

**DECOMPOSITION AND MINERALIZATION OF SOME ORGANIC  
RESIDUES IN TWO CONTRASTING AGRO-ECOLOGICAL ZONES**

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## DECLARATION

This is to certify that this thesis is the result of research work undertaken by Dodobi Martin Tetteh for the award of an M.Phil. degree in Nuclear Agriculture (Soil Water and Crop Nutrition Option), Department of Nuclear Agriculture and Radiation Processing, School of Nuclear and Allied Science (SNAS) of the University of Ghana, Legon, under the supervision of **Prof. Daniel K. Asare, Prof. Godfred K. Ofosu-Budu and Dr. Noah Adamtey.**

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## DEDICATION

This work is dedicated to my Lovely Father and Mother, Mr. G.S Dodobi and Mrs. Lily Korkor Dodobi, for their invaluable pieces of advice and support for me throughout my life. It also dedicated to my wife and my son, Mrs. Jennifer Dodobi-Inko and Dodobi Ezekiel Maukle for their prayers, support and care throughout this work. Finally I would like to mention few people who are very important to me. The success of this thesis would have not been possible without the support of my siblings Joyce, Emmanuel, Obed and Samuel as their endless understanding and encouragement made many things easier. May the almighty God bless you all.



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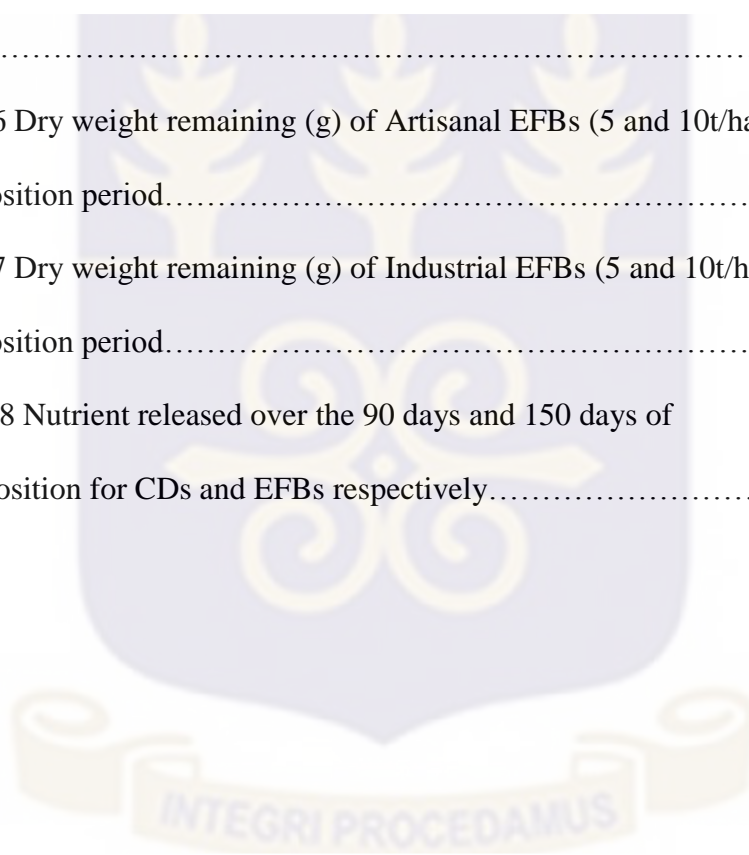
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## LIST OF ABBREVIATIONS

BNARI	-	Biotechnology Nuclear Agriculture Research Institute
Ca	-	Calcium
CD	-	Cow Dung
DNARP	-	Department of Nuclear Agriculture and Radiation Processing
EFB	-	Empty Fruit Bunch
EFB-AT	-	Empty Fruit Bunch Artisanal
EFB-IN	-	Empty Fruit Bunch Industrial
EBT	-	Eriochrome Black T
GAEC	-	Ghana Atomic Energy Commission
IF	-	Inorganic Fertilizer
K	-	Potassium
L	-	Dry Weight Loss for Decomposition
Mg	-	Magnesium
N	-	.Nitrogen
OC	-	Organic Carbon
OM	-	Organic Matter
ORM4Soil	-	Organic Resources Management for Soil
PRA	-	Participatory Rural Appraisal
P	-	Phosphorus
RCBD	-	Randomized Complete Block Design
R	-	Nutrient Released by Organic Resources
SOM	-	Soil Organic Matter
TBI	-	Tea Bag Index
W <sub>o</sub>	-	Initial Organic Resources Dry Weight
W <sub>t</sub>	-	Dry Weight of Organic Resources Remaining

## ABSTRACT

Decomposition and mineralization from plant and animal residues are important processes that can improve soil fertility and build-up soil organic matter. Decomposition and mineralization of 5 and 10 t/ha of matured cow dung (CD) in Ada soil series of the coastal savannah agro-ecological zone, as well as 5 and 10 t/ha of artisanal empty fruit bunch (EFB-AT) and industrial empty fruit bunch (EFB-IN) in Kokofu soil series of the semi-deciduous forest agro-ecological zone were studied using pots. The objective of the study was to assess the decomposition and nutrient release patterns of manured CD and EFB-AT and EFB-IN in order to give an estimate of the release patterns and to synchronize the nutrient release to meet the nutrient demands of crops. The study was conducted between February and June 2017. The dry CD at the two application rates were used for the study in Ada soil series, classified as Entisols (USDA classification) by Brammer (1960), which corresponds to Fluvisols under FAO (1970) classification. Also dry EFBs were used for the Kokofu soil series which are classified Ultisols USDA (Brammer, 1960). Dry CD was put in nylon litter bags, and was buried at 8 cm deep in the soil (in the pots) as practised by farmers in the Sege area, where CD is incorporated into the soil on application. Chopped EFBs of 2cm mesh size were put in nylon litter bags, and placed on the surface of soil in the pots as practised by farmers in the Kade area, where EFBs are placed on the soil surface in most oil palm plantations to serve as mulch. The EFB samples were taken from artisanal palm oil producers (EFB-AT) and industrial palm oil producers (EFB-IN). Buried CDs in pots were sampled at 7, 14, 21, 35, 56, 72 and 90 days whiles EFB-AT AND EFB-IN were sampled 7, 14, 21, 35, 56, 72, 90, 120 and 150 days after being placed on soil surface in pots. Sixty percent (60%) of the initial weight of the CD decomposed within 90 days with no significant difference ( $t=0.05$ ) in the fractions lost between 5 and 10t/ha by t-

test analysis, based on pair comparison. In the case of EFB-AT, about 20% of the 5 t/ha and 50% of 10 t/ha, of the initial weight had decomposed over the 150 days period. For EFB-IN about 78% of the 5 t/ha and 75% of the 10t/ha of the initial weight decomposed over the 150 days period. Comparatively, a t-test analysis, based on pair comparison, showed a significant difference ( $t=0.08$ ) between the fractions lost by EFB-AT and EFB-IN at the two application levels. The estimated half-life ( $t_{1/2}$ ) for the decomposition of CD were 82 and 99 days for 5 t/ha and 10 t/ha, respectively. For EFB-AT, the estimated half-life were 112 and 130 days for 5 and 10 t/ha, respectively, while for EFB/IN half-life was 83 and 87 days for 5 and 10 t/ha, respectively. Approximately between 10 and 20% of the initial TN content of the CD was released during the 90 days period with significant difference ( $t=0.07$ ) in the fractions released between 5 and 10t/ha of CD. Similarly, approximately 15-20% of the initial TN of the EFB-AT and between 30 and 38 % of TN in EFB-IN was released during the 150 days period. Based on pair comparison, the difference in the TN released between EFB-AT and EFB-IN was significant ( $t=0.07$ ) even between the two application rates (5 and 10t/ha). Between 30-38% of the initial P content of the CDs was released while about 60% of the EFBs was released with significant difference ( $t=0.06$ ) in the fractions released between 5 and 10t/ha, and between EFB-AT and EFB-IN. About 90% of the initial K content in EFBs was released while about 40-50% of the initial K content of the CDs was released during the experimental period, with significant difference ( $t=0.07$ ) in the fractions of K released between 5 and 10t/ha CD and between EFB-AT and EFB-IN.

Key words: Decomposition; Mineralization; Organic residue; Cow dung; Empty fruit bunch.



## CHAPTER ONE

### INTRODUCTION

#### 1.1 Background

Globally, arable lands are no longer naturally able to supply the needed nutrients required by plants due to increasing widening periods of drought spell and declining soil fertility, which is a threat to sustainable crop production and farmers' livelihood (Mohammed *et al.*, 2014). Over-exploitation of soil nutrients and nutrient reserves in soils of Ghana has resulted in nutrient imbalances on farmers' fields (Nartey *et al.*, 1997; Abekoe *et al.*, 2001; Adamtey N. 2010). Replenishing mined nutrients in soils and restoring soil quality is of a concern, generally.

In Ghana, farmers are becoming concern about low organic matter levels on their fields and how fragile their farm lands has become, a challenge that is expected to aggravate due to climate change (Mohammed *et al.*, 2014). Incorporation of plant and animal organic residues (organic resources) may help in improving physical, chemical and biological properties of soils, through soil organic matter build-up and maintenance, which subsequently enhances the soil fertility (Haynes, 1980; Kumar & Goh, 2000; Goh *et al.*, 2001; Kumar *et al.*, 2001).

The use of mineral fertilizers to overcome declining soil fertility in small scale farming in the Sub Saharan Africa is limited by economic constraints of farmers with no improvement in soil organic matter build-up after application (Walpola *et al.*, 2010). Consequently, the success of enhancing the soil fertility requires the building-up of the organic matter content to promote the mineral nutrient cycling processes in soils under cultivation (Walpola *et al.*, 2010)

The importance of the use of locally available organic resources (OR) in maintaining and improving the soil fertility status in resource poor farmers' field is widely acknowledged (Walpola *et al.*, 2010). The integration of locally available organic resources to complement that of mineral fertilizers in the nutrient management of cropping systems is of great importance in improving soil fertility and building-up soil organic matter.

In Ghana, among the common organic resources include stovers, straws of cereals and husk cocoa pod husk, empty fruit bunch, leaves and pods of leguminous plants, root and tuber waste, fruit and vegetable residues, poultry manure, cow dung, and pig manure. Residue decomposition is largely accompanied by the release of essential plant nutrients. The degree of decomposition and mineralization of these residues depends on internal and external factors such as the type, size and nature of the residue (Brady & Weil, 2002; Moradi *et al.*, 2005; Reshi & Tyub, 2007; Karberg *et al.*, 2008;), the volume and nutrient concentration of the residue (Oladoye *et al.*, 2008; Mohammed *et al.*, 2014), prevailing climatic conditions (Moradi *et al.*, 2005) and soil microbial population and activities (Moradi *et al.*, 2005). Efficient and effective application of these organic residues would, therefore, alleviate the problem of declining soil productivity, resulting from low organic matter content and nutrient status of soils (Molindo, 2008). These will reduce the cost of haulage fertilizer inputs and minimise the effect of the consequences the challenges associated with distribution and storage of mineral fertilizer poses to farmers.

A report on a Participatory Rural Appraisal (PRA) study held at Kwaebibrem district in the semi-deciduous forest zone (Kade area) and Ada East district in the coastal savannah zone (Sege area) in Ghana for the Organic Resource Management for Soil

Fertility (ORM4Soil) project indicated that farmers at Ada-east district (Sege) use cow dung only or in combination with inorganic fertilizers notably NPK (15:15:15) to address low soil fertility challenges. In the Kwaebibrem district (Kade area) farmers generally use inorganic fertilizers, empty fruit bunches of palm fruit (EFB) as mulch or as feedstock for ~~o~~ compost production for use and combinations of these in addressing low soil fertility challenges. Regardless of the availability and enormous benefits of organic residues in the Ada-east and Kwaebibrem districts, farmers use minimal amount of these residues to on the fertility of these soils.

There is an apparent lack of scientific basis for advising farmers on the appropriate rate, mode and depth of available organic resources to apply and the appropriate period that planting should be done after incubation of organic resources into the soil to synchronize the nutrient release to the nutrient demands of the crop (Molindo, 2008). This is highlighted because when organic residues are added to a soil, the nutrient status of the soil would not be instantly improved, it takes some days after incubation. This study therefore used the one available organic resource in Sege area (cow dung-CD) and two organic resources from the Kade area, Empty Fruit Bunch - EFB (Artisanal-unsteamed EFB from artisanal palm oil producer and Industrial – steamed EFB from large scale palm oil mills) to investigate the short term decomposition and mineralization pattern for 90 days and 150 days for CD and EFB respectively. This will enable us to know which organic resource(s) was the best in improving soil nutrient and to build-up soil organic matter (SOM).

### **1.2 Addressing the SOM and Nutrient constraints in Tropical Saline Soils in the Sege area.**

Soils in coastal savannah zone like Ada East District (Sege area) are saline soils and are mostly degraded and are characterised by low crop yield (Yassin, 2005; Anjum *et al.*, 2005). Low soil fertility is a threat to food security and livelihood of small holder farmers. These soils are low in SOM and N but have high concentrations of soluble sodium (Mohammed *et al.*, 2014). The effect of salinization decreases the stability of soil structure which may lead to soil slaking, swells and disperse under specific conditions (Qadir and Schubert, 2002). Moreover, the degree of soil salinity largely affects the rate of decomposition of organic matter and N release in animal manure amended saline soils (Walpola *et al.*, 2010).

A strategy of reducing the effect of ions responsible for salinity effects is the possible replacement with addition of organic manure or using chemical agents (Garcia, 2000). However, effective carbon mineralization enhances the release of inorganic forms of N, P and other organically-bound nutrients under decomposition (Mafongoya *et al.*, 2000).

### **1.3 Addressing the SOM and Nutrient constraints in Tropical Acid Soils in the Kade area**

Soils of the semi-deciduous forest zone of Ghana and in most humid tropical areas contain high level of mineral oxides and are acidic (Walpola *et al.*, 2010). Exchangeable iron and aluminium come into solution, leading to toxicity problems and causing the deficiency of nutrients, especially phosphorus at low soil pH in this conditions. Also, some soils in forest zone are acidic due to the nature of parent material, weathering and heavy leaching.

Farmers from the Kade area have been using EFB as an organic mulch to control weeds, conserve soil moisture, minimise evaporation, reduce erosion and soil capping, as the direct effect of raindrop energy is reduced. Soil organic matter is built-up and essential plant nutrients needed for crop growth and development are simultaneously released as EFBs decompose.

These peculiar challenges of the soils in the Kwabibrem District (Kade) if not addressed will affect sustainable crop production and income levels of farmers.

#### **1.4 Problem Statement**

Soils in tropical countries including Ghana are low in soil organic matter. The low soil organic matter content affects soil fertility management, and it is considered that building up of soil organic matter content is one of the options for improving soil fertility. Several organic resources abound in the environment in most of the farming communities, however in Sege area CD is the most abundant and used organic resource while in Kade, empty fruit bunch is the most commonly available organic resource. Cow dung has being suggested to be a soil amendment that could be used to build-up SOM in the coastal savannah zone of Ghana because of the presence of cattle kraals dotted along large pasture fields in these areas especially the Sege belt.

In spite of its availability, and the low organic matter content of the soil, farmers do not have much information on the use of these resources in improving soil fertility and building up SOM. The contribution of cow dung and EFB in building SOM and in enhancing soil fertility and crop production in Ghana cannot be underestimated (Opoku *et al.*, 2008). Although EFB is readily available in large quantities from industrial and artisanal palm oil mills in the Kade area, it not used on large scale by farmers for soil fertility improvement and SOM build-up purposes. EFB contains plant nutrients that can be can be recycled for plant use and also for soil organic matter build up purposes.

The decomposition and mineralization of this organic resource could improve on soil fertility and productivity, however little information exist on the resource use of the material in spite of its abundance in the communities. Information on the effective use of this resource will improve on its use by farmers.

The effective use of these organic resources by the farmers to build-up SOM and soil fertility is hampered by the limited information on the quality of the organic residues, decomposition and mineralisation patterns of these resources as affected by quantity applied.

Inorganic fertilisers (IF) are generally known for promoting soil fertility improvement. However, prices of IF continue to increase, and are not available at the right time and in sufficient quantities. Consequently farmers in the Kwaebibrem (Kade) and Ada East (Sege) districts do not apply inorganic fertilizers at the recommended rates and right time. Farmers are therefore compelled to use locally available organic resources to address soil fertility challenges. This challenge if not addressed, the ultimate goal of building-up soil organic matter and improve soil fertility may not be sustainably achieved.

