and Shea Products

Almost every part of the shea tree is used, for example, the fruit is eaten and the leaves are used as fodder for animals and a good alkaline for the paint industry. It also has a wide range of medical and industrial applications

2.4.1 Edible uses

Shea provides fruits for direct consumption, providing good quality vitamins and energy to rural dwellers. The shea seeds per kernels (nuts) from these fruits are sold raw as kernels or further processed into shea butter for cooking, skincare, medicine, and other benefits in many areas of human well-being and rural development (Lovett, 2004).

Again, the fruit pulp is an important local nutritional resource, widely eaten by adults and children, and provides a rich source of ascorbic acid, iron, calcium, and vitamins A and B (Hall *et al.*, 1996). The vitamin and mineral-rich vegetable butter extracted from the nut provides a preferred cooking oil of most households especially in rural settlements. It enhances the taste, texture and digestibility of the local dishes.

The kernel of the seed contains a vegetable fat known as shea butter (Karalliedde & Gawarammana 2008). High quality shea butter is consumed throughout West Africa as a cooking fat. Refined fat has been marketed as margarine and baking fat. It is used for pastries and confectionery because it makes the dough pliable (Howes, 1948). They are commonly eaten in savannah regions because they ripen during the land preparation and planting season. The pulp has a sweet flavour. The flowers are also considered an important local food. They are sometimes made into fritters.

2.4.2 Other uses

According to Godfred *et al.* (2015), the trees provide regulation through carbon sequestration, wind breaks, and preventing erosion in addition to serving as a habitat for other organisms and direct provisioning of fruits. Shea butter is also used locally as a skin and hair moisturizer, in soap making, as a waterproofing wax and illuminant. It is applied to African percussion instruments (djembe shells, calabash gourds) to increase the durability of wood and leather tuning straps (Hall *et al.,* 1996).

The wood is used for charcoal, construction, for furniture and as pounding mortars (Dalziel, 1937; Abbiw, 1990). The bark is used for traditional medicines and the latex is used for making glue. Shea trees provided fodder for 70% of surveyed households in Nyankpala, northern Ghana (Poudyal, 2011). The tree regenerates well, and is traditionally favoured and protected by farmers. As a result, it has played a significant role in soil and water conservation and environmental protection in semi-arid West Africa. The husks of the seeds make a good mulch and fertilizer (Akinjoba *et al.*, 2014). Studies on the by-products of shea-butter processing have shown that heavy-metal ions can be removed from aqueous solutions, for example waste water, using *Vitellaria* seed husks. Other uses Shea butter as a vegetable fat obtained from the seed (Howes, 1948).

Allantoin, an un-saponifiable compound, is responsible for the anti-inflammatory and healing effect on the skin. It is used in toothpastes and other oral hygiene products, in shampoos, lipsticks, cosmetic lotions and creams, and other cosmetic and pharmaceutical products (Ken, 2019). Shea butter is also very suitable for making candles because of its high melting point. The black sticky residue, left after oil extraction, is used to fill cracks in walls and also as a waterproofing material. Waste water from shea butter production has pesticidal properties. The press cake and the husks remaining after oil extraction are potential fertilizers and fuels. The leaves, soaked in water, produce a good lather for washing. The reddish latex which exudes from deep cuts in the bark is made into glue, chewing gum and balls for children's games. Musicians use it to repair drums. The wood is used for poles, house posts, rafters, flooring, domestic utensils and furniture. It is an excellent fuel wood, burning with great heat, and a source of charcoal (Ken, 2019).

2.4.3 Medicinal uses

Medicinally, Shea Butter is used for topical medicines against rheumatic and joint pains, wounds, swellings, dermatitis, bruises, and other skin conditions. It is also useful as relief from nasal congestion and rhinitis. The leaves are used to treat stomach pain and headache. Ground roots and bark are used to treat diarrhea, jaundice, and stomach ache. Bark infusions have antimicrobial properties and are used against dysentery. Bark decoction, on the other hand, are used in baths to facilitate childbirth and stimulate lactation among feeding mothers (Ken, 2019).

Marchand (1988) cited in Moore, 2008) also reported some of its medicinal applications as effective in relieving rheumatic and joint pains and to quicken healing times and prevent infection of open wounds. He further noted that it is widely used to treat skin problems such as dryness, sunburn, burns, ulcers and dermatitis. Secondary shea products include honey and edible caterpillars, while shea processing yields abundant quantities of shea husks used as compost and shea cakes provide a source of fuel.

2.5 Shea Fruit Processing

Every one of the processors harvest fruit themselves implying no division of labour. De-pulping of the fruit is done before drying. Drying of seeds takes a number of days as the processors always have seeds being dried every day. About 60% of the processors crack the seeds with machines and not manually, showing the level of mechanization in the process. Roasting, milling and cold-water mixing are done averagely twice a month or once a week.

The processing of shea fruits for the extraction of shea butter involves a few stages. Picking of shea nuts is carried out mainly by women and children (Hall *et al.*, 1996). This is done when the fruits are ready for consumption (Busson, 1965). The fruits are plucked from tree or collected after dropping from the tree (Hall *et al.,* 1996). De-pulping, the removal of fleshy part may be done by fermentation (through burying) or boiling to obtain the nuts. The depulped nuts are boiled to kill the embryo, coagulate latex in kernels and to cause kernel to shrink and detach from the shell, to facilitate dehusking. The nuts are dried prior to dehusking. Drying of nuts may take up to 10 days in the sun or shorter when mechanical dryers at higher temperatures are used. Sun-drying reduces the moisture content to about 15-30% and 6-7% at 56^0C (Hall *et al.,* 1996). Dehusking is the removal of the hard shell covering the kernel and is done by pounding in a mortar with pestle or by crushing with stone, after which the kernels are dried to further reduce moisture content to prevent fungal growth. The nuts may then be crushed and stored or used for shea butter extraction.

2.5.1 Methods of shea butter extraction

i. The traditional water-based extraction (Home-based) method is the commonly used method

ii. Mechanical extraction also known as the press method (Cold per Wet press and Hot-press) uses screws and hydraulic instruments.

iii. Chemical extraction method which uses solvents such as Ether is industrial-based extraction process, which depends on improved technology and inputs (Hall *et al.,* 1996).

2.5.1.1 *The traditional extraction method*

Iddrisu (2013) list the equipment for primary processing of shea nut into butter and cake to include pan for boiling water, drying mat, mallets, pestles, winnowing basket, and clay pot**.** He stated that there are two main methods for shea butter extraction: a traditional village process and a mechanical procedure. The traditional process involves many time consuming stages. Using a shea nut press does not only alleviate time consuming process but also improves the fat output. For example, using a shea press fat output will be between 40 to 45% whereas fat output using the traditional method will be about 25% (Niess, 1983).

The traditional processing of shea fruit and extraction of shea butter, also reported by Dalziel (1937) as labour-intensive, women dominated, time consuming and tedious, yielding only 25% of butter (Hall *et al.,* 1996 and Iddrisu, 2013). The dried kernel is crushed by pounding in large mortars, crushing with stones or mills and roasted to concentrate the oil. Roasted and crushed kernels are dried to further reduce moisture content and ground into paste. Kneading of paste vigorously with warm water is carried out until a white coagulated crude shea butter paste containing oil separates from the water suspension. This paste is whisked out of the water into a pot and boiled in water until oil floats on top. The remaining brown suspension containing mainly nut deposits which solidifies to form the shea nut cake is discarded as waste. The oil, in liquid form, is scooped out into containers leaving behind in the pot a black paste as waste being charred nut deposits that followed the crude shea butter. The oil is then allowed to cool and solidify at room temperature into shea butter. This process is aided by constant stirring with clean dry sticks. The solidified butter is then packaged either as balls or into large containers for market.

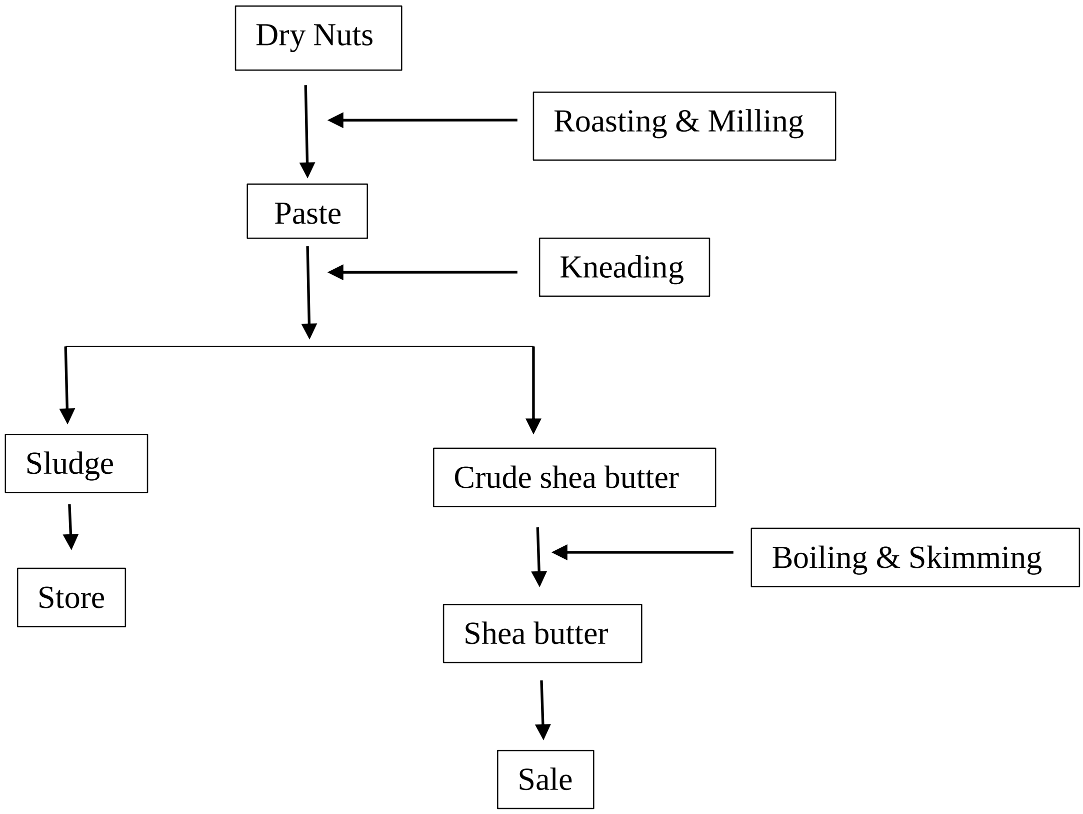

Figure 2.1: Flow chart for local processing of shea butter **(**Iddrisu, 2013)

2.5.1.2 *Mechanical extraction method*

Despite the introduction of some technological innovations in the traditional extraction Processes such as mechanical crushers, mills and kneading machines, shea butter yields and extraction efficiency by this method are still woefully low (Iddrisu, 2013 cited in Danikuu, 2016). The mechanical extraction method involves the use of expellers and hydraulic pressers.The mechanical extraction technique involves heating the nuts to 15-20^{o}C crushing and then pressing the crushed nuts to release the oil and a first extraction cake. The first extraction cake is further pressed in a second expeller to release more oil and a second extraction cake. As much as 25-80% of shea butter is produced from shea nuts with the mechanical process as against about 25% from the traditional water-based method (Danikuu 2016).

