MICROBIAL UPGRADING OF SHEA WASTES TO ORGANIC MANURE BY COMPOSTING WITH SAWDUST

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ISHAQ, Aisha
MTECH/SLS/2018/7951

THESIS SUBMITTED TO THE POSTGRADUATE SCHOOL, FEDERAL UNIVERSITY OF TECHNOLOGY, MINNA, NIGERIA, IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE AWARD OF THE DEGREE OF MASTER OF TECHNOLOGY IN ENVIRONMENTAL MICROBIOLOGY

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ABSTRACT

Agricultural-based industries produce vast amount of waste every year. The release of this waste without proper treatment leads to environmental pollution which is harmful to human and animal health. This study converted shea-waste to organic manure using sawdust as bulking agent. It determined the microbiological and physicochemical properties of shea waste (SW),sawdust (SD) and soil(SL) using standard methods. The shea waste and sawdust were mixed in the ratio (SW/SD) 1:1, 10:1, 10:5, and shea waste alone. The composting was done under aerobic condition by bin compost technique with frequent turning for proper aeration. The study identified the following bacteria in the SW, SD and SL; *Streptococcus faecalis* 12 (21 %), *Bacillus subtilis* 14 (24.56 %), *Bacillus cereus* 10 (17.54 %), *Lactobacillus bulgaricus* 7(12.28 %) *Enterococcus faecalis* 5 (8.77 %) and *Bacillus licheniformis* 9 (15.79 %).The fungi identified were *Aspergillus niger* 15 (23.81 %), *Aspergillus flavus* 13 (20.64 %), *Penicillium notatum* 8 (12.70 %), *Mucor pusillus* 7 (11.11 %), *Fusarium solani* 8 (12.69 %), *Candida tropicalis* 3 (4.76 %), *Candida parapsilosis* 7 (11.10 %) and *Trichophyton rubrum* 2 (3.18%). These microorganisms were the active agents in the composting process. After 84 days, the compost matured and had the following parameters: pH 7.80, Urea 14.3 %, Nitrogen 1.72 %, Potassium 1.7 %, Phosphorous 1.76 %, Organic carbon 25 % and Moisture 47 %. These parameters suit an ideal organic manure of National and International Standards. The compost SW/SD (1:1) showed positive effects on plant (*Zea mays*) parameters such as leaf height, leaf number, plant height and leaf width as well as the yield. Shea waste which is abundant in northern parts of Nigeria can form a good manure when composted with sawdust to boost agriculture.

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background to the Study

Shea tree is indigenous to sub-Saharan Africa, and generally found in semi-arid to arid north of the humid forest zone. The shea tree (*Vitellaria paradoxa*) occurs predominantly in the Northern region of Nigeria (Ebinizer, 2014). The tree is perennial and deciduous and occurs mainly on dry open slopes (Yidana, 2014). The shea tree attains height of about 6.1 m and girths of 61 centimeters in the wild when it is often ravaged by bushfires. They can however reach heights of about 15 m and 17 cm girths under protected conditions. The trees grow slowly from seeds, taking about 30 years to maturity (Mahboubi *et al.*, 2017). The tree has gained importance as an economic tree crop because of the heavy demand for its butter both locally and internationally. It has been reported that more than 2.5 million tons of shea kernel produced worldwide were used for the production of cosmetics, pharmaceuticals, confectionery and edible fats (Nigeria Export Promotion Council NEPC, 2015).

According to the Food and Agriculture Organization (FAO), Nigeria is the world largest producer of Shea nut, capable of producing 500,000 mt with the wildly grown Shea trees predominant in 21 States across the country (FAO, 2017). Shea butter is the fat extracted from the nut of the African shea tree. Raw unrefined shea butter has been produced in Nigeria for millennia. The 500,000 mt of unrefined shea butter produced in Nigeria annually has a trade value of N160,000,000 ($400,000). It is produced primarily in Kwara and Niger States; other States include Kogi, Kebbi and Ogun. Shea fruit processing is a common production activity in rural areas of Niger State (Solomon *et al.*, 2018). Niger State produces about 57% of Nigeria's

shea butter exports (Nigeria Export Promotion Council NEPC, 2015). Niger State produces Grade A quality shea butter.

Shea waste is one of the agro-industrial by-products produced in the processing of shea nut into shea-butter. This is abundant in Northern Region of Nigeria and is currently being disposed of or being used marginally as fuel. Some works have been done on the use of shea waste as manure for supplementing fertilizer (AitBaddi *et al.,* 2013; Senesi *et al.,* 2016), and adding humus to soils to stimulate plant growth and improve yields. Chen *et al.,* (1994) reported that adding humic substances and mineral elements simultaneously leads to much greater increases in yield than adding mineral elements alone. Organic matter contributes to recycling, storage and availability of the nutrient for the benefit of plants and also intervenes as a source of nutrient and energy for the micro-organisms and macrofauna of the soils (AitBaddi *et al.,* 2013; Senesi *et al.,* 2016). Recycling the shea waste by composting could be an advantageous alternative to incineration which generates toxic compounds like dioxanes and aromatic polycyclic hydrocarbons.

To correctly balance the compost to provide better conditions for microbes to fasten the decaying process, the Carbon: Nitrogen (C:N) ratio must be taken into account. Further, the successful composting of manures, which are usually rich in nitrogen (Zmora-Nahum *et al.*, 2014), with materials having a high carbon content, such as sawdust (Zhang and He, 2012) and wood chips (Adhikari *et al.,* 2016), has been reported. Lignocellulosic agricultural and forestry by-products such as pine shavings and sawdust are commonly used as bulking agents in composting with animal manures (Bernal *et al.,* 2012). These products are common and easily available from woodworking companies. An appropriate combination of waste materials is important for

attaining high temperatures as it yields a suitable combination of carbon and nitrogen for the growth and activity of the microbial population (Singh and Kalamdhad, 2012).

1.2 **Statement of the Research Problem**

Agricultural-based industries produce the vast amount of wastes every year. The release of these wastes without proper treatment leads to environmental pollution which is harmful to human and animal health. Most of the agro-industrial wastes are untreated and underutilized, therefore it is disposed off either by burning, dumping or unplanned landfilling. These untreated wastes create different problems with climate change by increasing a number of greenhouse gases. These wastes pose a serious disposal problem.

Of the several million tonnes of shea nut produced each year, shea waste constitutes about 25 percent of the total mass produced and their management thus, becomes very important. At present the majority of shea waste are either burned, dumped in forest areas or left to deteriorate naturally. The problems associated with shea waste are numerous; environmental problems (pollution) which can escalate into disastrous situations resulting from improper waste management and poor handling and disposal of shea waste. Shea waste is thus described as a waste product of no economic value resulting in the indiscriminate dumping of the waste in soil in an environmentally unfriendly manner . Earlier studies on shea waste have indicated that it is biodegradable (Ofosu, 2009). Finding viable means of utilizing this material will eliminate the problem of waste disposal with its attendant negative effects on the environment. Shea waste is applied to the soil as fertilizer though too bulky and recalcitrant to biodegradation by most soil microbes.

1.3 Justification for the Study

Shea waste is a waste from shea butter processing which pollutes the environment. Due to the environmental impacts and the need to conserve energy and resources, efforts have been made to convert shea waste into manure. Earlier studies on shea waste have indicated that it is biodegradable (Ofosu, 2009). Finding viable means of utilizing this material will eliminate the problem of waste disposal with its attendant negative effects on the environment. Shea waste is applied to the soil as fertilizer though too bulky and recalcitrant to biodegradation by most soil microbes. It is estimated that for every metric tonne nuts processed, 450–600 kg of shea waste is produced and about 60, 000 metric tonnes of shea kernels are consumed locally in a year. Thus, about 30,300,000 kg shea waste is generated locally in a year. If these amounts are converted enormous organic fertilizers could be obtained. Organic manure improves soil structure, water permeability, soil fertility, promote plant health, and even increase yields. Therefore, this study converted shea waste into organic manure using sawdust as bulking agent.

1.4 Aim and Objectives of the Study

1.4.1 Aim of the Study

The aim of the research was to upgrade shea waste to organic manure by composting with sawdust.

1.4.2 Objectives of the Study

The objectives were to:

1. Determine the Microbiological and Physicochemical Properties of Shea waste, Sawdust and Soil.
2. Isolate and Identify Microorganisms in shea waste, sawdust and soil.
3. Produce Organic Manure from Shea Waste using Sawdust as Bulking agent.

4. Determine the Physicochemical Properties of the Organic manure.
5. Determine the efficiency of the Organic Manure in the Field Using Maize as a test crop.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Shea: Occurrence and Uses

The shea tree, *Vitellaria paradoxa*, (Fig 2.1) belongs to the family Sapotaceae. The tree is an indigenous fruit tree distributed in the shea parklands of Africa. Olaniyan and Oje (2007) described the shea fruit asa green epicarp, a fleshy mesocarp (pulp) and a relatively hard shell (endocarp) which encloses the shea kernel (embryo). The shea fruit is an important source of food for rural communities especially at time of food shortages, hunger and other disasters in addition to providing enormous health benefit (vitamins A and C, etc) and income. The shea nuts can contain from 20% to 50% edible fat. The shea fruit produces more solid shea butter as compared to other oil-bearing fruits as it contains more stearic acid. The kernel contains about 60% edible fat (shea butter) and the residual product from which the butter is extracted (shea cake), is an excellent ingredient for livestock feed production.

Figure 2.1: The Shea tree
Source: Adomako (1985).

2.2The Processing of Shea Nut into Butter and Cake

2.2.1 Traditional method of shea butter extraction

Studies by Fleury (2011) listed 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. The pulps of the harvested berry are crushed under foot after fermentation. This berry (almond) sticks to the shell wall and to separate them, the nuts are immersed in boiling water and sun dried for a few days. During the drying stage, the berries become detached and the nuts can now be stored for months without deterioration. Shelling is carried out using stone, mallets and pestles. Winnowing is achieved by holding basket filled with the mixture of nuts and shells at arm's length and gradually pouring the mixture into a pan. If there is a strong wind, the piece of shell will be blown away, if not, then the operation is repeated many times. The day prior to oil extraction, the shelled almonds are dried again from a moisture content of 40 - 50% to 6 - 7%.

Fleury (2011) stipulates that there are two main methods for shea butter extraction: a traditional village process and a mechanical procedure. The traditional process (Figure 2.2) involves many time-consuming stages. After drying, the kernels are crushed by simultaneous strokes in a mortar using a pestle. The paste that is gradually formed needs to be kept at a temperature of about 40°C. Shea butter tends to solidify between 34 and 38ºC. Once the paste becomes a fluid, it is strained and heated in a pan. A kneading process takes place to break up oil cell and ease oil extraction. The paste is then mixed with water to separate the remaining oil. The paste is rapidly mixed by hand until it starts to cover itself with a white emulsion of fat.

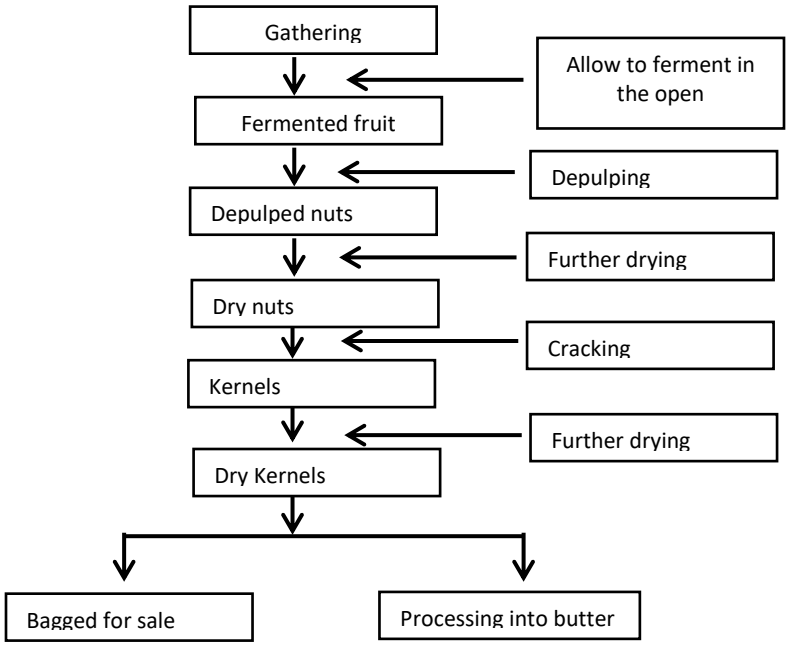

Figure 2.2: Flow chart for local collection and pre-treatment of shea nuts
Source: Agyente (2010)

Once this is achieved, the paste is left to rest and the oil that floats to the surface is scooped off, and poured into a container filled with lukewarm water for decantation. During decantation, a white film forms over the top of the surface, this is shea butter (Fig 2.3). It is separated and heated in a cauldron to evaporate remaining water and allow heavy impurities to settle at the bottom. The butter is left overnight to rest and solidify. Traditionally, it is then divided and hand-moulded into round shapes for sale or for storage. The butter will last for many years if kept away from light and heat as it is resistant to oxidative rancidity (Fleury, 2011).

Figure 2.3: Shea butter (Fleury, 2011).

It should be noted that using a shea nut press does not only alleviates time consuming process but also improves the fat output. For example, using a shea press fat output will be between 40 and 45% whereas fat output using the traditional method will be about 25% (Niess, 2013). Figure 2.4 show the flow charts for the processing of shea nut and how shea butter is extracted locally.

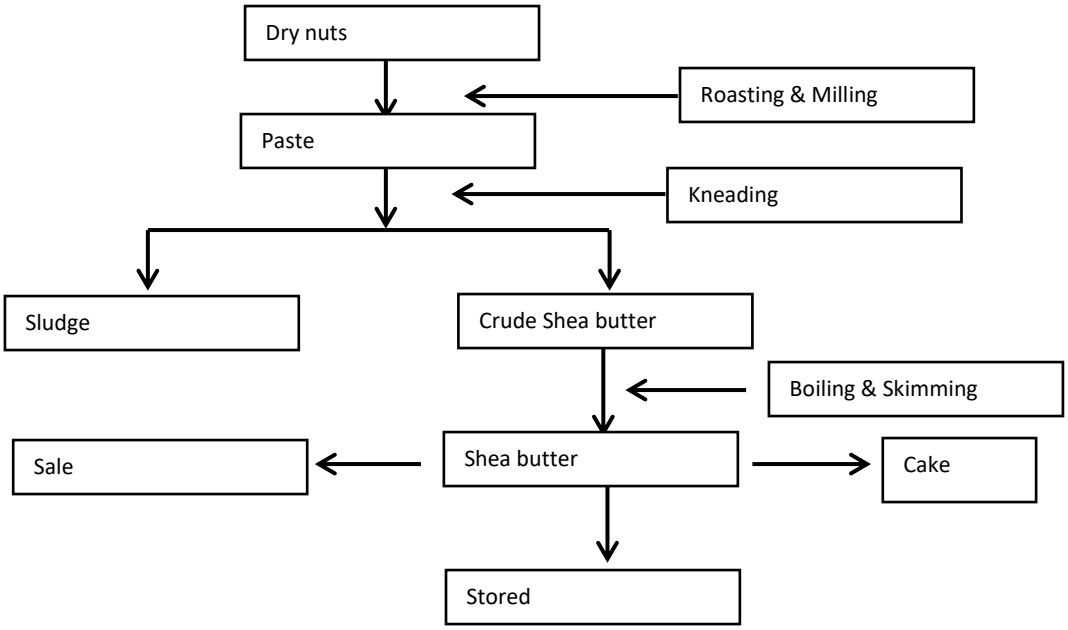

Figure 2.4: Flow chart for local processing of shea butter
Source: Agyente (2010)

2.2.2 Modern method of shea butter extraction

Much uncertainty still exists about the standard method of extraction of shea butter which will meet the standards declared by the various certification and standard organizations for shea butter quality. Thus, there still remains huge information regarding the reasons for differing approach to the extraction of shea butter and their efficiencies that are yet to be collected. This sort of information would extremely benefit not only the communities and industries but all the countries within the West African sub–region. Additionally, once the shea nuts have been harvested, a huge amount of time and effort is spent on the processing and extraction methods currently employed. To date, no extensive qualitative review of these methods has been carried out and as a result there is limited expert advice available to the local communities and women groups that would benefit most from it the American Shea butter institute (ASBI, 2004). The modern extraction processing technology is usually referred to as the Cold Press Extraction method so called because it does not involve the various different heating stages of the traditional procedure. The modern method of shea butter extraction has been reported by FAO (2012) but one of the earliest research works on the use of the mechanical press was Marchand (1988).

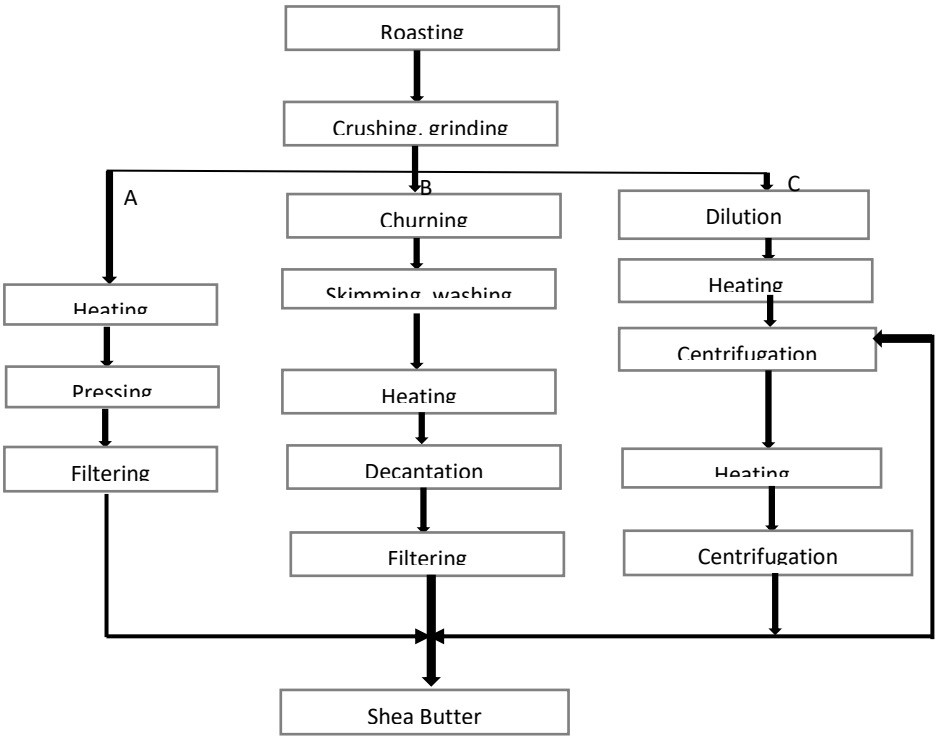

Figure2.5: Flow diagram for mordern extraction of sheanut cake

Source: Niess (2013)

The research revealed that, equipped with a jack that exerts 30 tonnes of force, a shea butter press could crush more than 3 kg of shea kernels within 20 min. The press could extract up to 85% of the fat contained in the kernel in a simplified process (Marchand, 1988) through a reduction in the various heating stages of the kernel and subsequently saves fuel wood. The processing of shea butter by this technique is carried out in a plant comprising a boiler, mechanical press system and a filter press system. The mechanical press applies a great deal of pressure to the pulverized seed to turn out more shea butter from the process (Yonas, 2014). Other inventions targeted single unit operations among which were a kneading machine, grinders, a hydraulic hand press, solar dryers, a heater and mixer. These inventions collectively achieved extraction efficiencies of 60 to 85% (Marchand, 1988; Cocoa Research Institute of Ghana CRIG, 2002;). Others have reported lower (35.9 to 45 %) fat output at 82.28°C for the

press (Alonge and Olaniyan, 2007; Olaniyan and Oje, 2007). About 30–33% of shea butter is extracted from the shea nuts with the mechanical expeller (Abdul–Mumeen, 2013) although combination of the mechanical with chemical methods has achieved 98% extraction efficiencies (Abdul– Mumeen, 2013).

The mechanical press is a method recommended for the large production of commercial quantity of shea butter. The method was not only developed to increase productivity and save time, but to reduce stress on the processors since traditional boiling method was found to be labour intensive and time consuming (Masters and Puga, 1994). The advantages of the mechanical press method notwithstanding, the equipment is expensive, scarce and unaffordable by most local industries (Alonge and Olaniyan, 2007) which predominates developing countries including Nigeria. Another shortcoming of the mechanical separation process using the press machine is that it does not completely remove all the oil from the mass of the paste (Apea and Larbi, 2013), that is about 19 % fat remains in the cake (Abdul–Mumeen *et al*., 2013).

2.2.3 Mechanical Extraction of Shea Butter

The supposedly tedious nature of the traditional shea butter extraction method, which yields about 25 % (Niess, 2013) of oil, called for the application of scientific principles and methods into the butter extraction process. This mind shift led to the introduction of mechanical pressing methods (such as expellers, hydraulic presses, etc) into the shea butter industry. The mechanical extraction process is outlined in a flow chart (Figure 2.6). The nuts are first heated to temperatures of between 15 ºC and 20 ºC then directed into a crushing unit where they are reduced in size to increase the surface area for effective butter yield. The pulverized nuts are then pressed to release oil and the first extraction cake (Niess, 2013).