### **1.5 Justification**

Soils in the Sege area are low in organic matter content. Cow dung is easily available locally organic resource that is used by farmers in the Sege area, according to a recent survey (unpublished Baba *et al.*, 2010). The use of CD by farmers for soil fertility management and SOM build-up is extensive in the Sege area. CD has been identified as a soil amendment, but there is little information on the contribution of this important organic resource in the nutrient release patterns and its contribution to soil organic matter build up. In order to maximize the use of this organic resource, it is important to know the decomposition and mineralization rates, so that the nutrient release can be synchronized to meet crops demand. The nutrient release from CD has been studied in other climatic and soil types in other agro ecologies. Decomposition and mineralization rates of organic resources are affected by several factors including soil type, temperature, soil moisture and microbial population and diversity. Sege lies in the coastal savanna region in Ghana, and the conditions are different from other areas where CD has been used. Since CD is the major locally available organic resource, it is important that studies are conducted and optimum rate of application and how it will influence the rate of decomposition and nutrient release so that it can be applied such that the nutrient release can be done such as to synchronize with the nutrient demands of the crop.

EFB (Artisanal and Industrial), is also readily available and abundant in the Kade area, it is not used on a large scale by resource poor farmers for soil fertility improvement.

Most soils in the semi-deciduous forest in the Kade area, where oil palm is widely cultivated, are acidic, low in P, and the basic cations are leached out of the soil profiles. This is a result of the intensity and levels of rainfall and the nature of the weathered

parent material of the soils. Initial analyses conducted on different EFBs from palm oil mills processing sites in Kade area show that besides K, EFB has high pH and some amount of Mg, P and Ca (Opoku *et al.*, 2008) and high carbon content. These properties of EFB make it suitable as soil fertility improvement resource in addressing low soil pH and phosphorus challenges in forest soils (Lim *et al.*, 2000), particularly in the Kade area. Also, during the decomposition of EFB, organic acids released could dissolve other tied-up mineral nutrients to improve the nutrient status of the soil.

However, there is limited information on the pattern of decomposition and nutrient release from CD and EFB over a short period, 90 and 150 days period respectively prior to planting or when spread on the soil surface after planting respectively. The knowledge of the decomposition and mineralization of CD and EFB will give the farmer an idea on when and how much of these resources to apply to maximize the benefits and improving the livelihood of these farmers.

### **1.6 Objective**

The overall goal of this study is to assess the decomposition and mineralization patterns of CD (Sege area) and EFB (Kade area) at different rates (5 and 10 tonnes/ha) of application in the dominant soils in these areas, in order to give an estimate of the release patterns and to synchronize the nutrient release to the nutrient demands of the crop. The study period was 90 days for CD and 150 days for EFB, possibility of nutrient release in the shortest possible period that could be suitable to farmers.

### **Specific Objectives**

- i.* Characterize CD from Sege area (coastal savannah agro-ecological zone) and EFB (Artisanal and Industrial) from Kade area
- ii.* Establish the decomposition pattern of CD and EFB (artisanal and industrial) in representative soils in the Sege and Kade area respectively. →
- iii.* Determine the short-term N, P, K, C and Ca release patterns from CD and EFB (Artisanal and Industrial).
- iv.* Determine the instantaneous decay constant ( $k$ ) for CD and EFB (Artisanal and Industrial) in a soil each from the coastal savannah and semi-deciduous forest agro-ecological zones

### **Hypotheses tested**

Ho: The quantity of CD applied to the soil (from Sege area) will not affect the decomposition and nutrient release patterns of applied CD.

Ho: The decomposition and (mineralization) nutrient release patterns of artisanal and industrial EFB applied at the same rate will be similar.

## CHAPTER TWO

### LITERATURE REVIEW

#### 2.1 Decomposition and Mineralisation

Decomposition and mineralization are biological processes that include the physical breakdown and biogeochemical transformation of complex organic molecules of dead materials into simpler organic and inorganic molecules for uptake (Mohammed *et al.*, 2014). Decomposition of organic residues (OR) releases energy, nutrients, CO<sub>2</sub>, water, resynthesized organic carbon compounds and nutrient for soil fertility improvement and soil organic matter (SOM) build-up ( Mohammed *et al.*, 2014).

Organically bound nutrients are released as free ions into soil solution and the environment. Generally, decomposition involves two simultaneous and fundamental set of processes:

- Concomitant mineralization and humification of lignin, cellulose, and other compounds by a group of micro-organisms and
- The leaching of soluble nutrients into the soil whose carbon and nitrogen are progressively mineralized or immobilized

The availability of nutrients in most soils is determined by decay dynamics of organic matter present. Additionally, increases in CEC improves nutrient holding capacity of soils as organic matter accumulation increases (Berg and McClaugherty, 2000). Decomposition can influence the pH of soil (Berg and McClaugherty, 2000); during litter decay and nutrient leaching pH may increase as a result of pumping basic cations from the soil to plants. However soil pH can be reduced through the formation of carbonic acid and the release of carbon dioxide and during the process of organic residue decomposition. Lastly, there is a temporal unavailability of most essential nutrients during early stages of decomposition as a result of immobilization and are out

of circulation for a while as the cycle of breakdown commence (Gholz *et al.*, 2000; Zhang *et al.*, 2000).

Moreover, soil processes responsible for the weathering in mineral soils for the active supply of soil mineral nutrients are influenced by decomposition (Gholz *et al.*, 2000; Zhang *et al.*, 2000). Humus serves as the major energy source to soil microbes that produce organic acids that contribute to the weathering process (Gholz *et al.*, 2000; Zhang *et al.*, 2000). Additionally, weathering, decomposition and humus formation are involved in the storage of dynamic carbon compounds and the regulated release of nutrients to plants and soil microbes (Berg *et al.*, 2000). Furthermore, precursors of other pathways are released as litter decomposes and humus is formed. (Berg *et al.*, 2000).

The process is characterized by the rate of mass/dry weight loss, rate and pattern of nutrient released or immobilization (Berg *et al.*, 2000). Additionally, the chemical composition of organic residues changes during decay but may not be linearly associated with mass loss in all cases and neither are the changes similar to same residues decomposing under different external conditions (Berg *et al.*, 2000). There exist more interactive and complex sets of factors such as population of active soil microorganisms' available, climate and litter quality that controls mass loss, nutrient dynamics and patterns of change in chemical composition of decomposing plant organic residue (Gholz *et al.*, 2000; Zhang *et al.*, 2000).

## 2.2 Decomposition Process

Decomposition is largely regulated by the external environmental conditions (soil moisture, temperature etc.) and internal physicochemical composition of substrate under decay (Williams and Gray, 1974; Gillon *et al.*, 1994)

Complex carbon chain compounds such as cellulose and hemicellulose originate from cell wall of crop residues attached to hydrogen, oxygen, phosphorus and sulphur in varying amount; the basis for strength and length of the carbon chain or ring bond formed (FAO Soil Bulletin 80, 2005). Depending on their chemical structure, decomposition is rapid (sugars, starches and proteins), slow (cellulose, fats, waxes and resins) or very slow (lignin) (FAO Soil Bulletin 80, 2005).

The process of decomposition allows microorganisms to convert carbon structures of fresh residues into transformed carbon products in the soil (FAO Soil Bulletin 80, 2005). There exist simple synthesized molecules like the soluble sugars, amino acids and cellulose or hemicellulose that are easily breakdown by a larger microbial population and the complex resynthesized organic molecules such as resin, waxes and lignin which are recalcitrant to decomposition from soil fauna and flora.

Although, humus is a major product of the decomposition cycle of organic matter, its complex structure does not make it easily accessible as a sole energy source for many soil fauna, allowing it to remain in the soil for a very long time (FAO Soil Bulletin 80, 2005).

## **2.3 Natural Factors Influencing Rate of Decomposition and Mineralization of organic resources.**

### **2.3.1 Temperature**

Various studies conducted have suggested that temperature and moisture are major factors that control microbial activity with consequent effect on the rate of decomposition and mineralization of plant and animal residues. Decomposition of organic residue normally occurs more rapidly in the tropics than in temperate areas because of temperature variations (FAO Soil Bulletin 80, 2005). Hence, to ensure sustainable levels of fertility in cultivated soils in the tropics large amount of organic inputs are needed to maintain an adequate labile soil organic matter pool for agriculture productivity (FAO Soil Bulletin 80, 2005). Slow mineralization rates of soils in the temperate regions give rise to more organic matter than soils in the tropics (FAO Soil Bulletin 80, 2005).

### **2.3.2 Soil Moisture and Water Saturation**

The higher the annual mean precipitation the higher the soil organic matter generated. Increase in biomass production under elevated soil moisture conditions mostly in the cooler regions give rise to more litter residues. This provides more food and energy for soil biota and enhances their activities vigorously.

Moisture and air are needed at about 60% field capacity for optimum microbial performance. However, sustained and long duration of water retention in soils lead to poor aeration which affect the growth and activity of soil microorganisms. As oxygen levels reduce, many organisms that depend on oxygen die or become inactive leading to a fall in the rate and levels of nutrients released (FAO Soil Bulletin 80, 2005).

Sustained production and slow breakdown of organic residue help generate a large organic matter reserve in saturated soils (FAO Soil Bulletin 80, 2005).

### **2.3.3 Soil Texture**

Soil particle size and aggregate greatly influence the rate of decomposition with consequent effect on mineralization and SOM levels. Dependent on strength of bonds existing between the charged colloid clay surface and organic matter, soils with higher clay content tend to have proportionally higher organic matter, which inhibits the breakdown cycle and secondly potential aggregate formation as clay content increases (FAO Soil Bulletin 80, 2005).

Most upland tropical soils have kaolinite as a major clay mineral, characterised by smaller nutrient exchange capacity and specific surface than other clay minerals (FAO Soil Bulletin 80, 2005).

The parent material influences soil texture with consequent effect on organic matter accumulation.

### **2.3.4 Topography**

Topography of a land is related to the SOM accumulation potential of the soil. There are variations in accumulation from the highest point of the slope to the bottom. Organic matter accumulation along the slope is often favoured at the bottom of the slope. There are two reasons for this accumulation: conditions are wetter than at mid- or upper-slope positions, and organic matter is transported to the lowest point in the landscape through

runoff and erosion. The factors that influence either rates or patterns of decay may be litter chemical composition, climate, nutrient availability, communities of soil organisms and site-specific factors

### **2.3.5 Acidity and Salinity**

Levels of biomass production is dependent on the toxicity and salinity extremes in soil pH, with resultant effect on the quantum of organic matter turn over. (FAO Soil Bulletin 80, 2005). Levels of biological oxidation of organic residues under decomposition become affected (low) under extreme soil acidity and alkalinity conditions which hamper microbial development and activity (FAO Soil Bulletin 80, 2005).

### **2.3.6 Quantity and Quality**

Many studies conducted have suggested that quantity and quality of litter (organic resources) are major factors that control microbial activity with consequent effect on the rate of decomposition and mineralization of plant and animal residues. Increase in resource input strongly stimulates decomposition rate of organic resource and increase the release of CO<sub>2</sub> (Li *et al.*,2015).

Hence, to ensure sustainable levels of fertility in cultivated soils in the tropics large amount of organic inputs are needed to maintain an adequate labile soil organic matter pool for agriculture productivity (FAO Soil Bulletin 80, 2005).

## **2.4 Soil Organic Matter and its importance**

### **2.4.1 Organic Matter (OM)**

The organic matter status of a soil reflects soil health and productivity. SOM is a biological product of litter breakdown by animal and plant activities in the decomposition cycle. Sustained organic matter production is very important and it is enhanced under optimum soil cover conditions to improve soil fertility and to maintain CEC for favourable soil microbial activity (FAO Soil Bulletin 80, 2005). Burning of cultivated lands accelerates organic matter breakdown as soil temperature rises.

At any given time, OM consists of a range of materials from the intact original tissues of plants and animals to the substantially decomposed mixture of materials known as humus. The remaining dry matter consists of carbon (C), oxygen (O), hydrogen (H) and small amounts of sulphur (S), nitrogen (N), phosphorus (P), potassium (K), calcium (Ca) and magnesium (Mg) (Vermeer, 1996; FAO Soil Bulletin 80, 2005). Soil organic matter consists of a variety of components. These include, in varying proportions and many intermediate stages, an active organic fraction including microorganisms (10–40 percent), and resistant or stable organic matter (40–60 percent), also referred to as humus (FAO Soil Bulletin 80, 2005).

The composition and breakdown rate of organic matter affect, the soil structure and porosity, the water infiltration rate and moisture holding capacity of soils, the diversity and biological activity of soil organisms, and plant nutrient availability (Vermeer, 1996; FAO Soil Bulletin 80, 2005). Common agricultural practices, especially ploughing, disc-tillage and vegetation burning, accelerate the decomposition of soil organic matter and leave the soil susceptible to wind and water erosion ((FAO Soil Bulletin 80, 2005).

#### **2.4.2 Forms and classification of soil organic matter**

Practically, organic matter can be categorized into two forms base on location, thus aboveground and belowground fractions. Plant and animal residues make-up the aboveground fraction whiles, belowground fraction is consist of living soil fauna and microflora, partially decomposed plant and animal residues, and humic substances (FAO Soil Bulletin 80, 2005).

Aboveground raw residues limit the negative effect of raindrop energy, runoff, wind and sun on the soil surface. Modification, transfer, incorporation or burning of above ground residues deprive soil microbes of their basic energy source and further exposes the soil to negative climatic impacts (FAO Soil Bulletin 80, 2005).

#### **2.5 Practices that influence the amount of organic matter in soils**

##### **2.5.1 Human activities that influence soil organic matter build-up**

Many human activities negatively affects soil microorganisms (biology, habitat and food) and soil organic matter build-up (FAO Soil Bulletin 80, 2005). However, to maintain or increase levels of organic matter content of soils, sustained efforts must be made to return plant and animal residues back to the soil and introduce high-residue crops and deep- or dense-rooting crops in rotations (FAO Soil Bulletin 80, 2005). The texture of the soil and the high temperature in the tropical regions make it extremely challenging to experience sustained improvement of organic matter content of soils that as incorporated materials decompose rapidly (FAO Soil Bulletin 80, 2005)

However, in the cold temperate regions, generation and accumulation of SOM are high even with less organic residue because of texture, temperature and aeration variations (FAO Soil Bulletin 80, 2005).

### **2.5.2. Practices that decrease soil organic matter**

System equilibrium and microbial activity in the decomposition cycle are largely influenced by human activities (FAO Soil Bulletin 80, 2005). Fauna and flora microhabitat is affected by, land degradation activities such as vegetation burning and excessive tillage, leading to the reduction of soil biomass and diversity. (FAO Soil Bulletin 80, 2005).

When population of decomposers is limited, there is a reduction in binding of soil particles, as soil structure is damaged easily by rain, wind and sun (FAO Soil Bulletin 80, 2005). This can lead to rainwater runoff and soil erosion, removing the potential food for organisms from the top soil. Therefore, soil biota are the most important property of the soil, and “when devoid of its biota, the uppermost layer of earth ceases to be soil” (Lal, 1991; FAO Soil Bulletin 80, 2005). The factors leading to the reduction in soil organic matter in an open cycle system can be grouped as follows:

- a decrease in biomass production;
- decrease in organic matter supply;
- increased decomposition rates

## **2.6 Factors that lead to decrease in organic matter supply**

### **2.6.1 Burning of natural vegetation and crop residues**

Bush burning is a predominant farm practise in tropical farming systems used to managing insect or disease infestation and to lessen field preparations burden ahead of a planting season. This activity leads to the depletion of litter layer and reduces organic matter turnover into the soil as it destroys the habitat of soil organisms on the soil surface and between litter layers (FAO Soil Bulletin 80, 2005). In assuring a continuous decomposition cycle for guaranteed organic turnover in the future, efforts must be made in re-establishing active microbial communities for sustained release of plant minerals. Although seed germination is stimulated by the rapid release of P on newly burnt lands, efforts must be made towards the minimization of burning of fallow lands before cultivation. However the long-term negative impacts of bush burning such as the loss of soil biota and plant nutrients, must be of concern to all. (FAO Soil Bulletin 80, 2005).

### **2.6.2 Overgrazing**

All over the world the issues overstocking of grazing lands beyond their carriage capacity has been of grave concern (FAO Soil Bulletin 80, 2005). In the tropics large and small animals graze indiscriminately and selectively destroying plant cover and exposing soil surface to direct sun, wind and runoff effect. Leguminous and useful pasture species are not protected and intentionally cultivated to feed ruminants on small scale to meet their nutrient demands. (FAO Soil Bulletin 80, 2005).

### **2.6.3 Removal of crop residues**

The removal and alternative use of crop residues that hitherto would have contributed to soil organic matter build-up if left on the farmer's field but are used as feed, bedding material and compost and might not return to the field again is a challenge. This practice deprives the soil the opportunity to recycle this plant nutrients present in the residues back into the soil (FAO Soil Bulletin 80, 2005)

## **2.7 Factors that increase the rate decomposition**

### **2.7.1 Tillage practices**

One major farm practice that leads to the reduction in soil organic matter levels in top soils is tillage (FAO Soil Bulletin 80, 2005). The soil is aerated anytime it is tilled leading to an acceleration in soil microbial activity as decomposition of organic residues and the release of C are all aerobic processes (FAO Soil Bulletin 80, 2005).