2.5.1.3 *Chemical extraction method*

This method employs a solvent such as hexane or ether and extraction efficiency is highest as compared to the two techniques described above. The solvent is mixed with the crushed shea nut and after the butter is extracted in the solvent the solvent is subsequently separated from the solvent-oil mixture by distillation. The method can be applied alone or in combination with the mechanical press method (Iddrisu, 2013). In this integrated method the second extraction cake is directed into a chemical plant where a suitable solvent, such as hexane is added at a ratio of 5 to a tonne of shea nut (Iddrisu, 2013). The solvent is subsequently separated in a distillation plant. The process yields 98% extraction efficiency (Iddrisu, 2013 cited in Danikuu, 2016). Extraction efficiency is higher in mechanical than traditional and highest in chemical method of extraction, especially when mechanical and chemical are combined.

2.6 Challenges and Effects of Shea Processing

A study conducted by Olorunfemi *et al.* (2017) on farm waste utilization among farmers in Irepodun Local Government Area, Kwara State, Nigeria revealed that majority of the farmers in the study area are not utilizing the waste generated from their farms and they result to disposing them predominantly through burning. The major constraints highlighted by the respondents inhibiting their efficient use of farm waste were inadequate access to extension services which results in them having inadequate awareness of the benefits they can derive from utilization of farm waste and low knowledge of its usage.

The disposed seed husks and the seed shells choke gutters and other water ways making the place more prone to flooding with the slightest downpour. Leachates from these wastes might reach nearby water source and then also introduce contaminants that can negatively change the chemical composition of the water (Sarkodie *et al.,* 2016). More so, the indigenous method requires large quantities of fuel wood and majority of processors rely on it as their main source of energy aside its deforestation and subsequent environmental effect, enormous heat and smoke generation can result in respiratory ailments, undue irritation of the eyes as well as nose and throat among processors (Jibreel *et al.,* 2013).

Methods for the traditional preparation of shea butter vary depending on locations, and the process involves the use of significant quantities of water and fuel wood and generates waste. Shea butter production is also labour-intensive; in studies reviewed by Pouliot and Elias (2013) labour involved in butter processing from nuts ranges from 2.5 hours to as many as 10 hours per person per kilogram of butter (Terpend, 1982 Hyman, 1991; Hall *et al.,* 1996; Crélerot, 1995; Faucon *et al.,* 2001). The need for heat occurs when roasting, smoking or boiling whole nuts to prevent germination. The heating of kernels by roasting or smoking prior to crushing, and the boiling of the butter paste which is rinsed multiple times. Hyman (1991) estimated that the traditional production of a single kilogram of shea butter demands between 8.5 to 10 kilograms of fuel wood. In Eastern Burkina Faso, Noumi *et al.* (2013) showed that it took 7.9 kg of wood to produce 1kg of butter (4.3 kg for processing into kernels and 3.6kg for processing into butter) with traditional methods. This amounted to a total energy cost of 246 CFA F/kg, which 31 % of all costs for butter production

In Northern Ghana, Lovett (2014) reports that the preparation of kernels (collection, boiling, drying, de-husking and drying) is a set of tasks that women prefer undertaking on their own (or with trusted friends and family) as their labour in the process asserts their ownership of the nuts and it can only be rewarded through sale after full processing when de-husked, dried kernels acquire the value of a marketable commodity. In contrast, butter processing stages are often done collaboratively. The insistence to work individually on post-harvest processing puts cultural constraints on more efficient use of resources like labour, firewood and dryers. Similar processing practices likely apply to most of the shea region. Education level, cultural habits, existence and membership in a local producer group and training experiences on improved technology efficiency and forest resource management. These factors deserve to be better understood and taken into account in approaches to reduce emissions of shea butter production.

Women have to walk long distances to collect it or incur high costs to purchase it. The issue of smoke from cook stoves causing respiratory diseases is an issue of great concern (Noumi *et al.,* 2013). Yet shea nut boiling fires systematically take place in the open air (Lovett, 2014) and may only affect women or children in smaller settings of cooperatives promoted by NGOs where fire density can be high and result in air pollution. Overall, techniques to reduce energy consumption can have significant benefits, including saving women’s key resource - time. Among those, methods that improve butter extraction also contribute to increasing butter quality and producers’ income.

Boffa (2015) identified some challenges and risks associated with shea fruit production as follows:

i. Extension of cultivation periods, decreasing length and frequency or disuse of fallow periods, which are required for the traditional regeneration of shea populations.
ii. Large-scale land investment and agricultural development projects for high-intensity, mechanized food and biofuel crop production removing shea trees in fields.
iii. Uncontrolled tree cutting for firewood and charcoal production.
iv. Past droughts have shifted the species distribution southward.
v. Recalcitrant seeds, long juvenile period and relative lack of successful studies on vegetative propagation.
vi. Very low outreach to farmers with improved planting material to date.
vii. Lack of a planting culture for indigenous tree species and shea, including cultural taboos against planting shea.
viii. Farmers with secondary land rights have weaker access rights to shea trees growing on borrowed fields. Demographic and resource commoditization trends lead to increased competition between users, stricter individualization of access rights to shea trees and an increased frequency of conflicts.
ix. Because it can be interpreted as a long-term claim to land, planting of improved shea trees on borrowed land is often restricted. Thus, caution is needed in selecting participating communities, households and planting locations not to increase social differentiation and resource conflicts between individuals or groups.

x. Organized shea cultivation may cause the intra-household distribution of rights to shea trees to shift resulting in greater control of benefits by men while women are currently the main beneficiaries of shea activities.

xi. Annual production of shea nuts can be under-collected due to constraints in women's labour availability relative to other activities.

xii. Common misperception that all harvesting of indigenous trees for firewood leads to woodland degradation, while sound management involves both culling and regeneration of trees.

xiii. Lack of knowledge about origin, management and governance of firewood production for sustainable sourcing.

xiv. Rainfall seasonality and frequency of extreme events will continue to increase with climate change. Shea parklands are better positioned to cope with extreme events than treeless areas, but unless flood resistance varieties are encouraged, shea could be more likely to be displaced where flooding occurs.

According to Boffa (2015), the following challenges and risks need to be managed when realizing opportunities for improving the shea resource and its management:

2.7 Shea Waste Management

Danikuu (2016) investigated the Management of Shea nut Waste with Indigenous Soil Bacteria. He collected three hundred and twenty-four (324) samples of soil at three depths (0-20 cm, 21-40 cm and 41-60 cm) from shea nut cake polluted and unpolluted locations in Jisonayili, Gurugu and Kasalgu in the Northern Region of Ghana, from September, 2010 to July, 2011. physico-chemical and microbiological properties of the soils were studied and potential microbes for the degradation of tannins in shea nut cake were identified. Dependent variables measured were pH, moisture, nitrogen, carbon, tannin contents, bacteria and fungi populations. Moisture, pH, carbon, nitrogen contents and microbial counts were significantly higher in shea nut cake polluted than unpolluted soils and highest (bacteria, 7.566 and fungi, 3.657 log10cfu) in the 0-20 cm depth. Shea nut cake added organic matter and nutrients to the experimented soil which probably increased the microbial populations. *Pseudomonas aeroginosa* (GUR/09), one of the bacteria identified degraded 92 % tannin in fresh shea nut cake in 20 days and 95% in 20 days when shea nut cake was boiled. in his conclusion, '*Pseudomonas aeroginosa* GUR/09 can be used to manage the waste. Polluted soils are reliable sources of bacteria to manage wastes'. *Pseudomonas aeroginosa* strain GUR/09 with a high ability to remove polyphenols from shea nut cake can be used to remove tannin, an anti-nutritional factor from shea nut cake, a waste product of shea butter extraction and permit its inclusion in animal feed and conversion to other economically useful products.

Quainoo *et al.* (2015) using Luttuce as a test crop showed that shea nut shells have the potentials of adsorption of heavy metals from contaminated soil and water hence suitable means of phytoremediation. Viruthagiri (2017) experimented the reuse of spent shea waste as an economic construction material in improving fired clay bricks manufacture. The result of his experiment revealed that spent shea waste addition increased the compressive strengths and water absorptions of the clay bricks products. Adewoye *et al.* (2013) investigated the impact of shea butter effluent on biochemical and haematological Profiles of *Clarias gariepinus*. The haematological indices revealed that increased in the concentration of the effluent brings about a corresponding decrease in the Packed Cell Volume (PCV), Red Blood Cell (RBC), and Haemoglobin of the test organism. In the other way round, the volume of white Blood cell decreased at concentration of 0.003, 0.005, 0.007, and 0.009 but increased sharply at 0.011ppt concentration. In the same vein, the shea butter effluents caused a decline in the biochemical composition of *Clarias gariepnus* vis-à-vis Albumin, protein, cholesterol, Glucose and Urea when compared to the control treatment. He therefore recommended that Shea butter effluent is highly toxic to freshwater organism.

Batch adsorption of cyanide ions from aqueous solution using activated carbon developed from Shea Butter Seed Husk (SBSH) was investigated by Tsunatu *et al.*, (2015). The Shea butter seed husk was carbonized at 450^0C -500^0C and activated at 700^0C using hydrochloric acid. The effect of adsorbent dose, initial cyanide concentration, contact time and pH were investigated and found to significantly affect the adsorption capacity with optimum adsorbent dose, contact time and initial cyanide concentration of 3.0g/100ml, 120mins and 100mg/l. The removal efficiency of cyanide ions by SBSH carbon black was 94.56% at lower concentration of 100mg/l and 58.7% was achieved at higher concentration of 600mg/l cyanide concentration. Similarly,

The removal of textile dyestuff from waste water was investigated in a batch sorption process using shea nut *(Vitellaria paradoxa)* shell activated carbon by Itodo *et al.*, (2010). The data were tested using the Rudishkevich – Dubinin and Temkin isotherm models. The result showed that removal efficiency increases with increase in contact time. Highlights of results presented in this paper clearly showed that shear butter shells are economically valuable adsorbent for industrial dyestuff with relatively high percent dye removal.

Itodo *et al.* (2011) again in a similar but different research work used Phosphoric acid (H_3PO_4) and Zinc chloride ($ZnCl_2$) catalyzed shea nut shells, subjected to a one-way activation scheme to study the adsorption kinetics and mode of diffusion of industrial dye uptake. The result indicated that shea nut shells could compare, to a good extent with commercial activated carbon for organic dye removal from dyestuff wastewater.

Physico-chemical analysis of shea fruit, pulp, kernel and butter from Mandoul region, Southern Chad by Mbaiguinam *et al.* (2007) showed that shea pulp is a rich source of carbohydrates, protein, and some minerals. Fat content of the kernels was found to be over 50% by solvent extraction and 30% by manual methods.

In terms of the effect of shea fruit residue on crop yield. Ugese *et al.* (2016) conducted a study on the effect of shea nut residue on growth, reproductive and yield performance of okra (*Abelmoschus esculentus*). The result of the experiment revealed that the effect of shea nut residue on the examined parameters was only marginal. In a research work conducted by Zievie *et al.* (2016), investigation on the potential use of shea nut shells ash, derived from the combustion of shea nut shells an agro-based waste, as partial replacement of cement in concrete. The cement content in the concrete mix was partially replaced 0%, 10% and 20% by mass with shea nut shells ash. The effect of the ash on setting time and workability were examined. There was a significant increase in strength of the experimental cubes over the control cubes at 90 days curing age.

