UNIVERSITY OF EDUCATION, WINNEBA

ENRICHING KITCHEN WASTE COMPOST WITH THE INDIGENOUS PLANT VELVET BEANS (*MUCUNA PRURIENS*)

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(MASTER OF PHILOSOPHY)

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OCTOBER, 2023

DECLARATION

STUDENT'S DECLARATION

I hereby declare that this work except for references to other people's work which have been dully acknowledged, this project work is the pure result of my work and it has neither in whole nor partially been presented anywhere.

SIGNATURE

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BERNARD ADU GYAN DATE

Certified by:

SIGNATURE

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PROF. BISMARK DWUMFOUR-ASARE DATE

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DEDICATION

This research work is dedicated to my family and to everyone who contributed one way or the other toward my education.

ABSTRACT

INTRODUCTION: Composting kitchen waste is a sustainable means of managing some organic portions of municipal solid waste to mitigate the huge problem at dumping sites. However, most of the compost produced has minimal nutritional composition. This study was conducted to enrich kitchen waste compost by co-composting kitchen waste and *Mucuna pruriens* in different mixing ratios and different turning frequencies. **METHODOLOGY:** Aerobic composting method was used for the study in a completely randomized design (CRD), with four treatments set in triplicates. The mixing was in ratios of 100:0, 70:30, 60:40, and 50:50 of kitchen waste *and Mucuna pruriens* by weight (kg) in aerated composting baskets. The mixture that produced the best compost was subjected to three different turning rates every 3 days, 5 days, and 7 days turning frequency to access the impact of the turning frequencies on the compost performance. The temperature of the treatments was monitored daily and was moisturized with water to about 40-60% by volume of all the treatments before turning. The physicochemical, nutritional, and biological properties were analysed at the time (0, on the 28^{th} day and 56^{th} day) of composting. **RESULTS:** The result indicated that compost quality in terms of physicochemical and nutritional content significantly increased in compost with *Mucuna Pruriens* properties as compare to the control with average (N%) (3.18±0.14%) as compare (1.96±0.1, phosphorus (P%) increased at the end at (1.76±0.11%) as compared to (1.00±0.14%) of the control and the potassium levels are as follow (2.62±0.20%) and (2.88±0.17%) of the raw kitchen waste. However, there was no significant difference among mixing ratio treatments. Again, the best turning frequency in terms of available nutrients NO_3-N, Potassium (K), and Phosphorus (P) are T1 (turned every 3 days) had NO_3-N (mg/kg)-(3792±1082.25), K (mg/kg)-(4875.33±406.87), P (mg/kg)-(279.89±47.48), T2 (turned every 5 days) also had NO_3-N (mg/kg)- (4752.67±1245.37) K (mg/kg)-(4875.33±390.29), P (mg/kg)-(294.65±47.09), T3 (turned every 7 days) also had NO_3-N (mg/kg)-(4296.33±1341.15), K (mg/kg)-(6062.67±1667.39), P (mg/kg)-(290.14±83.76). Control= NO_3 -N (mg/kg) -(2491±522.47), K (mg/kg)- (4988±298.21), P(mg/kg) (228.64±45.98). **CONCLUSION & RECOMENTDATION:** Generally, *mucuna pruriens* seeds have the capacity to enrich the nutritional value, improve the physico-chemical and the quality of compost with 60:40 as the best mixing ratio based on the nominal values with weekly turning interval was the best at ($p<0.05$) because it allowed time for microbial activities and the mineralization. Policy maker, compost industry and farmer should adopt and incorporate the use of *mucuna proriens* as a compost amendment factor to enriched and improve the quality of compost. These will foster environmental protection, improve socio-economic development and boost the agriculture industry for a sustainable development.

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CHAPTER ONE

INTRODUCTION

1.1 Background of the Study

The ever-increasing effect of solid waste is a global challenge. This global phenomenon of solid waste as an inevitable by-product of human activities comes with enormous management challenges in all societies especially in South-Saharan Africa (Thanh, 2019). As a result of the global population increase, urbanization, and high industrial development there is going to be an ever-increasing generation of solid waste with management complications (Goudie, 2018). According to Kaza *et al*., (2018), globally 2.01 billion metric tons of total municipal solid waste is being produced and it is projected to increase by 70% to about 3.40 billion metric tons by the year 2050 with organic waste as the greater proportion. Again, it was estimated that about 1.13 million tons of food waste or kitchen waste are globally disposed of daily (Chen *et al.*, 2020).