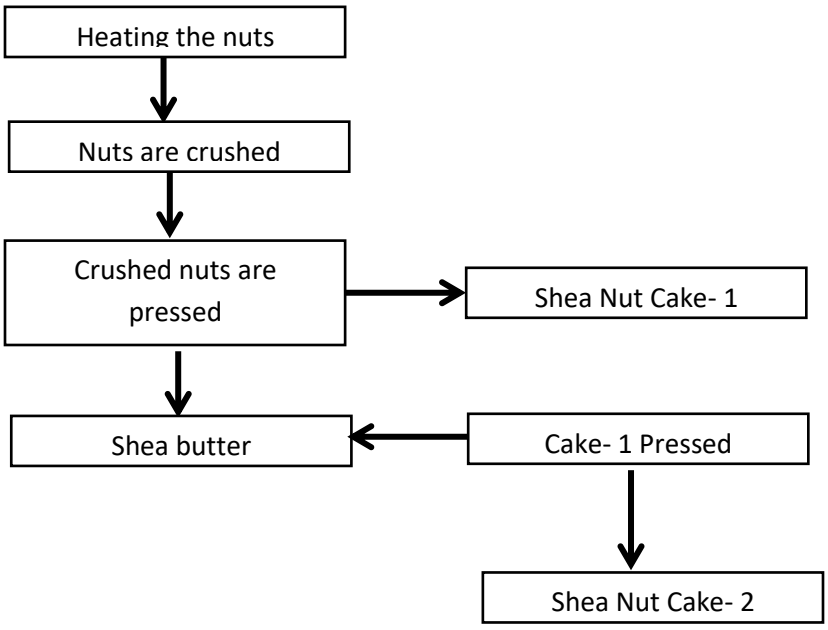

Figure 2.6: Flow chart for mechanical processing of shea butter

Source: Niess (2013)

2.2.4 Uses of Shea and Shea Products

Moore (2016) reported that the shea tree produces fruit which has multiple uses. It is highly nutritious and is also a valuable commodity on the local, national and international markets, making it the ideal candidate for research and investment. According to a study, the shea tree is the second most important oil crop in Africa after oil palm but as it grows in areas unsuitable for palm growth, it takes on primary importance in West Africa. The importance of the shea tree became even more significant in the early 1970s when it was reported that it was one of only six plant species whose vegetable fat could be used in the production of cocoa butter equivalents (CBEs) in chocolate as well as being a prized ingredient in the pharmaceutical and cosmetics industries Ofosu *et al.,* (2015) reported that shea nuts contain 40–55 % fat and it is estimated that

for every metric tonne of nuts processed, 450–600 kg of cake is produced. This amount of cake produced is substantial.

The American Shea Butter Institute, ASBI (2004) reported that 100 % pure natural shea butter is an all– natural vitamin A cream which has shown to be a superb moisturizer, with exceptional skin healing properties. ASBI (2004) has also asserted that shea butter has proved to be effective against skin and other skin related conditions such as dry skin, skin rash, skin peeling after tanning, blemishes and wrinkles, itching skin, sunburn, shaving cream for a smooth silky shave, small skin wounds, skin cracks and tough or rough skin, cold weather, frost bites, stretch mark prevention during pregnancy, insect bites, health skin, muscle fatigue, aches and tension, skin allergies such as poison ivy or poison oaks, eczema, dermatitis and skin damage from heat.

2.3 Bulking Agents and their Role in Composting

Bulking agents are fragments of material (sawdust, food wastes, rice husk, etc.) capable to create an effective structure which retains free ventilation spaces within the waste. The addition of a bulking agent for composting optimizes substrate properties such as aeration, moisture content, carbon to nitrogen (C:N) ratio, particle density, pH and mechanical structure, affecting completely the decomposition rate (Anwar *et al.,* 2015), and reduce the composting time as well as improved nutritive values of compost (Batham *et al.,* 2013). Additionally, the possibility of using a material produced by composting as an organic amendment depends on the quality of the product in relation to its nutrients content, its maturity and stability. Various bulking agents are used in dissimilar composting processes such as agricultural waste, industrial waste, food waste, composting of weeds as well as vermicomposting (Anwar *et al.,* 2015). It has been revealed in a study that the bulking agents like rice husk, sawdust and rice bran increase the disintegration and resulted in exact good quality compost (Batham *et al.,* 2013).

The use of bulking agents in composting process is very useful and efficient for producing good quality, time efficient and cost efficient compost. There are several instances of efficiency of bulking agents in composting as augmented nutritive value, fast degradation of materials which makes bulking agents to be used in a specific concentration with compost material (Anwar *et al.*, 2015). Low moisture bulking agents (peat, straw, peanut shells, sawdust, rice husk) usage are very suitable in the composting of wet materials like pig manure (Batham *et al.,* 2013). The bulking agents applied in composting play a very vital role to restraint the problem of the moisture content for the right composting, and it also reduces the problem of odour by preserving the moisture in composting (Batham *et al.,* 2013).

2.3.1 Compost

Organic matter that has been decomposed as result of the activities of community of living organisms (actinomycetes, bacteria, fungi, earthworms, maggots, etc.) in a process known as composting is termed compost. This practice recycles various organic materials otherwise considered as waste products and creates a soil conditioner. Compost is rich nutrients that support the growth of plants (Olowoake *et al.,* 2018). Compost form manures from the decayed refuse such as leaves, twigs, crop residues, stubble, hedge clippings, water hyacinth, sawdust and tannery sludge (Batham *et al.,* 2013). It is a dark brown, brittle and earthly smell when it is ready for use. Random mixing of the decomposing material will hasten the process and give more uniform product. Compost is organic manure, instead it is used for structural amendment of the soil. However, it is likely to get fertilizer in superior quality by adding enough nitrogen, phosphorus and potassium to the compost (Argun *et al.,* 2017). It is used in gardens, horticulture, organic farming, landscaping, etc.

2.3.2 Advantages of compost

Compost increases in the organic matter content of the soil in which it is applied, the water permeability of the soil, the space ratio between soil particles and subsequently the water holding capacity of the soil (Manyapu *et al*., 2017; Ayilara *et al*., 2020). It boosts root growth by easing the movement of plants roots. It also makes it easier to develop the soil. Humus prevents nitrogen from mixing into the ground water by providing nitrogen retention. Humus rich soil makes it possible for grown up plants to be healthier, more resilient to diseases and detrimental effects (Argun *et al*., 2017). In addition, application of compost also reduces soil erosion, recovers soil structure and increase water permeability (Manyapu *et al*., 2017).

Compost improves the physical, chemical and biological properties of soils (Weerasinghe and De Silva, 2017). Compost made from plant wastes comprises all the nutrients required by plants and are made accessible to them, when applied to soils (Weerasinghe and De Silva, 2017). The nutrients depleted from the soil are augmented back to the soil for use by plants. Also, compost encompasses these nutrients particularly nitrogen, potassium, phosphorus, and calcium in organic combination and when it decays, these nutrients are released in accessible form for the utilisation of plants (Verma and Verma, 2012).

2.3.3 Disadvantages of compost

The main disadvantages of composting are the following Large scale composting for example, aerated static pile as well as windrow composting occupies vast areas. There is the possible introduction of pathogens to the soil and it can also attract insects. During composting, it loses virtually half the obtainable nitrogen and emits greenhouse gases. It requires having a composting area where adverse environmental effect (such as controlled rainfall overflow) is averted from the composting area. It can produce odour at the initial stage of composting,

depending on type of starting materials applied and odour control is a common problem prolonged mineralization period (Ayilara *et al.,* 2020). Immature compost can be detrimental to plant roots as well as the growth (Elnasikh and Satti, 2017). Repeated as well as high usage of compost in some situations result in the buildup of metals, spare trace pollutants in the soil over period ,may include some pathogens that can survive extreme temperature to some degree, inadequate nutrient content and longer maturity period (Ayilara *et al.,* 2020). Uncertainty in nutrients composition (low) is attributed to compost, thus it has to be added in large quantities for fruitful outcomes (Marwanto *et al.,* 2020).

2.3.4 Problems associated with composting

Most often problems identified are due to presence of foreign matters such as glasses, plastics, bones (Hammed, 2015). It is hard to make with liquid manure and certain manures might require a carbon source. Other problems connected with composting are inadequate oxygen levels to facilitate the disintegration of compost; compost microbes essentially require a moist environment because they survive in the water layers surrounding composting organic matter particles (Tiquia, 2015). The ideal moisture and turning rate equally differ significantly depending on kind of raw material applied.

2.3.5 Aerobic composting

Aerobic composting is the decomposition of organic wastes in the presence of oxygen; products from this process include carbon dioxide (CO_2), ammonia (NH_3), heat and water (Batham *et al*., 2013). Organic matter usually disintegrates in the presence of oxygen, mainly as a result of the energy created from the aerobic respiration (Mehta and Sirari, 2018). Any significant variation inhibits the degradation process. The composting process may be more effective when the carbon

to nitrogen ratio and moisture are right according to material of compost (Batham *et al*., 2013). Aerobic microbes use oxygen to feed upon organic matter to develop their cell protoplasm from nutrients present into the raw material of compost.

Initially, mesophilic organisms (growth temperature range 20-45 ^{o}C) grow rapidly due to adequate presence of available amino acids and sugars. The common mesophilic microorganisms are *Alternaria Spp, Aspergillus Spp, Bacillus Spp, Cladosporium Spp, Flavobacterium Spp, Mucor Spp, Humicola Spp, Penicillium Spp, Pseudomonas Spp* and *Streptomyces Spp*, etc. (Mehta and Sirari, 2018). With correct accessibility of reasonable amount of nutrient source these microorganisms grow fast and produce heat by their own metabolism and raise the temperature of heap to the point where their own actions become repressed. Then several thermophilic fungi (*Aspergillus Spp, Mucor Spp, Chaetomium Spp, Humicola Spp, Absidia Spp, Sporotrichum Spp, Torula Spp*, (yeast and *Thermoascus Spp)*, thermophilic bacteria (*Bacillus Spp* and *Thermus Spp*) and few actinomycetes (*Streptomyces Spp, Micropolyspora Spp, Thermoactinomyces Spp* and *Thermomonospora Spp*) continue the process of raising heap temperature up to 65 ^{o}C – 70 ^{o}C or higher. The necessity of this peak heating period is that it can kill most of the pathogens and weed seeds that can contaminate the compost and later on soil as well as crop which are in contact of this compost (Mehta and Sirari, 2018).

2.3.6 Anaerobic composting

Anaerobic composting is the decomposition of organic wastes in the absence of oxygen, the products being methane (CH_4), carbon dioxide (CO_2), ammonia (NH_3) and trace amount of other gases and organic acids. Anaerobic composting was habitually used to compost animal manure and human sewage sludge; nevertheless it has become more common for some municipal solid wastes as well as green wastes to be handled in this manner (Tweib *et al*., 2011). The anaerobic

decomposition results in the breakdown of organic compounds by the application of anaerobic microorganisms. Anaerobic microorganisms use nitrogen, phosphorus, with other nutrients to develop their cell protoplasm. The principal part of anaerobic composting is the breakdown of organic matter through reduction process; but the last product is subject to have aerobic oxidation. There are no implications of this oxidation process on utilization of material as it is required for a short period (Mehta and Sirari, 2018).

2.4 Stages of Composting

Four composting phases are distinct assenting to the temperature, which is directly proportional to the biological action within the composting process (Tweib *et al*., 2011). These stages are:

2.4.1 Mesophilic phase

The mesophilic temperature range is 20 ^{o}C - 40 ^{o}C. At room temperature, mesophilic microbes (such as *Bacillus Spp, Pseudomonas Spp, Micrococcus Spp, Staphylococcus Spp, Aspergillus Spp, Candida Spp, Penicillium Spp, Saccharomyces Spp*) rapidly multiply in vegetative mass. As a result of metabolic activity, temperature rises and organic acids are generated lowering the pH. In this phase, different microbial communities initiate decomposition of organic matter into simpler nutrients (Anwar *et al*., 2015). The mesophilic bacteria raise the temperature of the compost heap to thermophilic phase (40 ^{o}C – 60 ^{o}C) (Lim *et al.*,2013).

2.4.2 Thermophilic phase

On the attainment of temperature of 40^{o}C, thermophilic microbes (such as *Bacillus subtilis, Thermus Spp, Aspergillus fumigatus, Mucor Spp*) begin their activity, converting nitrogen into ammonia, and the pH turns alkaline. At 60^{o}C, those thermophilic fungi vanish and actinomycetes and sporigen bacteria emerge which decompose waxes, proteins and complex carbohydrates such as cellulose and hemicellulose, the key structural molecules in plants. Thermophilic

temperatures are established due to heat production. The higher temperatures attained in this stage seem to be the most significant factor in killing heat-sensitive microorganisms (Anwar *et al*., 2015).

2.4.3 Cooling stage

Once temperature falls below 60 ^{o}C, mesophilic microbes recolonise the substrate and the number of microorganisms that decompose cellulose or starch is increased, among them are bacteria and fungi (Elnasikh and Satti, 2017). Below 40 ^{o}C, the mesophilic action resumes and the pH slightly decline.

2.4.4 Maturing stage

In a period of several months at ambient temperature, secondary reactions occur, basically condensation as well as polymerization of humus. Mature compost heaps become more even and less active to the microorganisms though mesophilic microorganisms recolonize the compost. The final composting material becomes dark brown to black in colour that increases the amount of humus. The particle size of mature compost is close to soil like texture and the ratio of carbon to nitrogen (C:N) decreases, pH close to neutral and the exchange capacity of the material increases (Mehta and Sirari, 2018).

2.5 Factors Affecting Composting Process

As in any biological process, the factors affecting the rate and speed of composting are of numerous kinds: type of waste to be treated, composting method, environmental conditions, microorganisms, nutrition (carbon and nitrogen), oxygen, and moisture. Other factors affecting the speed of composting include temperature, pH, volume and surface size/particle size. Constant inspection and control of these factors are important to quick compost maturity.

2.5.1 Temperature

Temperature is an important indicator of how clearly the composting process is continuing and how abundant oxygen is actually used. Optimal temperature range of 35 ^{o}C – 55 ^{o}C is important for the effective elimination of pathogens, parasites and weed seeds (Anwar *et al*., 2015). If the temperature goes higher or lower, the activity of beneficial composting microbes are adversely affected, which results to immature and non-effective composts. Thus, for good composting product temperature is a key factor and it can be controlled by turning and aeration of compost (Mehta and Sirari, 2018).

2.5.2 Moisture

Ideal moisture range is 40 – 60 %. Should larger amount of moisture be present, water could block every pore in the heap, and the process develops an anaerobic one, resulting in organic material rotting. If the process becomes too slow in the opposite case, it reduces the activity of microorganisms. Moisture contents will depend on the type of constituents selected; fibrous material must be in the range 50 – 60 % (Van-der Wurff *et al*., 2016).

2.5.3 pH

The compost contains number of microbes that work well under neutral to acid conditions. This occurs in a pH range of 5.5 to 8. Microorganisms react differently to it: fungi can resist a pH range of 5.0 to 8.0, and bacteria prefer a nearly neutral pH of 6.0 to 7.5 (Mehta and Sirari, 2018). The pH determines microbial activity and also works as an indicator of progression of the process. The organic acids are formed during the initial stages of decomposition, which favours the growth of fungi and the breakdown of lignin and cellulose. At the mesophilic phase, pH level begins to drop because of the activity of acid-forming bacteria. When this acidification stage finishes, the pH rises up to 8.0 and to 8.5 at the end of the process. While a significant fall in pH

value may result in anaerobic conditions, high values may cause loss of nitrogen through the volatilization of ammonia (Framis, 2018). At the last stage of the composting process, the compost becomes stable at pH range of 6 to 8.

2.5.4 Oxygen

Composting is an aerobic process. In aerobic composting oxygen is a primary limiting factor. Oxygen concentration depends on factors like material type, texture, moisture, tossing frequency and the availability of forced ventilation. The growth of aerobic microbes is directly affected by the oxygen supply. Slighter supply of oxygen to compost heap can limit the growth of aerobic microbes and also leads to slower decomposition of raw organic materials. In addition, proper aeration eliminates excessive heat, water vapour and other gases trapped in the heap. Thus, suitable aeration is required for capable composting, and can be attained by monitoring the particle size of raw materials used in composting and also with the frequent turning of the heap (Mehta and Sirari, 2018).

2.5.5 Carbon to Nitrogen (C:N) ratio

Carbon and nitrogen are main constituents of organic matter. The C:N ratio is one of the key factors affecting the quality of compost. The acceptable quality of any compost depends on a well-balanced C:N ratio range of 25 - 35. Higher C:N ratios make the process less quickly as there isan excess of degradable carbon for the microbes, but very low C:N ratios show an excess of nitrogen which might be missing from the process (MaciasCorral *et al.*, 2019), transforms into ammonia. Therefore, inadequate C:N ratios may need to be corrected by adding another material to get a balanced content of both elements. Wastes having different C:N ratios must be efficiently mixed so as ensure well-balanced compost. Organic materials with high C:N ratio are straw, leaves, dry hay, sawdust, branches (Anwar *et al*., 2015). Low C:N ratios are found in

young vegetables, animal faeces and slaughter-house residues. Anwar *et al*. (2015) reported that different studies have shown variation ranges of C:N ratios (14 - 40) for maturity of quality compost.

2.5.6 Microbial population

In composting process a wide range of bacteria, fungi and actinomycetes population are responsible for the completion of the aerobic decomposition of organic matter (Tweib *et al*., 2011). Microbes can degrade more complex molecules such as hemicellulose, lignin or starch. They are more plentifully present in the late phases of composting, when the majority of easily degradable substrates have already been used up. Fungi often form hyphae, which are strands of cells that are noticeable to the naked eye. The fungi are more important in the later stages of composting, when more resistant substances are being decomposed, such as lignin, hemicellulose and pectin (Van der Wuff *et al*., 2016).

2.6 Methods of Composting

There are various methods of composting systems. Irrespective of size, satisfactorily managed composting systems share a few compositions such as adequate microbes capable to digest organic materials, as well as enough oxygen, suitable moisture, nutrients for microorganisms (steady carbon to nitrogen ratio), an adequate volume of material to allow the microbial population to grow and flourish in order to decompose organic waste (Argun *et al*. 2017). A number of composting methods are used by community scale and farm-scale set ups:

2.6.1 Static pile

A compost heap that is prepared and then left completely unturned is named as a static pile. They are made on the ground without any equipment or piping underneath, though they may be covered, for example by a tarpaulin. Aeration can only be ensured if there is a high percentage of

porosity (more than 60 %) and high bulking materials present in the pile (Manyapu *et al*., 2017). With adequate porosity, the pile may still achieve high temperatures and maintain some level of aerobic activity. A static pile will only work suitably if it is getting sufficient airflow. Absence of oxygen will lead to anaerobic breakdown of materials and the production of methane, a powerful greenhouse gas. The pile can be inspected to gauge its progress.

2.6.2 In-vessel or enclosed composting

This is the latest technology which is motivating the interest of many composters and researchers. This is very advanced process of composting. The entire system is enclosed in a vessel or a tank. There is an opening exhaust for release of toxic gases and odour which get filtered through biofilters fitted at the exhaust unit (Manyapu *et al*., 2017). The airing is supplied either by turning of the container or through aeration pumps, to keep steady air flow rate. Since the entire system is enclosed, moisture is conserved within itself therefore lessening the dependence on water. The best moisture content 40-60 % can be maintained easily. A thermophilic condition which is favourable for aerobic thermophilic bacteria can be achieved due to the avoidance of heat loss (Manyapu *et al*., 2017). Meanwhile, the inside environment is unaffected by the external conditions. In-vessel composting can be used regardless of the climate condition of the place.

2.6.3 Bin composting

Composting in a bin basically refers to any process that employs open or closed container. It is the most common home composting system adopted to reduce wastes. This choice is mostly applied for small scale composting, smaller quantities of compost and yard wastes (Vich *et al*., 2017). It is stress free practice adaptable to various sustainable agricultural plots and suitable for

gardeners. Bins can be made from plastics, wood or concrete and may or may not have forced aeration, and is usually sheltered (Vaverková *et al.*, 2014).

2.6.4 Windrow composting

This term is usually used for a pile of arranged raw materials. This is the common method used as large scale composting in farming due to the fact that it requires large size of site where the pile mixture of organic materials forms long narrow pile known as windrow. The pile is turned mechanically using windrow turner, manure spreader or bucket loader. Turning enhances the aeration and allows all the raw materials exposed to the microorganisms to colonise (Manyapu *et al*., 2017). Heat, water vapour and other gases are expelled from the pile. The compost is turned manually using scrapers or spades and is aerated naturally. This method of composting is simple and can be changed according to the place and circumstances.

2.6.5 Vermicomposting

Vermicomposting is a non-thermophilic composting process using different species of earthworms to produce a blend of peat-like product of decomposed organic residues (Ebrahimi*etal*., 2019). The most commonly used earthworms include: *Eisenia foetida, Eurdilus eugeniae* and *Lumbricus rubellus* (Manyapu *et al*., 2017). It involves the bio-oxidation and stabilization of organic material by mutual action of earthworms and microbes (Mengistu *et al*., 2017). The worms engulf the organic matter and mix up with essential enzymes and hormones in their gut. They excrete the residue in form of worm casting which contains crucial plant nutrients which plants can easily take up. Thus, it promotes a large and active microbial biodiversity population in the soil as compared to composts produced by the thermal process. The thermophilic condition is not suitable for worms but pathogens and weed seeds get killed in vermicomposting. Vermicomposting can be done in small containers (Vaverková *et al.*, 2014) to

large tanks with a thatched roof. Therefore, vermicomposting allows biotransformation of wastes into valued organic manure (Sosnecka *et al.*,2016).

2.7 Commercial Organic Manure in Nigeria

Due to the depleted/poor soil quality in northern Nigeria, farmers use organic manure to improve the soil fertility. This practice of using organic manure has been there for over four to more decades. However, with the introduction of chemical fertilizers most farmers overlook the use of organic materials for agriculture (Usman and Kundiri, 2016). Over 80 % of all the fertilizers used in Nigeria by farmers is imported. The price of inorganic fertilizer (50kg) at the open market ranged from ₦6,000 to ₦12,000. This price is above the capacity farmers can afford, if this is not checked or substituted it will affect agricultural products yields. Hence, animal manures are frequently obtainable as own-farm made manure from the livestock kept by the farmers. Organic manure is also produced and obtainable at the commercial livestock farms, Fulani settlement, poultry farms and abattoirs (Olayide *et al.,* 2009). Organic manure is inexpensive and more effective than chemical fertilizer (Babasola *et al.,* 2017).