Abagale *et al.* (2012) tested the effect of Shea waste-slurry on soil physical properties in two peri-urban areas of Gumu and Kasalgu in Tamale Metropolis in Ghana. The study showed differences between the soil physical properties of sites where Shea waste-slurry was disposed and that of the non-disposal sites. Shea waste-slurry was found to improve soil physical properties and is consequently expected to have positive effects on crop growth and yield.

Waste water from shea butter extraction has been reported to have insecticidal properties, keeping termites away from places it is disposed (Hall *et al.*, 1996). Moki *et al.* (2018) confirmed that briquette produced from shea nut shell using a simple extruder briquetting machine at moderate temperature and die pressure has high ignition and burning rate. The proximate analysis of the raw and briquetted samples was carried out and were found that these properties were improved as a result of briquetting.

2.8 Status of the Shea Industry in West Africa

Africa produces about 1,760,000mt of raw shea nuts annually from its wild trees, mainly in the savannah and sahel region, but producers harvest and process only a fraction, but 35% (about 600,000mt) for export a butter or nuts. The West Africa variety, *paradoxa* has been traditionally processed and locally used, as cooking oil or as butter for the skin and hair (Salawu *et al.*, 2014). Niger State account for 57% of Nigeria's total production of shea butter for esport (Nairametrics, 2017).

2.8.1 Status of shea butter industry in Nigeria

Nigeria is the leading producer of Shea nut and butter in the world. Shea nut and shea products are mainly produced in Niger, Kwara, Katsina, Plateau, Kogi, Oyo, Benue, Edo, Zamfara, Taraba, Borno, Nasarawa, Kebbi, Sokoto, and Adamawa states. Estimated National Production is 500,000 MT annually Salawu *et al.,* (2014). In the international market, the price per ton for Shea butter packed in 20 pounds dark plastic sacks or 50 kilo dark plastic containers or coated steel drums ranges from $1,800 to 2,800/MT depending on the quality, while the local market price per tonne ranges from N180,000 to N250,000. The price of Shea nuts and butter follows the movement in the price of cocoa beans and butter (Salawu *et al.*, 2014). Major destinations for Nigeria's Shea nut and Butter are the Europe, United States and Japan. The export season for Shea nut commences by June and ends in October. The harvesting period for Shea Nuts in Nigeria, runs from July till about November. The fruits are allowed to ripen on the tree and then drop to the ground. Main buyers of Shea nut and Shea butter are chocolate manufacturers, Cosmetic Industries, Pharmaceutical Industries as well as households.

The National Bureau of Statistics (NBS) reported that Nigeria earned ₦101.97 million from the export of only She oil in the first quarter of 2018. Also, the total value of exported agricultural products in Q2 2018 was ₦85.9 billion, compared to ₦73.25 billion in the previous quarter of Q1 2018, showing a strong quarter on quarter growth of 17.3%. Also, total agricultural exports in Nigeria grew by 127.3% on a year on year basis, from ₦37.79 billion in Q2 2017 (Adesanoye, 2018).

2.8.2 Shea butter production in Niger state

Niger State is on the verge of becoming the main hub for Shea Butter in Nigeria. Currently, the state boasts of having the largest collection of Shea trees in the world, controlling about 54 per cent of all the trees in Nigeria and of the vaunted 325,000 metric tonnes of Shea nut and butter exported from Nigeria (Olumide, 2018). According to Olumide. (2018), in order for the State to tap fully into the economic potentials of the Shea tree, it appointed a consultant, First Heritage Global Investments Limited, leading a team of experts, to come up with the Niger State Shea Sector Development Programme (NSSSDP).

The need is to draw a Master plan for the expansion of the Shea sector value chain and structuring of a Shea sector economy. The NSSSDP has developed an advocacy concerning the work that needs to be done and the paradigm shift that it would entail. This advocacy has already been delivered to the local communities around the Shea trees, the women who constitute the “primary growers” who harvest from the snake infested forests during the season with nothing but their basins and bare hands. Under current supply chain structures used by middlemen, traders and some producers, thousands of women are formed into cooperatives to secure supply of nuts for butter extraction, refining and fractionating facilities mainly established outside Nigeria. The advocacy has also been shared with International Institutions, non-governmental organisations, relevant Civil Society organisations and government parastatals.

Women in Niger State have found the real gold mine in shea processing. From shea butter alone, they have established a major export hub in the state, reputed as the leading exporter of raw shea nut in Nigeria. From Lavun to Bosso, Katcha, Rijau, Mokwa, Mashegu, Mariga, Tafa, Agaie, Wushishi and Edati Local Government Areas (LGAs) lie sprawls of shea trees in the wild from which families in Niger State derive their subsistence, especially from shea butter, one of the most used products obtained from the shea nut (Onche, 2018).

A survey conducted by Solomon *et al.* (2017) in four local government area of Niger State (Lapai, Katcha, Gbako, and Bosso) with the highest shea butter producers revealed that about 63.2% of the respondents produce between 10 and 30kg of Shea butter per month at the peak period of production. Only about 1.3 percent of the respondents produce above 50kg of Shea butter per month during peak production period while about 5.2 percent produce less than 10kg. According to Solomon *et al.* (2017) the butter production output per month is very low considering the level of work done in the realisation of the butter and recommended that Adoption of improved Shea nut processing technologies and introduction of best practices in Shea butter production by the processors could provide needed intervention to improved butter production output.

Below is the table that shows the Respondents Shea Butter Production Output per Month.

2.9 Shea Cultivation: Women's Business

In Niger State, the shea resource is the domain of women because within the household they are traditionally responsible for gathering of non-agricultural products (wild fruits). Specifically, the collection and processing of shea nuts is most often done exclusively by women and girls. Very significantly, and unlike most cash crops, women control the revenues from the sale of shea butter which they use to take care of the financial needs of their households and families.

Table 2.1: Monthly Shea Butter Production in Niger State

Quantity of Shea Butter Processed per Month (Kg)	Frequency	Percentage
Below 10	4	5.3
11 – 20	10	13.2
21 – 30	38	50
31 – 40	20	26.3
41 – 50	3	3.9
Above 50	1	1.3

(Solomon *et al.*, 2017)

The rich knowledge system surrounding the processing of shea butter which women acquire at a young age has been passed on for generations from mother to daughter (Elias and Carney, 2007).

In some parts of Africa like Ghana, Mali, and Burkina Faso, Shea butter production is a woman's identity marker and is a way rural woman cement their social ties. High butter quality is a source of recognition and good reputation for them. Shea has socio-cultural values to women. The butter is used by women during pregnancy and on newborn babies, and is offered as a gift from women to women to celebrate marriage, births or for dowries (Boffa, 1995).

In northern Ghana in general and the Tamale Metropolis in particular, many women process shea butter as their main source of income and in recognition of this a number of stakeholders including the Metropolitan, Municipal and District Assemblies, Non-Governmental Organizations, the National Board for Small Scale Industries and other private businesses have taken keen interest in the sector culminating in the provision of resources to support the industry.

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Study Area

The study was conducted at Katcha Local Government area of Niger State, in the North Central agro-ecological zone of Nigeria with a land area of 74,244 square kilometres and a population of 3,950,249 (National Population Commission, 2006). The State lies between latitudes 8°20'N and 11°30'N and longitude 3°30'E and 7°20'E. Niger State is bounded by Kaduna State and FCT in the North-East and South-East respectively; Zamfara State to the North, Kebbi State in the West, Kogi State in the South and Kwara State in the South West, while the Republic of Benin boarders the State in the North West. Katcha Local Government is a Local Government in Niger State. Its head quarter is in the town of Katcha. It is located at the southern part of Niger State. The local government is located between Latitude 9°9'0"N to 10°14'3"N and Longitude 6°14'0"E to 7°17'4"E Figure 3.1.

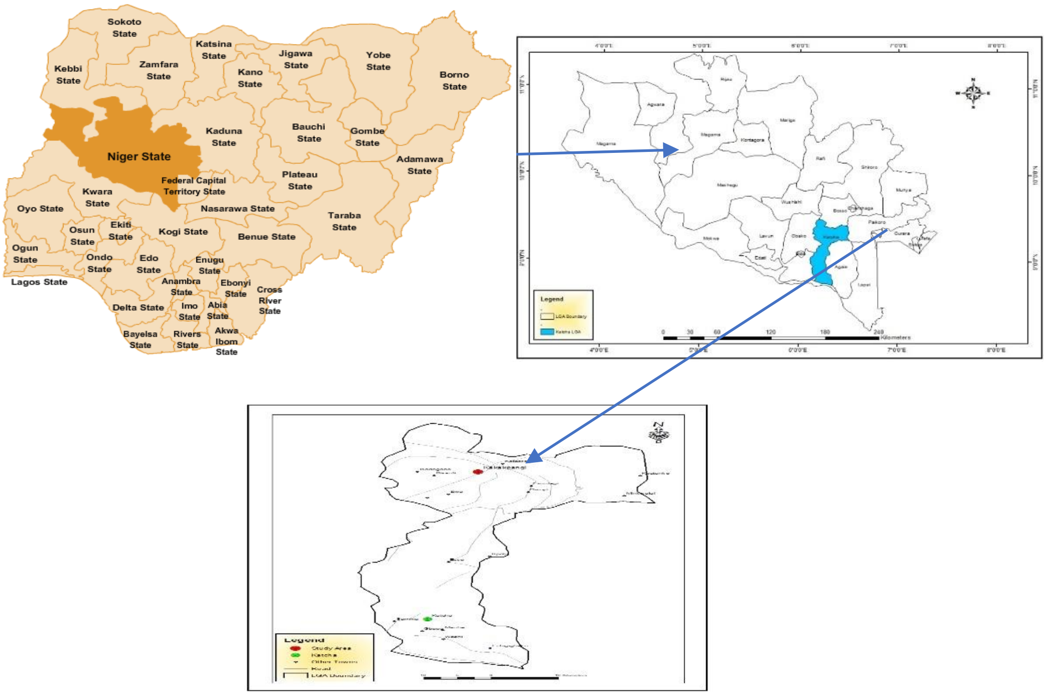

Figure 3.1: Nigeria, Niger State Inset Kakakpangi (Study area)

3.2 Design of the of Pits

A three D software application was used to design the experimental set up. The treatments to be carried out are aeration, addition of inoculum and addition of activated sludge.