The use of heavy farm equipment such as ploughs aids in the incorporate of residues together with air and other microbes into the soil which accelerates decomposition. This results in the formation of less stable humus and an increased liberation of CO<sub>2</sub> to the atmosphere, and thus a reduction in organic matter. There are two terms of organic matter loss, thus the short-term organic matter loss associated with frequency of tillage with proportional rate of breakdown of organic matter and the longer-term losses, as a result of repeated seasonal cultivation. Accelerated decline in SOM is mostly associated with farming systems that do not return much of its residue back to the soil, a precise description of many modern farming systems. Formerly, application of farm or animal manure was commonly used to maintain organic matter levels regardless of the continuous cultivation on same lands and low residue turnover into the soil (FAO Soil Bulletin 80, 2005). Organic matter production and conservation is affected dramatically

by conventional tillage, which not only decreases soil organic matter but also increases the potential for erosion induced by wind and water (FAO Soil Bulletin 80, 2005).

Ploughing affects the availability of food sources for soil microbes and destroys their habitat, affecting population size of useful species of soil biota. Moreover, the negative impact of a reduction in the population size of soil microbes (earthworm) by tillage activities, leads to poor soil porosity and aeration (macropores) since their burrowing effect is reduced. To facilitate rapid decomposition of organic matter, the ability of these microbes to bury and incorporate residues must be carefully attended to (FAO Soil Bulletin 80, 2005). Continuous use of the hoe smoothens the soil surface and render the natural soil aggregates destroyed, leaving channels that connect the surface with the subsoil, expose to erosion (FAO Soil Bulletin 80, 2005). Cracks emerge between natural aggregates when earthworm burrows and age root pathways are blocked, limiting infiltration of soil water (FAO Soil Bulletin 80, 2005).

## **2.9 Some of the Available Organic Resources Used**

### **2.9.1 Cow Dung**

Cow dung (CD) is a dung more than four weeks old, mixed with cow urine, straw or bedding material collected from a kraal and under a form of storage (Tanimu et al., 2013). Carbon dioxide (CO<sub>2</sub>) in aged dung increases with increasing depth from the surface layer of the dung in the kraal (Lyocks *et al.*, 2012). Tanimu *et al.*, (2013) stated that there may be significant difference in the quality and chemical composition of CD based on the pasture variation across agro ecological zones, the management system used in storing the dung and humidity levels of zone.

CD is high in organic matter and contains nutrients essential for crop production (Opoku *et al.*, 2008). The use of cow dung as a source of plant nutrient is very popular around the world especially in the tropics (Opoku *et al.*, 2008). Fening *et al.*, (2008) identified cow dung as soil amendment that possesses the potential for use in the interior savannah zone of Ghana, which includes the Sege area. Thus, cow dung has been used to improve soil fertility in the tropics as well as increase crop yield in Ghana.

The use of CD in agricultural production is often a problem because it is bulky and the nutrient content is low-grade. In addition, CD has high water content, making it cumbersome to transport far from the source to the point of use. Despite these shortcomings, it is suggested that CD has potentials to alleviate soil nutrient depletion problems in crop production.

### **2.9.2 Empty Fruit Bunch**

Empty fruit bunch (EFB) is one of the major waste products generated from the processing of the fresh fruit bunch (FFB) of oil palm in processing mills to produce palm oil and palm kernel oil. In the oil milling process about 22% of fresh fruit bunch has EFB as a by-product (Lim *et al.*, 2000). Ghana's production of FFB stands at about 1,900,000 metric tonnes annually (FAO Statistical Databases, 2009) generating about 418,000 metric tonnes of EFB annually, indicating that EFB is abundantly available. Unsteamed EFB is estimated to contain N(%)-1.60, P(%)-1.67, K(%)-1.05 and OC(%)-23.54 (Opoku *et al.*, 2008). The Kade area is known for large palm plantation and oil mills

In the large oil palm industrial estates, where about 40% of FFB is processed, EFB is either used as a fuel to provide energy for boiler in the fresh fruit bunch sterilization process or incinerated as waste products.

However, the small-scale mills in the Kade area also dispose of these EFB by means of burning (Opoku *et al.*, 2008). Currently there is no large-scale use of raw or modified palm fruit bunch from the large and artisan mills in Kade area, although some small scale soap manufactures use small portions because it is rich in potassium (Lim *et al.*, 2000).

### **2.9.2a Industrial EFB**

An industrial EFB, is an empty fruit bunch that has been steamed during the palm oil milling process. Fresh fruit bunches after harvest are directly poured into huge industrial boilers and steamed under high temperature. These steamed bunches are further subjected to high pressure in industrial shakers to shake-off the cooked fruit for processing.

### **2.9.2b Artisanal EFB**

These are empty fruit bunches from the indigenous (local) oil mills that have not been steamed during the palm oil milling process. Bunches containing ripe palm fruits are cut into pieces and covered with plantain leaves for partial fermentations before fruits are removed from the bunch manually EFBs from this mills are usually used as fuel after they are dried in the local milling industry.

## **2.10 Some methods used for studying the decomposition and mineralization of organic resources**

### **2.10.1 Carbon dioxide sequencing incubation analysis method**

This is a process used in estimating mineralizable C by trapping evolving CO<sub>2</sub>-C from incubated residue in soil in sealed glass jars under controlled decomposition conditions. Proportional weights of the samples are mixed to approximately 20 g of soil samples and are added to separate 50 mL beakers each containing 20 g soil samples and mixed thoroughly. An additional beaker with 20 g soil with no residue served as a control. Each treatment was replicated three times in separate beakers. The treated samples in the beakers were then plunged in sealed glass jars containing another 50 mL beaker with 10 mL 1 M NaOH solution to trap any evolving CO<sub>2</sub>-C in a dark room at a maintained temperature of approximately 25 °C. The NaOH solution was removed and fresh solution inserted after, according to the interval of sampling days of the duration of the incubation. The CO<sub>2</sub>-C trapped in the removed NaOH solutions were measured by titrating against 1 M HCl after precipitating carbonates by adding 12 mL of 1.5 M BaCl<sub>2</sub> (Alef, 1995). Estimation of the potential mineralizable C at the end of the period of incubation was done by fitting the data into a first order kinetic equation,  $C_m = C_o (1 - e^{-kt})$ .

Where;  $C_m$  is the actual CO<sub>2</sub>-C mineralized or evolved at time  $t$ ,  $C_o$  is the potential mineralizable C pool, and  $k$  is the rate constant.

### **2.10.2 Tea Bag Index Method**

The approach uses a standardised plant litter to measure decomposition and stabilisation at a scale and resolution not previously possible in generating a global database with volunteers worldwide. Characteristic of this approach is the use of commercially available tea bags as highly standardised test kits containing tea as

representative dead plant material (Keuskamp *et al.*, 2013). The data collected can be used to compute a Tea Bag Index (TBI) that provides process-driven information on soil functions at local, regional and global scales. TBI is determined through a simplified litter bag experiment (Wieder Lang 1982) which involves burial of green and rooibos tea bags, followed by measurement of mass loss after a period of time.

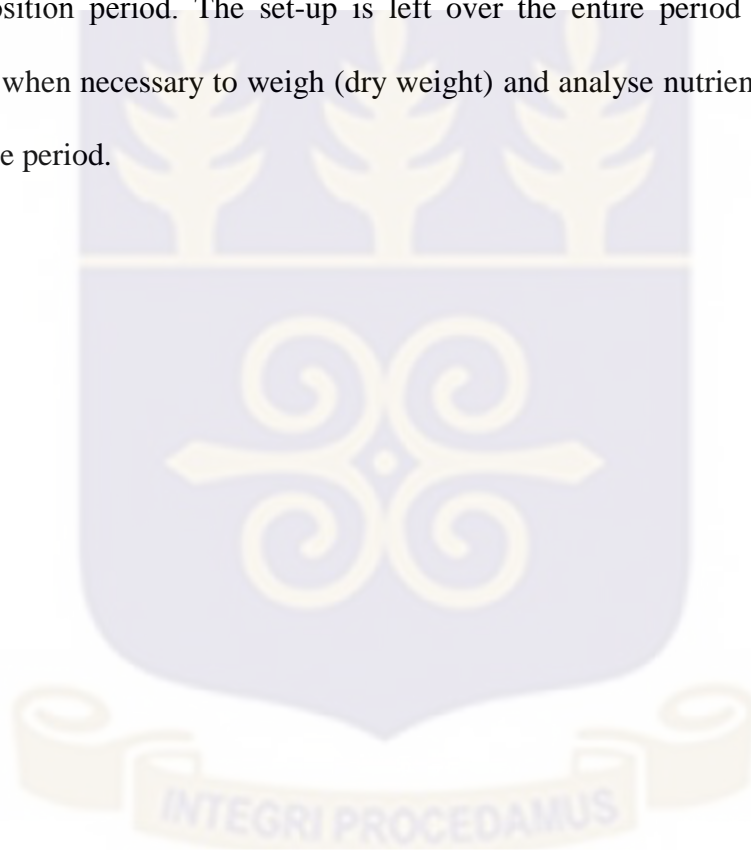
The TBI has two primary applications. First, it is an attainable way to increase the resolution of decomposition measurements (Keuskamp *et al.*, 2013). Secondly, TBI is a useful reference alongside decomposition studies to disentangle litter quality aspects from the full set of environmental conditions constituting the ‘decomposition matrix’ (Keuskamp *et al.*, 2013). The use of TBI as a reference facilitates data comparison between biomes, ecosystems and soil types (Keuskamp *et al.*, 2013).

### **2.10.3 Wooden Box Method**

A litter wooden box used by Sraha and Ulzen-Appiah, (1997) and Nkyi and Acheampong (2013), a modified method of the litter bag method, is used to study the decomposition and mineralization rate. A square wooden frame with two ends of the box covered with a nylon mesh material with a mesh size of 2 x 2 mm, to prevent or minimize the introduction or exit of litter from external natural factors such as wind, water or large insects. To ensure macrofauna contact and dwelling as one side of the box is firmly pressed to make contact with the ground for arthropods and earthworms to gain unrestricted access to the litter. This set-up is left over the entire period of incubation and sampled when necessary to weigh (dry weight) for mass loss under decomposition and analyse for nutrients release until the end of the period.

#### **2.10.4 Nylon Litter Bag Technique**

Nylon mesh bag technique by Bocoek and Gilbert, (1957) and Mohammed *et al.* (2014) is preferred to be the simplest method to evaluate decomposition and mineralization of even same plant litter in across ecosystems. Litter bags of 15 x 15 cm (Lipton Tea bag design) are sewn using synthetic nylon mesh of 2.0mm mesh size. The litter is then placed into the litter bag firmly and knotted. The filled bags were buried 8cm or more at the sites under study ensuring an unrestricted access to decomposer throughout the decomposition period. The set-up is left over the entire period of incubation and sampled when necessary to weigh (dry weight) and analyse nutrients content until the end of the period.



## CHAPTER THREE

### MATERIALS AND METHODS

#### 3.0 Experimental site

##### 3.1 Study Area

The experiment was conducted at the Soil and Environmental Sciences Research Centre of the Biotechnology and Nuclear Agriculture Research Institute in Accra (Lat. 05° 39" N; Long. 00° 09" W). The site is about 77.0 m above sea level and has an average monthly maximum temperature of 29.0°C and a minimum temperature of 24.0°C. The mean annual relative humidity ranges between 73 and 88% and the annual rainfall amounts to 725.0 mm (GMS, 2009).

##### 3.2 Soil and organic resource for the study

###### 3.2.1 Sege/Ada area

Ada series (soil) and CD were taken from the Sege area in the coastal savanna agro-ecological zone (located on latitude 5°52'58.34" and longitude 0°25'25.05"). The soil from 0-15cm soil layer. The soil in the area is classified as Entisols (USDA; 1960) by Brammer, (1960) which corresponds to Fluvisols under FAO (1970) classification. The soil is poor in fertility and mostly sandy in nature. The major crops cultivated are vegetables such as tomatoes, pepper and okra, sorghum, maize and water melon. The air temperature in the area ranges between 23.0 and 28.0°C. Rainfall is bimodal with an annual average of 750 mm. The relative humidity is about 60%.

###### 3.2.2 Kade area

The soil used for the study belonged to the Kokofu series (soil) and Empty fruit bunch (Artisanal and Industrial) were sampled from artisanal palm oil processors at Nkwantanang and Obooma Palm oil Processing Company at Damang. Both towns are

in the Eastern region and most often access their palm fruits from the same source. Kwaebibrem district is in the forest region, and is characterized by a bimodal rainfall pattern. The district lies between latitudes 1 degree 0'W and 0 degree 35.'E and longitudes 6 degrees 22'N and 5 degrees 75'S, with a land area of about 1,230 km<sup>2</sup> (472.4 sq. miles). Approximately 80% of the land area is suitable for agriculture. The soils are Ultisols USDA (Brammer, 1960).The annual rainfall is 1200.0-1400.0 mm. The peak of the rainfall is in June/July. Temperature ranges between a minimum of 23.5°C and a maximum of 33.0°C. The relative humidity ranges between 75% and 80%. Major crops cultivated are cocoa, oil palm, rubber, maize, rice, citrus, plantain, cassava, cowpea and some vegetables. Cocoa pod husks, poultry manure, tree prunnings, empty fruit bunch (EFB), rice straw and rice husk are applied by incorporation, side placement or through surface application

### **3.3 Locally available Organic Resources**

#### **3.3.1 Cow Dung Sampling**

Cow dung sampled from Twelve (12) abandoned cattle kraals within the Sege area were used. Three (3) kraals were randomly selected from which the dung was collected (0 - 10 cm) and mixed with the aid of a shovel to minimize heterogeneity. Cow dung samples were bagged and conveyed to the experimental site.

#### **3.4 Empty Fruit Bunch Sampling**

Out of five (5) industrial mills selected, a tonne of dry industrial EFB was randomly collected from the oil mill of the Damang. Oil palm plantation in Okumaning, a farming community in the Kade area. A tonne of a week old artisanal EFB was also randomly

collected from a local mill in the Okumaning community out of fourteen (14) available local mills in the locality.

### 3.5 Research Methodology

Nylon mesh bag technique by Bocoock and Gilbert, (1957) and Mohammed *et al.* (2014) was used to monitor the decomposition and mineralization from CD and EFB.

#### 3.5.1 Decomposition and Mineralization Protocol for CD

Litter bags of 15 x 15 cm (Lipton Tea bag design) was sewn using synthetic nylon mesh of 2.0mm mesh size. Polybags of 35cm x 23.8 cm were filled with 19.12 kg of soil (Ada series) of 1.65 g/cm<sup>3</sup> bulk density. Two CD treatments 5 and 10 t/ha were adopted. Into each bag, samples of CD were weighed and put into the bags for the 5 t/ha, **28.97g** of CD was weighed, whilst for 10 t/ha, **57.94g** of CD was weighed

For each CD rate, 7 treatments were applied such that sampling was conducted at 7, 14, 21, 35, 56, 72 and 90 days after burying in the soil in the pots as practised by farmers in the Sege area, where CD is incorporated into the soil on application. For each treatment, four replicates was adopted. The soil moisture was maintained at 60% field capacity throughout the experimental period.

At each sampling date, buried nylon bags were carefully removed and adhered soil were carefully removed. The amount of CD left in the bag was weighed, and the dry weights recorded after drying samples in the oven at 70 C for 48 h. Oven dried samples were ground to pass through sieve of 1 mm mesh size, and used for chemical analysis



Plate 1: Weighing of cow dung into nylon mesh litter bags.



Plate 2: Labelled Nylon litter bags filled with CD before burial.



Plate 3: Bagged CD on top of soil before burial

### **3.5.2 Determination of Mass of CD and EFB used for the decomposition and mineralization study.**

#### **3.5.2a Determination of mass soil in 1 hectare plot**

Area of 1 hectare = 10000m<sup>2</sup>

Plough layer of soil = 0.2m

Volume of soil in plough layer = 10000m<sup>2</sup> x 0.2m = 2000m<sup>3</sup>

At 1650kg/m<sup>3</sup> x 2000m<sup>3</sup> = **3,300,000kg**

#### **3.5.2a Determination of mass of Ada soil series be put in polybags**

Radius of polybag = 12.4 cm

r<sup>2</sup> = 153.76 cm<sup>2</sup>

Height of soil in polybag = 24cm

Volume of soil in polybag =  $\pi r^2 h = 3.14 \times 153.76 \text{cm}^2 \times 24 \text{cm} = 11587.35 \text{cm}^3$

Mass of soil in polybag = Bulk density x volume of soil

Mass of soil in polybag =  $1.65\text{g/cm}^3 \times 11587.35 \text{ cm}^3 = 19,119.13\text{g/polybag}$

Mass of soil in polybag = **19.12kg/polybag**

### 3.5.2b Determination of mass of Kokofu soil series to be put in polybags

Radius of polybag = 12.4 cm

$r^2 = 153.76 \text{ cm}^2$

Height of soil in polybag = 24cm

Volume of soil in polybag =  $\pi r^2 h = 3.14 \times 153.76 \text{ cm}^2 \times 24 \text{ cm} = 11587.35 \text{ cm}^3$

Mass of soil in polybag = Bulk density x volume of soil

Mass of soil in polybag =  $1.3\text{g/cm}^3 \times 11587.35 \text{ cm}^3 = 15063.56\text{g/polybag}$

Mass of soil in polybag = **15.06kg/polybag**

### 3.5.2b Determination of mass of CD (5t and 10t/ha) put into each Nylon litter bag for incubation.

i. Applying 5 tonnes of CD (Dry) to mass of soil in 1 hectare plough layer (3,300,000kg) will be;

If 5,000,000g of CD = 3,300,000kg of soil, then how much CD will be required for 1kg of same soil.