In Nigeria, the commercial organic fertilizers were used mostly by vegetables farmers (particularly by those who grow *Amarantus* sp., pumpkin leaf, Ewedu plants, etc). Fasina (2016), reported the existence of an organic fertilizers was less than that of inorganic fertilizers. The investigator attributed it to lack of awareness about the effectiveness and reliability of these commercial organic fertilizers. Other organic fertilizers that are produced in Nigeria include Amazing organic fertilizers, C&C Compost, Compost PLUS, Nano organic fertilizer, Grade A organic fertilizer, Grade B organic fertilizer, etc. The Amazing organic fertilizer is produced in Minna, (behind Hajj camp), Niger State. The product are sold within and outside Niger state. C&C Compost Services Limited is a fertilizer distributor in Owerri, Imo State. Elpis Enterprises

is also a distributor of organic liquid fertilizer made from poultry dropping located in Lagos, Nigeria. Nano organic fertilizer is produced in Kaduna. Compost PLUS is produced by EarthCare Nigeria Limited, Lagos. It is odourless, non-toxic and scientifically verified.

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Description of the Study Area

The study area was Chikodna in Bosso Local Government Area of Niger State, Nigeria. Bosso lies along longitude 6º28'E to 6º31'E and latitude 9º38'N to 9º41'N (Figure 3.1). The climate of Bosso is characterized by distinct raining and dry seasons. The rainy season starts in April and ends in October, with a maximum rainfall occurring in August and the dry season start from October to March. The mean monthly temperature is highest in March at 35 ºC and lowest in August at 22.3 ºC. The mean monthly relative humidity is highest in August at 60 % and lowest in January at 19 %. The vegetation consists of open savannah. The trees are scattered, short with some up to 16.5 meters' height. The trees include shear butter *(BytyraSpemumParki)*, locust bean *(TamarindusIndica*, rubber climber *landolphiahendeletti)*, Baubles silk cotton and bleb palms that are common along valleys of rivers which are identified by dense growth of woodland. The composition of the vegetation and its character are often caused by variations in soil types, topography, groundwater situation and human interference.

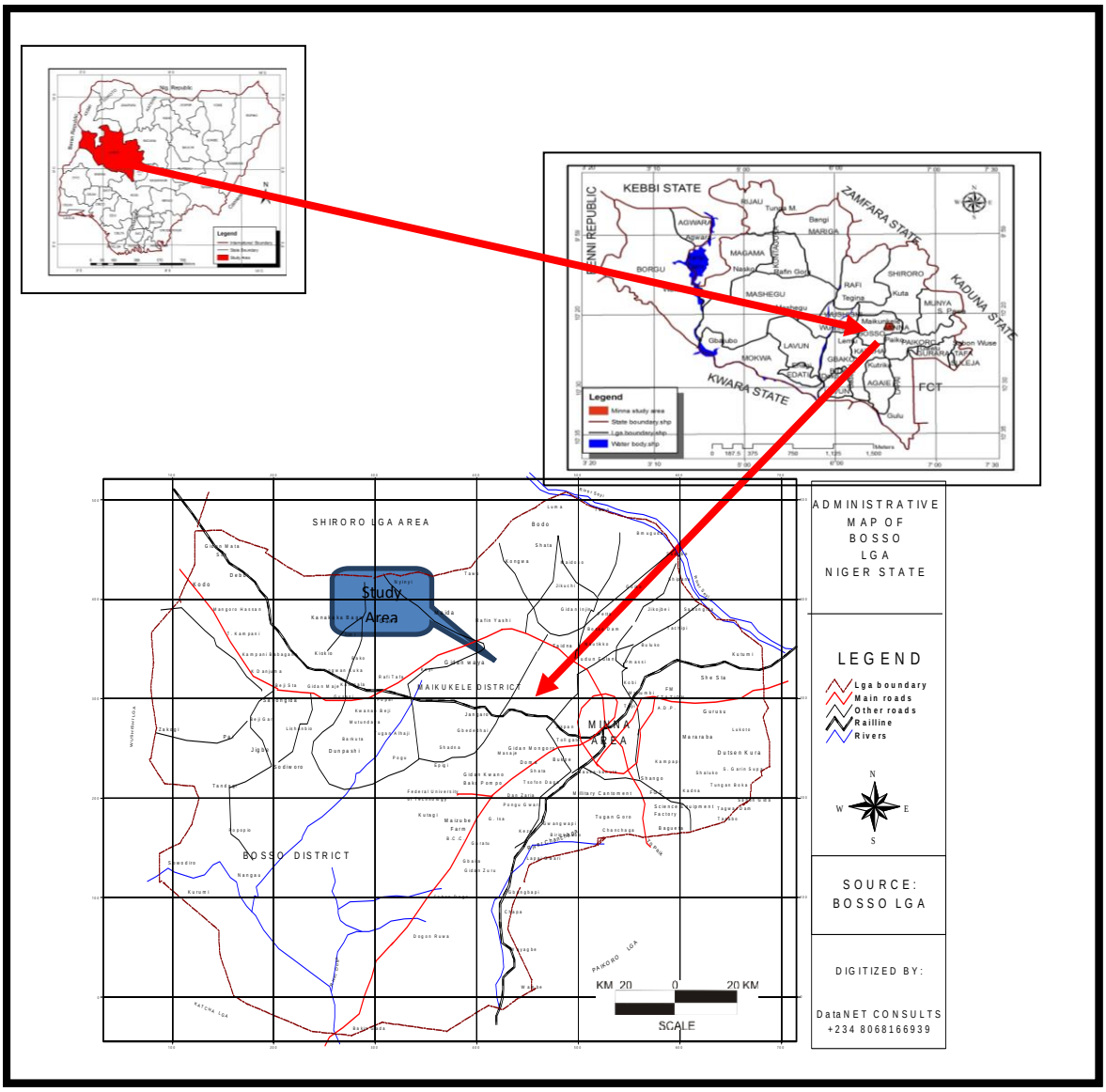

Figure 3.1: Map showing the study area.
Source: Geography Dept. FUT, Minna.

3.2 Collection and Processing of Samples

Sheanut waste sample was collected from shea nut waste dumpsite into clean polythene bags from a village called Chikodna, Bosso Local Government Area, Niger State, Nigeria. The sample was transported to the Microbiology laboratory, Federal University of Technology, Minna, Nigeria. Sample (100kg) of shea wastes was sieved with mesh of 1.7 mm diameter to remove large pieces of debris and plant materials and stored in polythene bags prior to analysis as well as composting.

The sawdust was collected from wood workshop at Mypa Road, Bosso, Bosso Local Government Area, Niger State, Nigeria. Sample (100kg) of fresh sawdust was partly air dried at room temperature for two days and then dried in the sun for three days. These wastes were packed in polythene bags, so as to prevent contamination with some other wastes and stored at room temperature until required.

Soil sample was collected into clean polythene bag from Talba Estate, Bosso Local Government Area. Niger State Nigeria. The sample was transported to the Microbiology Laboratory of the Federal University of Technology, Minna for analysis. The soil was sieved with mesh of 1.7 mm diameter to remove large pieces of debris and plant materials.

3.3 Microbiological Analysis of Samples

Samples from the raw materials (shea waste, sawdust and soil) and composted materials (shea waste/sawdust mixtures) at each stage of composting (0, 28, 56, and 84) days were analysed for total aerobic bacteria and fungi (yeasts and moulds) as described by Ahmed *et al,* (2007). A series of dilutions were prepared using sterile distilled water. In this procedure, a sample suspension was prepared by adding 1.0 g sample to 10 ml distilled water and was mixed well.

Each suspension was serially diluted. One milliliter (1.0ml) was introduced onto plates with Nutrient Agar (NA) and Sabouraud Dextrose Agar (SDA), for the enumeration of bacteria and fungi (moulds and yeasts) respectively. The NA plates were incubated at 37 ^{o}C for 24-48 hours, while the SDA plates were incubated at room temperature for 3-5 days. The colonies which developed were counted and expressed as colony forming units per gram (cfu/g) of sample. Pure isolates were obtained by repeated sub-culturing on media used for the primary isolation. Pure isolates were preserved on agar slants for further characterization and identification.

3.4. Isolation and Identification of Microbial Isolates from the shea waste, Sawdust, soil and Compost Samples

3.4.1 Bacterial Isolates

The bacterial isolates were characterized based on their cultural, morphological and biochemical characteristics which included: Gram's staining, production of catalase, oxidase, urease, coagulase, indole, H_2S, motility, Methyl Red and Voges Proskauer (MR-VP), and sugar fermentation. Biochemical tests and gram staining of each isolate was carried out using standard procedures as described by Cheesbrough (2006). The characteristics and identities of the isolates were confirmed by comparing their characteristics with those of known taxa using Bergey's Manual of Systematic Bacteriology (Garitty *et al.,* 2005).

(i) Gram staining

A wire loop was flamed until red hot to sterilize and was allowed to cool. A loopful of the isolate was picked and smeared on a clean grease free slide, air dried, heat fixed and was placed on staining rack. Drops of crystal violet stain were added on the smear for 60 seconds after which it was rinsed with clean water. Lugol's iodine was added for 30 seconds and rinsed with clean water. The slides were decolourised quickly (few seconds) with acetone-alcohol and were rinsed with clean water. Safranine stain was added to the slides for 30 seconds and was rinsed with

clean water. Slides were allowed to air dry and were observed under the microscope using l00x objective lens with oil immersion added onto slide (Cheesbrough, 2006).

(ii) Catalase test

Two drops of 3 % hydrogen peroxide ($H0_2$) added on each end of grease free slide was labeled 1 and 2. With the aid of a clean glass rod, the test organism was placed in drop 1, and was checked for gas bubbling while drop 2 served as control. Observed result was recorded as positive or negative based on the evolution of bubbles or gas formed (Cheesbrough, 2006).

(iii) Oxidase test

Three (3) drops of freshly prepared oxidase reagent (tetraethyl-p-phenylenediamine dihydrochloride) was placed on a piece of filter paper on a clean Petri dish. A sterilized wire loop was used to collect the test organism and smeared on the filter. The appearance of blue- purple colouration within ten (10) seconds signified a positive reaction, whereas the absence of blue-purple colouration after fifteen (15) seconds was noted as negative (Cheesbrough, 2006).

(iv) Citrate test

Twenty four point eight grams (24.8 g) of Simmon's citrate agar was weighed and dissolved in 100mL of distilled water by heating. Then it was poured into test tubes. The citrate agar in the test tube was sterilized by autoclaving at 121 °C for 15 minutes. The test tubes were placed in an angular position for the agar to solidify into a slant. The test organisms were streaked into the citrate agar slants and were incubated for 37 °C for 24 hours. Colour change from green to blue indicated a positive result; while no colour change (green colour retained) indicated a negative result (Cheesbrough, 2006).

(v) Indole test

Peptone water was prepared according to the manufacturer's guide and was introduced into bijou bottle. The test organisms were inoculated in to the peptone water and were incubated at 37 °C for 24 hours. Then 0.5 mL of Kovac's reagent was added to each test tube and observed within 10 minutes. Presence of red colouration ring at the reagent layer was confirmed as positive, while absence of colour ring indicated negative results (Cheesbrough, 2006).

(vi) Urease test

Bacterial isolates were inoculated in urea agar slants in bijou bottles and were incubated at 37 °C for 24hours. Bright pink (or red) colouration indicated a positive reaction while negative reaction was shown by the absence of colouration (that is, the colour was pale yellow) (Cheesbrough, 2006).

(vii) Coagulase test

The test was done using 18-24 hours old culture. A loopful of bacterium was combined with normal saline solution on a glass slide. A drop of undiluted plasma was added to the suspension and stirred for 5 seconds. A coagulase positive result was indicated by clumping of colonies (Cheesbrough, 2006).

(viii) Motility test

Motility medium was prepared in test tube using l0 g of peptone, 5 g of agar-agar, and 5g of sodium chloride (NaCI) per litre. It was sterilized by autoclaving at 121 °C for 15 minutes. The bacterial isolates were inoculated into a sterile motility medium by stabbing with a sterile needle to a depth of about 2 cm just about the centre of the medium. The tubes were incubated at 37 °C for 18 hours. Organisms that grew only along the line of stabbing as compared to the control was noted as non-motile, whereas those that grew and diffused into the medium away from line of

stabbing causing turbidity (rendering the medium opague or not clear) was noted as non-motile (Cheesbrough, 2006).

(ix) Methyl Red (MR) and Voges Prokauer (VP) test

The bacterial isolates were inoculated into test tubes containing 2 mL of sterile glucose phosphate peptone water labeled I and 2, and were incubated at 37 °C for 48 hours. To test tube 1, four drops of methyl red reagent was added using Pasteur's pipette; it was shaken gently to mix and observed for colour change. Positive or negative M-R inference was indicated by bright red rings on the surface of the medium and yellow colour respectively. To the tube 2, one (1) milliliter of 40 % Potassium hydroxide (KOH) and 3 mL of 5 % alcoholic alpha-naphthol was added and shaken vigorously. It was allowed to stay for three (3) minutes. A pink colour formation within 2-3 minutes was recorded as positive V-P reaction while no colour change (remained black) showed negative reaction (Cheesbrough, 2006).

(x) Carbohydrate utilization test (acid and gas production from carbohydrate)

One hundred millilitres (l00 mL) of peptone water was prepared with the addition of two grams (2 g) of the test sugar (sucrose, lactose, D-glucose) and 0.08 g of phenol red added as indicator. Five milliliters (5 mL) of the mixture was put into test tubes and sterilized by autoclaving at 121 °C for 15 minutes along with Durham's tube within the medium and was allowed to cool. Afterward, test organisms were inoculated into the sterile medium, and the control without inoculation of the test organism was set. It was incubated at 37 °C for 24-48 hours after which the medium was observed for colour change from red to orange indicative of acid production (Cheesbrough, 2006). Gas production was indicated by a void at the end of the Durham's tube.

3.4.2 Mould Isolates

Mould isolates obtained from the shea waste, sawdust, soil and compost were characterized based on their cultural characteristics (macroscopy); colour, colony surface as well as reverse, and morphological characteristics (microscopy); type of asexual spore appearance, characteristics of spore head, nature of hyphae, colour of aerial and surface mycelium (Rabah and Ibrahim, 2010; Bello *et al.,* 2020). Wet mount was prepared by adding a drop of lactophenol cotton blue on a clean grease free glass slide and a fragment of fungal growth was placed and teased out. A cover slip was placed on the sample (of organism to be identified) and was viewed under the microscope with 10 x and 40 x objective lens. The identification was done using the schemes of Watanabe (2010).

3.4.3 Yeasts Isolates

Yeasts isolates from the wastes, soil and compost samples were characterized based on morphological, biochemical and physiological characteristics such as the ability to grow at different temperatures, ferment sugar and growth in various concentrations of ethanol (Cheesbrough, 2006). The identification was done using the scheme of Barnett *et al.*,(1990).

3.5 Determination of Physicochemical Parameters of Samples

The shea nut waste, sawdust, soil and compost samples were analysed for their physicochemical properties:

3.5.1 Determination of Temperature

Temperature of the samples was measured using mercury in glass thermometer. This was done by dipping the thermometer into the sample and the reading was taken. The mercury level was regarded as the temperature of the sample and was stated in °C. The thermometer was allowed in the sample for about two minutes before the reading was recorded (Umar *et al.,* 2017). Readings

were taken every day at a depth of 40 cm at different points within the bin. The composting period lasted for 84 days.

3.5.2 Determination of pH and Electrical Conductivity (EC)

For pH determination, l0 g of sample was weighed into an extraction cup and 25 ml of distilled water was dispensed. It was allowed to stay for 15 minutes. With the aid of mechanical shaker, the sample was shaken for 30 minutes at 150 rpm (revolutions per minute), and was allowed to remain for 10 minutes. The pH meter was calibrated using buffer of pH 7.0 and 4.4, then the electrode of the pH meter was inserted into the mixture and the displayed pH value was recorded as described by Rabah and Ibrahim (2010).

The Electrical Conductivity (EC) was performed on filtered extract of 1:5 (w/v) sample to distilled water ratio. The conductance cell was washed with distilled water. The cell was dipped into solution of sample and the reading was observed on EC meter. Conductivity was displayed on mS /Cm (Ameen *et al.,* 2016).

3.5.3 Determination of Total Nitrogen

The nitrogen contents of the samples were determined using the Kjeldahl method (Sez-Plaza *et al.,* 2013). Five grammes (5 g) of the sample was weighed into the digestion tube and moistened with distilled water. Twenty milliliters (20 ml) of concentrated H_2SO_4 and 5 g of catalyst were added to the mixture. The digestion flask with the mixture was heated starting at a temperature of 80 ^{0}C and later the temperature was reduced. The content of the digestion flask was cooled and the volume made up to 100 ml in a volumetric flask. Ten milliliters (10 ml) of each sample digest was dispensed by means of pipette into a Kjeldahl distillation apparatus. To this 20 ml of 40 % boric acid and three drops of mixed indicator in a 250 ml conical flask for 5 minutes. The presence of nitrogen gave a light blue colour. Two hundred milliliters (200 ml) of the distillate

were titrated with 0.1 N HCL till the colour changed from blue to gray and suddenly flashed to pink. A blank was carried out with the solution sample.

$$\text{Total N in sample } (MgKg^{1}) = \frac{(S-B)xNx14x1000}{\text{weight of sample}} \quad \text{……..(3.1)}$$

Where

S= Volume of acid against sample

B=Volume of acid used against blank

N=Normality of acid

3.5.4 Determination of Carbon to Nitrogen (C:N) ratio

The C:N ratio was calculated using the separate values of organic carbon (OC) and total nitrogen (TN) (Mengistu *et al.,* 2017).

3.5.5 Determination of Phosphorus

Determination of total phosphorus in the organic waste was carried out spetrophtotometrically, using the Mo (molybdo-vanadate) blue colour method of Murphy and Riley (1962) and Hammed (2015). Ammonium molybdate; antimony potassium tartrate; 2.5M H_2SO_4 (148 ml conc. H_2SO_4 diluted to 1 litre); potassium hydrogen phosphate (KH_2PO_4); ascordic acid P-Niteophenol (0.25 % wt/vol); 5M NaOH and 5M HCl were used from ammonium molybdate, 12g dissolved in 250ml of distilled water. Also, 0.2908 g of antimony potassium tartrate was dissolved in 100 ml of distilled water. The two dissolved regents were added to 1000 ml of 2.5M H_2SO_4 and mixed carefully before being made up to 2 litres (Hammed, 2015). Then, the mixture was labeled as A and stored in pyrex glass vessel in dark cool room. At the time of analysis 0.5288 g of ascorbic acid was dissolved in 100 ml of the regent A above. It was then mixed thoroughly and labeled as

B. From the digested sample, 5 ml was pipetted into 50 ml volumetric flask and then made up to 40ml with distilled water. To this solution was added 4 ml of regent B and the mixture was carefully mixed. The absorbance of the coloured solution was matched against a reagent blank at 882 nm, after waiting for 30 minutes.

3.5.6 Determination of moisture

Moisture was determined by oven dry method. Two grammes (2 g) of well-mixed sample was accurately weighed in clean dried crucible (W1). The crucible was placed in the desiccator for 30 minutes to cool. After cooling, it was weighed again (W2). Moisture content was determined as weight loss upon drying in an oven at 105 ^{0}C to a constant weight as described by (Mengistu *et al.*,2017). The percentage moisture was calculated using the following formula:

$$\% \text{ Moisture} = \frac{W1-W2}{Weight\ of\ sample} x100 \quad \text{.....(3.2)}$$

Where W = Initial weight of crucible + Sample before drying

W2= Final weight of crucible + Sample after drying

3.5.7 Heavy metals analysis using atomic absorption spectrophotometer (AAS)

Atomic Absorption Spectrophometer was used for the analysis of Lead (Pb), Calcium (Ca), Iron (Fe), Zinc (Zn), and Copper (Cu). Sample (048 – 0.52 g) was weighed into a clean ceramic crucible and was recorded to the nearest 0.0001g. An empty crucible for a blank included was placed in a cool muffle furnace and temperature was raised to 500 ^{0}C over a period of 2 hours. It was further allowed to remain at 500 ^{0}C for an extra 2 hours. It was later allowance to cool within the oven particularly when ashing was done overnight (Zhou *et al.,* 2014). Samples removed from the oven were not allowed to come into contact with breeze. The ashed sample was poured into the labeled 50 mL centrifuge tube. Again the crucible was rinsed with aqua

regia, and was repeated two more times to make total volume of 20ml. The sample was vortexed for proper mixing. The sample was centrifuged at 3000 rpm for 10 minutes. The supernatant was decanted into clean vials for macro and micronutrients determination in atomic absorption Spentrophotometer (AA WIN 500 PG Instrument) and were run to get the readings (Sugasini and Rajagopal, 2015).

3.6 Composting Process

The process chosen was speedy composting process that took twelve weeks (84 days) (Kolade *et al.,* 2006). The process involved daily turning (manually) of the compost so as to allow the microbes to get enough oxygen to speed up their disintegration activities. Additionally, frequent turning prevents the compost from over-heating, which kills the microbes and drives the composting process to resume from the beginning (Kolade *et al.,* 2006).

3.6.1 Experimental Design and Treatments (composting)

The composting comprised of shea waste (SW) and sawdust (SD) as a bulking agent (plate 1a and 1b respectively). The composting was done under aerobic condition by bin compost technique (Vich *et al*., 2017).

The samples (shea waste and sawdust) were weighed using weighing balance (Amput Electronic scale, Model 5000G 5 Kg 0.1G Digital) separately before mixing. The experiment was small scale composting which was laid out in double replications. The treatment comprised of four levels of shea waste with sawdust mixed together. The shea waste with sawdust was mixed in the following ratios: SW/SD 1:1, 10:1, 10:5 and shea waste alone which served as control respectively. The composting mixture was prepared for each treatment and was composted for

84days in a 1 litre plastic bin following the method described by Zhou *et al.,* (2014) and Vich *et al.,* (2017). The bins were kept in a shade to keep away from adverse sunlight and rainfall (PlateII).

Plate 1a: shea waste (SW)

Plate 1b: sawdust (SD)

Plate II: Composting of shea waste (SW) and sawdust (SD)

3.6.2 Monitoring of the compost

The compost was turned manually every day for the attainment of aerobic condition throughout the 84 days of composting period and was moistened by the addition of water to retain moisture level of 50% and above according to Mehta and Sirari (2018).