(a)

(b)

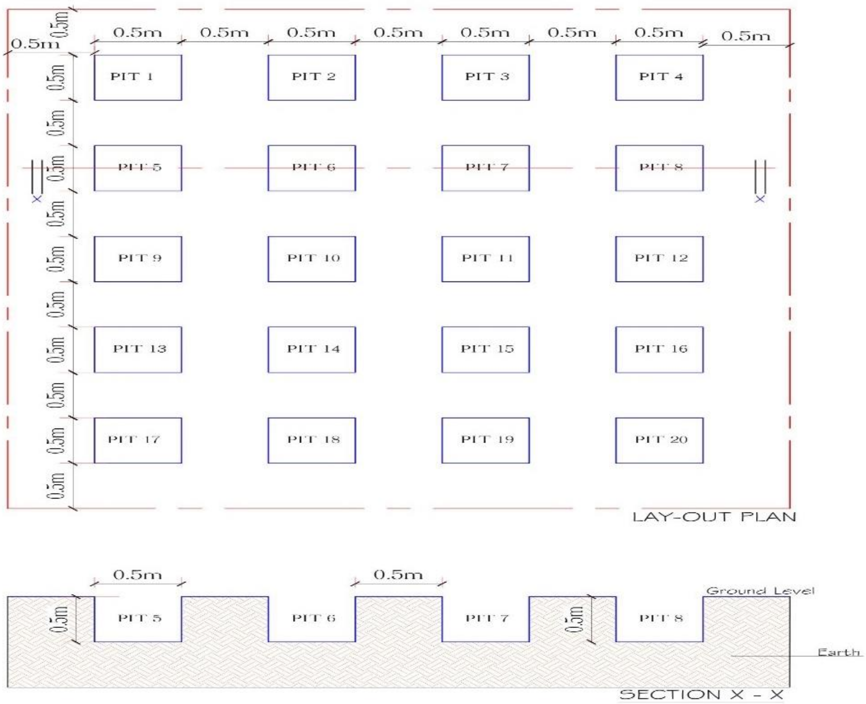

Figure 3.2(a) & 3.2(b): Layout Plan of the Pits and Sectional View of the Pits respectively

AREA = Length × Breadth

Volume = Area × Depth

AREA = L × B = 0.5m × 0.5m = 0.25m^2/Pit

Volume/Pit = L × B × D = 0.5m × 0.5m× 0.5m = 0.125m^3/Pit

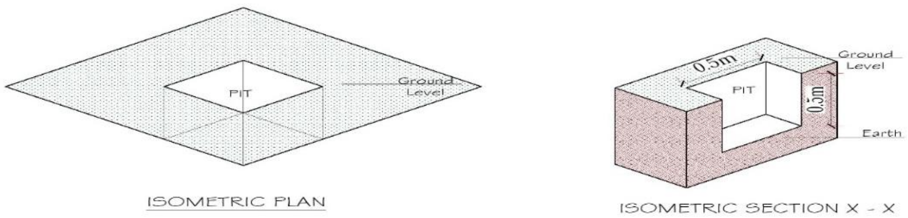

Figure 3.3: 3 – Dimensional View of the Pits

The aeration time, dosage of inoculum and activated sludge were inputted as independent variable while the responses are the od, Ammonia, Cyanogenic glycosides, cadmium, lead and total coliform values of the wastewater. Based on this, the experimental runs are as shown in the Table 4.1.

3.3 Excavation and Preparation of the Pits

Twenty 0.5 meter by 0.5 meter rectangular holes were created. The depth of the pits is 0.5m. The site for the excavation was at Kakakpangi shea butter processing site. Measuring tape was used to take the dimension of each pit. This was followed with the digging of the pit with the aid of digger. Thereafter, shovel was used to remove the sand. The pits were further dressed in conformity with the dimension. Figure 3.2. High density Polythene elastic material (HDPE) were introduced into each pit to avoid seepage of the shea butter waste water. Plate III & IV shown the excavation and preparation of the pits.

Plate III: Construction of the Pits

Plate IV: HDPE used to line the pits

3.4 Collection of Shea Butter Waste Samples for Pre-analysis

Shea butter waste which includes: shea slurry and wastewater were collected from the study site (Kakakpangi shea butter processing mill) with sample bottle and kept in a cooler jar to maintain the temperature of the waste water. Thereafter, the samples were conveyed to the Laboratory for analysis. This was taken as raw sample parameters. Thereafter, the HDP plastic bags were filled up to 75% capacity with shea wastewater collected from the sites and the three treatments, aeration, addition of inoculum and activated sludge commenced. The JAT inoculum was got cultured from microbiology Department, Federal University of Technology Minna while the activated sludge was prepared at River Basin laboratory. This were added to the pits in the doses recommended in the design.

3.5 Aeration and Sample Analysis

The shea Butter wastewater was collected from the processors and measured with the aid of 20 litres plastic bucket. A 30 litres of the shea wastewater was taken and carefully introduced into the polyethene bags for each of the pit. Thereafter, pneumatic pump of 1.5hp was used to aerate the pits each, while the inoculum and activated sludge were added according to recommended doses.

Plate V: Aeration of the Wastewater

The pattern of the treatments (Aerated and Unaerated) were alternately done in crop rotation form for even distribution. The aerated pits were tagged different collection time: 4 hours, 8 hours and 12 hours. After every 4 hours, 8 hours and 12 hours, sample were collected from each of the tagged pits and labelled to avoid mix up. Subsequent samples were also collected after day 0, 3 days, 6 days, 9 days and 12 days respectively. These samples were taken to water quality laboratory of upper Niger River Basin Authority, Minna, Niger State for analysis.

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

4.1 Results of the Analysis

The results of the analysis after the treatments are as shown in Table 4.1. The table shows the result in a randomised treatment based on the output from experimental design. Detailed discussions based on the number of days for the treatment are shown in Tables 4.2 to 4.7 respectively.

Table 4.1: Result of analysis after treatment

Factor 1	Factor 2	Factor 3	Res 1	Res 2	Res 3	Res 4	Res 5	Res 6
Aeration interval	JAT inoculum	Activated Sludge	BOD (mg/l)	NH3 (mg/l)	Cyanogenic glycosides (mg/l)	Cd (mg/l)	Pb (mg/l)	TC (cfu/100ml)
Hrs	mg/l	mg/l	1058.96	648.31	5.24	4.3	5.21	21.66
0	20	0	294.61	82.3	4.33	2.69	1.46	5.94
8	0	60	1021.5	339.32	1.61	1.2	0.84	17.23
0	60	80	61.88	33.91	1.78	1.99	0.61	6.73
12	20	80	1026.7	147.6	0.77	1.61	0.98	16.61
0	80	20	554.73	215	4.22	2.14	1.96	8.98
4	80	40	934.82	186.03	3.61	2	2.06	13
4	40	60	953.24	216.32	3.77	2.14	2.61	12.94
4	40	80	264.21	104.61	3.21	1.61	0.64	7.46
8	0	40	1002.42	224.62	3.75	2.09	0.94	13.44
4	40	60	79.43	74.29	5.36	3.02	3.02	11.61
12	40	60	964.8	521.09	5.33	4.01	4.86	18.61
4	0	20	937.64	106.7	3.58	2.06	1.34	10.21
4	40	20	1043.33	661.43	5.75	2.96	2.01	18.43
0	0	40	114.89	77.34	1.94	2.1	1.11	6.71
8	60	80	961.34	550.89	5.1	3.01	3.49	19.26
0	0	40	109.32	51.32	1.24	1.7	0.83	6.32
8	60	40	43.21	49.25	1.92	1.46	0.67	7.32
12	20	20	156.33	59.4	0.98	1.52	0.92	5.88
8	60	40	46.44	50.66	1.43	1.93	1.02	6.61
12	80	20	1058.96	648.31	5.24	4.3	5.21	21.66

Table 4.2. shows the analysis of shea butter waste water for the first day. The results for the biochemical oxygen demand (BOD) show a decrease in the trend of the values. With

unaerated recording the highest value BOD value of 1058.9 mg/l while the least of 61. 88 was recorded for 12 hours aerated interval of shea waste water. Similar trend of decrease in values from unaerated shea waste water to 12 hours aerated waste water were also recorded for Ammonia (NH_3), Cyanogenic glycosides, Cd, Pb and TC (cfu).

Table 4.2: Properties of Shea Waste Water for the first day

Hour (s)	B-JAT Inoculum	Activated Sludge	BOD (mg/l)	NH3 (mg/l)	Cynogenic glycoside (mg/l)	Cd (mg/l)	Pb (mg/l)	TC cfu/100m
0	20	0	1058.9	648.3	5.24	4.3	5.21	21.66
4	80	40	554.73	215	4.22	2.14	1.96	8.98
8	0	60	294.61	82.3	4.33	2.69	1.46	5.94
12	20	80	61.88	33.91	1.78	1.99	0.61	6.73

Table 4.3. shows the heavy metals analysis of shea waste water after three days. Downwards decrease in values from unaerated shea waste water to 12 hours aeration shea waste water were also recorded for BOD, $NH_{3,}$ while 1.61 mg/l of Cyanogenic glycosides was recorded for unaerated shea waste water, 4, 8 and 12 hours aeration interval of shea waste water recorded 3.61, 3.21 and 2.85 respectively. 12 hours aeration treatment had the highest Cd and Pb values of 3.02 mg/l each. The highest total coliform unit was recorded for unaerated treatment while the least of 7.46 cfu/100ml was recorded for 8 hours aeration interval.

Table 4.3: Properties of Shea Waste Water after three days

Hou r (s)	B-JAT Inoculum	Activated Sludge	BOD (mg/l)	NH3 (mg/l)	Cynogenic glycoside (mg/l)	Cd (mg/l)	Pb (mg/l)	TC cfu/100 m
0	60	80	1021.5	339.32	1.61	1.2	0.84	17.23
4	40	60	934.82	186.03	3.61	2	2.06	13
8	0	40	264.21	104.61	3.21	1.61	0.64	7.46
12	40	60	79.43	74.29	2.85	3.02	3.02	11.61

Table 4.4 shows the heavy metals parameters of shea butter waste water after six days. The BOD values show a descending trend. With unaerated recording the highest value

of 1026.7 mg/l while the least of 43.21 mg/l was recorded for 12 hours aeration. 4 hours aeration recorded the highest value of NH_3 (216.32 mg/l). While 12 hours aeration interval recorded the least of 49.25 mg/l. 4 hours aeration interval recorded highest value of 3.77 mg/l for cyanogenic glycosides. While 0 hours aeration had 0.77 mg/l. There was no significant difference ($p>0.05$) in the cyanogenic glycosides level of 8 hours and 12 hours aeration interval. The concentration level for Cd were 1.6, 2.14, 2.1 and 1.46 mg/l for 0 hour 4 hour, 8 and 12 hours treatment respectively. Also, 4 hours aeration recorded the highest level of lead in the shea waste water. The highest coliform forming unit of 16.61 cfu/100ml was recorded for 0 hour or unaerated shea butter waste water. This was followed with 12.94 cfu/100ml for 4 hour aeration interval. The least was 7.32 cfu/100ml for 12 hours aeration interval.

Table 4.4: Properties of Shea Waste Water after six days

Hour (s)	B-JAT Inoculum	Activated Sludge	BOD (mg/l)	NH3 (mg/l)	Cynogenic glycoside (mg/l)	Cd (mg/l)	Pb (mg/l)	TC cfu/100m
0	80	20	1026.7	147.6	0.77	1.61	0.98	16.61
4	40	80	953.24	216.32	3.77	2.14	2.61	12.94
8	60	80	114.89	77.34	1.94	2.1	1.11	6.71
12	20	20	43.21	49.25	1.92	1.46	0.67	7.32

Table 4.5 Depicts the physico-chemical properties of shea butter waste water after nine days. The BOD also shows a descending trend. With unaerated recording the highest value of 1043.33 mg/l while the least of 46.44 mg/l was recorded for 12 hours aeration interval. Unaerated shea waste water recorded the highest value of NH_3 (661.43 mg/l). Similarly, 12 hours aeration interval recorded the least of 50.66 mg/l. Also, 4 hours aeration recorded highest value of 3.75 mg/l for cyanogenic glycosides. While 0-hour aeration interval had 0.77 mg/l. There was no significant difference ($p>0.05$) in the cyanogenic glycosides level of 8 and 12 hours aeration interval. The highest concentration for Cd was recorded for unaerated treatment while 8 hours aeration

interval recorded the least of 1.7 mg/l. The lead concentration was 2.01, 0.94, 0.83 and 1.02 mg/l for 0 hour, 4 hours, 8 hours and 12 hours aeration interval respectively. The coliform forming unit were in descending order with 0 hour or unaerated shea butter waste water recording the highest of 18.43 cfu/100ml. This was followed with 13.44 cfu/100ml for 4 hours aeration. The least was 6.32 cfu/100ml for 12 hours aeration interval.