In developing nations, research by (Wilson *et al.*,2015) on municipal solid waste generation recorded that about 50–70% of the entire waste produced is organics which are predominantly organics which include kitchen waste. In Ghana, 3 million metric tons of solid waste is generated yearly, and out of this 65-70 percent is domestic waste which is predominantly kitchen waste (Fiagbe, 2020). Solid wastes must be properly managed to prevent possible environmental and economic effects (Stemn *et al.*, 2019).

Landfills are the main solid waste management practice, practiced by developing nations in both the public and private waste management organizations (Deus *et al.*,2020). Poor management of landfills leads to a lot of hygienic threats, the leachate from landfills pollute both surface and groundwater with high microbial load and heavy metals (Al-Khatib *et al.*, 2015; Han *et al.*, 2016). Also the challenges of securing a land for the construction of landfills is a major problem with many political inconsistencies as recorded in Ghana (Kansanga *et al.*,2020).

Globally people are looking for innovative ways to handle solid waste and minimize the environmental challenges that come with it (Mir *et al.,* 2016). It has been stated that proper waste management should not neglect waste prevention/reduce, waste re-use, recycling, and composting as the major priorities for solid waste management (Gusmerotti *et al.,* 2019).

Composting is catching attention globally as an environmentally friendly waste management technology with a lot of benefits (Joshi & Visvanathan, 2019; Indirapriyadharshini et al., 2020). Though compost is good since it is an environmentally friendly way of managing organic solid waste it has some nutritional deficit required by plants.

Rich compost, should not only improve soil quality, reduces soil loss, increases soil water retention, and balance soil pH, but must contain enough nitrogen, potassium and phosphorus, and other micro-nutrients in their right proportions required by the plant for growth and development (Ayilara *et al.*, 2020). As a result of these Imhoff & Badaracoo, (2019) stated that the desire for higher yield in both developed and developing nations also led to excessive use of synthetic fertilizers such as NPK, urea, etc. Some farmers also combine both compost and synthetic fertilizer for high yield (Iqbal *et al.*, 2015; Saeid & Chojnacka, 2019). However, according to Zheng *et al*.(2019), the call for synthetic fertilizer comes with high financial and environmental costs.

The indigenous plant velvet beans is a leguminous plant that is mostly grown as weed control and for purposes of food but it is noted to replenish nutrients on wastelands and mining sites by its capacity to fix the high amount of nitrogen into the soil to enhance plant growth on poor farm lands (Kumar & Sukul, 2020). Velvet beans are also noted for food and medicine by many people in Africa and Asia (Kaushik *et al.*, 2018). The velvet beans (*Mucuna pruriens*) have many medicinal properties including potentail to treat diseases such as hypoglycemia, Parkinson's disease, tumour, and microbial infections and increase semen in men and boost sexual behaviour (Pathania *et al.*, 2020). Of late many people have stopped eating it despite its medicinal property because of some side effects such as difficulties of use it to prepare food, nausea, and mostly as a result the impression of it causing abdominal bloating (Pathania *et al.*, 2020). These reasons account for the low usage of the velvet beans, but it has attracted attention for ways to make it beneficial again.

Since it is a leguminous plant used for replenishing soil nutrients and its seeds are of high protein, it was hypothesized in the current study that combining the velvet beans with kitchen wastes could produce rich organic composts to serve as soil conditioner for crop plant growth. The compost produced was evaluated for chemical, physical, biological, and nutritional value in comparison with available standard values for describing the quality of the compost for soil nutrient improvement for agriculture. The mixing ratios and the turning frequency for producing the composts were key parameters noted to establish which mixing ratio and turning frequency facilitated the production of quality composts for the recommendation for industrial and sector-specific practices.

1.2 Problem Statement

It is said that the space required for creating a landfill site is limited and its sitting also destroys much ecological life, as well as the leachates from landfills pollute both surface and groundwater and also generate methane a greenhouse gas that is a major contributor to global warming (Han *et al.*, 2016; Atkinson *et al.*, 2017; Powell & Chertow, 2019). To mitigate the challenges above composting the organic and the kitchen waste component of municipal solid waste can be useful but the compost nutrient level is low (Kaboré *et al.*, 2010). Again Kadir *et al.*, (2016), stated that kitchen waste compost with processed food materials produces acidic compost with a pH ranging from 5-6 and main plant nutrients such as NPK in the kitchen waste (food waste) are very low and do not match up to chemical fertilizers. Also according to Voběrková *et al.,* (2020), kitchen waste compost does not meet the condition and standard of mature compost in terms of nutritional composition.. Therefore, there is the need to enrich kitchen waste compost. It has been found that compost can be enriched with an increasing quantity of other green biomass but the use of *mucuna pruriens* to enrich compost nutrition and quality has not been study hence the utilization of the indigenous plant *Mucuna pruriens* to enrich kitchen waste in a co-compost to produce rich compost for agriculture purposes.