$5,000,000\text{g} \times 1\text{kg} / 3,300,000\text{g} = 1.52\text{g of CD/ 1kg of soil}$

Therefore; CD to apply at a rate of 5t/ha to 19.12kg of Ada series soil will be;

$= 19.12\text{kg} \times 1.52\text{g/kg} = \mathbf{28.97\text{g of CD (dry)}}$

ii. Similarly, for the application of 10t/ha of CD for the Ada series, a total of  $28.97\text{g} \times 2 = \mathbf{57.94\text{g of CD (dry)}}$  is required.

### 3.5.2c Determination of mass of EFBs (5t and 10t/ha) put into each Nylon litter bag for incubation.

i. Applying EFBs (Dry) at a rate of 5t/ha

$$\text{Surface Area of Polybag} = \pi r^2 = 3.14 \times 12.4\text{cm} \times 12\text{cm} = 482.81\text{cm}^2$$

$$1\text{ha} = 10,000\text{m}^2$$

$$\text{Amount of EFB/m}^2 = 5,000,000 / 10,000 \text{ m}^2 = 500\text{g/m}^2 = 0.05\text{g/cm}^2$$

$$\text{Therefore, Amount of EFB (Dry) to apply at a rate of 5t/ha} = (0.05\text{g/cm}^2 \times 482.81\text{cm}^2) = \mathbf{24.14\text{g}}$$

ii. Amount of EFB (Dry) to apply at a rate of 10t/ha =  $24.14\text{g} \times 2 = \mathbf{48.28\text{g}}$ .

### 3.5.3 Decomposition and Mineralization of EFB (Artisanal and Industrial)

EFB decomposition and nutrient release trials was conducted in (Kokofu-Series) which occurs extensively and most widely cultivated in the forest zone. N, P, K and C, pH and OM was monitored during the 150days incubation period.

#### 3.5.3a Decomposition and Mineralization Protocol for EFBs

Litter bags of 15 cm x 30 cm (Lipton Tea bag design) was sewn using synthetic nylon mesh of 2.0mm mesh size. Air-dried soil (15.06 kg) with 1.3 g/cm<sup>3</sup> bulk density was put into 35cm x 23.8 cm polybags. EFBs (Artisanal and industrial) were chopped to into uniform sizes (2cm). Two rates of application for the two EFBs (Artisanal and industrial) at 5t/ha (24.14g) and 10t/ha (48.28g) were weighed into the nylon litterbags. Each treatment was replicated 4 times and 7 sampling periods was adopted in a split plot design. Initial analyses for pH, C, N, P, K and Ca contents was conducted for all treatments. At 60% field capacity, each treatment was place on the soil surface in the bags. The EFBs were placed on the surface of soil in the pots as practised by farmers in the Kade area, where EFBs are placed on the soil surface in most palm plantations to

serve as mulch. After 7, 14, 21, 35, 56, 72, 90, 120 and 150 days burial intervals each treatment was removed from the bag and the soil or any other foreign material was carefully removed from the nylon bags. The remaining EFBs in each bag per treatment was oven dried for 48 hrs at 70 °C and weighed. The oven dried samples was then ground to pass through a 1mm sieve for chemical analysis N, P, C, Ca and K content of the residue Ayeni *et al.* (2012).

### 3.6 Estimation of Decomposition and Nutrient Release from CD and EFB

The decomposition and nutrient release for CD and EFB were estimated using the formula given by Guo *et al.* (1999) and Mohammed *et al.* (2014) shown below:

1.  $L (\%) = \frac{W_0 - W_t}{W_0} \times 100\%$
2.  $R (\%) = \frac{W_0 C_0 - W_t C_t}{W_0 C_0} \times 100\%$

Where **L** is organic resource dry weight loss for decomposition; **R** is nutrient release;

**W<sub>0</sub>** is the initial organic resource dry weight; **W<sub>t</sub>** is organic resource dry weight of the remaining organic resources in the litter bag.

**C<sub>0</sub>** is the nutrient concentration (mg g<sup>-1</sup>) in the initial organic resource; **C<sub>t</sub>** is the nutrient concentration (mg g<sup>-1</sup>) in the remaining organic resource.

However, percentage nutrient release or remaining are the two (2) ways of estimating nutrient loss of the initial amount in fractional or percentage forms for most litter residues under mineralization.

Decomposition rate constant ( $k$ ) is only estimable when most of the labile material is gone at the early stages of decomposition and require a time series to compute (Berg & Meentemeyer 2002).

Decomposition rates for CD and EFB was estimated using an exponential decay function (Olson, 1963):

$$W_t = W_0 e^{-kt}$$

Where  $W_t$  is the dry weight at time  $t$ ,  $W_0$  the dry weight of initial litter, and  $k$  the instantaneous decay constant. The half- life for the decomposition was determined.

### **3.7 Physical soil analysis**

#### **3.7.1 Particle size analysis**

Particle size distribution was determined by the Bouyoucos Hydrometer method as described by Day (1965). Thirty percent hydrogen peroxide (30%) was added to the soil and heated to destroy soil organic matter in order to promote easy dispersion. Forty grams sample of a 2 mm sieved soil were weighed into a beaker and 100 ml of 5% calgon (sodium hexametaphosphate) solution was added. The suspension was shaken on a mechanical shaker for two hours after which it was transferred into a graduated sedimentation cylinder and distilled water added to bring the level to one liter mark. A plunger was used to stir the suspension vigorously by moving the plunger in and out several times and the first and second hydrometer readings were taken at five mins and five hrs. from the time of mixing the suspension, representing silt + clay and clay fractions respectively. The sand fraction was obtained by decanting the suspension from the sedimentation cylinder and recording the dry weight after it had been oven-dried at 105° C for two days and cooled in a dessicator. Blank hydrometer readings of sodium hexametaphosphate solution at five min and five hours were also taken.

$$(i) \% \text{ silt} + \% \text{ clay} = \frac{\text{corrected hydrometer reading at 5mins} \times 100\%}{\text{oven-dried sample weight (g)}} \quad [1]$$

$$(ii) \% \text{ clay} = \frac{\text{corrected hydrometer reading at 5 hrs} \times 100\%}{\text{oven-dried sample weight (g)}} \quad [2]$$

$$(iii) \% \text{ silt} = i - ii \quad [3]$$

$$(iv) \% \text{ sand} = 100 - i \quad [4]$$

The texture of the soil was determined using the USDA textural triangle.

### 3.8. Laboratory Analysis

#### 3.8.1 Soil pH

Soil pH was determined in both distilled water and 0.01M calcium chloride using a pH glass electrometer. Ten grams (10 g) of the soil sample was weighed into a 50 ml beaker and 10 ml of distilled water (1:1 soil: water) was added. The solid- liquid mixture was then stirred several times for 30 min and allowed to stand for the suspended clay to settle out. Using standard solution of pH 4.0 and 7.0, the pH meter was standardized. The standardized electrode was then inserted into the supernatant of the suspension to measure the pH of the soil sample. The procedure was repeated with 20 g of soil and 40 ml of 0.01M CaCl<sub>2</sub> (1:2 soil: 0.01M CaCl<sub>2</sub>).

#### 3.8.2 Organic carbon determination

The wet combustion method of Walkley and Black (1934) was used to determine the organic carbon content of the soil. Ten millimeters of 0.167 M potassium dichromate (K<sub>2</sub>Cr<sub>2</sub>O<sub>7</sub>) solution and 20 ml concentrated Sulphuric acid (H<sub>2</sub>SO<sub>4</sub>) were added to 0.5 g soil sample (which had been sieved through a 0.5 mm sieve) in an Erlenmeyer flask.

The flask was then swirled to ensure full contact of the soil with the solution after which it was allowed to stand for 30 mins. The unreduced  $K_2Cr_2O_7$  remaining in solution after the oxidation of the oxidizable organic material in the soil sample was titrated against 0.2 N ferrous ammonium Sulphate solution after adding 10 ml of orthophosphoric acid and 2 ml of barium diphenylamine Sulphate indicator.

The percent organic carbon =  $[0.3 (10 - XN)/W]$  -----[2]

Where X = ml of ammonium ferrous sulphate used in the titration

N = normality of ammonium ferrous sulphate solution

W = weight of soil sample (g)

### 3.8.3 Total P determination in soil

Total P was determined by digesting 2 g of sieved soil with 25 ml of a mixture of concentrated  $HNO_3$  and 60%  $HClO_4$  prepared in ratio 2:3. The solution was heated on a digestion rack until the solution became colour less. The digest was cooled, diluted and filtered through a Whatman filter paper No. 42 into 250 ml volumetric flask and made to volume. Phosphorus in the filtrate was determined using the molybdate - ascorbic acid method of Watanabe and Olsen (1965). Suitable aliquots of the filtrate were taken (in duplicate) into 50 ml volumetric flasks containing distilled water. The pH was adjusted using P-nitrophenol indicator and neutralized with few drops 4 M ammonium hydroxide ( $NH_4OH$ ) until the solution turned yellow. Distilled water was used to dilute the solution to about 40 ml with after which 8 ml of reagent B was added and made to volume with more distilled water. The solution was mixed thoroughly by shaking and allowed to stand for 15 mins for the colour to stabilize. A blank was

prepared with distilled water and 8 ml of reagent B. The method was calibrated using a 25 mg /L standard P solution in the same manner as above. The intensity of the blue colour was measured using the Philips PU 8620 spectrophotometer at a wavelength of 712 nm.

P was calculated using the formula:

P (mg / kg) =

$$\frac{(\text{Sp. Reading} - \text{Blank}) \times \text{graph conc.} \times \text{Vol. of extract}}{\text{Vol. of aliquot} \times \text{weight of soil}} \quad [6]$$

where Sp. Reading is the spectrometer reading at a wavelength of 712 nm.

#### 3.8.4 Total N determination

Half of a gram (0.5 g) of air-dried soil was weighed into a 250 ml Kjeldahl flask and a tablet of digestion accelerator, selenium catalyst, was added followed by 5 ml of concentrated H<sub>2</sub>SO<sub>4</sub>. The mixture was digested until the digest became clear. The flask was then cooled and its content transferred into a 100 ml volumetric flask with distilled water and quantitatively made up to volume. A 5 ml aliquot of the digest was taken into a Markhan distillation apparatus. Five ml of 40% NaOH solution was added to the aliquot and the mixture distilled. The distillate was collected in 5 ml of 2% boric acid. Three drops of a mixed indicator containing methyl red and methylene blue were added to the distillate in a 50 ml Erlenmeyer flask and then titrated against 0.01M HCl acid solution (Bremner, 1965). The % nitrogen was calculated as:

$$\%N = \frac{\text{Molarity of HCl} \times \text{Titer value} \times 0.014 \times \text{volume of extractant} \times 100}{\text{Weight of soil sample} \times \text{volume of aliquot}} \quad [7]$$

where 0.014 = milliequivalent of nitrogen

### 3.8.5 Cation exchange capacity

Five grams of the soil was weighed into an extraction bottle and 50 mL of 1.0 M ammonium acetate at pH 7.0 added. The content was then shaken for 30 minutes and filtered through a Number 42 Whatman filter paper. The non-adsorbed  $\text{NH}_4^+$  was then washed off with methanol and the  $\text{NH}_4^+$  saturate soil leached four times with acidified 1.0 M KCl. The ammonium ion concentration (mol/L) in the KCl filtrate was then read on an ELIT 9808 ion analyzer and the CEC of the soil in cmol/kg estimated from that.

### 3.8.6 Exchangeable calcium and magnesium

An aliquot of 10 ml of the extract was taken into a conical flask and 10 ml of 10% KOH and 1 ml of methylamine was added. Three drops of KCN solution and a few crystals of Cal-red indicator were added. The mixture were then titrated with 0.2 N EDTA using Eriochrome Black T (EBT) as an indicator.

### 3.9 Data Analysis

Data collected were analysed using GenStat software (18<sup>th</sup> edition). Least Significant Difference (LSD) at  $P \leq 0.05$  and t-test were used to separate means whenever ANOVA results showed significant differences.

The litter decomposition was modelled exponentially according to Olson (1963):

$W_t = W_0 e^{-kt}$  Where  $W_t$  is the dry weight at time  $t$ ,  $W_0$  the initial leaf litter dry weight, and  $k$  the annual instantaneous decay constant

## CHAPTER FOUR

### RESULTS

#### 4.1 Characteristics of the Ada soil series and Kokofu soil series used for the experiment

The particle size fractions of the Ada soil series are 72%, 25% and 3% of sand, silt and clay respectively. On the other hand, Kokofu soil series has 39.2% sand, 24.8% silt and 36% clay. In addition, the pH (1:2, Soil: CaCl<sub>2</sub>) is 8.5 for the Ada Soil series and 4.2 for the Kokofu Soil series. Table 4.1 shows the detailed properties of the soils.

Table 4.1. Physical and chemical properties of the soils used for the study.

<b>Physical and Chemical Soil Properties</b>		
<b>Soil Properties</b>	<b>Kokofu soil series (Entisols)</b>	<b>Ada soil series (Ultisols)</b>
Soil depth (cm)	0-20	0-20
Bulk density (mg/m <sup>3</sup> )	1.3	1.65
Sand (%)	39.2	72
Silt (%)	24.8	25
Clay (%)	36	3
Texture	Clay loam	Sandy loam
pH (1:2, soil:water)	4.9	8.8
pH (1:2, soil:CaCl <sub>2</sub> )	4.2	8.5
Organic carbon (g/kg)	11.4	3.5
Total N (g/kg)	1.6	1.04
Total P (g/kg)	316	101
Available P (g/kg)	3.16	1.11
Ca (cmol/kg)	5.57	1.08
Mg (cmol/kg)	1.52	0.45
K (cmol/kg)	0.18	0.32
Na (cmol/kg)	0.49	0.33
Exchangeable acidity (cmolc/kg)	0.5	0.31
EC 1:5 ds/m	0.05	0.31
ECEC (cmolc/kg)	8.26	2.84

#### 4.2 Characteristics of CDs and EFBs (Organic residues) used for the study

Initial characterization of the organic residues showed that the organic residues have pH values above 7.0, with EFB having a pH above 8.0 while CD has pH of 7.8 (Table 4.2). In addition, the organic residue have appreciable levels of %OC, ranging between 18.2% for EFB-IN and 24.7% for CD (Table 4.2). Furthermore, EFB-IN had the lowest level of K (0.72%) while EFB artisanal had the lowest Ca content of 0.10% (Table 4.2).

**Table 4.2 Selected physical and chemical properties of the organic resources used for the study.**

Selected physical and chemical of organic resources						
Organic resource	Selected physical and chemical properties					
	pH	K(%)	Ca(%)	P (%)	TN(%)	OC(%)
CD	7.8	1.08	0.32	1.13	1.78	24.71
EFB /ATT	8.3	1.05	0.10	1.67	1.60	23.54
EFB /IN	8.6	0.72	0.10	1.24	0.96	18.20

CD- Matured cow dung, EFB/ATT- Empty fruit bunch from artisanal palm Oil mill and EFB/IN - Empty fruit bunch from industrial palm oil mill.

#### 4.3 Decomposition of organic residues

The amount/mass of CD or EFB left in the nylon mesh at the time of sampling was defined as “percentage mass remaining”

##### 4.3.1 Mass loss of organic residues

Less than half of the initial amount of CD1 and CD2 remained after the 90 days period.

Similar results were observed for EFBs with about 75% of the initial amount of EFB-

IN1 and EFB-IN2 remaining after 150 days period (Table 4.3).

**Table 4.3: Mass loss of organic resources during the experimental period.**

Organic Resources	Decomposition Period (Days)	Initial Weight (g)	Final Weight (g)
CD1	90	28.97±0.3	16.25±2.6
CD2	90	57.94±0.7	30.70±1.3
EFB-AT1	150	24.14±0.1	16.45±0.8
EFB-AT2	150	48.27±2.8	19.72±1.9
EFB-IN1	150	24.14±0.1	5.49±0.9
EFB-IN2	150	48.27±2.8	12.05±1.6

CD1=5 t/ha of CD, CD2= 10 t/ha of CD, EFB-AT1= 5 t/ha of EFB artisanal, EFB-AT2=10 t/ha of EFB artisanal,

#### 4.3.3 Model describing the decomposition of CDs and EFBs.

Decomposition rate constant ( $k$ ) require a time series and can only be estimated from the early stages of decomposition when the labile material is gone (Berg & Meentemeyer 2002).