Table 4.5: Properties of Shea Waste Water after 9 days

Hour (s)	B-JAT Inoculum	Activated Sludge	BOD (mg/l)	NH3 (mg/l)	Cynogenic glycoside (mg/l)	Cd (mg/l)	Pb (mg/l)	TC cfu/100m
0	0	40	1043.33	661.43	5.75	2.96	2.01	18.43
4	40	60	1002.42	224.62	3.75	2.09	0.94	13.44
8	60	40	109.32	51.32	1.24	1.7	0.83	6.32
12	80	20	46.44	50.66	1.43	1.93	1.02	6.61

Table 4.6 show the heavy metals of shea butter waste water after twelve days. The BOD also shows a descending trend. With unaerated recording the highest value of 961.34 mg/l while the least of 45.76 mg/l was recorded for 12 hours aeration interval.

Unaerated shea waste water recorded the highest value of NH_3 (550.89 mg/l). Similarly, 12 hours aeration interval recorded the least of 48.54 NH_3 mg/l. Also, 4 hours aeration recorded highest value of 3.58 mg/l for cyanogenic glycosides. While 0-hour aeration had 0.77 mg/l. There was a significant difference ($p<0.05$) in the cyanogenic glycosides level among all the treatments. The highest concentration for Cd was recorded for unaerated while 8 hours aeration interval recorded the least of 1.7 mg/l. The highest concentration of lead was recorded for unaerated sample at 3.49 mg/l, and the lowest was 0.92 for 8 hours aeration interval. The coliform forming unit were in descending order from 0 minute or unaerated shea butter waste water recording the highest of 19.26

cfu/100ml. This was followed with 10.21 cfu/100ml for 4 hours aeration interval. The least was 5.88 cfu/100ml for 12 hours aeration interval.

Table 4.6: Properties of Shea Waste Water after 12 days

Hour (s)	B-JAT Inoculum	Activated Sludge	BOD (mg/l)	NH3 (mg/l)	Cynogenic glycoside (mg/l)	Cd (mg/l)	Pb (mg/l)	TC cfu/100m
0	0	40	961.34	550.89	5.1	3.01	3.49	19.26
4	40	20	937.64	106.7	3.58	2.06	1.34	10.21
8	60	40	156.33	59.4	0.98	1.52	0.92	5.88
12	78	40	45.76	48.54	1.28	1.78	1.4	7.51

4.2 General Discussion

The result analysis of the study revealed that shea butter wastewater has higher accumulation of heavy metals. It also shows that aeration of shea waste water at different duration can reduce the concentration of the heavy metal in shea waste water. The heavy metal determined in this study includes: lead, cadmium and ammonia. Other parameters were cyanogenic glycosides, and total coliform unit Table 4.7.

Table 4.7 ANOVA for 2FI model ammonium

Source Model	**Sum of Squares**	**df**	**Mean Square**	**F-value**	**p-value**	
A-Aeration Time	7.42E+05	6	1.24E+05	17.65	< 0.0001	significant
B-JAT inoculum	1.34E+05	1	1.34E+05	19.14	0.0008	
C-Activated Sludge	17116.25	1	17116.25	2.44	0.1419	
AB	177.09	1	177.09	0.0253	0.8761	
AC	78904.23	1	78904.23	11.27	0.0051	
BC	5991.41	1	5991.41	0.8558	0.3718	
Residual	22950.38	1	22950.38	3.28	0.0934	
Lack of Fit	91010.37	13	7000.8			
Pure Error	84123.59	10	8412.36	3.66	0.1564	not significant
Cor Total	6886.78	3	2295.59	8.33E+05	19	

The ANOVA result shows that only Aeration Time as significant effect on the amount of Ammonium content test at P-value= 0.008 while the other two factors of JAT inoculum and Activated Sludge shows no significant effect at P-value of (0.14 and 0.87). respectively all the two factors interaction was not significant has the P-Value greater than (0.05) only for the two-factor interaction of Aeration Time and JAT inoculum with P- value of 0.05. The model developed for the amount of ammonium in the waste water treatment over the reaction time was presented in the equation below:

Final Equation in Terms of Actual Factors

$NH3(mg/l) = 765.58- 58.51X_1 –8.14X_2- 4.40X_3 +0.538 X_1X_2 +0.165X_1X_3 +0.071X_2X_3$

Heavy metal is toxic at low concentrations. The concentration of the heavy metal in the shea waste water in this study increases with days. Heavy metal toxicity depends on the type, its biological role, and their source (Tijani *et al*., 2006; Laniyan *et al*., 2013). Heavy metals after reaching the aquatic habitats cause serious problem due to bioaccumulation, biomagnification in the food chain and toxicity to the organisms. (Govind and Madhuri, 2014; Ahmad *et al*., 2015). Heavy metals are poisonous due to some factors. Firstly, they cannot be destroyed through biological degradation as in the case of most organic pollutants. Secondly, they are easily assimilated and can be bioaccumulated in the protoplasm of aquatic organism (Egborge, 1994). Heavy metals are transported as dissolved species in water as an integral suspended sediment (Wogu and Okaka, 2011). The trend of heavy metals obtained in this study is like the descending order of heavy metals Wangboje and Ekundayo (2013) obtained in their studies.

Biochemical oxygen demand in this study show an inverse relationship with an increase in aeration time. BOD is described as the amount of oxygen required to break down organic substances in liquid while COD is the amount of strong oxidant required to break down both organic and inorganic matters. The BOD profiles throughout the study period generally depict decline in level with increase in number of aeration days. BOD in liquid is caused by high levels of organic matters such as debris. The ANOVA for 2FI model on Lead content shows there was no significant effect of the three factors.

Table 4.8: ANOVA for 2FI model on Lead

Source Model	**Sum of Squares**	**df**	**Mean Square**	**F-value**	**p-value**	
A-Aeration Time	22.22	6	3.7	3.6	0.0252	Significant
B-JAT inoculum	0	1	0	0	0.9948	
C-Activated Sludge	0.0057	1	0.0057	0.0055	0.9419	
AB	0.0068	1	0.0068	0.0066	0.9363	
AC	2.96	1	2.96	2.87	0.1138	
BC	4.33	1	4.33	4.2	0.0611	
Residual	3.46	1	3.46	3.36	0.0899	
Lack of Fit	13.39	13	1.03			
Pure Error	11.66	10	1.17	2.03	0.3052	not significant
Cor Total	1.73	3	0.5755	35.61	19	

Lead concentration recorded in the study exceeded the World Health Organization maximum limit (WHO, 2021). The high concentration of lead obtained could be attributed to the slurry nature of the waste water from shea processing site. Lead is poisonous and can kill even in small qualities. Lead concentration in shea butter waste water declined with increase in rate of aeration. Cadmium concentration obtained in the study was very higher and this can find their way to river and others nearby water source. Sharma *et al.,* (2015) reported effects of cadmium to include diarrhoea, stomach pains, bone fracture, reproductive failure and possibly even infertility, damage to central nervous system and immune system, psychological disorders. Nickel also observed higher concentration in their study of wastewater than the permissible level (WHO, 2021). The mean concentration of 0.03±0.03 mg/l obtained was slightly higher than 0.02 mg/l. Obaroh *et al.* (2015) reported in Argungu River. (WHO, 2021) reported the major sources of nickel to be leaching from metals in contact with the water, it is used mainly in the production of stainless steels, electroplating, as catalyst in nickel-cadmium batteries and in certain pigment and electronics.

The results on ammonia concentrations varies with the degree of aeration and the length of days. The higher the aeration, the less the ammonia concentration. Agoro *et al.* (2018) reported 0.06-112 mg/L on ammonia in wastewater which differ significantly ($P<0.05$) at three treatment facilities. Discharged effluents at WWTP-A and WWTP-C treatment plants did not comply with the set limits and could cause pollution in the receiving watersheds in terms of ammonium. The concentration of ammonia in this study is far more than WWTP-B wastewater plant samples and within the DWAF recommended limit of 3.0 mg/L during the sampling months. High levels of ammonium in waste water could be either due to sewage, debris or industrial waste and fertilizer runoff. The analysis on **cyanogenic glycosides for Linear model showing in Table 4.8 the effect of each factors.**

Table 4.9: ANOVA for Linear model for Cyanogenic glycocides (mg/l)

Source Model	**Sum of Squares**	**df**	**Mean Square**	**F-value**	**p-value**	
A-Aeration Time	25.01	3	8.34	4.89	0.0133	significant
B-JAT inoculum	4.26	1	4.26	2.5	0.1335	
C-Activated Sludge	18.73	1	18.73	11	0.0044	
Residual	0.0801	1	0.0801	0.047	0.8311	
Lack of Fit	27.26	16	1.7			
Pure Error	27	13	2.08	24.45	0.0115	significant
Cor Total	0.2549	3	0.085	52.27	19	

The two of the three factors were not significant at P-value of 0.133 and 0.831 for aeration Time and Activated sludge while the JAT inoculation was significant at 0.004 P-value Cyanogenic glycosides is concentration in shea butter waste water in this study fluctuate with the rate of aeration and length of days. Bolarinwa *et al.* (2016) reported that processing techniques such as boiling, frying and soaking reduces the concentration cyanogenic glycosides. The concentration of cyanogenic glycoside in the shea butter waste water despite the processing techniques the shea nut went through in this study is an indication that the fruit is rich in the cyanogenic glycosides. Cyanogenic glycoside are natural plant toxins that are present in several plant and are group of nitriles containing plant secondary compound that yield cyanides. They are amino acid derived constituents of plant produced as secondary metabolites. Consumption of cyanogenic glycosides may lead to acute intoxications characterized by growth retardation and neurological symptoms. Total coliform analysis of variance (ANOVA) in Table 4.9, the Aeration time was significant having P-value (0.001).

Table 4.10: ANOVA for Linear model on Total coliform

Source Model	Sum of Squares	df	Mean Square	F-value	p-value	
A-Aeration Time	25.01	3	8.34	4.89	0.0133	significant
B-JAT inoculum	4.26	1	4.26	2.5	0.1335	
C-Activated Sludge	18.73	1	18.73	11	0.0044	
Residual	0.0801	1	0.0801	0.047	0.8311	
Lack of Fit	27.26	16	1.7			
Pure Error	27	13	2.08	24.45	0.0115	significant
Cor Total	0.2549	3	0.085	52.27	19	

The second factor JAT inoculum shows no significant effect on the total coliform in the treated water sample analyse in the study. The level of total coliform (TC) in the shea butter waste water shows remarkable decrease with the intensity of aeration. Coliform are large group of gram-negative bacteria. Table 4.11 show the cadmium content of the two factor interaction of the waste water treated.