1.3 Justification of the Study

Composting is not something new in the south Saharan Africa sub-region including Ghana. Researchers have shown how some indigenous plants such as citrus plants had been used to enrich compost and have shown the ability to stimulate plant growth (Bernal-Vicente *et al.*, 2015). It has been found that compost can be enriched with an increasing quantity of green biomass from *Moringa oleifera* to increase the amount of nitrogen in finished compost

(Taguiling, 2016). In Ghana, much research has been conducted where composting had been enriched with various substances. Also, the enhancement of soil nutrient status by composting cow dung using a dynamic kraaling strategy has been studied in the Northern part of Ghana by Abagale & Ayuegabe, (2015). Mushroom is also noted to enrich compost according to Wiafe-Kwagyan. (2014). There were also studies done by Nikiema *et al,.(*2013), Impraim *et al.* (2014), and Cofie *et al.* (2016) on how faecal sludge can be processed to enrich compost and soil fertility with low-cost technology. However, the ability of leguminous crops especially *Mucuna pruriens* has not been fully studied to see if it can enrich compost, although Hogarh *et al., (2015)* studied the potential and coupling effect of compost and *Mucuna pruriens* for quarry site restoration at the Yongawa Limestone quarry in Ghana and concluded it is effective for soil amendment. Wong *et al.*, (2001) co-composted soybean residues with leaves and resulted in high plant nutrient compost. *Mucuna pruriens* leaves have been used as green manure and have proven to improve soil physicochemical properties and increase crop yield (Poku *et al.*, 2014; Cordeiro *et al.*, 2018). The *Mucuna pruriens* seeds are known to contain high amount of protein but how it is able to improve compost quality is not known. Therefore, it is important to study the utilization of *Mucuna pruriens* (seeds) enrich kitchen waste compost. This study revealed an innovative way of managing our kitchen waste than to let them end up at landfill site to pollute the environment. It will also help us to know and have the importance of applying compost to our farmlands than to over depend on synthetic fertilizer, which could introduce chemical contamination into the enveroment.

1.4 Objectives of the Study

The main objective of the study was to assess the potential of indigenous plant *Mucuna pruriens* to enrich kitchen waste, compost through co-composting.

1.4.1 The specific objectives were:

- Determine the proximate characteristic of the kitchen waste and the *Mucuna pruriens* seeds.
- Determine the best mixing ratios of *Mucuna pruriens* seeds and kitchen waste for co-composting.
- Determine the effect of turning frequency on the co-compost quality.
- Determine the available nutrient values for plants in the co-compost.

1.5 Organization of the Report

The report has been put into six chapters. An introductory chapter provides the background of the study, the problem the research addresses and its contribution to scientific knowledge, the hypothesis to be tested, and the objectives propelling the research. Chapter two evaluates details of the literature that justifies the relevance of the study. Chapter three describes the methodology for achieving the outcomes of the study. Chapter four presents the results; chapter five presents the discussion against relevant literature. Chapter six provides the concluding remarks. These include a conclusion and recommendation.

CHAPTER TWO

LITERATURE REVIEW

2.1 Solid Waste

Solid waste is the by-product of human domestic, institutional, business, and industrial activities which are collected and disposed of indiscriminately or properly (Okot-Okumu, 2015). According to Muthuraman & Ramaswamy, (2019), solid waste is any substance such as garbage and refuse, sludge from wastewater treatment plants and chimneys, and unwanted materials resulting from industrial, residues from commercial, mining, farming, and community activities. Also, all forms of waste from various sources which are dumped openly in landfills are classified as solid waste and demand immediate and proper management (Ministry of health (MoH), 2017).

2.2 Solid Waste Composition

Solid waste composition is the distinctive percentage weight of all solid materials that make up solid waste in their relative separations. It was stated that the composition of solid waste differs from country to country and municipality to municipality (Sunil Kumar et al., 2016). According to (Ezeudu *et al.,* 2019) organic waste is the highest proportion of municipal solid waste generated annually in developing countries as compared to developed countries. According to Otu, (2011), a study comparing solid waste composition in Ghana, India, Britain, and U.S. stated that waste in developing nations is predominantly organics of about 90% food waste. Ghana as a developing country is not different. A study by Boateng *et al.,* (2016) revealed that organic waste which includes kitchen waste is very high in rural communities as compared to urban cities, and next to organic waste is plastic waste.