3.6.3 Sample collection and analysis during composting

Composted materials (SW/SD) were collected every month (28 days), for a total duration of 84days from the composting bin and mixed thoroughly for use in microbiological and physicochemical analysis (Ahmed *et al.,* 2007) at the Central Services Laboratory of the National Cereals Research Institute, Badeggi, Niger State, Nigeria and Federal University of Technology, Minna, Food/Animal Production Department. Microbiological analysis was conducted in the Department of Microbiology, Federal University of Technology, Minna, Niger State, Nigeria following standard methods as stated in Sections 3.2 of the present study.

3.7 Determination of Qualities of Compost Produced

The chemical and physical parameters of compost were determined with emphasis on the parameters such as pH, organic carbon, nitrogen, carbon to nitrogen ratio (C:N), moisture content, phosphorus, potassium, electrical conductivity and organic matter as in Section 3.2 as described by *Ameen et al* (2016). Heavy metal analysis was also conducted. Other qualities were the physical parameters of the compost which include: appearance, colour and odour, to ascertain the maturity and stability of the compost produced (Hammed, 2015).

3.8 Field studies

The effectiveness of the organic manure produced was tested in a field study carried out at Talba Housing Estate, Minna, Niger State, Nigeria.

Plate III: Field studies

3.8.1 Description of experimental site

Minna is the capital of Niger State of Nigeria, and is densely populated having a land area of roughly 6,784 square kilometers. The capital lies on latitude DMS: 9 ^{0} 35’ 0.8”N and longitude DMS: 6^{0} 32’ 46.74”E or 9.583555 and 6.54631 respectively. It lies in the middle belt of Nigeria and falls within the temperature humid which tallies with the tropical hinterland and Guinea savannah region of the nation (Simon *et al.,* 2018). The town is characterized by warm and dry climate, daily average humidity at 44.4 % and has yearly rainfall of 1334 mm averagely. The rainy season starts on the average in April, and lasts till October. The highest mean monthly rainfall is September with almost 300 mm, temperature rarely drops less than 22 ^{0}C, and the highest above 40 ^{0}C in February/March, and 35 ^{0}C within last two months of November and December (Simon *et al.,* 2018).

3.8.2 Collection of maize and test for viability

The maize variety used was open pollinated variety (OPV) Wacot Seed from Agricultural Development Project, Minna, Niger Sate, Nigeria. The viability test was based on seed

germination. This was performed by arranging maize grains on a damp towel. The towel was doubled over to maintain moisture, one of the conditions for germination. It was kept in a warm environment and the seeds were monitored every day for germination (Ezeagu *et al.,* 2017b).

3.8.3 Experimental plot preparation and sowing of maize

The experimental plot (7.7m X 3.3m) was located at Talba Housing Estate Minna, Niger State, Nigeria. Ridges were raised using hoe at 0.4 m length and at a distance of 0.65 n between ridges on a plot size 0.96 m x 0.41 respectively. The maize was hand sown (in Aguste, 2019) by planting three seeds per hole of 5cm deep at a gap of 25 cm separately as described by Law-Ogbomo *et al* (2012).

3.8.4 Seed germination and germination potential

After 4, 5 and 6 days seeds were observed for emergence. Germination refers to the projection of a shoot or root from the seed test (coat), whilst emergence is the visible penetration of the shoot above the soil surface (Kader, 2005). Germination potential is the index used to evaluate the seed germination rate and germination uniformity. Germination potential is given by Liu *et al.,*

(2015) as:

$$\text{Germination potential (\%)} = \frac{\text{Germinated seed number at germinated peak}}{\text{tes seed number}} \text{ x } 100 \quad \ldots\ldots\ldots\ldots\ldots\ldots (3.3)$$

3.8.5 Application of compost manure and fertilizers in the field

Eight (8) gram of Compost manure was applied by mixing with the soil before planting (Tanimu *et al.*, 2013). The inorganic fertilizer that was used as positive control (NPK: 20:10:10), was applied two weeks after planting (WAP) by placing the fertilizer around the maize 5cm and was buried as described by Olowoboko *et al* (2017). Another control, Amazing organic fertilizer (commercial fertilizer) was also applied to the maize plants two weeks after planting. The

fertilizers (NPR 20:10:10) and Amazing organic fertilizer were also applied four weeks and eight weeks after planting along with the compost produced respectively.

3.8.6 Monitoring of plant growth parameters

The maize plants were thinned from three to two plants per stance one week after Manual plant weeding was applied throughout the experiment set up as described by Ebrahimi *et al.* (2019). The growth vigour rate was determined by taking the measurement of six (6) maize plants for each row every two weeks and average reading was recorded (Olowoake *et al.*, 2018). Plant height was measured as the distance from the base of the plant to the height of the first tassel branch and ear height as the distance to the node bearing the upper ear (Hammed, 2015). This was achieved through direct observation method (DOM) using a meter rule as reported by Usman *et al.* (2013). Leaf length was determined manually to the nearest centimeter from the leaf tip to the point at which the lamina was attached to the petiole as described by Ezeagu *et al.*, 2017b). The agronomic data observed were plant height, leaf length, leaf number and leaf width (recorded in centimeters) by metric rule and crop yield (by physical observation of the cobs produced).

3.9 Statistical Analysis

Data acquired from the laboratory were analysed using simple descriptive statistics (frequency and percentages), while data collected from the field study were analyzed using one- way analysis of variance (ANOVA) and the significant level was determined at 5% level of significance using SPSS software (Version 21. IBM SPSS). Differences were considered significant at $P< 0.05$.

CHAPTER FOUR

RESULTS AND DISCUSSION

4.0

4.1 Results

4.1.1 Microbiological Properties of Shea wastes, Sawdust and soil

The counts of bacteria and fungi isolated from shea waste (SW), sawdust (SD) and soil (SL) are presented in Table 4.1. The bacterial counts in shea waste (SW), sawdust (SD), and soil (SL) were 3.90 x 10^8 cfu/g, 1.24 x 10^9 cfu/g and 3.82×10^8 cfu/g respectively, while the fungal counts from shea waste (SW), sawdust (SD) and soil (SL) were4.80 x 10^4 cfu/g, 2.91 x 10^5 cfu/g and 4.52×10^4 cfu/g respectively. The bacterial counts were quite high, particularly in the sawdust (Table 4.1)

Table 4.1: Bacterial and fungal counts of shea waste (SW), sawdust (SD) and soil (SL) used

Sample	Bacterial counts (cfu/g)	Fungal counts (cfu/g)
Shea waste (SW)	3.90 x 10^8	4.80 x 10^4
Sawdust (SD)	1.24 x 10^9	2.91 x 10^5
Soil (SL)	3.82×10^8	4.52×10^4

cfu/g: colony forming units per gramme

4.1.2 Identity and frequency of occurrence of bacterial isolates in shea wastes, sawdust and soil

The cultural and biochemical characteristics of bacterial isolates from the shea waste (SW), sawdust (SD) and soil (SL) respectively are presented in Table 4.2. The bacterial isolates identified include; *Streptococcus faecalis, Bacillus subtilis, Bacillus cereus, Lactobacillus bulgaricus, Enterococcus faecalis* and *Bacillus licheniformis*. The isolates *Streptococcus faecalis* had a frequency of (21.05 %), *Bacillus cereus* (17.54 %), *Lactobacillus bulgaricus* (12.28 %), *Enterococcus faecalis* (8.77 %) and *Bacillus licheniformis* (15.79 %). it was observed that *Bacillus subtilis* had the highest frequency of occurrence of 24.56 % (Table 4.3). Sawdust had more bacterial isolates 23(40.35 %) than Shea waste 21(36.84 %) and Soil 13(22.80 %).

4.1.3 Identity and frequency of occurrence of fungi isolates

Table 4.4 shows the moulds and yeasts respectively identified in shea waste (SW), Sawdust (SD) and soil (SL). Moulds were species of *Aspergillus*, *Penicillium*, *Fusarium*, *Mucor*, and *Trichophyton*. The yeasts were species of *Candida*. The frequencies of occurrence of fungi in shea waste (SW), sawdust (SD) and soil (SL) are presented in Table 4.5 The frequencies of occurrence of *Aspergillus niger* in shea waste (SW), sawdust (SD) and soil (SL) were 7.94 %, 6.35 % and 9.52 % respectively, *Aspergillus flavus* 4.76 %, 7.94 % and 7.94 %, and *Penicillium notatum* (1.59 %, 6.35 % and 4.76 %) respectively. Generally, *Aspergillus niger* had the highest frequency of occurrence (23.81 %) followed by *Aspergillus flavus* (20.64 %), *Penicillium notatum* (12.70 %) and *Fusarium solani* (12.69 %). The fungus *Trichophyton rubrum* had the lowest frequency of occurrence (3.18 %) (Table 4.6). The yeasts, *Candida tropicalis* had a total frequency of (4.76 %) while *Candida parapsilosis* had (11.10 %). *Candida*

tropicalis occurred in shea waste (SW) and sawdust (SD) only while *Candida parapsilosis* occurred in shea waste (SW), sawdust (SD) and soil (SL) (Table 4.5).

Table 4.2: Cultural and Biochemical Characteristics of Bacterial Isolates from Shea Waste (SW), Sawdust (SD) and Soil (SL)

Isolate code	Colonial Morphology	Microscopy	Gram reaction	Catalase	Coagulase	Urease	Indole	Citrate	Methyl Red	Voges Proskauer	Motility	H_2S	Sugar formation (Acid and gas)			Probable Organism
													S	G	L	
SW 1	Dry Surface Usually Larges irregular	Rod	+	+	-	-	-	+	-	+	-	-	-	+	-	*Bacillus subtilis*
SW 2	Rough Edge Not creamy	Rod	+	+	-	-	-	+	-	-	-	-	+	+	+	*Bacillus cereus*
SD 1	Dry Surface Usually Larges irregular	Rod	+	+	-	-	-	+	-	+	-	-	-	+	-	*Bacillus subtilis*
SD 2	Whitish and dry	Rod	+	+	-	-	-	-	-	-	-	-	+	+	+	*Lactobacillus bulgaricus*
SL 1	Smooth white colonies	Cocci	-	-	-	-	-	-	-	+	-	-	+	+	+	*Streptococcus faecalis*
SL 2	Small round colonies	Cocci	+	-	-	-	-	-	-	+	-	-	-	+	+	*Enterococcus faecalis*
SL 2	Rough Edge	Rod	+	+	-	-	-	-	-	+	-	-	-	+	-	*Bacillus licheniformis*

Key: SW: Shea waste, SD: sawdust, SL: Soil, +: positive, -: Negative, H_2S: Hydrogen sulphide, S: Sucrose, G: Glucose, L: Lactose

Table 4.3: Frequency of Occurrence of Bacteria in Shea Waste (SW), Sawdust (SD) and Soil (SL)

Bacterial	Sheawaste (SW)	Sawdust (SD)	Soil (SL)	Total
Bacillus subtilis	4 (7.02)	5 (8.77)	5 (8.77)	14 (24.56)
Bacillus cereus	4 (7.02)	5 (8.77)	1 (1.75)	10 (17.54)
Lactobacillus bulgaricus	3 (5.26)	4 (7.02)	0 (0.00)	7 (12.28)
Bacillus licheniformis	5 (8.77)	4 (7.02)	0 (0.00)	9 (15.79)
Enterococcus faecalis	2 (3.51)	0 (0.00)	3 (5.26)	5 (8.77)
Streptococcus faecalis	3 (5.26)	5 (8.77)	4 (7.02)	12 (21.05)
Total	21(36.84)	23(40.35)	13(22.80)	57(100)

Number in parenthesis is percentage (%) frequency of occurrence

Table 4.4: Cultural and Morphological Characteristics of Fungal Isolates From Shea Waste (SW), Sawdust (SD) and Soil (SL).

Isolate Code	Colour of aerial hyphae	Nature of hyphae	Types of asexual spares	Names of fungi
A (SW, SD, SL)	Initially white and changed to black as it grew older	Septate hyphae	Conidia contained in chain-like structure called sterigma	*Aspergillus niger*
B (SW, SD, SL)	Yellow green in color	Septate hyphae	Conidia contained in chain like structure called sterigma	*Aspergillus flavus*
C (SW, SD, SL)	Woolly and whitish with numerous black dots on top of its edges	Septate hyphae	Spores contained in sporangiophore	*Mucor pusillus*
D (SW, SD, SL)	The colonies were pinkish, powdery in nature and filled the plate	It had septate hyphae	Microconidia contained increscent shaped structure	*Fusarium solani*
E (SW, SD)	Whitish creamy in nature	Single cell structure	Single cell structure, oval in shape	*Candida tropicalis*
F (SW, SD, SL)	Velverty and blue green in colour	It had septate hyphae	Conidia contained in broom like structure called multilink conidiophores	*Penicillium notatum*
G (SW, SD, SL)	The colonies were white, creamy with alcohol odour	Single cell structure and loony oval in shape	Single cell	*Candida parapsilos*
H (SW, SL)	Velverty white to light yellow with radial grooves	It had septate curved hyphae	Microcondia contained in a peared shape long multiseptate structure	*Trichophyton rubrum*

Key: SW: Shea Waste; SD: Sawdust; SL: Soil

Table 4.5: Frequency of Occurrence of Fungi in Shea Waste (SW), Sawdust (SD) and Soil (SL)

Fungi	Shea waste (SW)	Sawdust (SD)	Soil (SL)	Total
Aspergillus niger	5 (7.94)	4(6.35)	6 (9.52)	15 (23.81)
Aspergillus flavus	3 (4.76)	5 (7.94)	5 (7.94)	13 (20.64)
Penicillium notatum	1 (1.59)	4 (6.35)	3 (4.76)	8 (12.70)
Mucor pusillus	1 (1.59)	3 (4.76)	3(4.76)	7 (11.11)
Fusarium solani	2 (3.17)	3 (4.76)	3 (4.76)	8 (12.69)
Candida tropicalis	1 (1.59)	2 (3.17)	0 (0.00)	3 (4.76)
Candida parapsilosis	2 (3.17)	2 (3.17)	3 (4.76)	7 (11.10)
Trichophyton rubrum	1 (1.59)	0 (0.00)	1 (1.59)	2 (3.18)
Total	16(25.40)	23(36.50)	24(39.67)	63(100)

Number in parenthesis is percentage (%) frequency of occurrence

4.1.4 Microbial counts during shea waste and sawdust composting process

The bacterial counts recorded during shea waste/sawdust (SW/SD) are presented in the Table 4.6. The Counts ranged from 1.04 x 10^7 cfu/g to 3.0 x 10^7 cfu/g for 0 days, 2.16 x 10^7 cfu/g – 6.80 x 10^6 cfu/g for 28 days, 3.8 x 10^6 cfu/g - 7.6 x 10^6 cfu/g for 56 days and 1.29 x 10^7 cfu/g, - 6.9 x 10^6 cfu/g for 84 days. Generally, it was observed that the bacterial counts increased which was later followed by a gradual decrease till the end of the composting process, that is, after 84 days.

The fungal counts recorded during shea waste/sawdust (SW/SD) composting ranged from 6.2 $x10^4$ cfu/g to 7.12 x 10^4 cfu/g for 0 days, 1.00 x 10^6 cfu/g – 6.8 x 10^4 cfu/g for 28 days, 2.6 x 10^4cfu/g - 6.0 x 10^4 cfu/g for 56 days and 2.8 x 10^4 cfu/g – 5.3 x 10^4 cfu/g for 84 days. Typically, it was observed that the fungal counts increased after which the counts decreased steadily till the end of the composting process, that is, after 84 days.

Table 4.6: Bacterial Counts (cfu/g) of Shea Waste and Sawdust During Composting

	Treatment (SW/SD)			
Time (days)	**10:5**	**10:1**	**1:1**	**SW**
0	16.50 ± 0.50	18.22 ± 0.50	21.23 ± 0.23	25.50 ± 0.50
28	8.21 ± 0.41	12.15 ± 0.41	19.06 ± 0.43	22.21 ± 0.41
56	5.12 ± 0.22	7.21 ± 0.22	15.23 ± 0.11	11.12 ± 0.22
84	2.11 ± 0.10	5.28 ± 0.10	6.19 ± 0.20	8.11 ± 0.10

Mean values represented by different letters along same column are significantly different from each other at $P<0.05$

4.1.5. Microorganisms identified during shea waste/sawdust composting

The microbial isolates identified during the composting periods are presented in Table 4.7. At the mesophilic temperature range (<40, ℃) (0- 28 days) the following bacterial species were identified: *Streptococcus faecalis, Bacillus subtilus, Bacillus cereus* and *Bacillus licheniformis,* while the fungal species identified at this stage were: *Aspergillus niger, Aspergillus flavus, Penicillium notatum, Candida tropicalis* and *Mucor pusillus*. At the thermophilic temperature range (>40 ℃), 56 days of compositon) the following bacterial isolates were identified: *Bacillus Subtilus, Bacillus cereus, Bacillus licheniformis* and *Lactobacillus bulgaricus,* while the fungal species identified at this stage were *Aspergillus niger, Aspergillus flavus, Fusarium solani* and

Mucor pusillus. At the curing/maturing stage (about 84 days of composting process) few bacterial species were identified: *Bacillus subtilis and Bacillus cereus.* The fungal species identified at this stage were *Aspergillus flavus, Aspergillus niger, Candida tropicalis, Candida parapsilosis* and *Trichoplyton rubrum* (Table 4.7).

Table 4.7: Microbial Isolates Identified at Different Stages of Composting Process

Stage of Composting	Bacteria	Fungi
Mesophilic temperature (<40^{0}C, 0-28)(days)	*Streptococcus faecalis* *Bacillus subtilis* *Bacillus cereus* *Bacillus licheniformis*	*Aspergillus niger* *Aspergillus flavus* *Penicillium notatum* *Mucor pusillus* *Candida tropicalis*
Thermophilic Temperature (>40 ^{0}C,56 days)	*Bacillus cereus* *Bacillus subtilis* *Bacillus licheniformis* *Lactobacillus bulgaricus*	*Aspergillus niger* *Aspergillus flavus* *Mucor pusillus* *Fusarium solani*
Curing/Maturing 84 (days of composting)	*Bacillus subtilis* *Bacillus cereus*	*Aspergillus flavus* *Aspergillus niger* *Candida tropicalis* *Candida parapsilosis* *Trichophyton rubrum*

4.1.6 Physicochemical properties of Shea Waste (SW), Sawdust (SD) and Soil (SL)

The physicochemical properties of the shea waste (SW), sawdust (SD) and soil (SL) are presented in Table 4.8. The shea waste (SW), sawdust (SD) and soil (SL)were acidic pH ranging from 5.29 % to 5.90 %. The shea waste, sawdust and soil had organic carbon of 40.00 %, 53.07 % and 11.26 % while the Nitrogen content ranged from 0.2 % to 2.9 %. The shea waste, sawdust and soil had phosphorus content of 0.19 mg/kg, 25.00 mg/kg and 4.20 mg/kg and electrical conductivity of 41.00 µs, 37.00µs and 34.00 µs respectively (Table 4.8). The moisture contents

of the samples were SW (4.80 %), SD (8.25 %) and SL (15.20 %). The soil was not too rich in humus and had a content of 1.98 % (Table 4.8).

Table 4.8: Physicochemical Properties of Shea Waste (SW), Sawdust (SD) and Soil (SL)

Parameter	Shea waste	Sawdust	Soil
pH	5.48	5.29	5.90
Color	Black	Brown	NA
Moisture (%)	4.80	8.25	15.20
Organic carbon (%)	40.00	53.07	11.26
Nitrogen (%)	2.90	0.28	0.36
Phosphorus (mg/kg)	0.19	25.00	4.20
Electrical conductivity (µs/cm)	41.00	37.00	34.00
Humus	NA	NA	1.98

NA: Not Applicable, mg/kg: Milligramme per kilogramme, (µs/cm): microsiemens per centimeter

4.1.7 Heavy metal contents of Shea waste (SW), Sawdust (SD) and Soil (SL)

Heavy metal analysis was conducted on the shea waste (SW), sawdust (SD) and soil (SL) and the results (Table 4.9) revealed that lead content ranged from 0.9 to 2.653 mg/kg with the highest content (2.65 mg/kg) in the soil. The potassium content of the sawdust (SD) was higher (37.53 mg/kg) than that of the soil (0.108 mg/kg) and shea waste (23.17 mg/kg). Similarly, the sodium content of the shea waste (SW) was higher (21.37 mg/kg) than that of the sawdust (13.55 mg/kg) and soil (0.451 mg/kg). Other heavy metals and their concentrations detected in the SW, SD and SL are presented in Table 4.9. The heavy metals were zinc, mercury and copper. The

concentrations of these metals in soil (SL) were higher than the concentrations observed in either SW or SD (Table 4.9).

Table 4.9: Heavy Metal Content of Shea Waste (SW), Sawdust (SD) and Soil (SL)

Heavy metal	Sheawaste (SW)	Sawdust (SD)	Soil (SL)
Lead (mg/kg)	0.9	1.157	2.653
Mercury (mg/kg)	0.11	0.087	0.975
Sodium (mg/kg)	21.37	13.55	0.451
Copper (mg/kg)	0.06	1.35	14.472
Potassium (mg/kg)	23.17	37.53	0.108
Zinc (mg/kg)	2.052	2.264	11.401

Mg/kg: milligramme per kilogramme

4.1.8 Physicochemical Properties of The Shea wastes and Sawdust During composting

1. pH

Table 4.10 shows changes in pH of the compost over a period of 84 days. The initial pH in all treatments was acidic and after 28 days became alkaline, ranging from 7.50 to 8.47. After 84 days, the pH remained alkaline and ranged from 7.32 to 7.80 (Table 4.10). The treatment SW/SD 10:5 had pH ranging from 6.40 to 8.0, SW/SD10:1 had pH 6.36 -8.11, SW/SD1:1had pH 6.44-7.50 while the untreated control had pH 6.41-8.47 over the period of 84 days (Table 4.10).