Table 4.11: ANOVA for 2FI model on Cadmium

Source Model	Sum of Squares	Df	Mean Square	F-value	p-value	
A-Aeration Time	9.6	6	1.6	6.35	0.0027	significant
B-JAT inoculum	0.2497	1	0.2497	0.9904	0.3378	
C-Activated Sludge	0.2069	1	0.2069	0.8208	0.3814	
AB	0.0014	1	0.0014	0.0057	0.941	
AC	1.67	1	1.67	6.62	0.0232	
BC	2.83	1	2.83	11.23	0.0052	
Residual	0.5232	1	0.5232	2.08	0.1733	
Lack of Fit	3.28	13	0.2521			
Pure Error	3.26	10	0.3256	45.43	0.0047	significant
Cor Total	0.0215	3	0.0072	12.88	19	

The three factors in the experiment show no significant effect on the amount of cadmium in the waste water.

4.3 Optimisation Process

Following the analysis of two factor interaction between the factors the treatment parameters are as presented in Figures 4.1 – 4.6

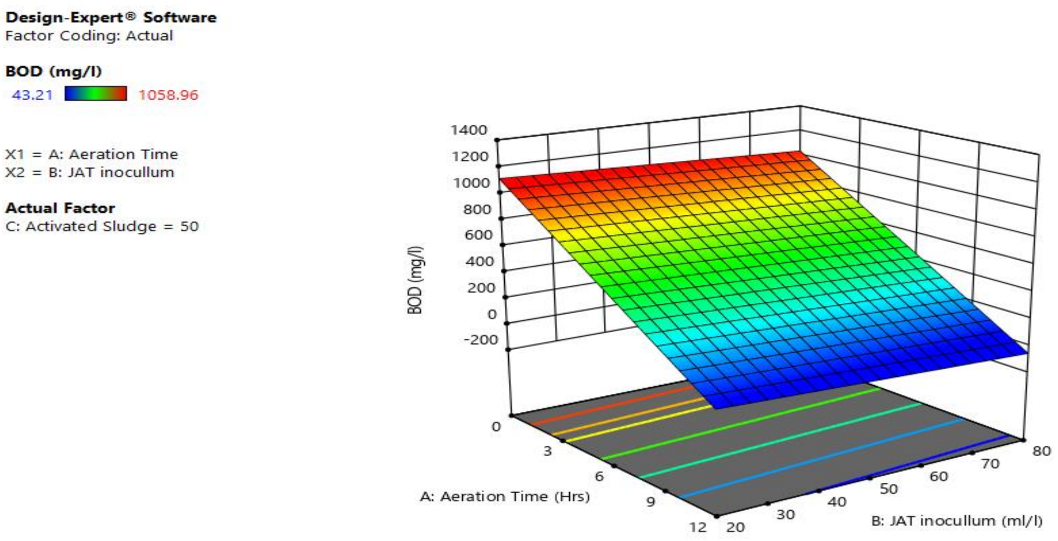

Figure 4.1: 3D Plot showing the interaction between Aeration Time and JAT Inoculum on BOD

The experimental results show that BOD ranged from 19-24.62%. Statistical analysis is presented in Figure 4.1. From the 3D plot this condition less than three to zero aeration time and JAT inoculum of 20 to 80 shows the boundary at which the highest amount of BOD can be gotten and the less amount of BOD was at point above 9 to 12 and the JAT inoculum of 20 to 80. The figure also shows the maximum and minimum level of BOD at 1058.96 mg/l and 43.21 mg/l respectively.

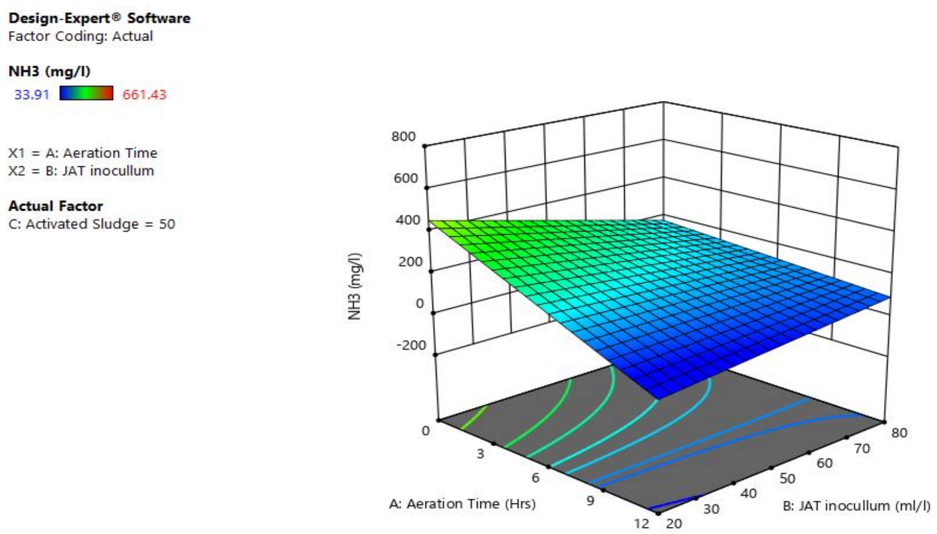

Figure 4.2: 3D plot showing the interaction between Aeration Time and JAT Inoculum on NH_3

The figure shows the maximum and minimum level of Ammonia at 661.43 mg/l and 33.91 mg/l respectively. The experimental results show that ammonium (NH_3) ranged from Statistical analysis is presented in Figure 4.2 From the 3D plot this condition less than three to zero aeration time and JAT inoculum of 20 to 40 shows the boundary at which the highest amount of ammonium can be gotten and the less amount of Ammonium was at point above 9 to 12 and the JAT inoculum of 20 to 80.

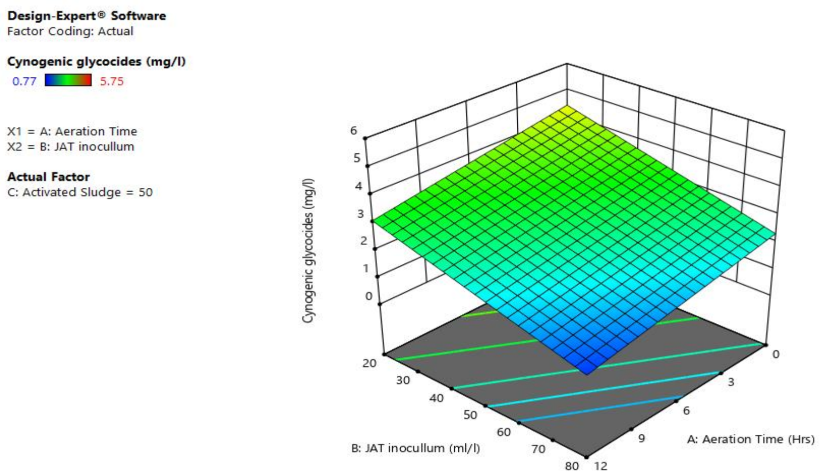

Figure 4.3: 3D plot showing the interaction between, Aeration Time and Inoculum Cyanogenic glycosides

The experimental results show that Cyanogenic glycosides ranged from O.77 – 5.75 (ml/g) Statistical analysis is presented in Figure 4.3. From the 3D plot this condition less than three to zero aeration time and JAT inoculum of 20 to 50 shows the boundary at which the highest number of Cyanogenic glycosides can be gotten and the smaller number of Cyanogenic glycosides was at point above 9 to 12 and the JAT inoculum of 60 to 80.

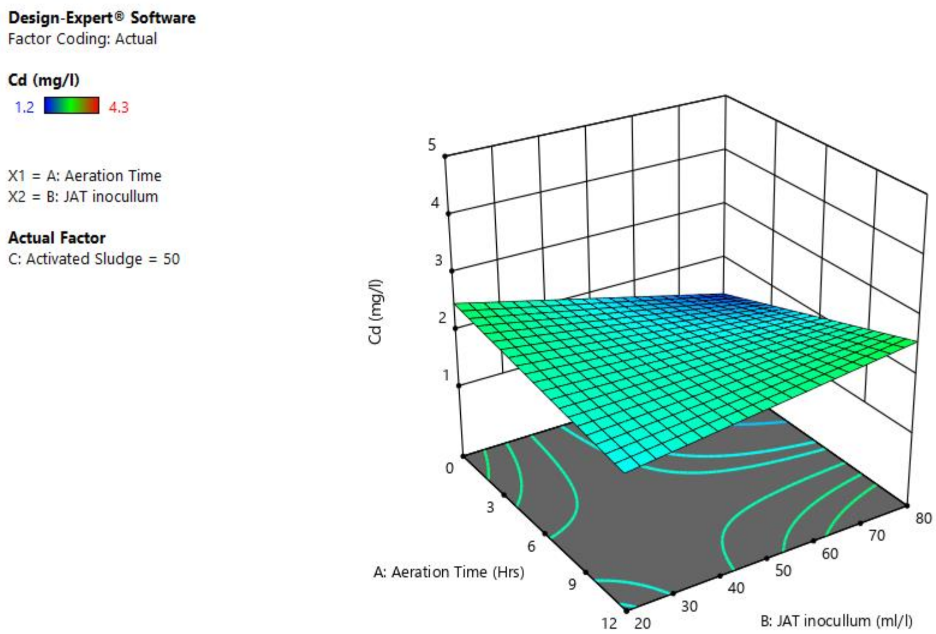

Figure 4.4: 3D plot showing the interaction between Aeration Time and JAT Inoculum on Cadmium

The investigational results show that Cadmium ranged from O.77 – 5.75 (ml/g) Statistical analysis is presented in Figure 4.4. From the 3D plot this condition less than six to zero aeration time and JAT inoculum of 20 to 30 shows the boundary at which the highest number of Cadmium can be gotten and the smaller number of Cadmium was at point above 9 to 12 and the JAT inoculum of 60 to 80. The 3D figure shows the maximum and minimum level of Cd at 4.3 mg/l and 1.2 mg/l respectively.

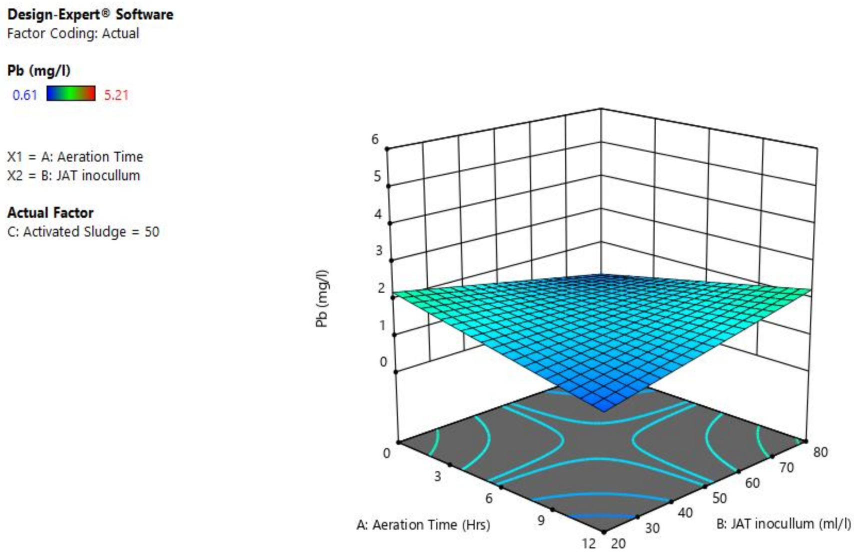

Figure 4.5: 3D plot showing the interaction between Aeration Time and JAT Inoculum on Lead

The 3D figure shows the maximum and minimum level of Lead at 21.66 mg/l and 5.88 mg/l respectively. The investigational results show that Cadmium ranged from 0.61–5.21 (ml/g) Statistical analysis is presented in Figure 4.5. From the 3D plot this condition less than three to zero aeration time and JAT inoculum of 20 to80 shows the boundary at which the highest number of Cadmium can be gotten and the smaller number of Cadmium was at point above 10 to 12 and the JAT inoculum of 50 to 80.