The exponential decay function by Olson, (1963) was used to calculate the rate of decomposition rates for all organic residues used as shown in Table 4.4.

**Table 4.4 Fitted decomposition model for organic residues**

Organic resources	Fitted Model of Decomposition	R <sup>2</sup>	t <sup>1/2</sup> (day)
CD1	$W_t = 28.97 e^{-(0.0058)(t)}$	0.88	81.5
CD2	$W_t = 57.94 e^{-(0.0070)(t)}$	0.96	99.0
EFB-AT1	$W_t = 24.14 e^{-(0.0018)(t)}$	0.93	99.8
EFB- AT2	$W_t = 48.27 e^{-(0.0053)(t)}$	0.97	110.6
EFB-IN1	$W_t = 24.14 e^{-(0.0084)(t)}$	0.95	82.5
EFB-IN2	$W_t = 48.27 e^{-(0.0080)(t)}$	0.93	86.6

CD1=5 t/ha of CD, CD2= 10 t/ha of CD, EFB-AT1= 5 t/ha of EFB artisanal, EFB-AT2=10 t/ha of EFB artisanal.

The decay constant  $k$  is the numerical number on the power of the exponential function,  $R^2$  is the co-efficient of determination,  $t$  is the time (day) in the fitted model and  $t^{1/2}$  the time (days) taken for half of the original mass of the organic residue to get extinct.

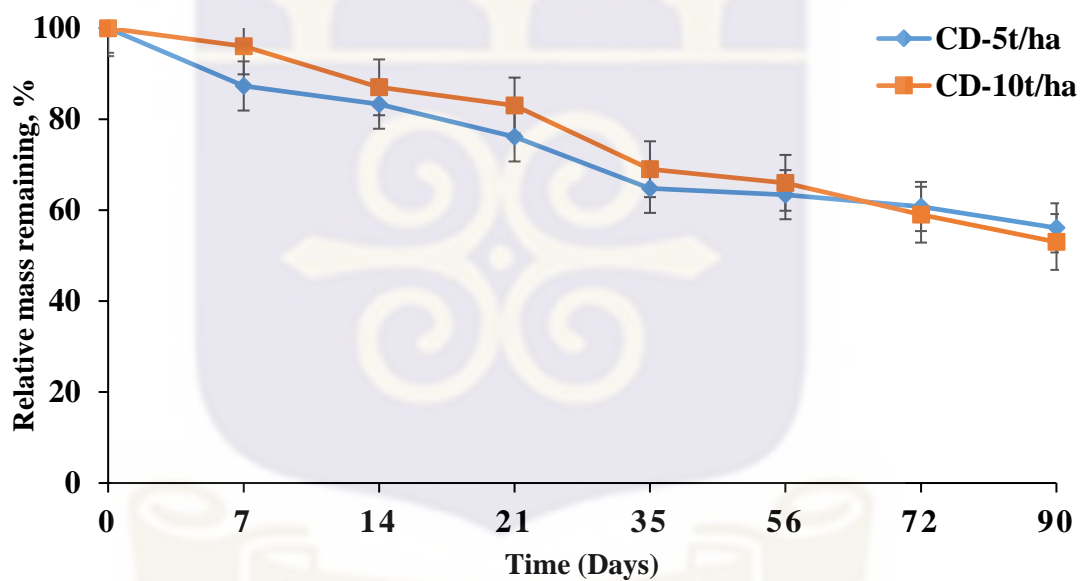
#### 4.3.4 Decomposition pattern and mass remaining for cow dung (CDs) (5 and 10t/ha)

About 15% of the initially available CD1 (5t /ha) decomposed during the first 7 days of incubation, after which the decomposition was gradual up to 35 days and remained

fairly constant thereafter (Fig 4.1). A similar pattern of decomposition was observed for CD2 (10 t/ha) except that about 5% of the initial amount Of CD2 decomposed during the first 7 days (Fig.4.1). Table 4.5 shows the dry weight of CDs remaining over the decomposition period.

Also, the amount of CD available after decomposition was greater for CD1 than for CD2 up to about 65days of incubation period, after which the remaining amount of CD2 after decomposition was greater than that of CD1.(Fig 4.1).

Pair comparison of the decomposition patterns using t-test analysis showed that CD1 and CD2 had similar decomposition patterns ( $t= 0.70$ ).



**Fig 4.1:** Relative mass remaining (%) of 5 and 10 t/ha of cow dung left after 90days decomposition.

**Table 4.5: Dry weight remaining (g) of CDs (5 and 10t/ha) over the decomposition period.**

COW DUNG		
Days	Dry Weight Remaining, g	
	CD1	CD2
0	28.97	57.94
7	25.29	55.68
14	24.13	50.65
21	22.06	48.05
35	18.78	39.75
56	18.38	38.41
72	17.61	34.48
90	16.25	30.70

CD1 = 5t/ha of Cow Dung and CD2 10t/ha of Cow Dung

#### 4.3.5 Decomposition pattern and mass remaining of EFBs

Decomposition of EFB-AT1 was gradual over the 150 days of incubation. About 10% of the initial mass had decomposed by the 14<sup>th</sup> day of incubation and the remaining amount decomposed fairly constantly and by the 150 day study period, about 15% of the initial amount had decomposed (Fig 4.2).

In the case of EFB-AT2, the decomposition was fairly linear up to 28 days after treatment of incubation to about 25% of the original amount after which the decomposition remained fairly constant to reach about 50% of the initial amount of EFB-AT2 being decomposed (Fig 4.2). A t-test analysis showed that the decomposition patterns of EFB-AT1 and EFB-AT2 were not different ( $t= 0.20$ ). Table 4.6 shows the dry weight of artisanal-EFBs remaining over the decomposition period.

For both EFB-IN1 AND EFB-IN2, the amount decomposed was about 25% of the initial amount on the 14<sup>th</sup> day of incubation (Fig.4.2). Thereafter, the amount decomposed increased up to 65% of the initial amount on the 150<sup>th</sup> day of incubation of EFB-IN1 and EFB-IN2 (Fig.4.2). Table 4.7 shows the dry weight of industrial-EFBs remaining over the decomposition period. A t-test analysis showed that EFB-IN1 and

EFB-IN2 had similar patterns of decomposition ( $t=4.0$ ) during the 150 days of incubation.

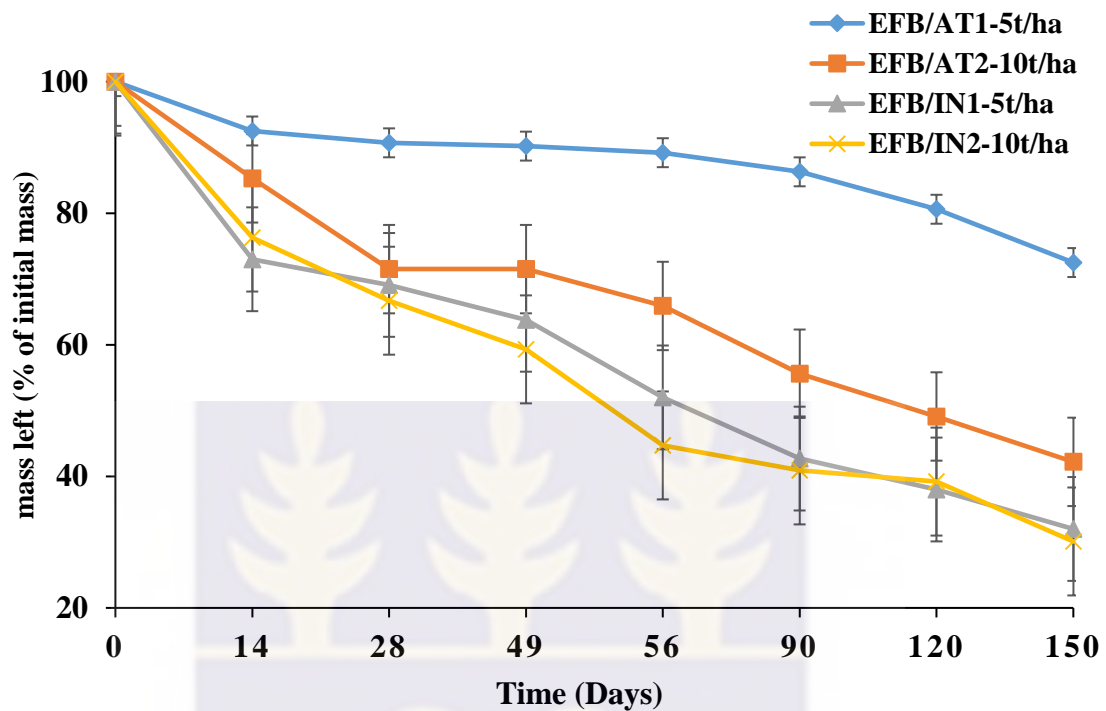


Figure 4.2. Relative mass remaining (%) of 5 and 10 t/ha of EFBs (Artisanal and Industrial) over 150 days decomposition period.

Table 4.6: Dry weight (g) of Artisanal EFBs remaining over the decomposition period.

EFB-Artisanal		
Days	Dry Weight Loss, g	
	EFB/AT1	EFB/AT2
0	24.14	48.27
14	21.99	41.64
28	21.93	35.05
49	21.93	35.05
56	20.91	31.81
90	20.84	26.37
120	19.72	24.09
150	16.45	19.72

EFB/AT1= 5t/ha of Empty fruit bunch of palm fruit artisanal and EFB/AT2= 10t/ha of Empty fruit bunch of palm fruit artisanal

**Table 4.7: Dry weight (g) of Industrial EFBs remaining over the decomposition period.**

<b>EFB-Industrial</b>		
<b>Dry Weight Remaining, g</b>		
Days	EFB/IN1	EFB/IN2
0	24.14	48.18
14	17.53	37.18
28	16.45	31.80
49	15.33	28.48
56	12.10	21.86
90	9.89	19.71
120	8.82	18.64
150	5.49	12.05

EFB/IN1= 5t/ha of Empty fruit bunch of palm fruit artisanal and EFB/IN2= 10t/ha of Empty fruit bunch of palm fruit artisanal

The percentage of the initial mass of the EFB (both Industrial and artisanal) decreased over the study period. Among the EFB –AT, about 80%, of the initial mass of the 5 t/ha and 50% of the EFB 10t/ha was left after the 150 day study period. The decomposition rate was faster in the EFB –IN than the EFB artisanal throughout the period. There was no significant difference in the mass left between the 5 and 10 t/ha treatments after 14 days.



#### 4.4 Mineralization of organic resources

The corresponding chemical composition defined as “percentage of initial chemical content left”.

##### 4.4.1 Mineralization of CD

Mineralization was assessed by the percentage of the initial amount of nutrient that a resource lost during the period of decomposition for all nutrients. Evaluating nutrient released based on the percentage loss of the initial amount gives a standard and an impartial reflection when comparing amount released regardless of different rate of application and the nature/ types of resources involved using the t-test to separate mean when analysing for variance (GenStat 18<sup>th</sup> Edition).

Comparatively, highly significant percentage ( $t=8.0$ ) of the initial amount of nutrients in CD1 was released than from CD2 over the period of 90 days of decomposition, especially for TN, P, Ca and OC (Table 4.5). However, CD2 released 77.1 % K, a percentage higher compared to that of CD1 61.8% over the entire decomposition period (Table 4.5).

**Table: 4.8 Nutrient released over the 90 days and 150 days of decomposition for CDs and EFBs.**

OR	% Total released over decomposition period					
	Initial (%)	TN%	P %	K %	Ca %	OC %
CD1	100	50.7	43.8	61.8	80.6	53.1
CD2	100	39.3	30.7	77.1	77.1	51.6
EFB-AT1	100	44.4	60.5	94.2	50.0	18.1
EFB-AT2	100	25.0	59.9	91.4	40.0	19.1
EFB-IN1	100	45.3	58.9	95.8	60.0	23.7
EFB- IN2	100	37.9	55.7	66.7	40.0	22.2

*CD1=5t/ha of CD, CD2= 10t/ha of CD, EFB-AT1= 5t/ha of EFB artisanal, EFB-AT2=10t/ha of EFB artisanal, EFB-IN1=5t/ha of EFB industrial and EFB-IN2= 10t/ha of EFB industrial*

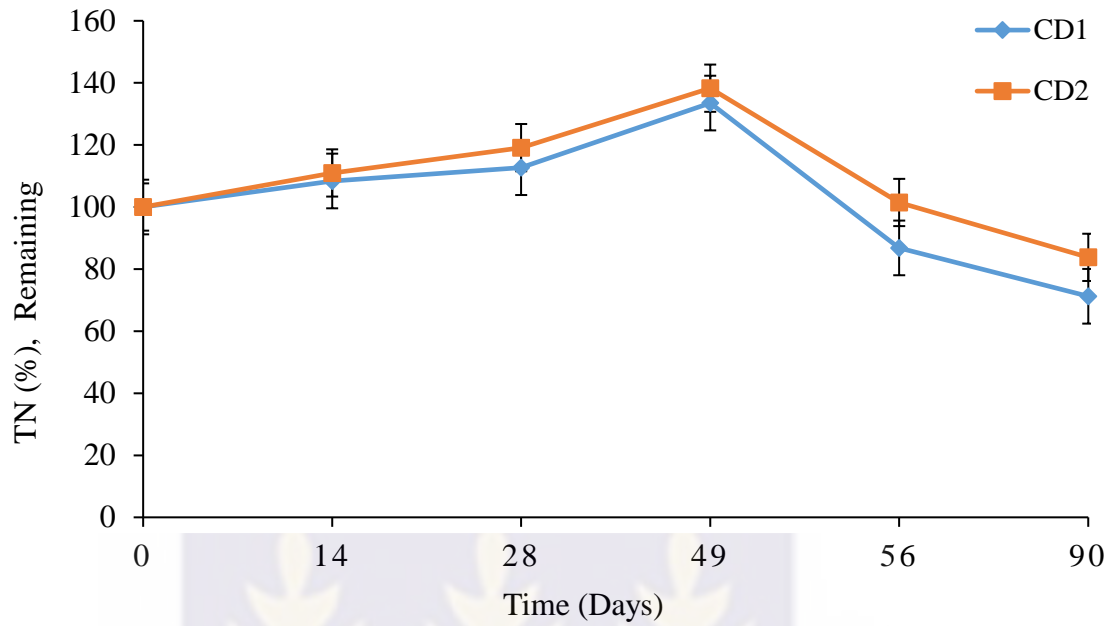
Amount of TN released steadily increased up to 130% of the initial 100% from day 1 to 49 days of decomposition for both CD1 and CD2, after which a gradually decreased to about 60% for CD1 and 70% for CD2 (Fig 4.3) was observed with significant

difference ( $t = 5.0$ ) in the amount of TN released between CD1 and CD2 at the end of the 90 days period. A similar trend of was observed for the amount of P remaining in CD1 and CD2, as amount of P remaining peaked at about 120% and 110% for CD1 and CD2 respectively on 14 days of decomposition, after which there was a gradual decrease till the end of the period (Fig.4.3).

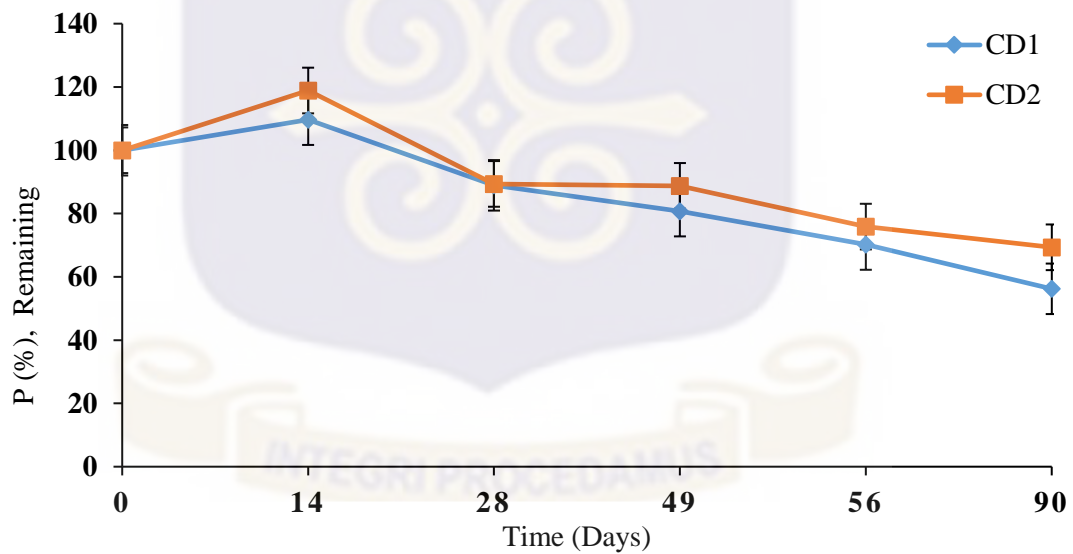
Amount of K remaining in CD2 was fairly stable up to 28 days of decomposition, being close to 100% before decreasing gradually to about 75% at 90 days (Fig.4.3). Generally, amount of K remaining over the 90 days of decomposition for CD2 was higher than CD1 (Fig.4.3). Furthermore, amount of K remaining in CD decreased gradually from the initial 100% to 85% on the 28<sup>th</sup> day of decomposition. Also the decrease in amount of over time more sharper, comparatively.