2.3 Kitchen Waste

Kitchen waste is any substance such as food that is lost or uneaten and other waste materials such as peel in the kitchen which form an important part of the municipal solid waste composition that occupies larger space of all landfills and poses a dangerous threat to the environmental (Baig *et al.,* 2019; Stemn & Kumi-Boateng, 2019). In developing nations, research by Wilson *et al.,* (2015) recorded that about 50–70% of the total waste generated comes from organics. In Ghana, a study by Fei-Baffoe *et al.*, (2015) indicated 48% to 79% of municipal solid waste are organics which are mainly kitchen waste. Currently in Ghana, out of 3 million metric tons of annual solid waste is generated, 65-70 percent is domestic waste which is mainly made up of kitchen waste (Fiagbe, 2020).

2.4.1 Kitchen waste composition

The composition of kitchen waste varies greatly from house to house and it also varies with time (Sunil Kumar et al., 2016). According to Coker *et al.,* (2008), in almost all food items that enter the kitchen a reasonable portion of it is lost to waste. A study conducted by Coker *et al.,* (2008) on the analysis of waste components of different food materials in Nigeria provided for comparison (Table 2.1). This study considered a typical household as having a membership of 7-8 people.

Table 2. 1 Fraction of kitchen wastes generated in a household in Nigeria.

Food Item	The quantity used by the family in one serving	Fresh Weight Range (g)	Waste generated Range (g)	Waste Generated %
Yam	1 tuber	1035.6-1085.2	138.5-179.7	12.8-16.6
Rice (Polished)	1 Congo	1535.1-1675.0	0.0-7.6	0.0-0.45
Beans	1 Congo	1418.2-1465.5	381.2-418.6 (husk)	26.9-28.6
Groundnut	1 Congo	1021.0-1036.0	429.2-437.2	42.1-42.2
Maize	7 Cobs	1002.8-1005.7	518.3-615.1	51.7-61.2
Banana	12 Pieces	1023.1-1057.0	351.2-417.3	34.3-39.5
Plantain	8 Pieces	1000.9-1037.5	354.6-372.5	35.4-35.9
Orange	8 Pieces	1013.2-1072.4	583.4-673.2	57.6-62.8
Pineapple	1 Piece	920.0-1563.9	504.1-593.2	54.8-37.9
Cassava	3 tubers	1042.9-1063.8	221.5-228.2	21.2-21.5
Yam powder (Elubo)	1 Congo	723.6-724.3	58.2-62.2	8.04-8.6
Meat	8 Pieces	334.0-453.2	43.0-65.2	12.9-14.4
Fish	4 Fish	970.6-1012.9	107.3-257.4	11.1-25.4
Lime / Lemon	43 Pieces	981.2-1151.7	567.3-635.8	57.8-55.2
Eggs	17 Pieces	1008.8-1016.5	116.2-118.7	11.51-11.7
Carrot	43 Pieces	1010.5-1038.2	81.5-87.0	8.1-8.38
Coco yam	12 Tubers	1019.5-1053.5	342.8-384.1	33.6-36.5
Garden egg	42 Pieces	1009.9-1012.6	39.2-48.3	3.9-4.8
Pawpaw	3 Pieces	985.6-1293.6	391.2-483.5	39.7-37.4
Pepper	1 Congo	1031.2-1051.5	36.4-41.3	3.53-3.93
Potatoes	9 tubers	949.7-1052.0	253.6-282.6	26.7-26.9
Pear	5 Pieces	827.5-1017.8	349.0-423.3	42.2-41.6
Onion	9 Pieces	548.3-601.3	53.6-62.6	9.8-10.4
Guava	59 Pieces	982.1-1002.3	32.1-59.3	3.3-5.9
Okro	48 Pieces	983.5-1006.4	89.4-107.2	9.1-10.65

‘Congo’ is a local measure, usually a gourd bowl used by traders; a ‘Congo’ filled with grains (e.g., rice, maize, etc.) weighs approximately 1.67 kg (Coker *et al.*, 2008).