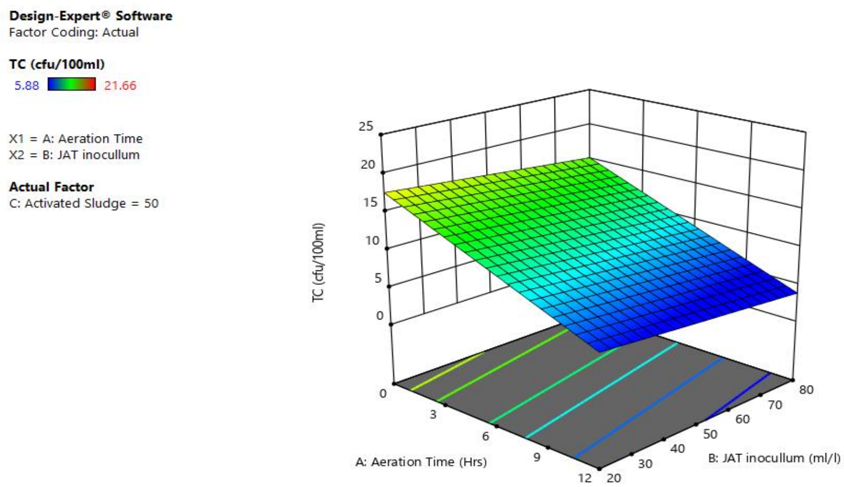

Figure 4.6: 3D plot showing the interaction between Aeration Time and Inoculum on Total coliform

The 3D figure shows the maximum and minimum level of TC at 21.66 mg/l and 5.88 TC (cfu/100ml) respectively. The investigational consequences show that Total coliform ranged from 5.88 – 21.66 (ml/g) Statistical analysis is presented in Figure 4.4. From the 3D plot this condition less than six to zero aeration time and JAT inoculum of 20 to 30 shows the boundary at which the highest number of Total coliforms can be gotten and the smaller number of Total coliforms was at point above 11 to 12 and the JAT inoculum of 20 to 80.

4.3.1 Constraints in optimisation process

Table 4.12: Constraints in Optimisation Process

Responses	Goal	Lower Limit	Upper Limit	Lower Weight (Kg)	Upper Weight (Kg)	Importance
A: Aeration Time	is in range	0	12	1	1	3
B: JAT Inoculum	is in range	20	80	1	1	3
C: Activated Sludge	is in range	20	80	1	1	3
BOD (mg/l)	minimize	43.21	1058.96	1	1	3
NH3 (mg/l)	minimize	33.91	661.43	1	1	3
Cyanogenic glycosides (mg/l)	minimize	0.77	5.75	1	1	3
Cd (mg/l)	minimize	1.2	4.3	1	1	3
Pb (mg/l)	minimize	0.61	5.21	1	1	3
TC (cfu/100ml)	is in range	5.88	21.66	1	1	3

Table 4.13: Results of the Optimisation process

Number	Aeration Time	JAT inoculum	Activated Sludge	BOD (mg/l)	NH3 (mg/l)	Cyanogenic glycosides (mg/l)	Cd (mg/l)	Pb (mg/l)	TC (cfu/100ml)	Desirability
*1	**10.656**	**80.000**	**20.000**	**60.206**	**10.530**	**1.255**	**1.649**	**0.679**	**5.880**	**0.943**
5	10.650	80.000	20.243	60.813	11.350	1.255	1.655	0.691	5.880	0.942
11	10.732	78.148	20.000	55.718	11.351	1.312	1.655	0.694	5.880	0.941
12	10.751	77.691	20.000	54.612	11.531	1.326	1.656	0.698	5.880	0.940
15	10.784	76.872	20.000	52.625	11.829	1.351	1.658	0.705	5.880	0.939
16	10.420	79.998	20.000	81.669	13.393	1.281	1.649	0.687	6.104	0.938
18	10.858	75.076	20.000	48.270	12.379	1.405	1.663	0.718	5.880	0.937
19	10.870	74.785	20.000	47.563	12.454	1.414	1.663	0.720	5.880	0.936
20	10.329	79.998	20.000	90.005	14.505	1.291	1.649	0.690	6.191	0.936
23	10.762	75.440	20.000	56.538	13.462	1.403	1.663	0.719	5.957	0.935

***Selected from table**

Solutions

After series of optimisation processes, 63 solutions were obtained and the one that has the highest desirability index of 0.943 was of aeration time of 9 days interval, JAT inoculum of 80 mg/l. activated sludge of 20 mg/l.

CHAPTER FIVE

5.0 CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

The result of the study revealed that shea butter wastewater has higher accumulation of heavy metals such as lead and cadmium. The biochemical oxygen demand in the study also revealed declined in concentration with increase in rate of aeration. Also, there was an upsurge in the level of BOD of the shea wastewater as the number of days increases. It also shows that aeration of shea wastewater at different time can reduce the concentration of the heavy metal in shea wastewater. Shea butter wastewater as a product of shea fruit is also rich in cyanogenic glycosides which can be harmful when consumed. The shea butter wastewater also has accumulation of coliform bacterial due to it turbid nature and contamination occasioned by handling and processing.

5.2 Recommendations

Base on the result of the study, it is recommended that:

(i) Shea wastewater should be subjected to preliminary treatments before releasing into either soil or water course because it contains toxic waste capable of polluting the environment.

(ii) Aeration process, addition of activated sludge and addition of JAT inoculum should be employed in the treatment of shea wastewater before discharge.

(iii) More researches should be conducted on the appropriate biological methods of shea waste treatment. Stabilisation pond and oxidation pit methods should be tested for their capability. This is with a view to having a complex integrated treatment technique of shea wastewater.

5.3 Contribution to Knowledge

The study has contributed to knowledge in the following ways:

The study established the presence of heavy metals in shea butter wastewater which are toxic to the soil microbes. The study also established the best optimization time for aeration, JAT inoculum and activated sludge that reduce the concentration of the heavy metals on shea butter wastewater.

REFERENCES

Abagale, F.K., Abdulai, N. & Ojediran, J.O. (2012). Effects of Shea Waste Slurry on soil physical properties in Peri-Urban Tamale. Northern Ghana. *Asian Journal of Science and Technology*, 4(12), 036-041.

Abbiw, D.K. (1990). Useful Plants of Ghana, West African Uses of Wild and Cultivated Plants. Intermediate Technology Publications and the Royal Botanic Gardens, Kew, London, pp 66–67

Addaquay, J. (2004). The Shea butter value chain, refining in West Africa. *West Africa Trade Hub (WATH) Technical Report No, 3*, 1-28

Adeoye, S.A., Adedigba, A.E. & Opasola, O.A. (2013). A preliminary Study on Toxic Potentials of Shea Butter Effluent using Clarias gariepinus as a Biological Model. *Journal of Pharmacy, Biological Sciences* (JPBS) 7(2), 23-28

Adewoye, S.O. (2013). Impact of Shea Butter Effluent on Biochemical and Heamatological Profiles of *Clarias gariepinus*. *IOSR Journal of Environmental Science, Toxicology and Food Technology*, 5, 59 – 63.

Adesanoye, D. (2018). How Nigeria can earn 10 billion dollars annually from Shea butter exports. *Nairametrics* Publication by Dennis Adesanoye on October 29, 2018. Accessed [24th January, 2019]

Agamuthu, P. (2009). Challenges and opportunities in agro-waste management: An Asian perspective. In *Inaugural meeting of first regional 3R forum in Asia* (Vol. 11, p. 12).

Agoro, M. A., Okoh, O. O., Adefisoye, M. A., & Okoh, A. I. (2018). Physicochemical properties of wastewater in three typical South African sewage works. *Polish Journal of Environmental Studies*, (2), 491-499.

Ahmad, H., Yousafzai, A. M., Siraj, M., Ahmad, R., Ahmad, I., Nadeem, M. S., ... & Muhammad, K. (2015). Pollution problem in River Kabul: Accumulation estimates of heavy metals in native fish species. *BioMed research international*, *2015*, 1-7

Ajayi, A.O. (2004). Emerging Roles for Extension in Promoting Sustainable Rural Environment: Lessons from Food Processing Cottage Industries and Their Wastes in Rural Oyo State, Nigeria. *Journal of Human Ecology,* 16(4), 283-289.

Akinjoba, U., Abiola, T., & Eniola, G. (2014). Production and utilization of organic fertilizers using palms and shea tree as sources of biomass. *African Journal of Crop Science*, *2*(4), 83-93.

Boffa, J.M. (1995). Productivity and management of Agroforestry Parklands in the Sudan zone of Burkina Faso, West Africa. Ph.D. Thesis, Purdue University, West Lafayette, Indiana, USA. pp101

Boffa, J. M. (2015). Opportunities and challenges in the improvement of the shea (Vitellaria paradoxa) resource and its management, Pp *24*.

Bolarinwa, I.F., Oke, M.O., Olaniyan, S.A. & Ajala, A.S. (2016). A Review of Cyanogenic Glycocides in Edible Plants, Toxicology – New Aspect to this Scientific Conundrum, Sonia Soloneski and Marcelo L. Larramendy, IntechOpen. DOI: 10.5772/64886

Bup, D.N., Mohagir, A.M., Kapseu, C. & Mouloungui, Z. (2014). 'Oil crops and supply chain in Africa', *OLC Journal*, 21(2), Pp206.

Busson, I. (1965). Plantes alimentaires de l`OuestAfricain.'etudebotanique, biologique et chimique.*Leconte*, Marseilles. Pp568.

Crélerot, F. (1995). Importance of Shea Nuts for Women's Activities and Young Child Nutrition in Burkina Faso: The Case of the Lobi. Ph.D. Thesis. University of Wisconsin Madison, Madison.Pp 500

Dalziel, J.M. (1937). The Useful Plants of West Tropical Africa, Crown Agents, London. pp 350–354.

Danikuu, F. M-I-M. (2016). Management of Shea Nut Waste With Indigenous Soil Bacteria. University for Development Studies, Tamale.

Egborge, A.B.M. (1994). Water pollution in Nigeria Vol. 1. Biodiversity and Chemistry of Warri River, Nigeria Ben Miller Publisher Warri .331.

Elias, M. & Carney, U. (2007). African shea butter: A feminized subsidy from nature. Africa 77:37–62

Faucon, M., Sauvageau, A. & Bahl, S. (2001). Coût de production pour le beurre de karité du Groupement Laafi. PACK/UNIFEM/CECI, Ouagadougou. Foraminifera Market Reasearch on Shea Butter Production in Nigeria; The Feasibility Report, 2015.

Foraminifera Market Reasearch on Shea Butter Production in Nigeria; The Feasibility Report, 2015. Retrieved from https://foramfera.com/marketresearchreports/agriculture-agro-processing-forestry-and-fishing/shea-butter-production-in-nigeria-the-feasibility-report/

Godfred, S. J., Osamu S. & Kazuhiko T. (2015). Shea (*Vitellaria paradoxa*) Butter Production and Resource Use by Urban and Rural Processors in Northern Ghana. *Sustainability*, 7, 3592-3614; doi:10.3390/su7043592.