In the case of Ca, the amount of Ca remaining drop sharply from the initial 100% to about 50% for CD2 and about 35% for CD1 at 28 days of decomposition. After the 28days of decomposition the amount of Ca in CD2 decreased gradually while that of CD1 remained fairly constant until the experiment ended (Fig 4.6).

On the other hand, amount of OC remaining decreased gradually from the initial 100% for both CD1 and CD2 to about 75% after which there was a gradual decrease up to about 55% (Fig 4.7).



*Figure 4.3. Total N (%) left in CD1 and CD2 over the 90 days study period.*



*Figure 4.4. Phosphorus (%) remaining in CD1 and CD2 over the 90 days study period.*

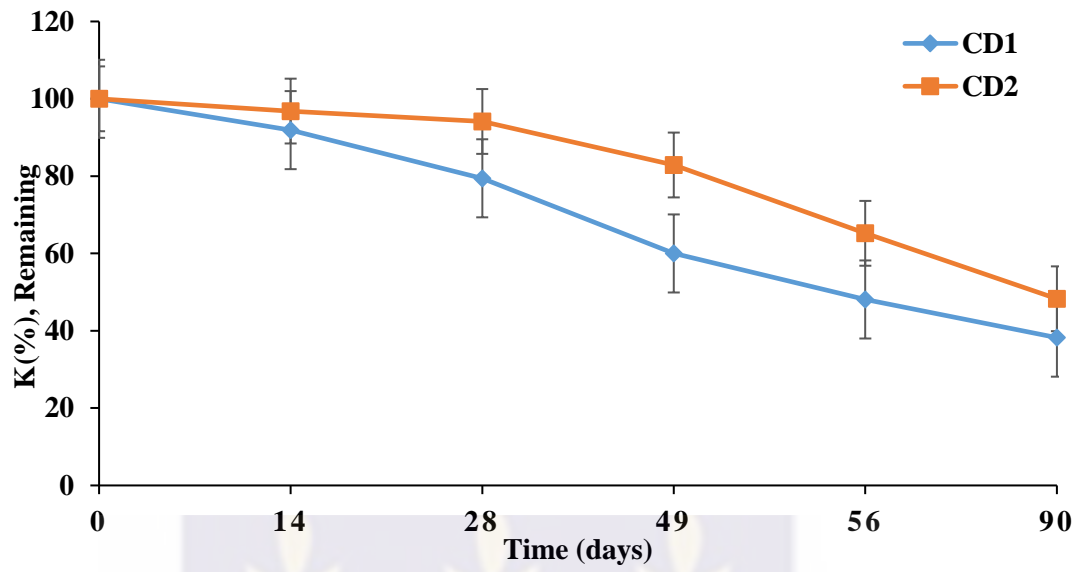


Figure 4.5. Potassium (%) remaining in CD1 and CD2 over 90 days of decomposition period.

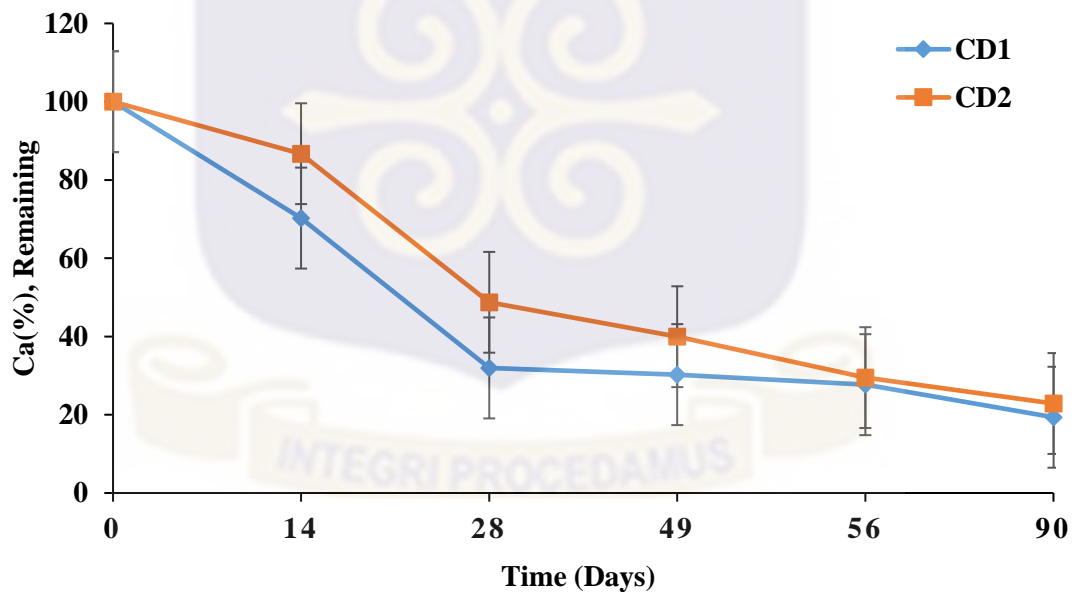
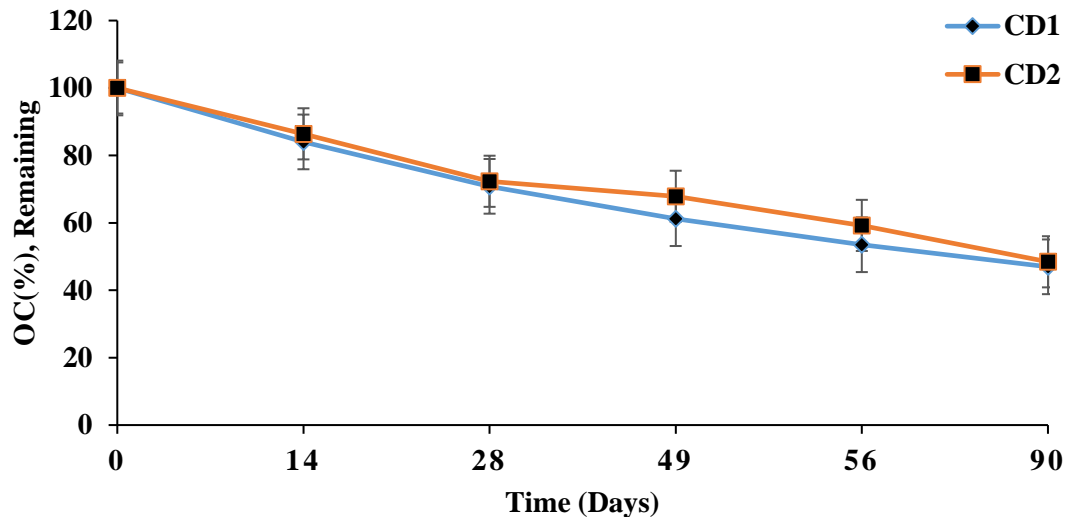


Figure 4.6. Calcium (%) remaining in CD1 and CD2 over the 90 days of decomposition period.



*Figure 4.7. Organic carbon (%) remaining in CD1 and CD2 over 90 days of decomposition period.*

#### 4.4.3 Mineralization of EFBs

The amount of nitrogen in the EFB-IN1 and EFB-IN2 increased from the initial 100% to about 160 and 130%, respectively, by 14th day of decomposition. There was, a gradual decrease in the amount of N remaining in EFBs after the 14 days. Generally the N amount left in EFB-IN2 was higher than that of EFB-IN1 (Fig. 4.9). A t-test analysis showed that EFB- IN1 released a significantly ( $t=6.0$ ) higher amount of nitrogen over the 150 days decomposition period than EFB-IN2.

The trend in the amount of nitrogen released for EFB-AT1 and EFB-AT2 was similar to that observed for EFB-IN1 and EFB-IN2 with no significant difference ( $t=1.0$ ) except that the amount of N rise to about 130% by the 49<sup>th</sup> day of decomposition for both EFB-AT1 and EFB-AT2 (Fig. 4.9). However, amount of N released was not significantly different ( $t=3.0$ ) between EFB-AT1 and EFB-AT2.

Comparatively, EFBs-IN released significantly higher ( $t=7.0$ ) amount of TN than EFBs-AT at both application rates.

The amount of P remaining increased from the initial 100% to peak at about 125% for EFB-IN2, 110% for EFB-AT2 and EFB-IN1 and about 105% for EFB-AT1 on 28 days of decomposition, after which there was generally a gradual decrease in %P remaining (Fig.4.10). A t-test analysis showed no significant difference ( $t=2.0$ ) between the release pattern of EFB IN1 and EFB IN2.

In the case of amount of K released, the fraction remaining decrease gradually from the initial 100% for all the organic residues, ranging between 5 and 10% by the 150th day of decomposition (Fig 4.12). However, the amount of K remaining was comparatively less with no significant ( $t=2.0$ ) between EFB-AT2 and all the other EFBs (Fig.4.12). A t-test analysis showed no significant difference ( $t=3.0$ ) in the amount of K released over the 150 days of decomposition for the organic residues.

Generally, amount of Ca remaining for EFB-AT2 decreased from the initial 100% to about 70% by 49th day of decomposition and remained constant without any release from 49 days to 120 days before dropping to 60% (Fig.4.11). The release pattern of Ca in EFB-IN1, EFB-IN2 and EFB-AT2 was similar to that observed for EFB-AT1 except that the periods where no release of Ca occurred were different (Fig 4.11). A t-test analysis showed no significant difference ( $t=2.0$ ) in the amount of Ca released between all EFBs at both rates.

Furthermore, the amount of OC for EFB-AT2 increased by 10% by the 14th day of decomposition, after which the amount of OC remaining decreased gradually to about 95% by 150th day after decomposition. The %OC remaining for EFB-AT1 decreased sharply from the initial 100% during the first 14 days of decomposition, after which it decreased slightly till the last day decomposition (Fig.4.8). Additionally, amount of OC remaining for EFB-IN1 and EFB-IN2 increased from the initial 100%, to about 105 and

110% respectively on the 14<sup>th</sup> day of decomposition, after which, decreased gradually to about 80% and 85% for EFB-IN1 and EFB-IN2, respectively on 150 days of decomposition (Fig 4.8).

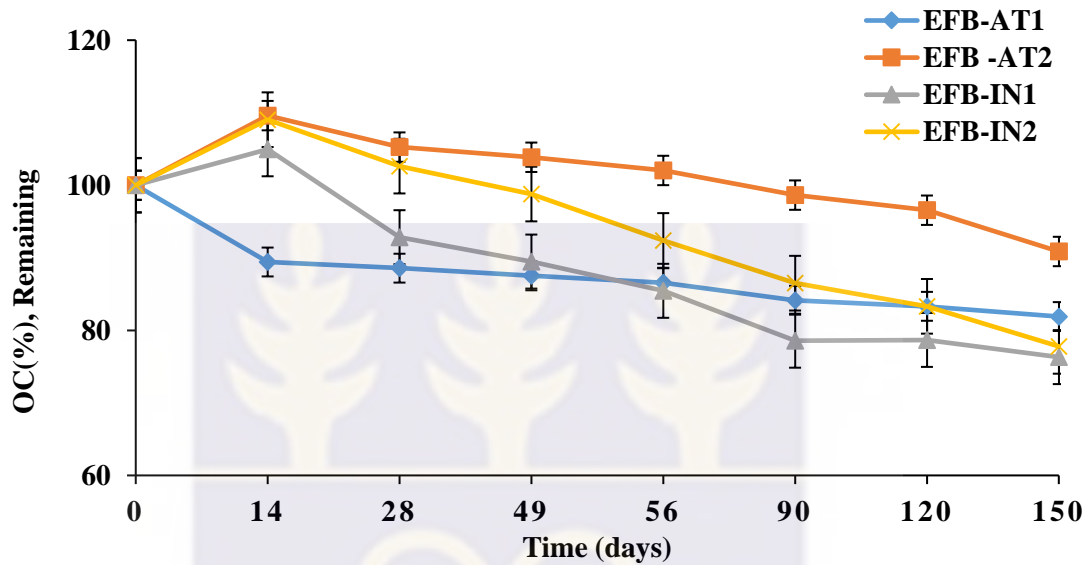


Figure 4.8. Organic carbon (%) remaining in EFBs over 150 days of decomposition period.

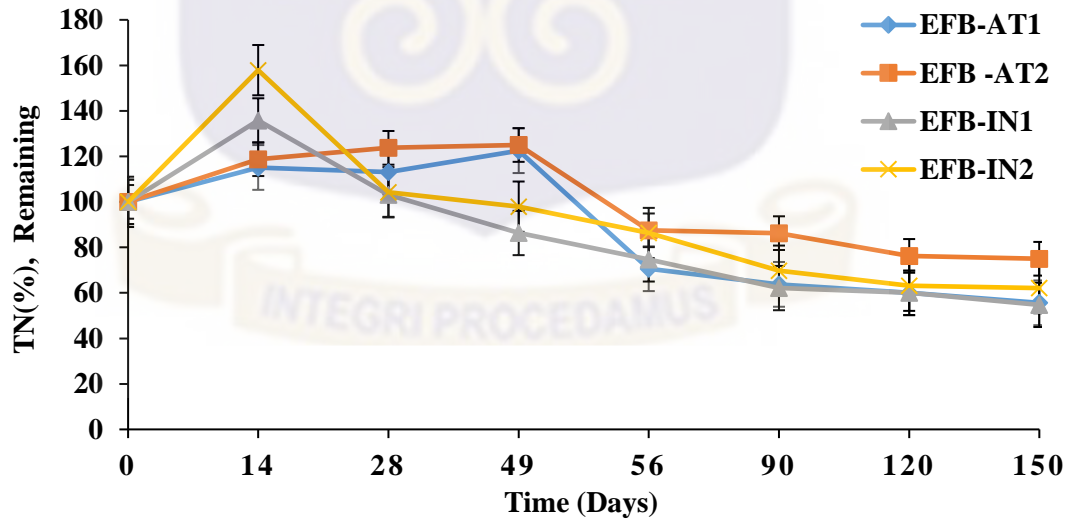


Figure 4.9. Total Nitrogen (%) remaining in EFBs over 150 days decomposition period.

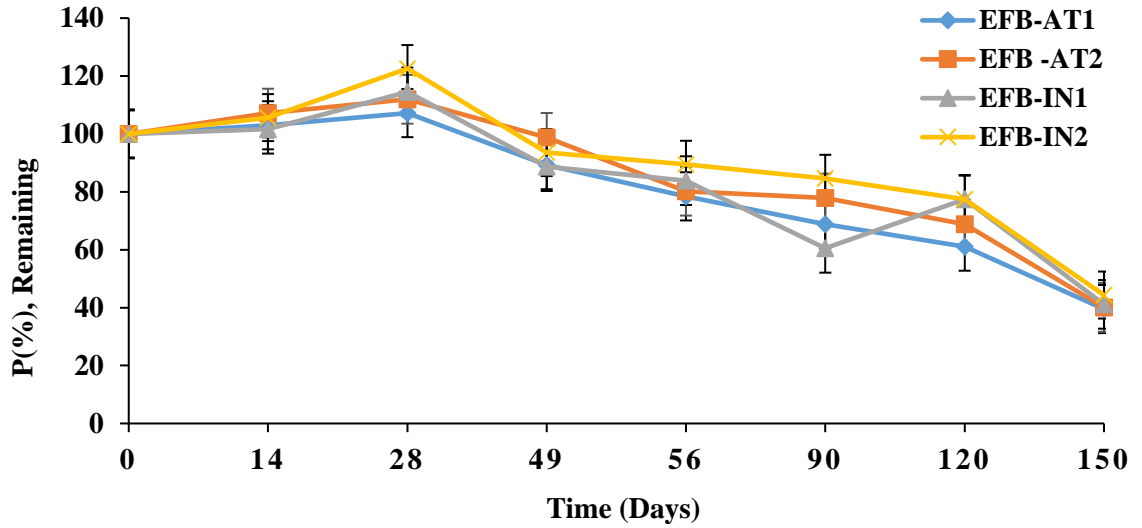


Figure 4.10. Phosphorus (%) remaining in EFBs during the 150-day decomposition period.