2.5 Solid Waste Management

Solid waste management is the various professional activities that seek to control waste generation, separation, collection and storage, transportation, processing, reuse, recovery, and final disposal (Dongballe, 2016) and Amritha & Kumar, 2019). It is expected that the solid waste management process move following the best practices within the recommended principles of public health, economics, and engineering, conservation of nature and aesthetics, and the general environmental conditions and social standards (Almasi *et al.*, 2019). Solid waste management differs in many areas, including urban, rural areas, residential zones, and industrial areas (Zohoori & Ghani, 2017; Procházková *et al.*, 2019). In Africa, a study by Makarichi *et al.*, (2019) on waste from countries management concluded that solid waste management is very slow as compared to the high-income developed nations. According to them, less than 50% of solid waste generated is collected for management. In Ghana, most of the solid wastes are dumped on the street. Others burn them and the remaining end up in landfills with about 83.9% of waste not sorted (Alhassan *et al.*, 2020).

2.6 Solid Waste Management Options

Solid waste management options considered in the form of a waste management hierarchy can also be defined as the ranks in the management of solid waste options from a more sustainable and most preferable option to the least ideal options taking into account carefully financial, social, and environmental considerations (Adipah & Kwame, 2019). It is also stated by Cole *et al.*, (2019) that to achieve quality waste management goals, waste reduction or prevention, waste reuse, waste recycling, and composting, recovery should be esteemed high in the waste management hierarchy. The final disposal at the landfill is expected to be considered last and least in other reduce the quantum of solid waste on landfill sites because of the environmental complication associated with landfills (Allen *et al.*, 2019).

2.6.1 Waste Prevention/Reduce

Waste prevention stands tall and at the top in priority on every waste management hierarchy as a means for sustainable waste management (Gusmerotti *et al.,* 2019). To optimize waste prevention and reduction, behaviour change is to be advocated (Hebrok & Heidenstrøm, 2019). Waste prevention reduces the number of waste on the landfill site and ends up preventing landfill site problems (Crowe *et al.*, 2017). Waste prevention is a favourable scenario because according to Bizcocho & Llatas, (2019), waste prevention can reduce 60% of solid waste that is supposed to end up in landfills. However, Azimi *et al.*, (2012) stated that waste prevention and reduction at source can help in the following: save natural resources; conserve energy; reduce pollution; Reduce the toxicity of our waste; and save money for consumers and businesses alike.

2.6.2 Solid waste reuse

The reuse of waste materials reduces environmental pollution and overexploitation of natural resources (Demirkan & Afacan, 2018). Reusing of solid waste is noted to prevent costs and help generate revenue for community development (Rai *et al.,* 2019). It was recorded that this can be done by taking into account the premise that one man's waste is another man's resource (Sayadi-Gmada *et al.*, 2019). For example in Ghana Korley & Fianko, (2017) stated in their study that households reuse the waste in many parts of our societies, most of the waste organic are used to feed farm animals, and the waste bottles are used as refill bottles for cooking oil and liquid soap packaging and this they stated was mostly done by the low-income earners.

2.6.3 Recycling of solid waste

Recycling of waste is an important aspect of waste management and stands the third on the modern-day waste management option (Lienig & Bruemmer, 2017). Recycling is the process of processing waste into completely new products by altering the nature of the waste materials into other useful products (Singh *et al.,* 2017). It is recorded that the recyclable waste which forms part of solid waste largely materials such as plastics, wood, paper, cardboard, rubber, ceramics, metals, glass, textiles, and leather they are mostly moulded into a useful artifact (Aziz, 2019; Stephen & Temitope, 2017).

2.6.4 Recovery of waste

When the management of waste failed to prevent waste or reused it at the source and it was not recycled, then the next strategies to pursue before ultimate disposal is recovery. The waste management officers in some parts of Ghana according to (Seshie, 2016) hopes that more than 20% of the volume of waste will be recovered before disposal and they encourage waste picking.

2.6.5 Disposal and Incineration

Mostly, after the final disposal of solid they are been burnt but such practices should not be encouraged especially if the waste contains chemical and pesticide containers (Mohiuddin, 2018). When material recovery fails, treating waste using effective and efficient methods such as incineration, while lessening power usage and the generating of new streams of waste should be used (Zaman & Lehmann, 2013).

2.6.6 Landfill

Landfills are a place of dumping waste, it is a place which has a high load of bacteria concentration (Cyprowski *et al.,* 2019). It is on record that landfills are the main solid waste management option, practiced by the developing nations by both public and private waste management organizations on municipal landfills (Deus *et al.,* 2020). In Africa, the impact of landfills on human and environmental health has been very dangerous and poses health threats to a residence near the landfills according to (Sankoh *et al.,* 2013). According to Al-Khatib *et al.,* (2015); Han et al., (2016) poor management of landfills leads to a lot of hygienic threats, bad scent, with almost 90% of methane emissions coming from waste, water leaching from landfills polluting both surface and groundwater with even heavy metals.