Goreja, W.G. (2004). 'Shea butter – the nourishing properties of Africa's best-kept natural beauty secret'. New York: Amazing Herbs Press.

Govind, P. and Madhuri, S. (2014). Heavy Metals Causing Toxicity in Animals and Fishes. *Research Journal of Animal, Veterinary and Fishery Sciences.* 2(2): 17 – 23.

Hall, J.B., Aebischer, P.D., Tomlinson, H.F., Osei-Amaning E. & Hindle, J.R. (1996). *Vitellaria paradoxa*: a monograph. School of Agricultural and Forest Sciences. University of Wales, Bangor, UK, Pp. 105.

Howes, F.N. (1948). Nuts, Their Production and Everyday Uses. Pp. 264

Höfer, R. (2009). Sustainable solutions for modern economies. Cambridge: Royal Society of Chemistry.

Hyman, E. L. (1991). A comparison of labour saving technologies for processing shea nut butter in Mali. World Development, 19(9), 1247–1268

Iddrisu A. (2013). Biochemical and Microbiological Analysis of Shea nut cake: A waste product from Shea butter processing. MPhil Thesis, KNUST, Kumasi. *African Journal of Biotechnology*.

IPGRI (International Plant Generic Resources Institute (IPGRI) (2006). 'Descriptors for Shea tree (*Vitellaria paradoxa*)'. Rome: IPGRI.

Itodo, A.U., Abdulrahman, F.W., Hassan, L.G., Maigandi, S.A. & Happiness, U.O. (2011). Chemistry of Pyrolysis and Kinetics Studies of Shea Nut (*Vitellaria paradoxa*) Shells Activated Carbon for Textile Wastewater Treatment. *Iranian Journal of Chemical Engineering,* 30(2), 51 – 57.

Itodo, A.U., Itodo, H.U. & Gafar, M.K. (2010). Evaluation of Dyestuff Removal by Shea Nut (*Vitellaria paradoxa*) Shells. *J. Appl. Sci. Environ. Manage*. 14(4), 163 – 168.

Jibreel, M.B., Mumuni, E., Al-Hassan, S. & Baba, N.M. (2013). Shea butter and its processing impacts on the environment in the Tamale Metropolis of Ghana, *International Journal of Development and Sustainability*, 2(3), 2008-2019.

Karalliedde, L. & Gawarammana, I. (2008). Traditional Herbal Medicines – A Guide to the Safer Use of Herbal Medicines, Hemmersmith Press, London, 2008.

Ken, F. (2019). Plants for A Future. Retrieved from https://pfaf.org/user/Plant.aspx?LatinName=Vitellaria+paradoxa

Laniyan, T.A., Bayewu, O.O. & Ariyo, S.O. (2013). Heavy metal characteristics of ground water in Ibadan South Western, *Nigeria. African Journal of Environmental Sciences and Technology,* **7**(7), 641-647.

Lovett, P.N. (2004). The Shea Butter Value Chain: Production, Transformation and Marketing in West Africa, West Africa Trade Hub/USAID, Technical Report No. 2, Pp. 13.

Lovett, P.N. (2014). Pilot Study to Determine Opportunities for Carbon Neutral Shea Production. Fair Climate West Africa Program Development. ICCO, Bamako. Pp 40

Lovett, P.N. & Haq, N. (2013). Progress in developing in vitro systems for shea tree (*Vitellaria paradoxa*) propagation. Forests, Trees and Livelihoods. 22(1), 60–69

Lovett, P.N. & Philips L.D. (2018). Agroforestry Shea Parklands of Sub-Saharan Africa: Threats and Solutions. Leveraging Agricultural Value Chains to Enhance Tropical Tree Cover and Slow Deforestation (LEAVES).

Maranz, S. & Wiesman, Z. (2003). Evidence for indigenous selection and distribution of the shea tree, *Vitellaria paradoxa*, and its potential significance to prevailing parkland savanna tree patterns in sub-Saharan Africa north of the equator. *Journal of Biogeography*, 30, 1505–1516.

Mbaiguinam, M., Mbayhoudel K. & Djekota, C. (2007). Physical and chemical characteristics of fruits, pulps, kernels and butter of shea *Butyrospermum parkii* (Sapotaceae) from Mandou, southern Chad. *Asian Journal of Biochemistry*, 2(2), 101 – 110.

Mbam, B.N. & Nwibo S.U. (2013). Entrepreneurship development as a strategy for poverty alleviation among farming households in Igbo-Eze North Local Government Area of Enugu state Nigeria: *Greener Journal of Agricultural Sciences*, 3(10):736-742.

Mohammed, F., Boateng, S. & Al-hassan, S. (2013). Effects of Adoption of Improved Shea butter Processing Technology on Women's Livelihoods and their Microenterprise Growth. *American Journal of Humanities and Social Sciences*, 1(4), 244-250 DOI: 10.11634/232907811301419

Moki, E. C., Abubakar, B. Y. U., Bayewa, M. A., & Mu'azu, M. (2018). Ignition and Burning Rate of Sheanut Shell Briquettes Produced at Moderate Temperature and Die Pressure. *American Journal of Earth and Environmental Sciences*, *1*(3), 145-149.

Moore, S. (2008). The role of *Vitellaria paradoxa* in poverty reduction and food security in the Upper East region of Ghana. Earth & Environment, 3: 209-245

Nairametrics,2017. Shea Butter Advantage: Lessons from Niger State. Retrieved from https://nairametrics.com/2017/03/16/comparative-advantage-lessons-from-niger/

National Population Commission, NPC, (2006). Report on the Census 2006, Final Results of Federal Republic of Nigeria. Official Gazette No. 2 Abuja 2nd Federal 2009. Vol. 96. Abuja Printed and Published by Federal Government Printer, Abuja, Nigeria.

Niess, T. (1983). New shea butter technology for West African Women. GATE.

Noumi, E.S., Dabat M. H. & Blin, J. (2013). Energy efficiency and waste reuse: A solution for sustainability in poor West African countries? Case study of the shea butter supply chain in Burkina Faso. *Journal of Renewable and Sustainable Energy* 5, 053-134; doi: 10.1063/1.4824432

Obaroh, I.O., Abubakar, M., Haruna, M.A. & Elinge, M.C. (2015). Evaluation of some heavy metals concentration in River Argungu. *Journal of Fisheries and Aquatic Sciences,* **10:** 581-586.

Obi F. O., Ugwuishiwu, B. O. & Nwakaire, J. N. (2016). Agricultural Waste Concept, Generation, Utilization and Management. *Nigerian Journal of Technology (NIJOTECH*), 35(4), 957 – 964.

Olorunfemi O.D., Oladipo, F.O., Adetoro O.D. & Oladele T.O. (2017). Farm waste utilization among farmers in Irepodun Local Government Area, Kwara State, Nigeria: Implication for extension education service delivery. *Ruhuna Journal of Science*, 8: 1-11.

Olumide, S. (2018). Niger seeks economic turnaround through shea butter production. An article by Seye Olumide published in The Guardian Newspaper on 18th March, 2018. Retrieved from https://guardian.ng/features/niger-seeks-economic-turnaround-through-shea-butter-production/

Onche, O. (2018). In Niger State, Women Are Turning Shea Nut to Gold. A publication on Independent Newspaper on July 26, 2018.

Poudyal, M. (2011). Chiefs and Trees: Tenures and Incentives in the Management and Use of Two Multipurpose Tree Species in Agroforestry Parklands in Northern Ghana. *Society and Natural Resources*, 24: 1063 – 1077.

Pouliot, M. & Elias, M. (2013). To process or not to process? Factors enabling and constraining shea butter production and income in Burkina Faso. Geoforum 50, 211–220.

Quainoo A.K., Konadu, A. & Kumi, M. (2015). The Potential of Shea Nut Shells in Phytoremediation of Heavy Metals in Contaminated Soil Using Lettuce (*Lactuca sativa*) as a Test Crop. *J Bioremed Biodeg* 5: 268. doi:10.4172/2155-6199.1000268.

Rousseau K., Gautier D. & D.A. Wardell. (2015). Coping with the Upheavals of Globalization in the Shea Value Chain: The Maintenance and Relevance of Upstream Shea Nut Supply Chain Organization in Western Burkina Faso. World Development, 66: 413–427

Salawu, O. L., & Ayanda, I. F. (2014). Assessment of the Contribution of Sheabutter Processing to Poverty Reduction Among Women in Kwara State, Nigeria. *Journal of sustainable Development in Africa*, *16*(3), 12.

Sarkodie, P.A., Agyapong, D., Mumuni, S. & Amponsah, F.Y. (2016). Assessing the Impact of Indigenous Shea Butter Processing Activities in Northern Ghana. *International Research Journal Environment Science,* 5(3), 18-26.

Sharma, H., Rawal, N. & Mathew, B.B. (2015). The characteristics, toxicity and effects of cadmium. *International Journal of Nanotechnology and Nanoscience*, 3: 1-9.

Solomon, O., Gold, I. L. & Igene, L. (2017). Assessment of Shea Fruit Processors in Niger State for Improved Livelihood and Entrepreneurial Activities. *Global Journal of Pure and Applied Sciences.* 24: 17 – 23.

Tijani, M.N., Okunola, O.A. & Abimbola, A.F. (2006). Lithogenic concentrations of trace metals in soils and saprolite over crystalline basement rods. A case study from SW Nigeria. *Journal of African Earth Sciences,* **46:** 427-238.

Teklehaimanot, Z. (2004). 'Exploiting the potential of indigenous agroforestry trees: Parkia biglobosa and *Vitellaria paradoxa* in sub-Saharan Africa', New Vistas in Agroforestry 1: 207–20.

Tsunatu, D., Taura, U. & Jirah, E. (2015). Kinetic Studies of Bio-sorption of Cyanide Ions from Aqueous Solution Using Carbon Black Developed from Shea Butter Husk as an Adsorbent. *American Chemical Science Journal*. 8(2), 1 – 12.

Ugese, F.D., Sijuwola, T.O. & Ortserga, F. (2016). Effect of Shea Nut Residue on Growth, Reproductive and Yield Performance of Okra (*Abelmoschus esculentus (L.) Moench*). *Journal of Organic Agriculture and Environment*, 4(1), 59 – 66.

Viruthagiri, G., Adazabra, A.N. & Shanmugam N. (2017). Manufacture of lightweight clay bricks with improved thermal insulation properties via the incorporation of spent shea waste. *Journal of Applied Research and Technology*. 16: 186 – 203.

Wangboje, O. M., & Ekundayo, O. T. (2013). Assessment of heavy metals in surface water of the Ikpoba reservoir, Benin City, Nigeria. *Nigerian Journal of Technology*, *32*(1), 61-66.

World Health Organization. (2021). *Nickel in drinking water: background document for development of WHO Guidelines for drinking-water quality* (No. WHO/HEP/ECH/WSH/2021.6). World Health Organization.

Wogu, M.D. & Okaka, C.E. (2011). Pollution studies on Nigerian Rivers. Heavy metals surface water of Warri River Delta State. *Journal of Biodiversity and Environmental Sciences*, 1(3), 7-12.

Zievie, P., Yalley, P.P. & Saan, R. (2016). Experimental Investigation of Sheanut Shells Ash as Partial Replacement of Cement for Sustainable and Affordable Concrete Production. *International Journal of Engineering and Science*. 6(6), 21 – 27.