Table 4.10: Changes in pH Compost of Shea Waste (SW) With Sawdust (SD)

	Treatment (SW/SD)			
Time (days)	**10:5**	**10:1**	**1:1**	**SW**
0	6.40±0.00^{c}	6.36±0.00^{c}	6.44±0.00^{c}	6.41±0.00^{c}
28	8.00±0.00^{e}	8.11±0.00^{e}	7.50±0.00^{e}	8.47±0.00^{e}
56	7.70±0.00^{b}	6.60±0.00^{c}	6.75±0.25^{a}	7.00±0.00^{b}
84	7.80±0.00^{b}	7.320±0.00^{b}	7.50±0.50^{c}	7.75±0.25^{b}

SW: Shea waste, SD: Sawdust
Mean values represented by different letters along same column are significantly different from each other at $P<0.05$

2. Nitrogen

Table 4.11 shows changes in nitrogen of the compost over a period of 84 days. The nitrogen in all treatments was within the acceptable quality standards for finished compost. The treatments SW/SD 10:5 had nitrogen ranging from 1.06 to 2.55 %, SW/SD 10:1 had nitrogen 6.36-8.11 %, SW/SD 1:1 had nitrogen 6.44-7.50 % while the untreated control had nitrogen 6.41-8.47 % over the period of 84 days (Table 4.11)

Table 4.11: Nitrogen (%) During Composting of Shea Waste (SW) with Sawdust (SD)

	Treatment (SW/SD)			
Time (days)	**10:5**	**10:1**	**1:1**	**SW**
0	2.00±0.00^{b}	2.23±0.00^{b}	1.98±0.00^{b}	2.1±0.00^{b}
28	2.48±0.01^{a}	2.33±0.01^{a}	2.62±0.01^{a}	2.11±0.01^{a}
56	2.55±0.00^{a}	2.41±0.00^{a}	2.33±0.00^{a}	2.11±0.00^{a}
84	1.06±0.00^{c}	1.28±0.00^{c}	1.16±0.00^{c}	1.726±0.00^{c}

SW: Shea waste, SD: Sawdust
Mean values represented by different letters along same column are significantly different from each other at $P<0.05$

3. Organic carbon

Table 4.12 shows changes in organic carbon of the compost over a period of 84 days. The carbon in all treatment was high. The treatments SW/SD 10:5 had carbon ranging from 25.05 to 48.00 %, SW/SD 10:1 had carbon 22.05-44.00 %, SW/SD 1:1 had carbon 26.05-43.00 %. while the untreated control had carbon 21.05-45.00 % over the period of 84 days (Table4.12).

Table 4.12: Organic Carbon (%) During Composting of Shea Waste (SW) with Sawdust (SD)

	Treatment (SW/SD)			
Time (days)	**10:5**	**10:1**	**1:1**	**SW**
0	25.05±0.05[a]	22.05±0.05[a]	26.05±0.05[a]	21.05±0.05[a]
28	48.00±0.00[f]	44.00±0.00[f]	43.00±0.00[f]	45.00±0.00[f]
56	31.00±0.00[b]	33.00±0.00[b]	29.890±0.00[b]	36.00±0.00[b]
84	38.95±0.05[d]	36.41±0.05[d]	34.22±0.05[d]	37.66±0.05[d]

SW: Shea waste, SD: Sawdust
Mean values represented by different letters along same column are significantly different from each other at $P<0.05$

4. Moisture

Table 4.13 shows changes in moisture of the compost over a period of 84 days. The moisture in all treatments was high. The treatments SW/SD 10:5 had moisture ranging from 40.00 % to 69.00 %, SW/SD 10:1 had moisture 45.00-69.00 %, SW/SD 1:1 had moisture 47.50-66.25 % while the untreated control had moisture 44.75-67.00 % over the period of 84 days (Table4.13).

Table 4.13: Moisture (%) During Composting of Shea Waste (SW) with Sawdust (SD)

	Treatment (SW/SD)			
Time (days)	**10:5**	**10:1**	**1:1**	**SW**
0	61.25±0.00^{b}	68.00±0.00^{b}	66.25±1.25^{b}	60.00±0.00^{a}
28	59.50±0.50^{c}	54.50±0.50^{a}	60.00±0.00^{c}	56.35±0.35^{b}
56	69.00±1.00^{c}	69.00±0.00^{c}	64.75±0.25^{a}	67.00±0.00^{b}
84	40.00±0.00^{a}	45.00±0.00^{b}	47.50±0.50^{c}	44.75±0.25^{b}

SW: Shea waste, SD: Sawdust
Mean values represented by different letters along same column are significantly different from each other at $P<0.05$

5. Temperature

Table 4.14 shows changes in temperature of the compost over a period of 84 days. The temperature in all treatments was not above 58 ^{o}C, fell within the range (>55 ^{o}C) stipulated for normal compost. The treatments SW/SD 10:5 had temperature ranging from 20.00 to 43.00 ^{o}C, SW/SD 10:1 had temperature18.00-46.00 ^{o}C, SW/SD 1:1 had temperature 16.25-44.00 ^{o}C while the untreated control had temperature20.50-43.00 ^{o}C over the period of 84 days (Table 4.14).

Table 4.14: Temperature (^{o}C) variation During Composting of Shea Waste (SW) with Sawdust (SD)

	Treatment (SW/SD)			
Time (days)	**10:5**	**10:1**	**1:1**	**SW**
0	20.00±0.00^{c}	18.00±0.00^{a}	16.25±0.25^{bc}	20.50±0.50^{bc}
28	28.50±0.50^{a}	30.00±0.00^{b}	32.00±0.00^{c}	36.00±0.00^{a}
56	43.00±0.00^{b}	46.00±0.00^{d}	44.50±0.50^{c}	43.00±0.00^{a}
84	26.00±0.00^{a}	26.00±0.00^{a}	28.00±0.00^{b}	35.00±0.00^{c}

SW: Shea waste, SD: Sawdust
Mean values represented by different letters along same column are significantly different from each other at $P<0.05$

6. Phosphorous

Table 4.15 shows changes in phosphorous of the compost over a period of 84 days. The phosphorous in all treatments was within the acceptable quality standards for finished compost. The treatments SW/SD 10:5 had phosphorous ranging from 0.90 to 2.48 %, SW/SD 10:1 had phosphorous 0.74-2.31 %, SW/SD 1:1 had phosphorous 0.91-2.49 % while the untreated control had phosphorous 0.89-2.66 % over the period of 84 days (Table 4.15).

Table 4.15: Phosphorous (%) Content During Composting of Shea Waste (SW) with Sawdust (SD)

	Treatment (SW/SD)			
Time (days)	**10:5**	**10:1**	**1:1**	**SW**
0	0.90. ±0.00[b]	0.74. ±0.00[b]	0.91. ±0.00[b]	0.89. ±0.00[b]
28	2.48±0.00[a]	2.31±0.00[a]	2.49±0.00[a]	2.66±0.00[a]
56	2.41±0.15[a]	2.31±0.15[a]	2.47±0.15[a]	2.44±0.15[a]
84	1.00±0.00[ab]	1.76±0.00[ab]	1.210±0.00[ab]	1.06±0.00[ab]

SW: Shea waste, SD: Sawdust
Mean values represented by different letters along same column are significantly different from each other at $P<0.05$

7. Potassium

Table 4.16 shows changes in potassium of the compost over a period of 84 days. The initial potassium in all treatments in 0days was normal and from 28 days to 56 days was high. After 84 days, the potassium was within the acceptable quality standards for finished compost. The treatment SW/SD 10:5 had potassium ranging from 1.00 to 2.51 %, SW/SD10:1 had potassium 1.09 -2.31 %, SW/SD1:1 had potassium 0.96-2.71 % while the untreated control had potassium 1.7-2.33 % over the period of 84 days (Table 4.16)

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Table 4.16 Potassium (%) Content During Composting of Shea Waste (SW) with Sawdust (SD)

	Treatment (SW/SD)			
Time (days)	**10:5**	**10:1**	**1:1**	**SW**
0	1.00±0.00^{b}	1.17±0.00^{b}	0.97±0.00^{b}	1.41±0.00^{b}
28	2.51±0.01^{a}	2.21±0.01^{a}	2.71±0.01^{a}	2.33±0.01^{a}
56	2.11±0.01^{a}	2.31±0.01^{a}	2.61±0.01^{a}	2.01±0.01^{a}
84	1.16±0.00^{b}	1.09±0.00^{b}	0.96±0.00^{b}	1.7±0.00^{ab}

SW: Shea waste, SD: Sawdust
Mean values represented by different letters along same column are significantly different from each other at $P<0.05$

8. Electrical conductivity

Table 4.17 shows changes in electrical conductivity of the compost over a period of 84 days. The treatments SW/SD 10:5 had electrical conductivity ranging from 220 to 420 µs/cm, SW/SD 10:1 had electrical conductivity 170 to 530 µs/cm, SW/SD 1:1 had electrical conductivity 180-370 µs/cm while the untreated control had electrical conductivity ranging 140 to 490 from over the period of 84 days (Table 4.17)

Table 4.17: Electrical Conductivity (µs/cm) Profile During Composting of Shea Waste (SW) with Sawdust (SD)

	Treatment (SW/SD)			
Time (days)	**10:5**	**10:1**	**1:1**	**SW**
0	225±0.00^{b}	190±0.00^{b}	280±0.00^{b}	140±0.00^{b}
28	420±0.01^{a}	390±0.01^{a}	370±0.01^{a}	460±0.01^{a}
56	300±0.01^{a}	530±0.01^{a}	320±0.01^{a}	490±0.01^{a}
84	220±0.00^{b}	170±0.00^{b}	180±0.00^{b}	170±0.00^{ab}

SW: Shea waste, SD: Sawdust
Mean values represented by different letters along same column are significantly different from each other at $P<0.05$

9. Urea

Table 4.18 shows changes in urea of the compost over a period of 84 days. The treatments SW/SD 10:5 had urea ranging from 2.6 to 14.3 %, SW/SD 10:1 had urea content of 3.33-12.22 %, SW/SD 1:1 had 2.78 -12.22 % while the untreated control had 3.52 - 12.28 % over the period of 84 days (Table 4.18).

Table 4.18:Urea (%) Content During Composting of Shea Waste (SW) with Sawdust (SD)

	Treatment (SW/SD)			
Time (days)	**10:5**	**10:1**	**1:1**	**SW**
0	2.9±0.00[b]	3.33±0.00[b]	2.78±0.00[b]	3.52±0.00[b]
28	2.6±0.01[a]	3.48±0.01[a]	3.36±0.01[a]	3.98±0.01[a]
56	2.7±0.01[a]	3.51±0.01[a]	3.28±0.01[a]	9.11±0.01[a]
84	14.3±0.00[b]	12.22±0.00[b]	12.22±0.00[b]	12.28±0.00[ab]

SW: Shea waste, SD: Sawdust
Mean values represented by different letters along same column are significantly different from each other at $P<0.05$

Plate iv: Mature compost made from Shea waste (SW) and Sawdust (SD)

4.1.9 Efficacy of Compost in the field

4.1.9.1 The Germination Index (Emergence Percentage) of Maize

Table 4.19 shows the germination index (% emergence) of maize planted in soil amended with compost. The mean emergence ranged from 27.39±4.61 to 44.34±4.1 %, 60.75±4.5 %-100±0.0 % and 94.59±2.89 - 100±0.0 % for day 4, 5 and 6 respectively. Four days after cultivation of the maize seeds, SW/SD 10:5 and SW/SD 10:1 recorded 44.34±41.1 % and 33.26±2.9 % emergence, while SW/SD 1:1 recorded 27.78 % emergence. At fifth (5) day of cultivation, SW/SD 1:1 had 60.75±4.5 % emergence, while SW/SD 10:1 recorded 88.89±0.0 % emergence. After 6 days of cultivation of the maize seeds, only SW/SD 10:5 recorded 94.46±2.11 % emergence as compared to 100±0.0 % in all other treatments including unfertilized soil (Table 4.19).

Table 4.19: Germination Index (% emergence) of Maize Planted in Soil Amended with Compost

	Time (days)		
Treatments	**4**	**5**	**6**
SW/SD 1:1	27.39±4.61[a]	60.75±4.5[a]	100±0.0[b]
SW/SD 10:1	33.26±2.9[b]	88.89±0.0[e]	100±0.0[b]
SW/SD 10:5	44.34±4.1[d]	72.22±2.0[b]	94.4±2.11[a]
Shea waste	33.47±1.15[b]	100±0.0[g]	100±0.0[b]
No manure	27.39±3.14[a]	81.84±2.26[d]	100±0.0[b]
Amazing organic fertilizer (Commercial)	38.51±3.62[c]	94.4±3.05[f]	100±0.0[b]
NPK fertilizer (20:10:10)	61.11±1.11[e]	77.57±2.57[c]	100±0.0[b]

SW: Sheawaste, SD: SawdustMean values represented by different letters along same column are significantly different from each other at P<0.05

4.1.9.2 The effects of compost on leaf width

The effects of the compost (SW/SD 1:1, 10:5, and 10:1 respectively) on leaf width are presented in Figure 4.10. At 2 weeks the width were almost of equal length (2.7±0.0 – 3.65±0.5 cm). The highest mean value for leaf width of 3.65±0.5 cm was recorded at SW/SD 10:5, while the least value (2.7±0.0 cm) was observed in plants raised with SW/SD (10:1). At 4 and 6 weeks the leaf width ranged from 6.25±0.05 cm to 10.00±0.0 cm and 10.05±0.05 cm – 11.35±0.05 cm respectively with the highest leaf width (10.00±0.0 cm and 11.35±0.05 cm) observed at SW/SD 1:1, while the least leaf width (6.25±0.05 cm and10.05±0.05 cm respectively) were recorded at SW/SD 10:1. At 8 to 10 weeks, the mean leaf width were 12.05±0.05 cm and 13.60±0.00 cm,

higher at SW/SD 1:1 than other treatments while the least values (10.35±0.05 cm and 11.15±0.05 cm respectively) were observed at SW/SD 10:1.

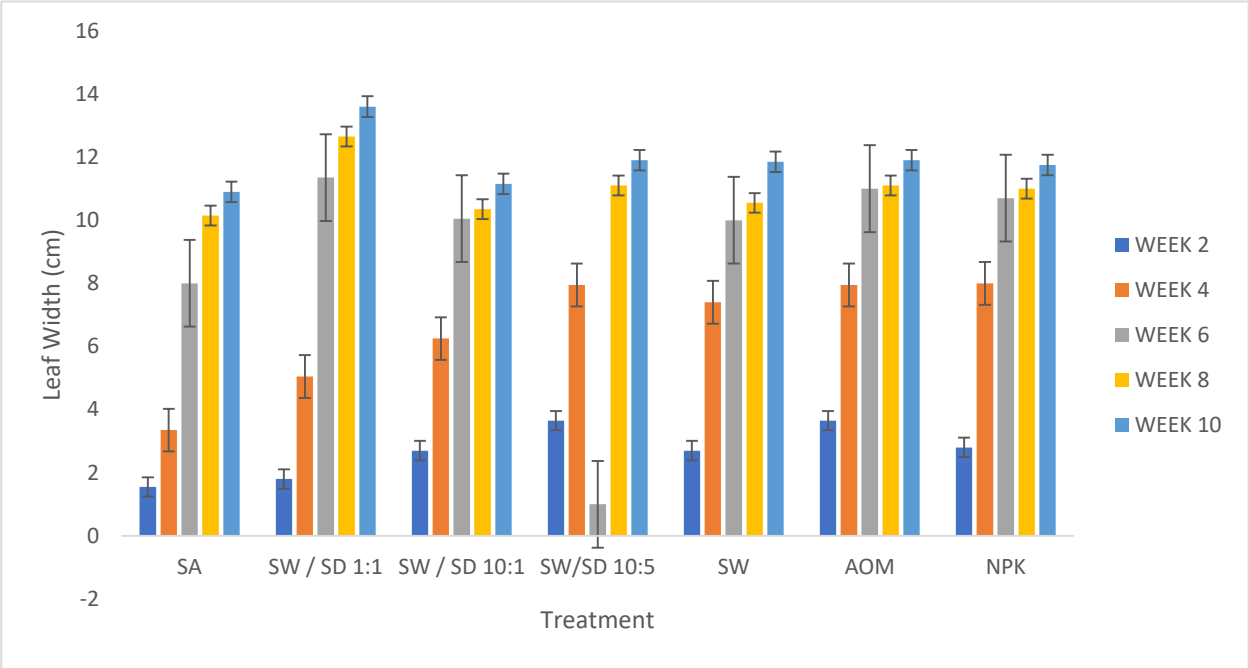


Figure 4.5: Leaf width (cm) of maize plant grown on soil amended with compost: SA (Soil alone); SW/SD (Shea waste and Sawdust); AOM (Amazing Organic Manure)

4.1.9.3 The effects of compost on leaf length

The effects of the compost (SW/SD 1:1, 10:5, and 10:1 respectively) on leaf length are presented in Figure 4.11. At 2 weeks the leaves were almost of equal length (56.05±0.05 to 99.80±0.00 cm). The highest mean value for leaf length of 99.80±0.00 cm was recorded at SW/SD 1:1, while the least value (56.05±0.05 cm) was observed in plants raised with SW/SD (10:1 and 10:5). At 4 and 6 weeks the leaf length ranged from 269.70±0.00 cm to 532.75±0.25 cm and 772.45±0.25 cm – 820.75±0.05 cm respectively with the highest leaf length (532.75±0.25 cm and 820.75±0.05 cm) observed at SW/SD 1:1, while the least leaf length (269.70±0.00 cm and 772.45±0.25 cm respectively) were recorded at SW/SD 10:1. At 8 to 10 weeks, the mean leaf

lengths were 952.45±0.05 cm and 987.35±0.05 cm, higher at SW/SD 1:1 than other treatments while the least values (857.55±0.05 cm and 898.45±0.05 cm respectively) were observed at SW/SD 10:5.

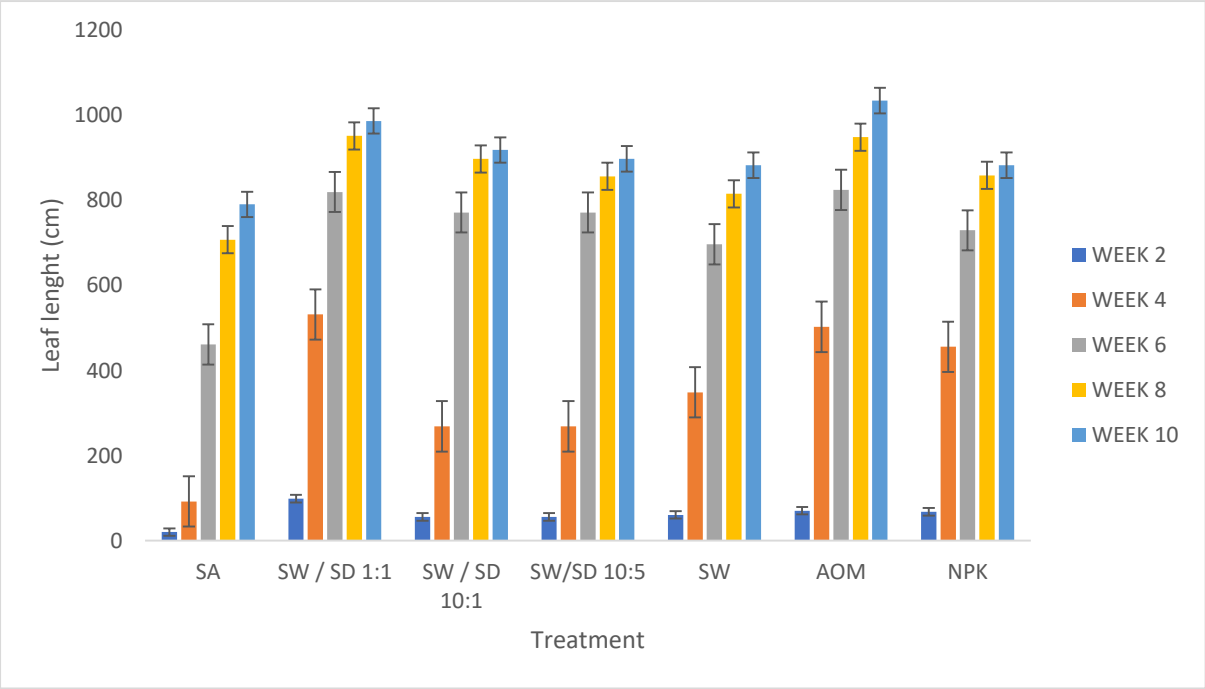


Figure 4.6: Leaf length (cm) of maize plant grown on soil amended with compost: SA (Soil alone); SW/SD (Shea waste and Sawdust); AOM (Amazing Organic Manure)

4.1.9.4 The effect of compost on the plant height

The effects of compost on maize plant heights are presented in Figure 4.7. The lowest mean value (19.00±0.05 cm) was observed in maize plants raised with SW/SD 10:1 and 10:5 while the highest mean value (27.65±0.05 cm) was recorded at SW/SD 1:1. At 4 weeks the heights ranged from 55.90±0.10 to 85.05±0.05 cm, with the highest mean value (85.05±0.05 cm) recorded at SW/SD 1:1. The lowest mean height (55.90±0.10) was at SW/SD (10:1). Six (6) and eight (8) weeks after planting the maize, plants raised with SW/SD 10:5 was significantly tall in height with mean values of 226.00±0.00 cm and 239.00±0.00 cm respectively. Maize heights

(226.00±0.00 cm, 239.00±0.00 cm and 242.00±0.10 cm) recorded at SW/SD 10:5 at 6, 8 and 10 weeks respectively had remarkable growth compared to the control and SW/SD 10:1. At 8 and 10 weeks lowest plant heights (224.10±0.10 cm and 228.00±0.05 cm respectively), were recorded at SW/SD 10:1, while the highest value (233.00±1.00 cm) were recorded at SW/SD 10:1 (Figure 4.7). At 8 week treated maize plants at SW/SD (1:1) were the first to produce tassels among the treatments.