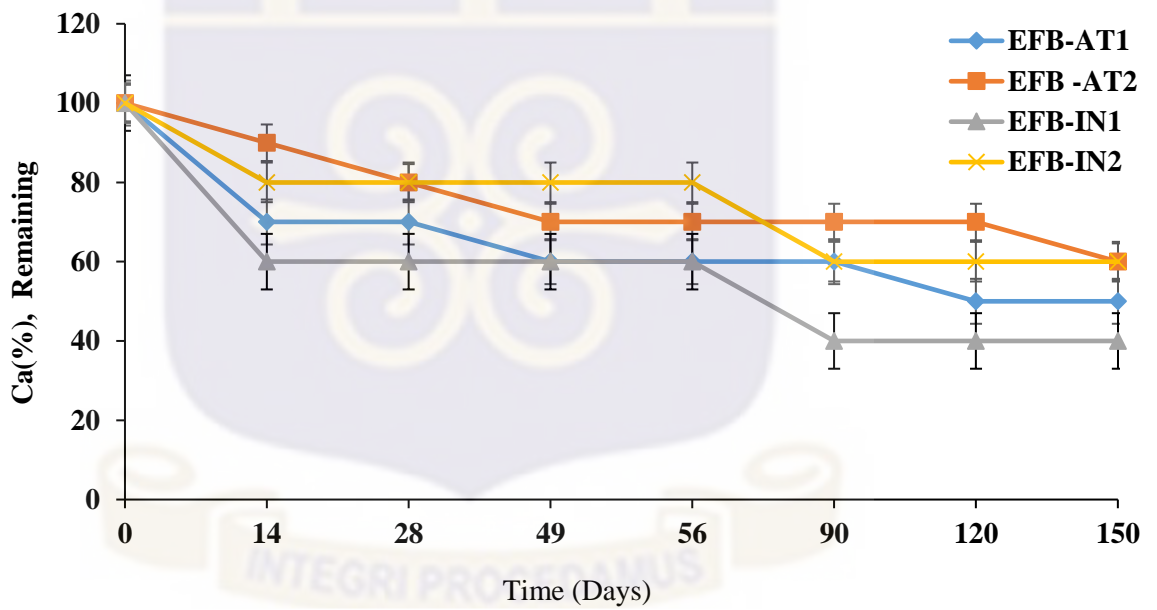


Figure 4.11. Calcium remaining in EFBs over the 150 days decomposition period.

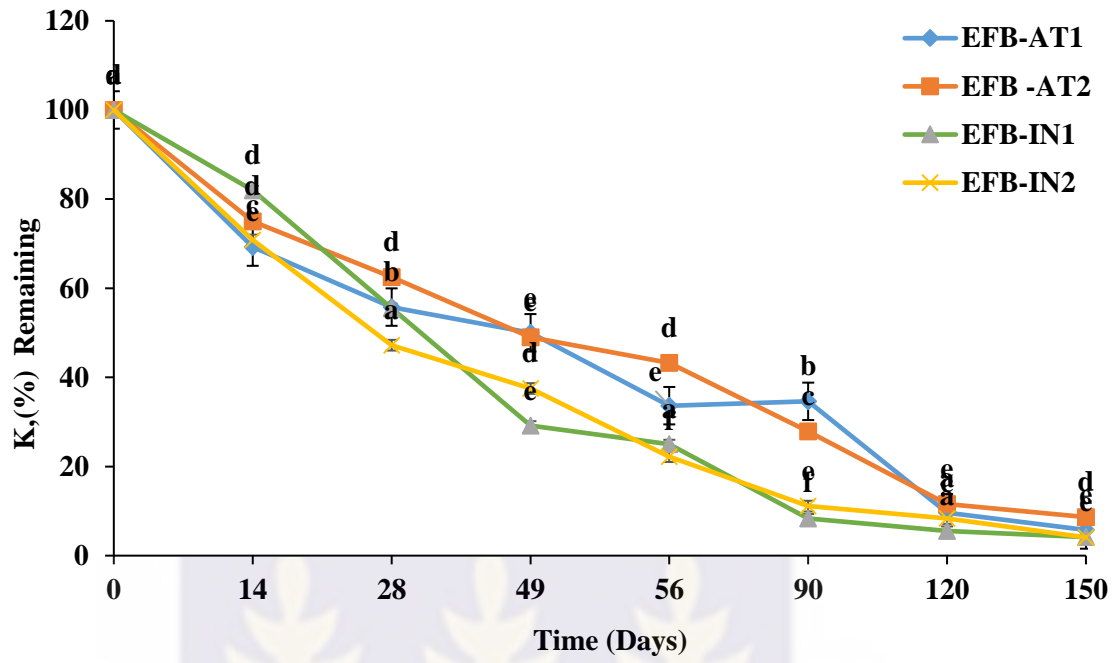
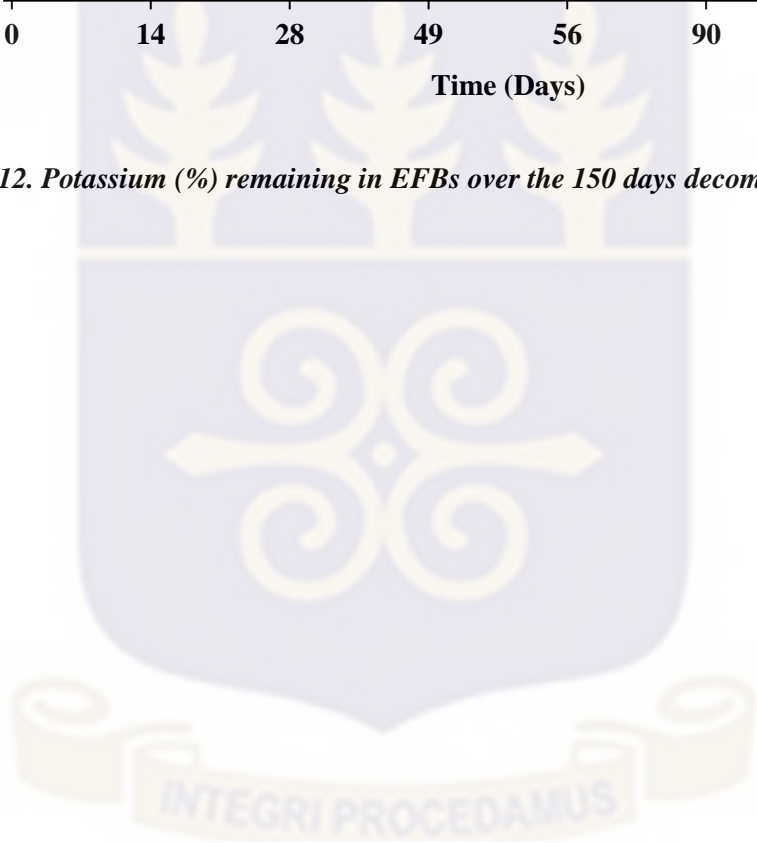


Figure 4.12. Potassium (%) remaining in EFBs over the 150 days decomposition period.



## CHAPTER 5

### DISCUSSION

#### 5.0 Organic Resources Used

##### 5.1 Characteristic of CD and EFBs used for the study

Cow dung (CD) is high in organic matter and contains nutrients essential for crop production (Opoku *et al.*, 2008). The pH of CD was 8, which falls within the optimum range for usage as a soil amendment (Verdonck, 1988) The exchangeable cations are very low, leading to a low effective cation exchange capacity (ECEC) of 4.17 cmol (+) / kg. Similar low ECEC values have been reported for CD in the savannah belt of Ghana by Nartey *et al.* (1997).

Overall, the N content of the CD is low. The low N content of CD could be as a result quality of the pasture animals are fed with and the age of the ruminant that does the digestion (Opoku *et al.*, 2008).

Similarly, EFBs had very low initial total N, OC and Ca, with EFB industrial having the least of total N. The low N contents of the EFB-industrial could be attributed to the kind of processing the fruit bunch goes through before being emptied. EFB-INS are subjected to high temperature and pressure in the oil milling process. This could possibly alter the nutrient quality of EFB-INS (Moradi *et al.*, 2013). Nitrogen is a key nutrient for microbial growth, and hence has tremendous effects on residue breakdown by microbes.

The K amount in the EFBs was low, K released from EFBs is not affected by the level of microbial activities in a soil, as K release is by a gradual process of leaching and EFBs quality (Swift *et al.*, 1979; Reshi and Tyub, 2007; Moradi *et al.*, 2013) thereby affecting the amount and rate of its release. Detailed chemical compositions of CD and EFB used for the experiment are shown in Table 4.3. Litter decomposition is largely controlled by the litter quality and by the external environmental factors such as soil moisture and temperature under which the decomposition is taking place (Williams and Gray, 1974; Gillon *et al.*, 1994).

Generally, the level of nutrients, particularly TN, K, P and Ca in CD and EFB used in this study are low, suggesting that high amount of these resources may have to be applied in order to generate appreciable nutrient levels to meet crop nutrient demand and support sustainable crop production.

## **5.2 Decomposition of CDs and EFBs**

The decomposition of CD and EFB over time is adequately described by the exponential decay function proposed by Olson (1963) as evidenced by the  $R^2$  value of 0.88. Moradi *et al.*, (2013) observed similar exponential decay trend using the Olson's decay model.

### **5.2.1 Relative Mass Remaining (%) for CD, 5 and 10 t/ha**

CD1 decreased by 44% while, CD2 decreased by 47% of the initial amount over the 90 days decomposition period showing an exponential decrease in mass loss (Table 4.1). The physical and chemical properties of substrates under decomposition affect the rate of breakdown (Fox *et al.*, 1990) and (Moradi *et al.*, 2013), decomposition slows down when substrates under decomposition have low N content (< 20 g/kg) under decomposition, as in the case for CD, which has low TN 1.78%

In the early days of litter decomposition, the more easily decomposable portion of the residue breaks down rapidly, leaving behind the recalcitrant portion which decays slowly. This is because large number of soil microbes are able to work the soluble sugars, amino acids and the cellulose that are easily decomposable as compared to the waxes, resin and lignin which are more recalcitrant and takes time to breakdown (Mohammed *et al.*, 2014 and Moradi *et al.*, 2013).

### **5.2.2 Relative Mass Remaining (%) for EFBs**

The exponential decay function adequately describes the decomposition of EFBs over the 150 days decomposition period. Generally, the decomposition of EFBs progressed slowly over time.

The high OC content of EFBs, makes it largely recalcitrant to decomposition (Reshi and Tyub, 2007; Moradi *et al.*, 2013) leaving more than 50% of its initial masses undecomposed.

This trend of decomposition of EFBs could be attributed to the fact that, the more easily decomposable part of the EFBs such as amino acids, soluble sugars, organic acids which decompose 20 faster and cellulose and hemicelluloses which also decomposes 8 times faster than the lignin and wax component of the EFBs are broken down at the early stages of decomposition (Swift *et al.*, 1979; Foth, 1990; Green *et al.*, 1995;

Rosenani *et al.*, 1996; Mohammed *et al.*, 2014; Moradi *et al.*, 2013). The fact that about 50% of the initially available EFB remained undecomposed over the 150 days period suggests that EFB could be a good organic resources for building soil organic matter over time.

Studies by Moradi *et al* (2013) Zaharah and Lim (2000) and Wingkis (1998) showed that EFB from the oil milling industry lost 50% of its dry matter weight within 3 months, 70% within 8 months and 90% within 10 months under decomposition, a situation similar to what was observed in this study.

### **5.2.3 Instantaneous decay constants ( $k$ ) for 5 and 10t/ha applied CD.**

The instantaneous decay constants for the rate of decomposition of CDs is 0.006 for CD1 and 0.007 for CD2 (Table 4.3, Fig4. 1, Fig4. 2), indicating that 5t/ha and 10t/ha of CD have relatively similar rates of decomposition. This further suggests that the soil (Ada series soil) could support the decomposition of a higher rate of CD.

The similarities in the decay constant for CD1 and CD2 could be attributed to fact that both residues have the same internal physicochemical properties and are subjected to the same environmental conditions during decomposition (Gillon *et al.*, 1994).

Knowing the rate of decomposition per day gives a fair ideal of what amount will be lost of the initial mass for application planning purposes to meet crop nutrient uptake demand during or ahead of a planting season under same/similar environmental condition and soil series for which study was conducted.

#### **5.2.4 Instantaneous decay constants ( $k$ ) for EFB-IN and EFB-AT.**

The instantaneous decay constants ( $k$ ) for the rate of decomposition was **0.0084** and **0.008** for 5 t/ha and 10 t/ha EFB- industrial respectively (Table 4.4).

EFB-IN2 decomposed faster than EFB-IN1 but not significant. This signifies that the EFB-IN and EFB-IN2 decompose at a similar over the 150 days decomposition period. Also the K-value for EFB-AT1 was 0.002 as against 0.005 for EFB-AT2. However there is not significant difference in the K-value for EFB-AT1 and EFB-AT2.

The similarities in the decay constant ( $k$ ) between (EFBs IN1 and IN2) and between (EFB AT1 and AT2) could be attributed to the fact that both residues have the same internal physicochemical properties and are subjected to the same environmental conditions under decomposition, hence trend observed (Gillon et al., 1994).

### **5.3 Mineralization**

#### **5.3.1 OC released**

The gradual and uniform release of OC in CDs is an indication that the low level of OC in CDs initially could promote fast multiplication of soil microbes. The about 40% OC released at 90 days from the CD is high and it indicates less recalcitrant materials present in CD initially. For EFBs, amount OC released was negative (as more than the 100% OC present) up to 120 days of decomposition for EFB-AT2 but positive (10% released) for EFB-AT1 and EFB-IN2 for the same period and about 15% released for EFB-IN1. As stated by Moradi *et al.*, (2013), %OC released by organic residues is dependent on the litter quality. Thus, EFBs with initially high %OC content released relatively less amount of OC as observed in the case of EFB-AT2, EFB-AT1 and EFB-IN2.

### **5.7.2 Nitrogen (N) released (CD)**

The initial level the amount TN gradually increased till the 49<sup>th</sup> day of decomposition.

Similar results pattern was obtained for EFBs except that released of TN peaked from EFB-IN2 and EFB-IN1 at 14 days of decomposition and at 49 days of decomposition for EFB-AT1 and EFB-AT2. The observed amount of TN release and the pattern of released is a reflection of the initial relatively high content of C and low N content in the organic resources.

According to Kanye and Harth (1997), Schroth (2003) and Bardgett (2005). Addition of material with high C/N ratios to the soil, encourages the rapid proliferation of microbes and the introduction of a limiting N conditions. These microbes then immobilizes N present in the decomposing residues, limiting the release of N from the residues.

### **5.7.3 Potassium released**

Potassium released from CDs and EFBs reflects the available K in the organic resources. For CDs with minimal K content, the released K over the 90 days decomposition period ranged between 40 and 50% as against 60-90% over the same period for EFBs comparatively rich in K. Potassium is not a structural component of plant tissue and exists in ionic form in the cell sap of the vacuoles (Swift *et al.*, 1979; Reshi and Tyub, 2007; Moradi *et al.*, 2013) which then dictates the amount and rate of K release over time.

### **5.7.4 Phosphorus (P) released**

Generally, P release pattern from CDs and EFBs was similar to that for N (Fig. 4.4), as also observed by Moradi *et al* (2013), Berg & Staaf (1980) and Khalid *et al.* (2000) for organic residues. The release pattern of P from CDs and EFBs reflects the available P

present in the organic residues. The % P released follows this sequence **EFBs-AT1> AT2> IN1 >IN2** from the highest to the lowest for all the residues.

#### **5.7.5 Calcium (Ca) released.**

Ca is a structural component of plant cell wall and its release is expected to be proportion to the active mass loss in resource decomposition (Demarty, 1984 and Hodges 2010), until it gets to the recalcitrant materials (lignin and waxes) . However, this trend is in contrast to what was observed in this study because the calcium component of the plant cell wall has undergone digestion. When cattle feed on this plant materials, the calcium is assimilated for the animals own use and growth, this process of digestion takes a greater part of the Ca affecting the Ca quality of the dung. The remaining altered portion of the dung is acted upon by enzymes and get depleted faster under soil decomposition (Fatoma *et al.*, 2014), a reason that could be attributed to the pattern of Ca release in CDs.

For EFBs, the slow release of Ca could be accounted for by the slow decomposition of the residues over time.



## CHAPTER SIX

### CONCLUSION AND RECOMMENDATION

#### 6.1 Decomposition conclusion

The exponential decay function adequately describes the pattern of decomposition. Similar decay constants within the range of 82-87, were observed for the decomposition of CD1 and CD2, EFB-IN1 and EFB-IN2

The half-life ( $t_{1/2}$ ) for 5 and 10t/ha CD were **82 and 99**days respectively out of the 90days decomposition period for CD; meaning it will take 82 and 99days for half the amount of these resources to decomposed. EFB –Artisanal 5 and 10t/ha had **185 and 131**days half-life, while, EFB – Industrial 5 and 10t/ha, **83 and 87** days half-life respectively.

In general 56% and 53% of the initial 5 and 10t/ha of CD respectively remained undecomposed after 90 days of incubation. In case of EFB artisanal 68% and 41% of the initial 5 and 10t/ha remained after 150days of incubation. Additionally, 22% and 25% of the initial 5 and 10 t/ha of incubated EFB-industrial remained after 150 days. This shows that artisanal EFB could contribute better to a sustainable organic carbon build up in the Kokofu series than the industrial EFB.