2.7 The Concept Composting

Composting is the degradation of organic waste resources by aerobic or anaerobic means in a well-organized and controlled manner to form a rich soil amendment manure as the final product (Cofie *et al.*, 2016; Mehta & Sirasi, 2018). According to (Cofie *et al.* 2016), composting is the cheapest, simplest, and most sustainable way to stabilize and reduced the biodegradation of different waste materials to enhance soil nutrients. Compost aids in improve soil quality, decreases soil loss, improves soil water retention, and balances soil pH, while reducing the need for extra synthetic nutrients (Weindorf *et al*., 2008; Zakaria *et al.*, 2019). Compost is used as organic fertilizer, is odourless, and free of pathogens though not free. According to Sharholy *et al. (2008)*, the result of the composting process can reduce the waste volume to about 50–85%.

2.7 Factors affecting composting

Many factors affect composting and the quality of the compost after production but they are mainly classified into biotic and abiotic factors (Karamanlioglu *et al.*, 2017; Sun *et al.*, 2019). Some of these factors are as follows:

A. Compost materials

The compost materials are mostly made up of degradable waste materials. However, improper materials such as glass and plastic affect the quality of compost negatively (Rodrigues *et al.*, 2020). Materials that are made up of green pigments are more nitrogen constituents. The size of the composting feedstock is important in mixing the pile and enhancing microbial activities. Smaller particles size have larger surface areas which would lead to faster decomposition (Lin *et al.*, 2022). Conversely, larger particle sizes can lead to excessive ventilation, diminished water-holding capacity, and lower degradation (Zhao *et al.*, 2017). There is no consensus about the best possible particle size for composting. Many Studies employed different particle sizes in their surveys, ranging from, 1.5-3 cm in food waste feedstock (Lin *et al*., 2021) and ≤ 1 cm in cattle, chicken, and other faecal feedstocks (Wang *et al.*, 2015).

Shredding Particle size is essential for moisture retention, porosity, and the surface to volume ratio of the compost. The particle size depends on the specific feedstock in the compost and the pile size affects the rate of decomposition (Zhang & Sun, 2014). Smaller particles size have a larger specific surface area and lower permeability, which helps microbial activities on the compost as compared to materials with bigger sizes (Hettiarachchi *et al.*, 2019).

B. Mixing ratio

The carbon to nitrogen ratio of compost is the ratio between carbon and nitrogen content in compost. It is an important parameter of composting because it shows the compost quality. Composting may be more effective when a C/N or mixing ratio of 20:1 to 40:1 is noted to decompose quickly for organics (Chang & Chen, 2010; Kumar *et al.*, 2010). It is also recorded that compost that has more nitrogen stinks (Ma *et al.*, 2022).

C. Temperature

According to the study done by De-Guardia *et al*.(2012); Giełżecki, & Jakubowski, (2020); Wang *et al.* (2021), the composting process can be characterized by four successive stages whereby biological oxidation takes place which include 1) the mesophilic stage; 2) the thermophilic stage; 3) the cooling stage; and 4) the curing stage. The mesophilic stage is the commencement of the decomposition process where the temperature is below 40°C. The thermophilic stage is where the temperature begins to raise from 40°C to 60°C which involves rapid decomposition of the waste materials accompanied by the increase in the microbial population which again increases the temperature of the compost material above 60°C to kill any weeds seeds and pathogenic present in the compost (Fontenelle, 2011). In the third stage the decomposition reduces very low and the temperature of the decomposed material drops to ambient temperature. At this point, most of the materials are near or at the endpoint of the decomposition process so it starts the cooling process. During the final stage, the material is said to be "curing" and settle to cool down completely (Gautam *et al.*, 2010).

D. Moistening

Water acts as an essential element and solvent for microbial activity. A moisture content of 40 to 60% is preferred during the composting process. Moisture content below 40% or above 60% prevents microbial growth and affects organic matter (Shimizu et al., 2018).

Excess water restricts air space leading to gas diffusion (Abd-El-Kader *et al.,* 2007). Excessive moisture will lead to anaerobic decomposition and odour formation (Onwosi *et al.,* 2017). However, keeping the compost moist is necessary to compensate for dryness and improve decomposition during composting process (Richard *et al.*, 2002).