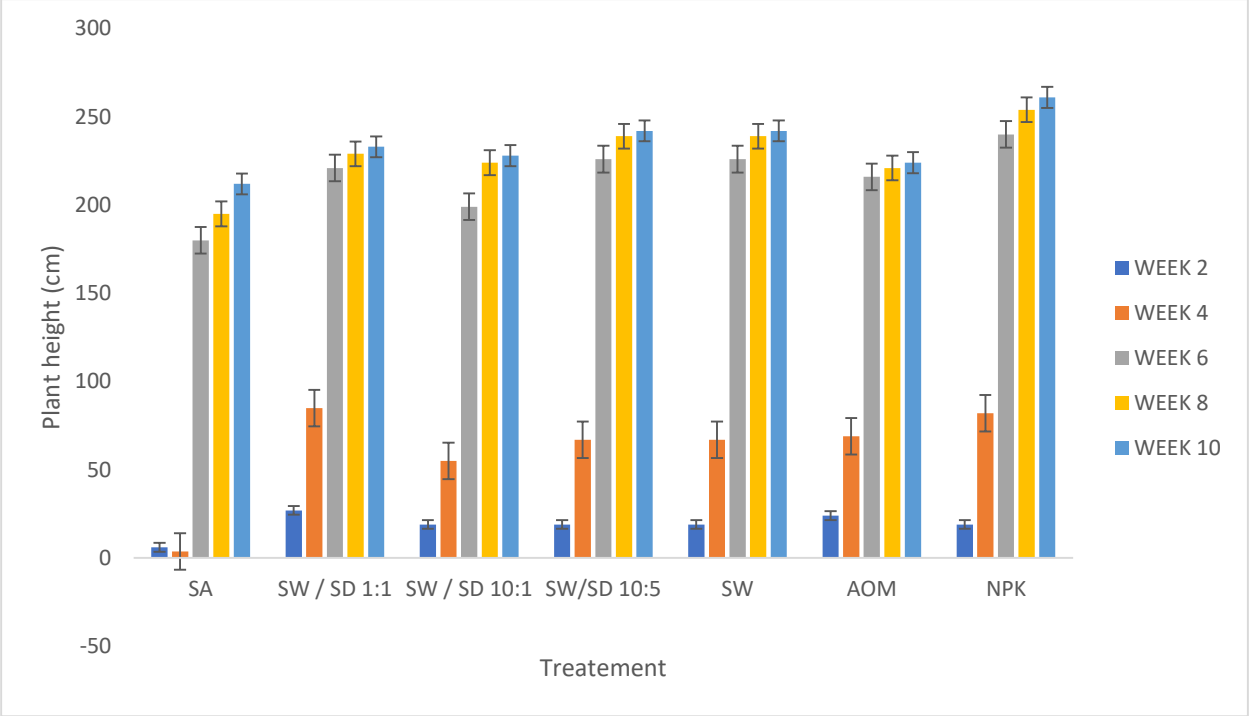


Figure 4.7: Height (cm) of maize plant grown on soil amended with compost: SA (Soil alone); SW/SD (Shea waste and Sawdust); AOM (Amazing Organic Manure)

4.1.9.5 The effect of compost on the leaf number

The effects of the compost (SW/SD 1:1, 10:5, and 10:1 respectively) on leaf number are presented in Figure 4.8. At 2 weeks the leaf number were almost equal number (5.00±0.0 to 6.00±0.0 cm). The highest mean value for leaf number of 6.00±0.0 cm was recorded at SW/SD 1:1, while the least value (5.00±0.0 cm) was observed in plants raised with SW/SD (10:1 and

10:5). At 4 and 6 week the leaf number ranged from 11.70±0.00 cm to 10.00±0.0 cm and 12.00±0.00 cm to 14.00±0.00 cm respectively with the highest leaf number (10.00±0.0 cm and 14.00±0.00 cm) observed at SW/SD 1:1, while the least leaf number (11.70±0.00 cm and 12.00±0.00 cm respectively) were recorded at SW/SD 10:1. At 8 to 10 weeks, the mean leaf number were 14.45±0.05 cm and 15.55±0.05 cm, higher at SW/SD 10:5, than other treatments while the least values (14.00±0.0 cm) were observed at SW/SD 1:1.

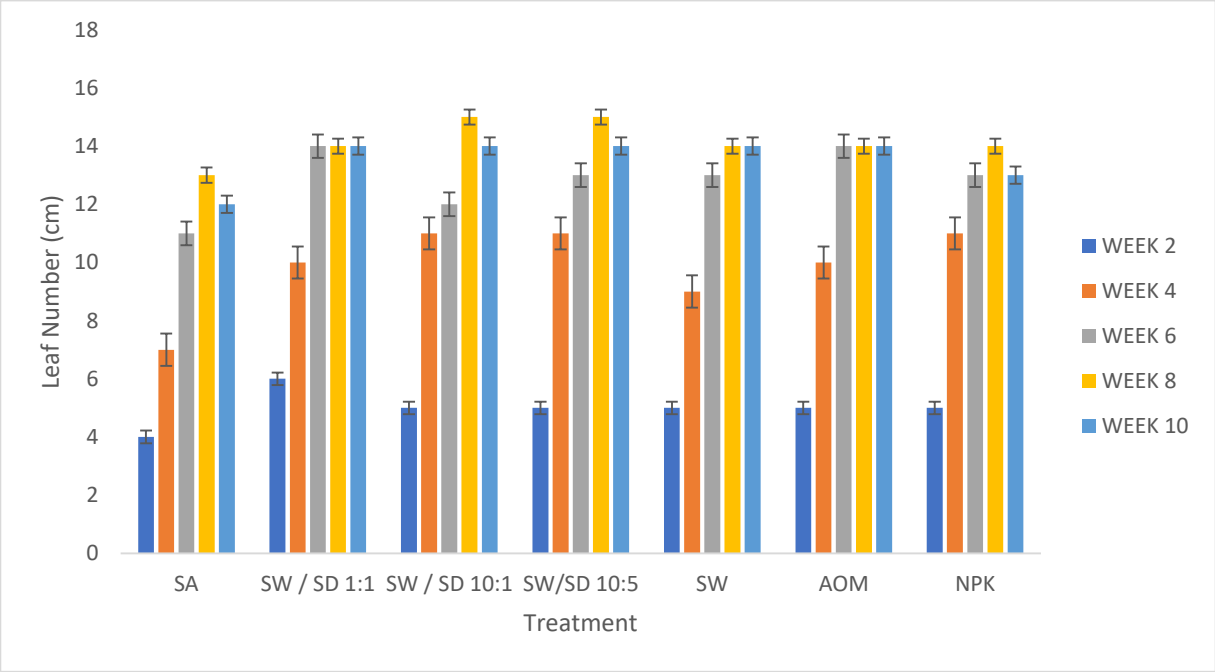
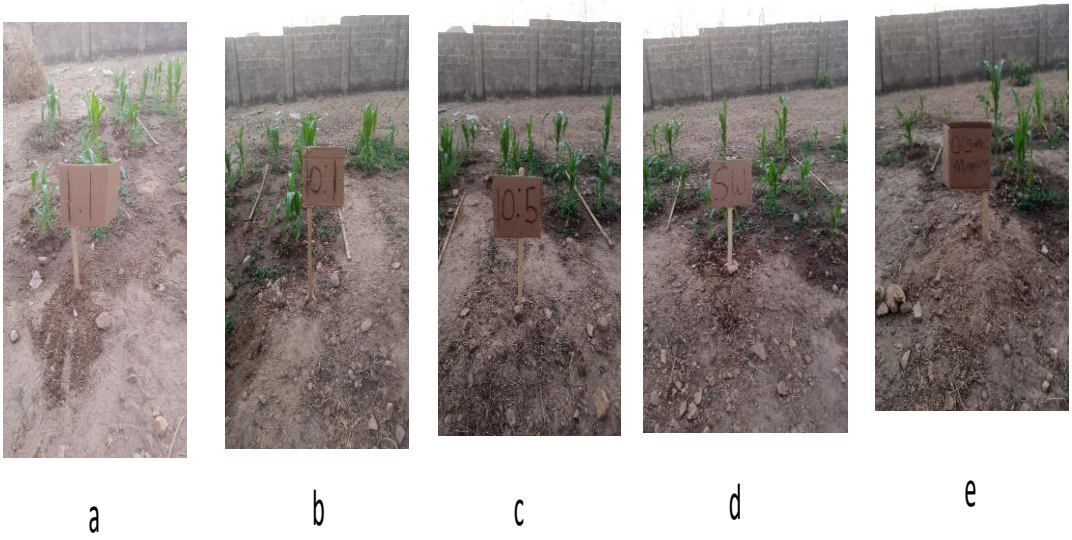


Figure 4.8: Leaf number (cm) of maize plant grown on soil amended with compost: SA (Soil alone); SW/SD (Shea waste and Sawdust); AOM (Amazing Organic Manure)

4.1.9.6 Effect of compost on maize yield

Maize plants raised with the compost SW/SD (1:1, 10:1, 10:5, SW respectively) had yields. The yields are shown in plate I, ii and iii



a b c d e

f g

Plate 1: Maize plant emergence in the field:
a: SW/SD 1:1, b: SW/SD 10:1, c: SW/SD 10:5, d: SW, e: AOM -amazing organic manure, f: NPK and g: SA=Soil alone

40

a

b

c

d

e

f

g

Plate ii: Maize plant with cobs growing in the field:
a: SW/SD 1:1, b: SW/SD 10:1, c: SW/SD 10:5, d: SW, e: AOM -amazing organic manure, f: NPK and g: SA=Soil alone

41

a

b

c

d

e

f

g

Plate iii: Yield of maize after 10 weeks:
a: SW/SD 1:1, b: SW/SD 10:1, c: SW/SD 10:5, d: SW, e: AOM -amazing organic manure, f: NPK and g: SA=Soil alone

4.2 Discussion

The bacterial counts in shea waste (SW),sawdust (SD) and soil (SL) were 3.90×10^8 cfu/g, 1.24×10^9 cfu/g and 3.82×10^8 respectively, while the fungal counts in the shea waste (SW), sawdust (SD) and soil (SL) were 4.80×10^4 cfu/g, 2.91×10^5 cfu/g and 4.52×10^4 respectively. Many researchers have reported the microbial counts of shea wastes, sawdust and soil. *Das et al.* (2017) reported that the microbial load in shea waste samples contained massive counts of bacteria and fungi in the average 10^8 cfu/g; higher bacterial and fungal counts for sawdust waste was also reported by (*Haseena et al.*,2016 & Idu *et al.,* 2019). The higher microbial counts might be due to the available nutrients (carbon, nitrogen or energy) present in the wastes, which are required for proliferation and survival of microorganisms. Adebola *et al* (2019) evaluated the microbial loads of the soil (from fadama, hydromorphic and uncultivated field) of National Cereal Research Institute rice field, Badeggi, Niger State, Nigeria and found that some bacterial and fungal species were higher in hydromorphic and in uncultivated soil. Wani *et al.,* (2018) reported that higher microbial counts were observed in forest soils and lower in agricultural soils of North western zone of Kashmir, possibly because of the fact that greater carbon source in the form of organic matter existed in the forest soils as compared to other land use system.

The study showed that the isolated bacteria from the shea waste, sawdust and soil were *Bacillus subtilis, Streptococcus faecalis, Bacillus cereus, Lactobacillus bulgaricus, Enterococcus faecalis* and *Bacillus licheniformis,* while the fungi species isolated were *Aspergillus flavus, Aspergillus niger, Penicillium notatum, Muccor pusillus, Fusarium solani, Trichoplyton rubrum, Candida tropicalis,* and *Candida parapsilosis.* Different studies have shown that shea wastes habour common indigenous microorganisms present in the soil. These include *Bacillus subtilis, Bacillus*

cereus, Aspergillus niger and Penicillium notatum (Emmanuel *et al.,* 2017; Mohammed *et al.,* 2017; Adebola *et al.,*2019). Lennox *et al.* (2010) reported that these indigenous bacterial species and fungal isolates played significant role in the degradation of sawdust. The microbial species such as *Bacillus, Aspergillus, Mucor,* have strong decomposting ability to solid wastes and use it for carbon and energy generation. Soil is a common reservoir for microorganisms as saprophytes or pathogens. Similar, microbial isolates were observed in this study. Different microbial populations are maintained by soil thus the organisms play a vital function in ecosystem level processes such as, nutrient cycling as well as decomposition of organic matter (Wani *et al.,* 2018). Gbolagunte and Silas (2016) also isolated *Aspergillus flavus, Aspergillus niger,* from landfills and shea waste and most of these fungi are waste degraders.

The frequency of occurrence of bacterial isolates revealed that *Streptococcus faecalis* had a frequency of (21.05 %), *Bacillus cereus* (17.54 %), *Lactobacillus bulgaricus* had (12.28 %) frequencies of occurrence and *Bacillus lichiniformis* (15.79 %). It was observed that *Bacillus subtilis* had the highest frequency of 13 (37.14 %) while *Enterococcus faecalis* (8.77 %) had the lowest frequency each (Table 4.4). This agrees with the results of Chukwuemeka *et al.* (2013) and Akinnibosun and Ayejuyoni (2015). These bacterial species use organic and inorganic compounds for growth (as sole source of carbon and energy). Mohammed *et al.* (2017) also reported higher percentage occurrence of some bacterial species in shea waste, and these bacteria participate in the breakdown of organic and inorganic compounds.

The frequency of occurrence of fungi in shea waste (SW) (25.40 %), sawdust (SD) (36.50 %) and soil (SL) (39.67 %) were high. *Aspergillus niger* had (23.8 1%), *Aspergillus flavus* (20.64 %), *Muccor pusillus* had (11.11 %), *Penicillium notatum* (12.70 %), *Fusarium solani* (12.69 %),

Candida parapsilosis (11.10 %). *Candida tropicalis* (4.76 %) and *Tricophyton rubrum* (3.18 %), had the lowest frequency of occurrence. Adebola *et al.* (2019) reported the percentage frequency occurrence of fungal species from rice field soil of Badaggi, Niger State, Nigeria, to be *Aspergillus niger* (24.28 %), *Aspergillus flavus* (23.33 %), *Mucor* sp. (4.47 %), and attributed the highest frequency of *Aspergillus* sp., to farming activities observed on the soils as well as the usage of fertilizers. Akpomie and Ejechi (2016) reported the occurrence of *Aspergillus niger* and *Muccor pusillus* as the major isolates of shea waste samples.

The physicochemical characteristics of shea waste (SW), sawdust (SD), and soli (SL) are shown in Table 4.8. The shea waste pH (5.48) was acidic. The acidic nature of the shea waste is probably due the presence of oil (Dias *et al.,* 2012; Yakob *et al.,* 2012; Chang *et al*., 2013; Silitonga *et al.,* 2013; Adepoju *et al.,* 2018a) The pH (5.29) of the sawdust was strongly acidic. Omosebi and Adekunle (2018) reported lower pH (4.36 acidic) for sawdust. The acidity might be due to the type of tree species used. Ikenyiri *et al* (2019) reported the pH values variations of some wood sawdust; soft wood (5.29 – 5.48, strongly acidic), hard wood (5.75 – 6.18, moderately acidic) and that the variations in pH values depends on wood species. The soil pH obtained in this study was 5.9. The result is in agreement with Ezeagu *et al.* (2017b) who found the pH of the soil of the Federal University of Technology, Minna, Niger State, Nigeria, to be 5.93. Abdulhamid *et al.* (2015) also reported the pH values of some soil samples in Minna, analyzed from seven different farms to range from 5.77 to7.70, and that this soil pH was normal for plant growth. The pH range of the three samples used in this study was within the ideal values for the growth of bacteria (6 – 7.5) and fungi (5.5 – 8.0) (Ahmed *et al.,* 2007; Mehta and Sirari, 2018).

The organic carbon (40 %), total nitrogen (2.9 %), and potassium contents (23.17 %), of shea wastes used in this study (Table 4.8) were high. Owing to the high organic carbon as well as high nitrogen contents, shea wastes are a good source of plant nitrogen (Nabavinia *et al.*, 2015). These variations in results might be attributed to different samples being used, and coupled to environmental factors. Khater (2015) studied the physicochemical properties of three raw materials (cattle manure, herbal plant residues and sugar cane plants residues) used in producing compost. The high potassium might be attributed to ash added. Some other researchers reported lower results for potassium concentration in shea waste with range from 0.02 to 2.6 % (Ahmed *et al*., 2007; Nabavinia *et al.*,2015).

The sawdust was rich in organic carbon content (53 %) and electrical conductivity was high. Similar results were reported by Mahdi *et al.* (2007). The organic carbon of sawdust obtained in this study was 53 %. Other researchers recorded organic carbon content for sawdust to be 54 % (Nwankwo *et al.*, 2014; Ogunwande *et al*., 2014). The variations in organic carbon could be due different plants species that generated the sawdust. Dan *et al.* (2018) reported higher C:N ratio (499.64) for sawdust used in composting. Generally, sawdust has wide variations of C:N ratio depending on the wood species.

The total nitrogen content obtained in this study was soil (0.36 %), sawdust (0.28 %) and shea waste (2.90 %) respectively. Jeyapandiyan *et al.* (2017) reported the total nitrogen contents of some raw materials used in composting including coir pith (0.31 %), raw sludge (0.44 %) and poultry waste (3.21 %). Nitrogen is the most vital nutrient for plants; it plays a significant role in ecosystem and is influenced by organic processes. Shea wastes having high nitrogen content might supply utilizable nutrients for microorganisms for survival, growth and the capability

for degradation. The shea waste (SW) had high phosphorus content of 0.19 mg/kg. Nabavinia *et al.* (2015) reported that collagens in shea waste possessed enough phosphorus which could serve as good substitute for phosphorus fertilizer; which exhibited satisfying outcomes for rice (*Oryza sativa* L.).

The Lead (Pb) contents were high; the highest content was detected in the soil (SL) (2.653 mg/kg), while least was observed in shea waste (0.9 mg/kg). Generally, lead (Pb) in Minna soils is dispersed from industrial waste (such as old paint, storage batteries, and plumbing hardware) dumped in and around agricultural lands, moved to farms by excess water (Ahaneku and Sadiq, 2014). Okoye and Iteyere (2014) attributed lead distribution to atmospheric deposition as well as weathering of minerals. The potassium content of the sawdust (SD) was higher than that of the soil and shea waste. Ogbonna *et al.,* (2012) observed higher metal content such as potassium (39.36 mg/kg), magnesium (32.41 mg/kg) from Utisoils in Port Harcourt, Nigeria.

Other heavy metals detected in the SW, SD and SL were Zn, Hg, and Cu. The concentrations of these metals in soil (SL) were higher than those observed in either SW or SD (Table 4.9). Amadi *et al.* (2017) reported that a high level of zinc in the soil could impede the uptake of copper, which is a microelement for plants utilization. In addition, too much concentration of zinc in soil can cause phytotoxic effect on germinating seeds. Iyaka and Kakulu (2009) studied the heavy metal content of soil samples from cultivated farmlands in Minna, Niger State, and found higher concentration of copper (Cu) above 12.0 mg/kg, and the zinc contents varied from 2.8ppm to 41ppm which is lower. Both copper and zinc are trace elements required by living organisms in less quantity. However, higher concentration in the soil might cause contamination and thus affect plant growth.

Microbiological properties of the compost are were studied. The common mesophilic microbial species identified in the Mesophilic stage were *Streptococcus faecalis, Bacillus subtilis, Bacillus cereus, Bacillus licheniformis, Aspergillus niger, Aspergillus flavus, Mucor pusillus, Candida tropicalis* and *Penicillium notatum.* The most dominant species identified in this study were the most probable compost microbes reported by different researchers. The finding is in agreement with Mehta and Sirari (2018) who reported the occurrence of such microbes during mesophilic stage of composting (temperature between 20 and 40℃). Similarity, Chinakwe *et al.,* (2019) reported the following microbial isolates such as *Bacillus*, *E. coli*, *Micrococcus, Proteus, Pseudomonas, Staphylococcus, Aspergillus,Candida albicans*, *Fusarium*, *Mucor*, *Rhizopus* and *Saccharomyces* species during composting of some organic wastes in greenhouse. Mesophilic microbes are known to be the most prevalent degraders if different organic waste materials and their occurrence in the compost relied on the type of organic waste involved, pH and the temperature of the composting materials. Ezeagu *et al.,* (2017b) also observed similar species of microbes in a study conducted on enhanced biodegradation of organic municipal solid wastes for organic fertilizer production. *Ezeagu at al.,* (2017a) also observed that the fungi *Aspergillus niger* had the ability to degrade cellulose by enzymatic (cellulase) hydrolysis of sawdust and the bacteria *Bacillus subtilis* also utilized cellulose.

During the thermophilic stage of composting the occurrence of *Bacillus subtilis, Bacillus cereus, Bacillus licheniformis, Lactobacillus bulgaricus, Muccor pusillus, Aspergillus niger, Aspergillus flavus* and *Fusarium solani* were observed. Chinakwe *et al.,* (2019) also reported similar microbes. The decline in microbial counts might be as a result of depletion of nutrients within the compost. It was observed that the number of *Aspergillus* species in this study was higher than the other mould isolates. This study corroborates with Haas *et al.,* (2016) who also found the

persistence of *Aspergillus* species within the compost during decomposting. This might be because thermophilic fungi grow and persevere during the rotting process due to generation of heat. In addition, Escobar and Solute (2015) reported the domination of the genera *Aspergillus* and *Penicillium* associated with organic manure obtained by composting of agricultural waste.

The composting process of SW/SD was achieved in 84 days (twelve weeks) and the qualities of the compost were good. Similar duration (84 days) was reported in the composting of palm kernel cake (PKC), goat manure and poultry droppings by Kolade *et al.* (2006). Zakarya *et al.* (2018) reported the composting of food waste with rice straw ash to maturity in 80 days. Physical characteristics of the resultant compost were compared to the minimum Nigeria standard that is required of matured compost (Hammed, 2015). These include pH (6.5 – 7.5), colour (dark brown to black) though variable, with pleasant earthly smell, free from non-biodegradable materials (glasses, plastics, metals, etc.)

The pH profile obtained in the 84 days of composting SW/SD ranged from 7.320±0.00 to 7.80 ±0.00 (neutral). However, pH of matured compost relies on the types of raw material which was being used and decomposed. Too much nitrogen could trigger an increase in the pH level which is harmful to certain microorganisms. Various wastes used for composting had different ranges of pH. Ameen *et al.*, (2016) suggested a range of pH from 6.5 to 8.23 at the end of composting. The pH obtained in this study, was compared with the Nigeria minimum quality standards for finished compost as well as Thailand, and California (Hammed, 2015), and the pH fell within the accepted quality standards for finished compost.