#### 6.2 Mineralization Conclusion

The study revealed that substantial amount of nutrients in CDs and EFBs were not released, particularly, TN and P over the decomposition period.

Generally, it was observed that all the resources studied had a minimum of 80 days half-life (when half the total mass applied got extinct), but not more than half of the initial amount of nutrients in all these resources were released before the 80days except for potassium (K).

### **6.3 Recommendation**

The following recommendations are suggested;

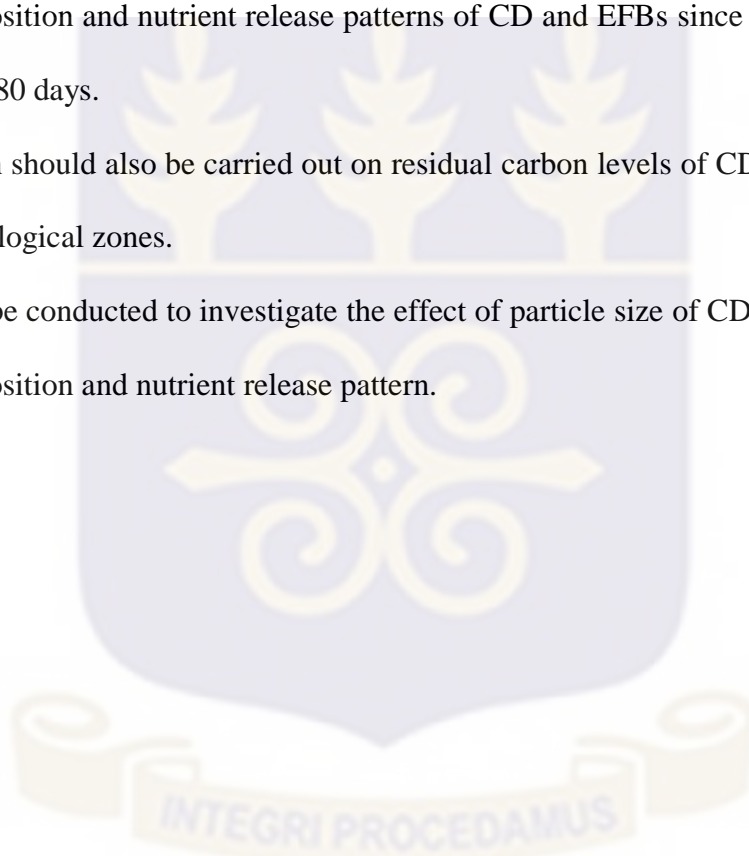
Field experiment be conducted in the future, instead of pot experiment, in the two agro-ecological zones to evaluate the decomposition and mineralization for CD and EFBs under the natural environment of these agro-ecological zones.

Further work should be carried out to investigate the effect on decomposition and nutrient release of CD and EFBs under varying moisture conditions.

Future work should have longer incubation periods to allow for detailed study on the decomposition and nutrient release patterns of CD and EFBs since the minimum half-life was 80 days.

Research should also be carried out on residual carbon levels of CD and EFBs in both agro-ecological zones.

Studies be conducted to investigate the effect of particle size of CD and EFBs on their decomposition and nutrient release pattern.



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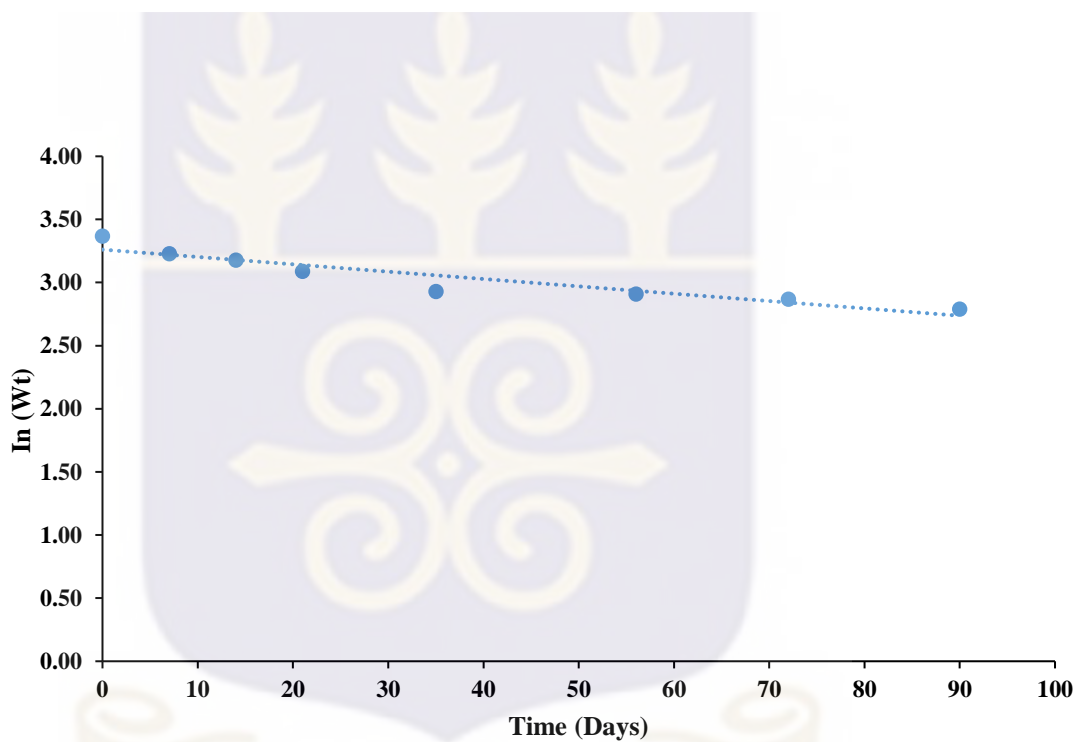
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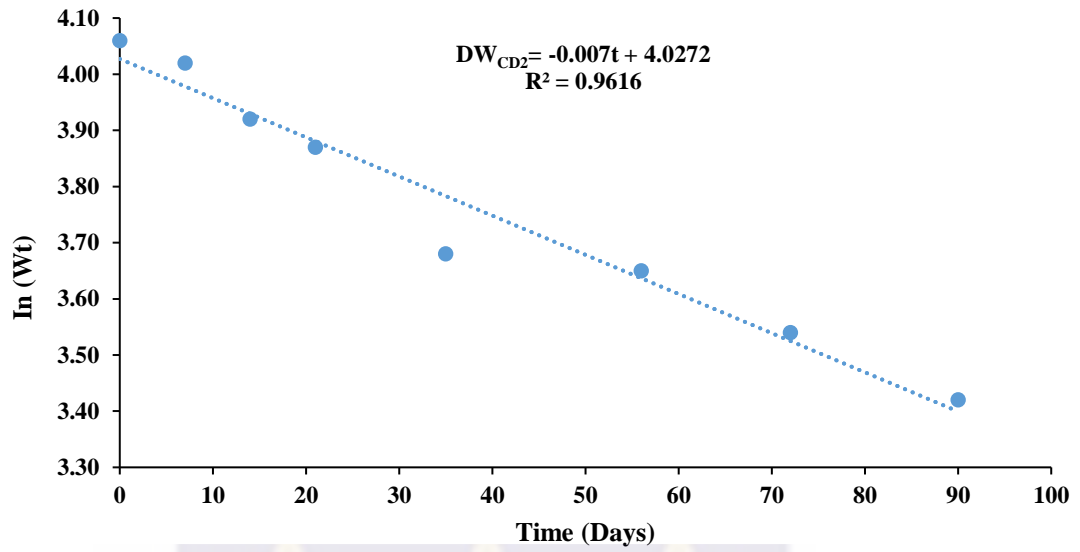
## APPENDIX

**Appendix 1:: Electrical conductivity and p H of well water on the Sege experimental site where the Ada series soil was taken for the study**

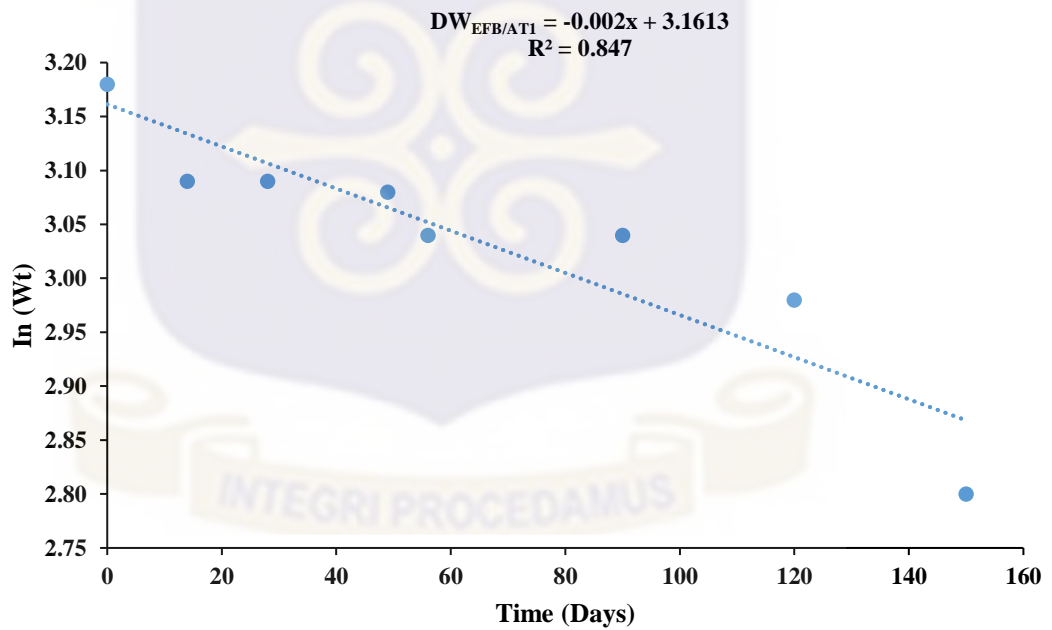
Month	EC mg/L	pH
February	1673	7.5
March	1480	7.4
April	1373	7.1
May	909	6.7
June	733	6.2



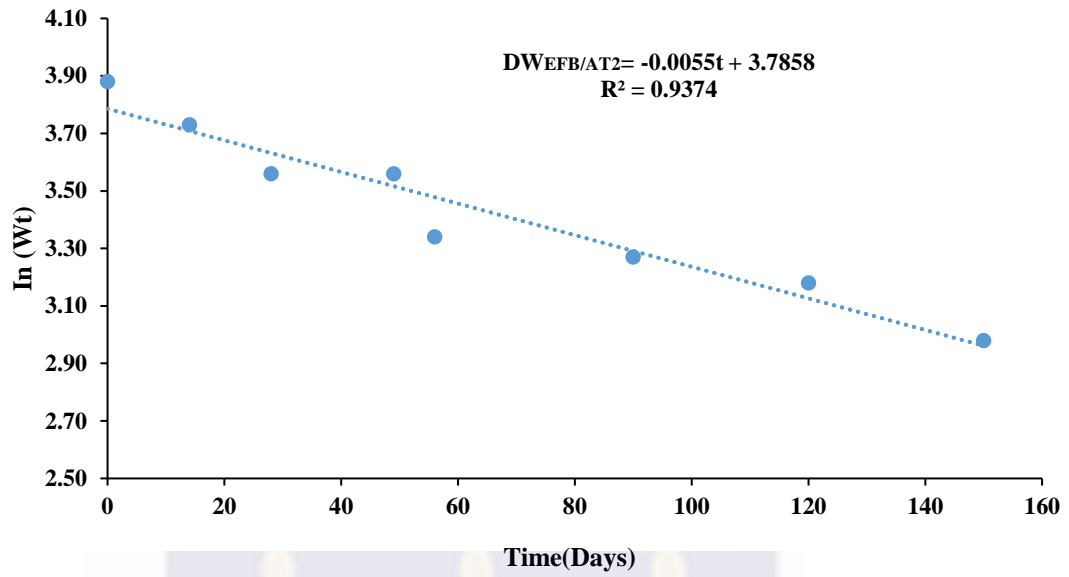
*Appendix 2: Instantaneous decay constant (K) for 5t/ha of cow dung under decomposition for 90 days.*



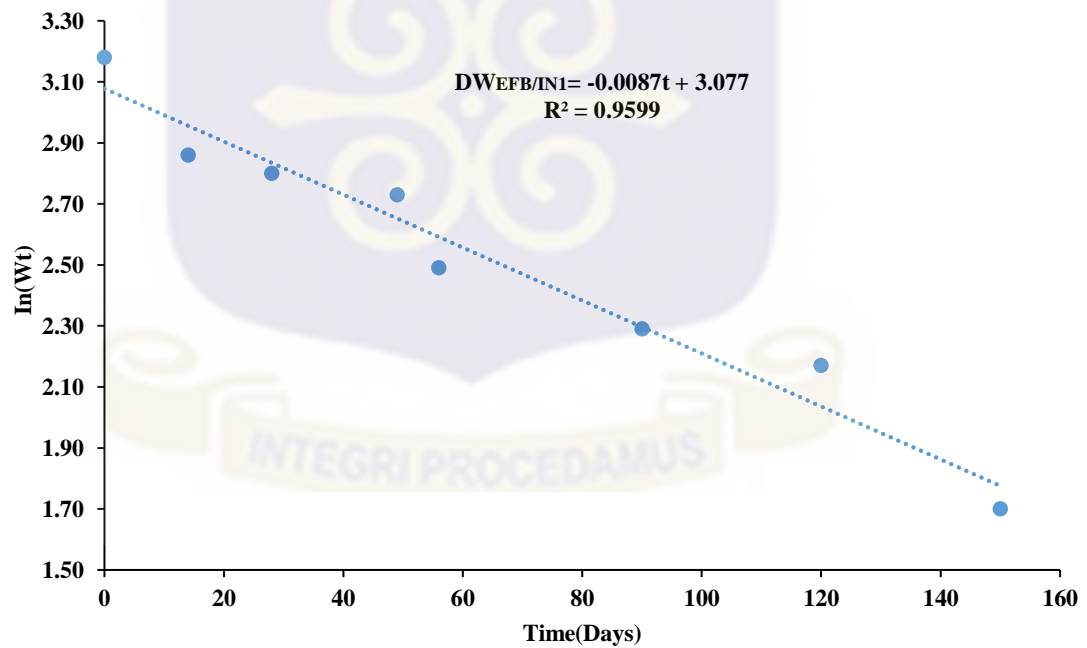
*Appendix 3: Instantaneous decay constant (K) for 10t/ha of cow dung under decomposition for 90 days.*



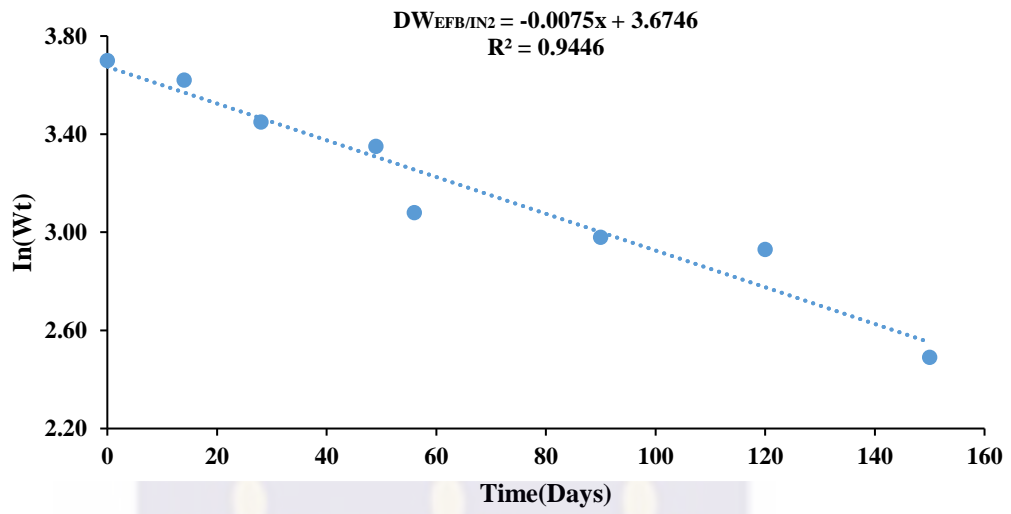
*Appendix 4: Instantaneous decay constant (K) for 5t/ha of EFB- artisanal under decomposition for 150 days.*



*Appendix 5: Instantaneous decay constant (K) for 10t/ha of EFB- artisanal under decomposition for 150 days.*



*Appendix 6: Instantaneous decay constant (K) for 5t/ha of EFB- industrial under decomposition for 150 days.*



*Appendix 7: Instantaneous decay constant (K) for 10t/ha of EFB- industrial under decomposition for 150 days.*