E. Turning

The oxygen level of the compost material also determines the occurrence of nitrification and denitrification (Abd-El-Kader *et al.,* 2007). The right oxygen concentration that ranges from 5% to 10% is a desirable range for composting and the availability of oxygen controls the effectiveness of biochemical processes in the compost (Waszkielis *et al.,* 2013). The amount of oxygen that enters the compost is a result of the turning rate which has a corresponding effect on maturing and quality of the compost (Zhou *et al.*, 2018). According to Wong et al., (2001) daily turning, three days and seven days are feasible for compost treatment. According to (Mahankar *et al.*, 2021) the rate of turning is governed mainly by moisture content and the type of materials. They also stated that moisture content of 60%-70% should be turned approximately 4 to 5 on the turning day. Moisture content of 40%-60% can turn at 3-day intervals or above, Moisture below 40% means water should be sprinkle on the compost materials to enhance the moisture level before turning (Ugak *et al.*, 2022).

F. Microbial activities during composting

Compost quality and the composting process depend on the metabolism of the microbial activities. The health and systemic nutritional balance of the compost depends on the activities of the microorganisms. The composting process involves the activities of microorganisms such as bacteria and fungi (Jurado et al., 2014; Pepe *et al.*, 2013). Bacteria take part in the biodegradation of compost materials and release carbon dioxide and heat energy (Insam *et al.*, 2007). Microorganisms growth causes higher temperatures and their activities increase the quality of the compost (Pan *et al.*, 2012; Awasthi *et al.*, 2017). Oxygen is highly needed during the thermophilic phase to increase microbial activities

(Awasthi *et al.*, 2016). Many microbes such as Pseudomonas, Bacillus, and Sphingomonas are noted to generate an abundance of nitrogen gas during composting (Nemet *et al.*, 2016).

2.8 Benefits of Compost

There have been several reported benefits to the use of compost both for the environment and as agricultural amendments (Otu, 2011). It was reported by Bugbee, (2002) that there is an increased plant growth and yield when compost was added at about 50 – 100 % (vol) rates to soil. It is recorded that compost releases macronutrients found in compost to stimulate plant growth as compared to plant growth in unfertilized soil (Bhogal *et al.*, 2018). It was also recorded by Sánchez-Monedero *et al.*, (2004); Paradelo *et al.*, (2019) that compost applied to soil increases its water-holding capacity. The fertilizer value of composts prepared from (green waste and kitchen waste) would increase the nitrogen content of the compost. It is noted that compost prepared from food waste and yard trimmings compost also increased Nitrogen uptake in plants and produced the highest yields as compared to the synthetic fertilizer (Oviedo-Ocaña *et al.*, 2019). Compost usage has been shown to increase plant-available micro-nutrients such as Fe, Mn, Zn, and Cu in the soil (Wang *et al.*, 2016). Composting is an effective means of managing possible water contamination (eutrophication) because of the maximum nitrate and phosphate leachate from landfills (Sharma *et al.*, 2019; Pan *et al*., 2020).

2.9 Problems of Compost Use

There are a lot of possible profits to the use of composted materials in agriculture and the environment, there can also be some problems associated with its use. The heavy nitrogen in the compost load led to possible groundwater contamination (Khan *et al.*, 2018). It was stated that long-term excessively high compost application rates; or applications of compost in combination with mineral nitrogen fertilizer could lead to high nitrate leaching exceeding critical levels on a loam soil (Xu *et al.*, 2020). Heavy metals are also recorded found in compost prepared from faecal sludge which can be introduced to crops planted (Liu *et al.*, 2017). Again, Svensson *et al.*, (2004) expressed concern that compost-amended plots received high doses of heavy metals (especially lead) compared to those supplied with mineral fertilizer only. Some of the problems associated with compost application to agricultural land are as the result of the application of poorly prepared and poor compost material (Liu *et al*., 2019).