The temperature recorded during the composting process was not above 58 ^{o}C, but fell within the range (> 55^{o}C) stipulated for compost mixture with rice husk by Ogunwande *et al*. (2014), who

established that the ability to attain maturity quicker was by the rate of decrease of the carbon to nitrogen ratio. Verma *et al.* (2014) also reported the ideal temperature range for composting to be between 55 ^{o}C and 60 ^{o}C. The increase rate of biological disintegration of organic materials and the rate of temperature rise is attributed to microbial activity, and the rise in temperature was observed within a few days of making the composting. Mehta and Sirari (2018) reported that most pathogens die at 55 ^{o}C and above, but for the destruction of weed seeds temperature about 65 ^{o}C and above is required (Anwar *et al.*, 2015). Heat production arises from microbial activity; during the composting process there was an early increase in temperature, then declined and later stabilised as microbial action declined due to depletion of organic matter. Subsequently, compost turning and moisture improvement caused no temperature rise which is an indication of compost maturity. The rise and fall in temperature could also be attributed to the size (quantity) of the mixture, the type of raw material used (especially the sawdust) and composting bin. Microbes with their metabolic activities within the composting material cause a rise in temperature as they decompose the materials (Verma *et al.*,2014).

The phosphorus content in the compost ranged from 0.74±0.00 to 2.66±0.00 % and potassium content in the compost ranged from 0.96±0.00 to 1.7±0.00 % The phosphorus and potassium obtained in this study, was compared with the Nigeria minimum quality standards for finished compost as well as Thailand, and California (Hammed, 2015), and the phosphorus and potassium fell within the accepted quality standards for finished compost.

The total organic carbon (TOC) of the matured compost ranged from 21.05 % to 48.00 % These results are in agreement with Khater (2015) who also found the total organic carbon of compost in the range of 16.6 – 23.89 %. The carbon to nitrogen ratio of the compost obtained in this study

ranged from 10.96 to 31.46. Anwar *et al.* (2015) reported that different studies have revealed wide ranges of C:N ratio (14 – 40) for quality and maturity of compost.

Escobar and Solarte (2015) reported that the higher C:N ratio (>40), the microbes require sufficient time to disintegrate waste due to shortage of nitrogen declining composting activity, significant temperature rises can cause loss of nitrogen in ammoniac form yielding low C:N ratio. Some of the characteristics observed in the finished compost include: pH 6.5 to 7.5 colour (dark to brown), pleasant earthly smell and absence of non-biodegradable material such as glasses, stones, plastics. Compost maturity relied on many factors such as characteristics of primary wastes materials (C:N ratio, moisture, organic matter, pH and porosity) as well as process situations. Thus, the compost produced is of good quality. Lim *et al.* (2013) reported that the use of mature compost is of great significance because direct use of organic matters into soil may generate toxins and threaten the environment. It was very difficult to ascertain which compost got matured before others, however based on temperature readings and C:N ratio SW/SD 1:1 matured before SW/SD 10:1 and SW/SD 10:5 and SW alone took a longer time to manure probably due to slow rate of decomposition. The slow rate of composition could be due to high ratio of sawdust to shea waste in the composting mixture. Lennox *et al.,* (2019) reported that microbial degradation of sawdust was very difficult due to the presence in lignin, a highly recalcitrant constituent.

The resultant compost (SW/SD) produced were applied as treatment to maize plant. The ability of the maize seeds to germinate in all treatments showed that the compost SW/SD (1:1, 10:1, 10:5, and SW alone respectively) had no phytotoxic effects on the maize plants. Jeyapandiyan *et al.,* (2017) and Tibu *et al.* (2019) have reported that compost displaying more than 80 % germination index is free from phytotoxic compounds and maturity is satisfactory.

Compost (SW/SD 1:1) supported good growth pattern. At two weeks after planting the plants heights were almost the same in the different treatments. At four, six, eight and ten weeks after planting, the maize had shown significant increase in height and leaf length. During growing period, it was observed that, with this compost mix (SW/SD 1:1), the leaves were greenish with extensive leaf sizes. This suggests that the nutrient content of the compost (SW/SD 1:1) was being utilized by the plants for their growth. Organic manure has specific characteristics nature of slow release of nutrients (Makinde and Ayoola, 2010). For vegetable plants such as spinach, ogwu, sorrels, cabbage, salads etc., this particular ratio might be recommended, since the leaves are of interest most. Olowoke *at al., (*2018) acknowledged that compost enriched crop yield by improving nutrients status and microbial action in the soil.

Maize plants treated with compost (SW/SD 1:1), supported good growth pattern as well as seed formation. This result is in agreement with Weerasinghe and De Silva (2017) who reported the use of compost made from municipal solid waste (MSW) to grow *Zea mays* (maize), and found that the best soil compost ratios that significantly improved the growth parameters of maize was 1:1 followed by 1:0.5. In addition, it was in this treatment (SW/SD 1:1), that tassels were produced ten weeks (70 days) after planting which resulted in the production of good seeds as well as yield. Khan (2015) reported that compost use heightens days to tasselling. This suggests that when this compost (SW/SD 1:1) is applied to cereals and legumes good harvest could be obtained, since the seeds are of interest.

The finding showed better performance yield output under plot treated with compost SW/SD 1:1, followed by SW/SD 10:1 and then SW/SD 10:5 However, maize treated with SW alone had poorest yield. In this study, it has been shown that yields have differed between the compost

ratios as well as the controls (with or without fertilizer). Thus it showed that there were significant differences ($P<0.05$) among the treatments.

CHAPTER FIVE

5.0 CONCLUSION AND RECOMMENDATION

5.1Conclusion

Some of the characteristics in the finished compost were: pH (7.30 – 8.05), color (dark to brown), pleasant earthly smell and absence of non-biodegradable materials.

Total organic carbon ranged from 21.05% to 48.00% while heavy metals were found to be within the permissible limit for mature and quality compost.

Composting of shea waste and sawdust, SW/SD in the ratio 1:1 was more effective followed by SW/SD (10:1) and SW/SD (10:5) when plant parameters such as height, leaf length, leaf number and yields were considered.

Composting is a means of reducing organic waste materials from the environment.

Unattended dumps of shea waste and sawdust on the environment can be converted to organic manure by microorganisms, particularly species of *Bacillus, Aspergillus, Penicillium* and *Candida.*

1.2 Recommendations

Based on the results obtained in this study, the following recommendations are made:

Shea waste and sawdust compost produced is good for crops particularly maize and therefore, its production should be encouraged.

Composting of organic wastes should be encouraged as this will help people to make money and boost crop yield.

Use of organic fertilizer instead of inorganic fertilizer should be encouraged to avoid environmental pollution.

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APPENDICES

Appendix I: Analysis of Variance (ANOVA) for Leaf Length at weekly intervals

		Sum of Squares	Df	Mean Square	F	Sig
WEEK 1	Between Groups	113.067	3	18.211	711.219	.000
	Within Group	.015	4	.001		
	Total	113.082	8			
WEEK 2	Between Groups	6625.550	4	1123.012	141187.105	.000
	Within Group	.060	4	.020		
	Total	6625.610	9			
WEEK 3	Between Groups	33580.177	4	4217.041	2235620.678	.000
	Within Group	.020	7	.014		
	Total	33580.197	7			
WEEK 4	Between Groups	278702.697	5	43210.431	1367541.664	.000
	Within Group	.220	4	.022		
	Total	278702.917	7			
WEEK 5	Between Groups	174008.814	7	34801.421	1488554.022	.000
	Within Group	.135	4	.017		
	Total	174008.949	8			
WEEK 6	Between Groups	182439.424	4	45612.661	1476652.231	.000
	Within Group	.145	6	.022		
	Total	182439.569	9			
WEEK 7	Between Groups	89397.468	4	16773.785	6543227.433	.000
	Within Group	0.15	5	.008		
	Total	89397.383	7			
WEEK 8	Between Groups	86776.537	4	19854.101	4556217.456	.000
	Within Group	.020	6	.022		
	Total	86.776.547	8			
WEEK 9	Between Groups	72762.034	10	21667.665	1778649.543	.000
	Within Group	.515	8	.054		
	Total	72762.539	7			
WEEK 10	Between Groups	85317.644	7	22878.122	6675321.225	.000
	Within Group	.265	6	.010		
	Total	85317.909	4			

Appendix II: Analysis of Variance (ANOVA) for Leaf Height at weekly intervals

		Sum of Squares	Df	Mean Square	F	Sig
WEEK 1	Between Groups	13.067	4	11.211	3211.220	.000
	Within Group	.015	5	.014		
	Total	13.082	10			
WEEK 2	Between Groups	25.550	5	23.012	12270.205	.000
	Within Group	.060	4	.062		
	Total	25.610	5			
WEEK 3	Between Groups	80.177	2	117.041	15620.478	.000
	Within Group	.020	9	.011		
	Total	80.197	10			
WEEK 4	Between Groups	102.697	8	210.431	67541.264	.000
	Within Group	.220	9	.019		
	Total	102.917	6			
WEEK 5	Between Groups	208.814	9	801.421	18554.322	.000
	Within Group	.135	8	.161		
	Total	208.949	12			
WEEK 6	Between Groups	439.424	7	612.661	76652.431	.000
	Within Group	.145	8	.012		
	Total	439.569	11			
WEEK 7	Between Groups	497.468	6	773.785	43227.033	.000
	Within Group	0.15	8	.023		
	Total	497.383	9			
WEEK 8	Between Groups	476.537	6	854.101	56217.230	.000
	Within Group	.020	7	.022		
	Total	476.547	11			
WEEK 9	Between Groups	462.034	8	667.665	78649.610	.000
	Within Group	.515	8	.054		
	Total	462.539	5			
WEEK 10	Between Groups	317.644	9	878.122	75321.320	.000
	Within Group	.265	6	.010		
	Total	317.909	9			

Appendix III: Leaf Height (cm) at weekly intervals

		Sum of Squares	Df	Mean Square	F	Sig
WEEK 1	Between Groups	1.017	4	.211	.	.
	Within Group	.000	5	.000		
	Total	1.082	9			
WEEK 2	Between Groups	5.550	10	812	.	.
	Within Group	.000	6	.000		
	Total	5.610	11			
WEEK 3	Between Groups	4.177	8	7.041	.	.
	Within Group	.000	9	.000		
	Total	3.197	9			
WEEK 4	Between Groups	2.697	6	3.431	.	.
	Within Group	.000	8	.000		
	Total	25.917	4			
WEEK 5	Between Groups	18.814	4	4.421	.	.
	Within Group	.000	6	.000		
	Total	18.949	5			
WEEK 6	Between Groups	15.424	5	2.661	2.231	.013
	Within Group	.000	4	.000		
	Total	19.569	6			
WEEK 7	Between Groups	17.468	6	3.785	1.433	.211
	Within Group	0.15	8	.008		
	Total	17.383	9			
WEEK 8	Between Groups	16.537	8	1.101	3.456	.011
	Within Group	.020	4	.022		
	Total	16.547	5			
WEEK 9	Between Groups	12.034	8	1.665	.543	.060
	Within Group	.515	10	.054		
	Total	12.539	4			
WEEK 10	Between Groups	7.644	5	1.122	1.225	.020
	Within Group	.265	6	.010		
	Total	17.909	9			

Appendix IV: Leaf Width (cm) at weekly interval

Week	Treatments						
	SA	**SW1:SD1**	**SW10:SD1**	**SW10:SD5**	**SW**	**Organic manure**	**NPK**
1	1.30±0.00[a]	1.80±0.00[c]	1.55±0.0.05[b]	1.70±0.00[c]	1.75±0.05[c]	1.70±0.00[c]	1.75±0.05[c]
2	1.55±0.05[a]	3.55±0.05[c]	2.70±0.00[b]	3.65±0.05[c]	2.7±0.00[b]	3.65±0.05[c]	2.80±0.00[b]
3	3.00±0.00[a]	5.05±0.5[c]	4.85±0.05[b]	5.90±0.00[e]	5.55±0.05[d]	5.90±0.00[e]	6.00±0.00[e]
4	3.35±0.5[a]	10.00±0.00[e]	6.25±0.05[b]	7.95±0.05[d]	7.4±0.05[c]	7.95±0.05[d]	8.00±0.00[d]
5	7.55±0.05[a]	10.05±0.05[c]	10.00±0.00[c]	10.00±0.00[c]	9.00±0.00[b]	10.00±0.00[c]	10.45±0.05[d]
6	8.00±0.00[a]	11.35±0.05[e]	10.05±0.05[b]	11.00±0.00[d]	10.00±0.00[b]	11.00±0.00[d]	10.70±0.00[c]
7	10.00±0.00[a]	11.50±0.05[f]	10.20±0.00[c]	11.10±0.00[e]	10.10±0.00[b]	11.10±0.00[e]	10.85±0.05[d]
8	10.15±0.05[a]	12.05±0.05[e]	10.35±0.05[b]	11.10±0.00[d]	10.55±0.05[c]	11.10±0.00[d]	11.00±0.00[d]
9	1.065±0.05[a]	13.00±0.00[f]	11.00±0.00[b]	11.85±0.05[e]	11.60±0.00[d]	11.85±0.05[e]	11.50±0.00[c]
10	10.90±0.00[a]	13.60±0.00[e]	11.15±0.05[b]	11.90±0.00[d]	11.85±0.05[c]	11.90±0.00[d]	11.75±0.05[c]

SW: Shea waste, SD: Sawdust and SA: Soil alone

Appendix V: Leaf Length (cm) at weekly intervals

Week	Treatments						
	SA	**SW1:SD1**	**SW10:SD1**	**SW10:SD5**	**SW**	**Organic manure**	**NPK**
1	1.30±0.00[a]	1.80±0.00[c]	1.55±0.0.05[b]	1.70±0.00[c]	1.75±0.05[c]	1.70±0.00[c]	1.75±0.05[c]
2	1.55±0.05[a]	3.55±0.05[c]	2.70±0.00[b]	3.65±0.05[c]	2.7±0.00[b]	3.65±0.05[c]	2.80±0.00[b]
3	3.00±0.00[a]	5.05±0.5[c]	4.85±0.05[b]	5.90±0.00[e]	5.55±0.05[d]	5.90±0.00[e]	6.00±0.00[e]
4	3.35±0.5[a]	10.00±0.00[e]	6.25±0.05[b]	7.95±0.05[d]	7.4±0.05[c]	7.95±0.05[d]	8.00±0.00[d]
5	7.55±0.05[a]	10.05±0.05[c]	10.00±0.00[c]	10.00±0.00[c]	9.00±0.00[b]	10.00±0.00[c]	10.45±0.05[d]
6	8.00±0.00[a]	11.35±0.05[e]	10.05±0.05[b]	11.00±0.00[d]	10.00±0.00[b]	11.00±0.00[d]	10.70±0.00[c]
7	10.00±0.00[a]	11.50±0.05[f]	10.20±0.00[c]	11.10±0.00[e]	10.10±0.00[b]	11.10±0.00[e]	10.85±0.05[d]
8	10.15±0.05[a]	12.05±0.05[e]	10.35±0.05[b]	11.10±0.00[d]	10.55±0.05[c]	11.10±0.00[d]	11.00±0.00[d]
9	1.065±0.05[a]	13.00±0.00[f]	11.00±0.00[b]	11.85±0.05[e]	11.60±0.00[d]	11.85±0.05[e]	11.50±0.00[c]
10	10.90±0.00[a]	13.60±0.00[e]	11.15±0.05[b]	11.90±0.00[d]	11.85±0.05[c]	11.90±0.00[d]	11.75±0.05[c]

SW: Shea waste, SD: Sawdust and SA: Soil alone

Appendix VI: Plant Height (cm) at weekly intervals

Week	Treatments						
	SA	**SW1:SD1**	**SW10:SD1**	**SW10:SD5**	**SW**	**Organic manure**	**NPK**
1	1.30±0.00[a]	1.80±0.00[c]	1.55±0.0.05[b]	1.70±0.00[c]	1.75±0.05[c]	1.70±0.00[c]	1.75±0.05[c]
2	1.55±0.05[a]	3.55±0.05[c]	2.70±0.00[b]	3.65±0.05[c]	2.7±0.00[b]	3.65±0.05[c]	2.80±0.00[b]
3	3.00±0.00[a]	5.05±0.5[c]	4.85±0.05[b]	5.90±0.00[e]	5.55±0.05[d]	5.90±0.00[e]	6.00±0.00[e]
4	3.35±0.5[a]	10.00±0.00[e]	6.25±0.05[b]	7.95±0.05[d]	7.4±0.05[c]	7.95±0.05[d]	8.00±0.00[d]
5	7.55±0.05[a]	10.05±0.05[c]	10.00±0.00[c]	10.00±0.00[c]	9.00±0.00[b]	10.00±0.00[c]	10.45±0.05[d]
6	8.00±0.00[a]	11.35±0.05[e]	10.05±0.05[b]	11.00±0.00[d]	10.00±0.00[b]	11.00±0.00[d]	10.70±0.00[c]
7	10.00±0.00[a]	11.50±0.05[f]	10.20±0.00[c]	11.10±0.00[e]	10.10±0.00[b]	11.10±0.00[e]	10.85±0.05[d]
8	10.15±0.05[a]	12.05±0.05[e]	10.35±0.05[b]	11.10±0.00[d]	10.55±0.05[c]	11.10±0.00[d]	11.00±0.00[d]
9	1.065±0.05[a]	13.00±0.00[f]	11.00±0.00[b]	11.85±0.05[e]	11.60±0.00[d]	11.85±0.05[e]	11.50±0.00[c]
10	10.90±0.00[a]	13.60±0.00[e]	11.15±0.05[b]	11.90±0.00[d]	11.85±0.05[c]	11.90±0.00[d]	11.75±0.05[c]

SW: Shea waste, SD: Sawdust and SA: Soil alone

Appendix VII: Leaf Number (cm) at weekly intervals

Week	Treatments						
	SA	**SW1:SD1**	**SW10:SD1**	**SW10:SD5**	**SW**	**Organic manure**	**NPK**
1	1.30±0.00[a]	1.80±0.00[c]	1.55±0.0.05[b]	1.70±0.00[c]	1.75±0.05[c]	1.70±0.00[c]	1.75±0.05[c]
2	1.55±0.05[a]	3.55±0.05[c]	2.70±0.00[b]	3.65±0.05[c]	2.7±0.00[b]	3.65±0.05[c]	2.80±0.00[b]
3	3.00±0.00[a]	5.05±0.5[c]	4.85±0.05[b]	5.90±0.00[e]	5.55±0.05[d]	5.90±0.00[e]	6.00±0.00[e]
4	3.35±0.5[a]	10.00±0.00[e]	6.25±0.05[b]	7.95±0.05[d]	7.4±0.05[c]	7.95±0.05[d]	8.00±0.00[d]
5	7.55±0.05[a]	10.05±0.05[c]	10.00±0.00[c]	10.00±0.00[c]	9.00±0.00[b]	10.00±0.00[c]	10.45±0.05[d]
6	8.00±0.00[a]	11.35±0.05[e]	10.05±0.05[b]	11.00±0.00[d]	10.00±0.00[b]	11.00±0.00[d]	10.70±0.00[c]
7	10.00±0.00[a]	11.50±0.05[f]	10.20±0.00[c]	11.10±0.00[e]	10.10±0.00[b]	11.10±0.00[e]	10.85±0.05[d]
8	10.15±0.05[a]	12.05±0.05[e]	10.35±0.05[b]	11.10±0.00[d]	10.55±0.05[c]	11.10±0.00[d]	11.00±0.00[d]
9	1.065±0.05[a]	13.00±0.00[f]	11.00±0.00[b]	11.85±0.05[e]	11.60±0.00[d]	11.85±0.05[e]	11.50±0.00[c]
10	10.90±0.00[a]	13.60±0.00[e]	11.15±0.05[b]	11.90±0.00[d]	11.85±0.05[c]	11.90±0.00[d]	11.75±0.05[c]

SW: Shea waste, SD: Sawdust and SA: Soil alone

Appendix VIII: Analysis of Variance (ANOVA) Temperature

		Sum of Square	Df	Mean Square	F
10:5	Between Groups Within Groups Total	3021.859 2.125 3032.984	7 8 15	431.694 .266	1625.202
10:1	Between Groups Within Groups Total	3419.640 .010 3419.650	7 8 15	488.520 .001	390816.000
1:1	Between Groups Within Groups Total	2411.767 5.130 2416.897	7 8 15	344.538 .641	537.292
SW	Between Groups Within Groups Total	566.438 1.500 567.938	7 8 15	80.920 .188	431.571

Appendix IX: Analysis of Variance (ANOVA) Moisture

		Sum of Square	Df	Mean Square	F	Sig.
10:5	Between Groups Within Groups Total	1492.688 6.250 1498.938	7 8 15	213.241 .781	272.949	.000
10:1	Between Groups Within Groups Total	1077.518 1.020 1078.538	7 8 15	153.931 .128	1207.303	.000
1:1	Between Groups Within Groups Total	754.379 3.805 758.184	7 8 15	107.768 .476	226.583	.000
SW	Between Groups Within Groups Total	958.589 2.815 961.404	7 8 15	136.941 .352	389.176	.000

Appendix X Compost Standards/Guidelines in some selected Countries

There is no straight forward approach to offer an outline as to compost quality standards as they occur in the world, and how they originated currently, some European countries have agreed on definite standards and several other nations, plus Nigeria, are in the course of adoption. Appendix present some variations of recognised and published standards in Nigeria and other countries of the world.

National Minimum Quality Standards for Compost (Nigeria)

Parameters	National Standard
Ph	6.5 to 7.5
Odour	Odourless
Colour	Variable
Texture	Variable
Pathogens	None
Moisture content	15 to 25%
Total Organic Carbon	At least 20%
C:N Radio	10 to 1.5
Nitrogen (N)	1.0 to 4.0%
Phosphorus (P)	1.5 to 3.0%
Potassium (K)	1.0 to 1.5%
Non-biodegradable materials (glass, metal, plastic, stone, slugs etc)	Free

Source:hammed, (2015).

Compost quality standard in Thailand

Property	Compost Quality
pH	5.5-8.5
Conductivity (mS/cm)	≤3.5
Nitrogen (N (%, w/w)	≥1.5
Phosphorus (P) (%,w/w)	≥ 0.5
Potassium (K) (%, w/w)	≥ 0.5
Carbon-to-nitrogen (C/N)	≤ 20
Germination index (%)	≥ 80
Cadmium (Cd) (mg/kg)	≤ 5.0
Chromium (Cr) (mg/kg)	≤ 300
Copper (Cu) (mg/kg)	≤ 500
Lead (Pb) (mg/kg)	≤ 500

Source: Hammed, (2015)

Heavy Metal Standards in Compost in Germany

Elements	A Max. Conc. Recommended (mg/kg)	B German Standard (mg/kg)
Lead (Pb)	75	150
Copper (Cu)	50	150
Zinc (Zn)	200	500
Chromium (Cr)	75	150
Nickel (Ni)	30	50
Cadmium (Cd)	0.75	3
Mercury (Hg)	0.5	3

Source: (Hammed, 2015).

Heavy metal standard in Danish composts (mg/kg of dry matter) soil Analysis

Heavy metal	Limit Values
Lead (Pb)	120 (80 for private gardens)
Cadmium (Cd)	0.8
Mercury (Hg)	1.2
Nickel (Ni)	30

Source: Nielsen and KÜger (1992) and (Hammed, 2015).

California quality standard for finished compost

Indicator	Quality Standard for Finished Compost	
Visual	All material is dark brown (black indicates possible burning). Parent material is no longer visible. Structure is mixture of fine and medium size particle and humus crumbs	
Physical	Moisture: 30-40%, Fine Texture (all below 1/8'' mesh)	
Odour	Smells like rich humus from the floor; no ammonia or anaerobic odour.	
Nutrient	Carbon: Nitrogen Ratio	<17:1
	Total Organic Matter	20-35%
	Total Nitrogen	1.0-20%
	Nitrite nitrogen	250-350 mg/kg^{-1}
	Sulfide	0 $mgkg^{-1}$
	Ammonium	0 $mgkg^{-1}$
	pH 6.5-8.5	0 0r trace
	Cation Exchange Capacity (CEC)	>60 $Cmolkg^{-1}$
	Humic Acid Content	5-15%
	ERGS Reading	5,000-15,000 mS/cm
Microbiological	Heterotrophic Plate Count	$1x10^8 – 1x10^{10}$ CFU/gdw
	Anaerobic Plate Count	Aerobes: Anaerobes at 10:1 or
	Yeasts and Moulds	greater
	Actinomycetes	$1 x 10^3 - 1 x 10^5$ CFU/gdw
	Pseudomonads	$1 x 10^6 – 1 x 10^8$ CFU/gdw
	Nitrogen-Fixing Bacteria	$1 x 10^3 - 1 x 10^6$ CFU/gdw
	Compost Maturity	$1 x 10^3 - 1 x 10^5$ CFU/gdw
		>50% on Maturity Index at dilution
	Compost Stability	rate appropriate for compost
	E. coli	application.
	Faecal Coliforms	<10 mg O2/Kg compost dry solids-
	Salmonella	hour
		< 3 *E. coli*/g
		<1000 MPN/g of dry solids
		< 3 MPN/4g total solids

Source: hammed, (2015).

Canadian Council of Ministers of the environment heavy metal standards in compost (mg/kg of dry weight)

Trace Elements	Concentration
Arsenic (As)	13
Cobalt (Co)	34
Chromium (Cr)	210
Copper (Cr)	400
Molybdenum (Mo)	5
Nickel (Ni)	62
Selenium (Se)	2
Zinc (Zn)	700
Others	
Cadmium (Cd)	3
Mercury (Hg)	0.8
Lead (Pb)	150

Source: Hammed (2015)

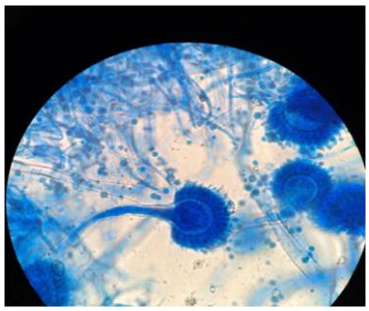
Parameters of compost produced in comparison with Nigerian standard for compost

Parameters	Compost produced	Nigerian Standard
pH	7.30 – 7.80	6.5 -7.5
Nitrogen (%)	1.06 – 1.72	1.0 - 4.0
Organic carbon (%)	34.22 – 38.15	At least 20
Moisture (%)	40.00 – 47.50	15 – 25
Phosphorus (%)	1.00 – 1.70	1.0 - 4.0
Potassium (%)	0.96 – 1.7	1.0 - 1.5



1a: *Aspergillus niger* 1b*: Aspergillus niger* 1c*: Aspergillus niger*





2a: *Aspergillus flavus*2b*: Aspergillus flavus* 2c*: Aspergillus flavus*

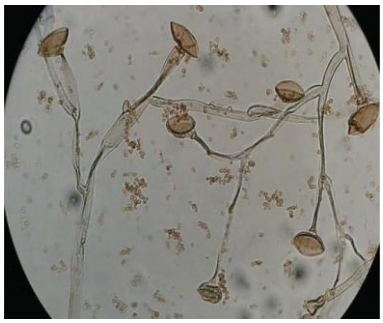


3a: *Fusarium solani* 3b: *Fusarium solani* 3c: *Fusarium solani*

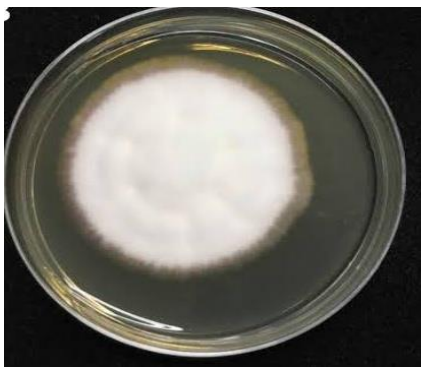
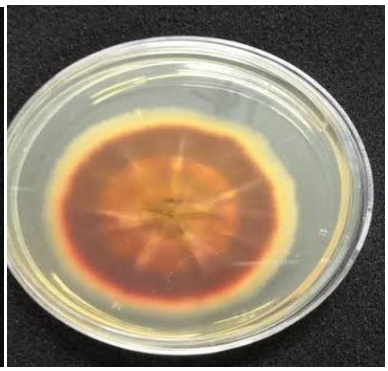
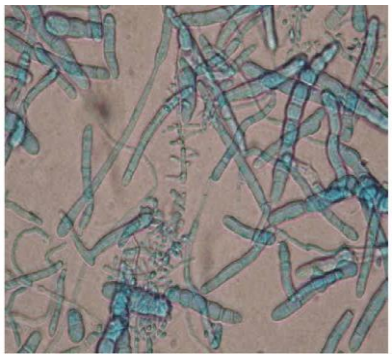
a= Surface characteristics, b= Reverse side, c= Microscopic characteristics view (x40 objective)



4a: *Penicillium notatum* 4b*: Penicillium notatum* 4c*: Penicillium notatum*

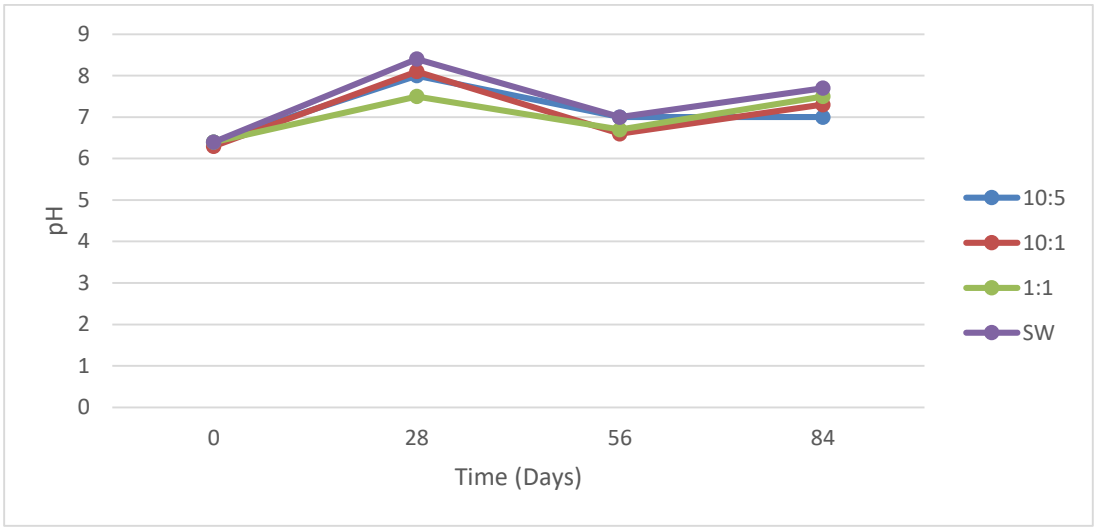
5a: *Mucor pusillus* 5b*: Mucor pusillus* *5c: Mucor pusillus*

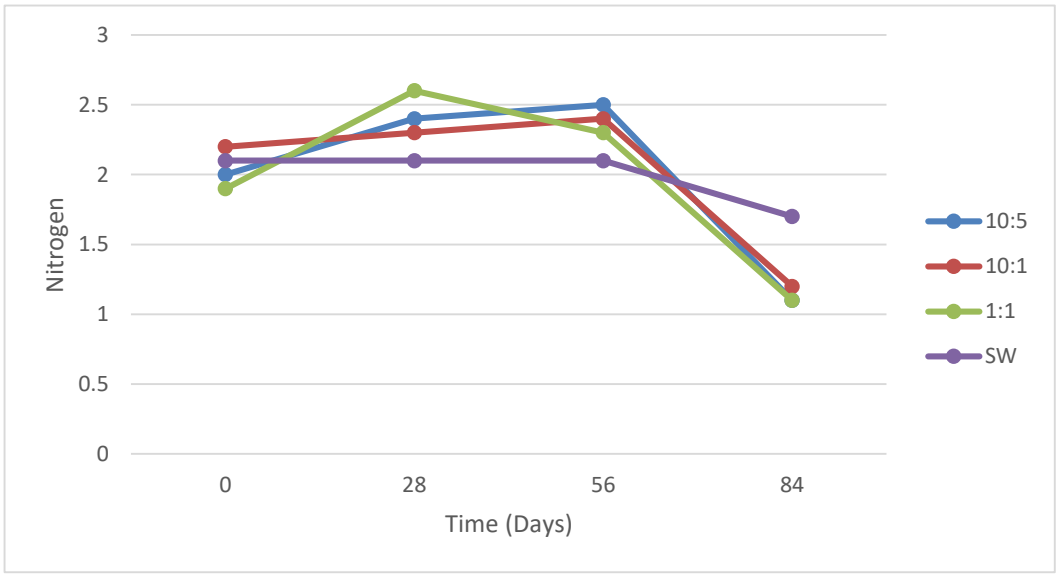
6a: *Trichophyton rubrum* 6b*: Trichophyton rubrum* 6c*: Trichophyton rubrum*

a= Surface characteristics, b= Reverse side, c= Microscopic characteristics view (x40 objective)

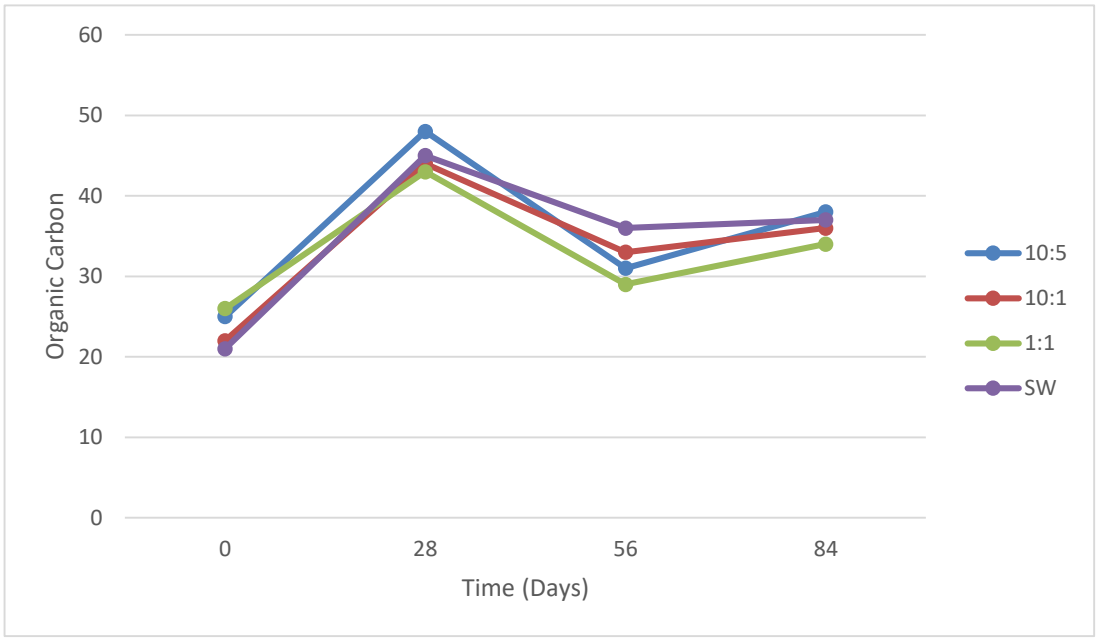
pH during composting of shea waste (SW) with sawdust (SD)



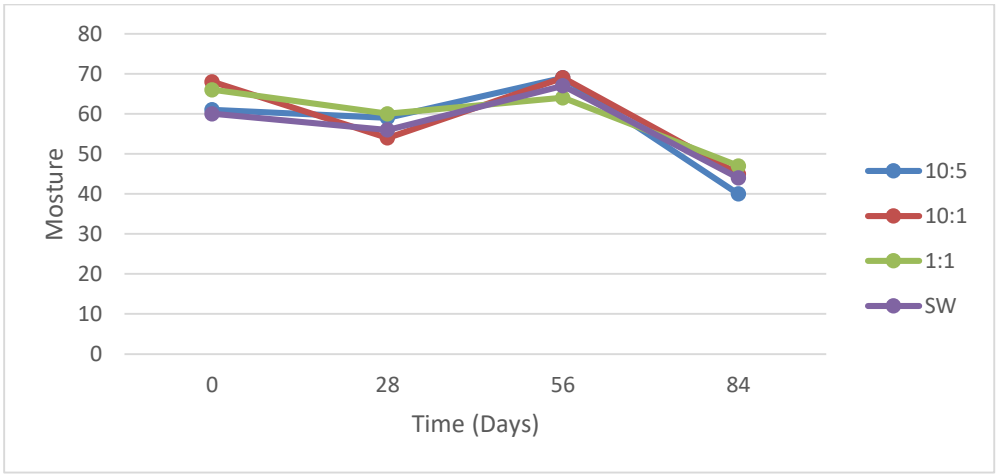
Nitrogen during composting of shea waste (SW) with sawdust (SD)



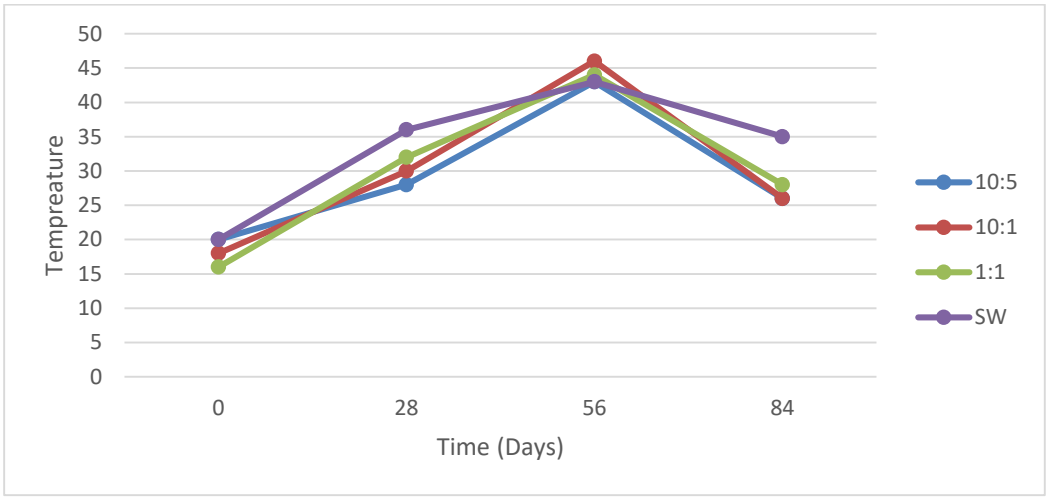
Organic carbon during composting of shea waste (SW) with sawdust (SD)



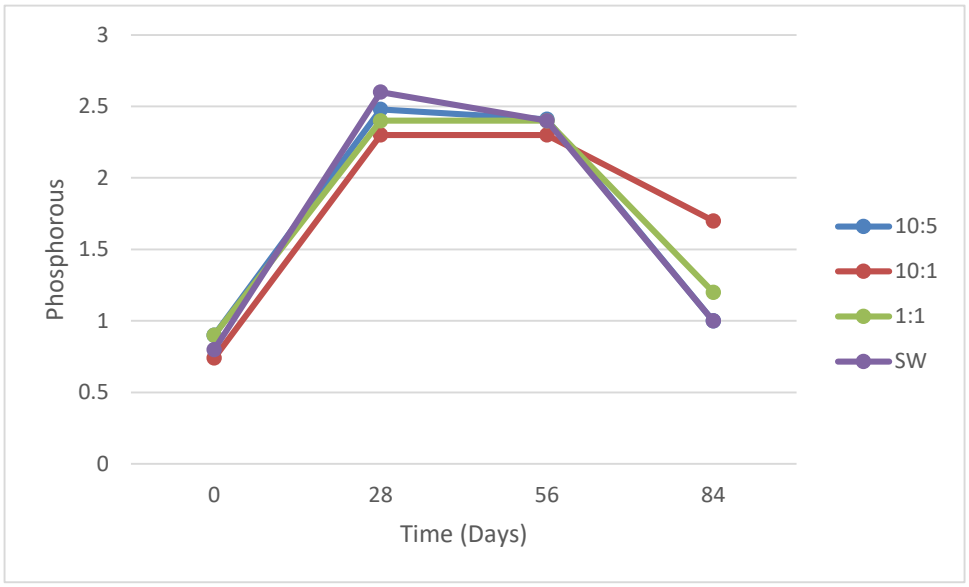
Moisture during composting of shea waste (SW) with sawdust (SD)



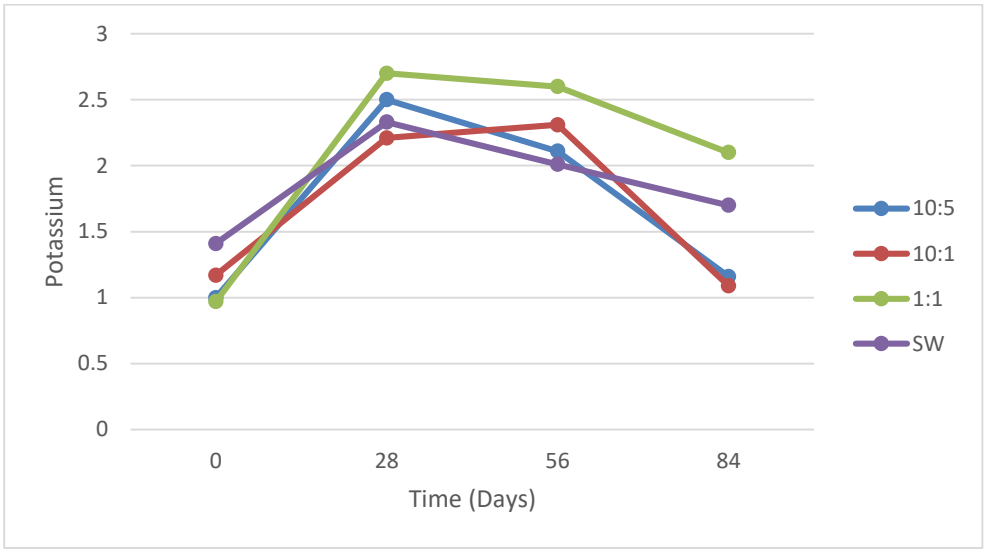
Temperature during composting of shea waste (SW) with sawdust (SD)



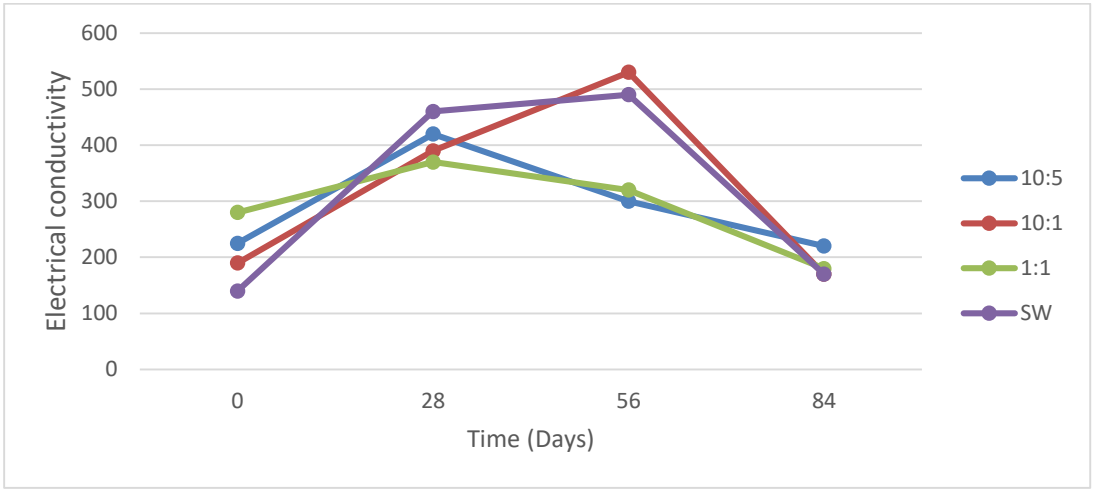
Phosphorus during composting of shea waste (SW) with sawdust (SD)



Potassium during composting of shea waste (SW) with sawdust (SD)



Electrical conductivity during composting of shea waste (SW) with sawdust (SD)



Urea during composting of shea waste (SW) with sawdust (SD)