2.9 Velvet beans

2.9.1 Velvet beans (*Mucuna pruriens*) plant

Mucuna pruriens which is commonly known as velvet bean is a climbing plant, an indigenous cover plant with 3–18m in height according to (Chinapolaiah *et al.*, 2019; Joyful & Pieterse, 2019). According to (Ezeagu et al., 2003; Lampariello *et al.*, 2012). *Mucuna pruriens* is mostly planted in Asia, America, Africa, and the Pacific Islands. They also stated that the young pods and the seeds are used by the indigenous people as food, and their young leaves are used as feed for farm animals. This plant is noted for its extreme irritation and itchiness on contact with the body (Deokar *et al.*, 2016). The plant also can fix atmospheric nitrogen in the soil (Hartkamp *et al.*, 2002). According to Coultas *et al.*, (1996); Marchesan *et al.*, (2016); Campbell *et al*.,(2019) *Mucuna prureins* could also serve as a weed control mechanism in some farms, for instance, was proven useful in controlling weeds in sugar cane farms and maize farms. Medically, *Mucuna prureins* are noted as useful for both traditional and modern medicine (Rao et al., 2017; Saikarthik *et al.*, 2017). The roots are bitter and contain substances such as thermogenic, emollient, stimulant, purgative, aphrodisiac, and diuretic (Taylor, 2005). The *Mucuna pruriens* plant, flowers, pods, and seeds in (plate 2.1).

A=Flowers B=Pods C=Seeds D=Leaves

Plate 2. 1The picture of *Mucuna pruriens* plant, flowers, pods, and seeds

Source: (Yadav *et al.*, 2017).

2.9.2 *Mucuna pruriens* leaves

Mucuna pruriens leaves serve as a cover crop to protect arable lands and as a green manure desired by farmers (Gyamfi *et al* 2001; Agynim-Boateng *et al.*, 2001). *Mucuna pruriens* leaves have been used as a green manure and have proven to improve soil physicochemical properties and increase crop yield (Poku *et al.,* 2014; Cordeiro *et al.*, 2018). The leaf extract has proven to have medicinal properties (Table 2.2), (Taylor, 2005).

2.9.3 *Mucuna pruriens* seeds

The seeds contain enough minerals which serve as major sources of essential nutrients to feed poultry, livestock, and human and possess high medicinal properties (Table 2.2) (Hlabano, 2017; Ricalde *et al*., 2019; Tuleun *et al*., 2008).

Pharmacological activities	Plant component	Extract	Material/compound
anti-venom	plant seeds	water	proteins
anti-microbial	plant leaves	methanol	tannins, alkaloids, L-dopa
Neuro-protective	plant seeds, whole plant	ethanol/water (1:1)	L-dopa, amino acids, alkaloids
anti-diabetic	plant seeds	ethanol/water (1:1)	cyclitols, oligosaccharides
anti-oxidant	plant seeds, leaves, and whole plant	methanol	phenols, tannins

Source: Lampariello *et al*., (2008)   Pharmacological activity of *Mucuna pruriens*.

2.9.4 Minerals and Composition of *Mucuna pruriens* seeds

According to (Tuleun *et al.*, 2008) the seeds of *Mucuna pruriens* contains high dry matter and crude protein. It was also stated that the *Mucuna pruriens* seeds were found to contain a comparatively high content of nitrogen and essential amino acids (Kouakour *et al.*, 2022). *Mucuna pruriens* also contain high fibre (Monge *et al.*, 2022). Again according to (Tuleun *et al.*, 2008) *Mucuna pruriens* show the promising levels of phosphorus, calcium, sodium, magnesium, iron, manganese, and zinc (Table 2.3 and Table 2.4).

Table 2. 4 Nutritional compositions of some varieties of *Mucuna pruriens*

Nutritional compositions	***Mucuna .puriens* cream**	***Mucuna puriens* mottled**	***Mucuna utilis***	***Mucuna poggei***	***Mucuna cochinchinensis* mottled**	***Mucuna cochinchinensis* maroon**	**Range**
Sodium, %	0.077	0.057	0.05	0.07	0.141	0.079	0.05-0.14
Potassium,%	1.253	0.893	0.860	0.93	1.367	0.970	0.86-1.37
Calcium, %	0.867	0.573	0.453	0.65	0.943	0.803	0.45-0.94
Phosphorus,%	0.497	0.27	0.183	0.36	0.593	0.437	0.18-0.59
Magnesium,%	0.407	0.233	0.173	0.28	0.457	0.350	0.17-0.46
Iron, mg/kg	131	116	114	119	135	124	114-136
Manganese,mg	72	52	45	56	86	64	45-86
Copper, mg/kg	17	13	12	14	20	15	12-20
Zinc, mg/kg	103	74	69	85	114	95	69-114

Source: Ihedioha & Okoye ,(2011)

In conclusion, the poor management of solid waste and landfills leads to a lot of hygienic threats endangering both human and other life species within the environment, the production and emissions greenhouse gases from organic portion of municipal solid waste such as kitchen waste is a contribution factor for global warming, water leaching from landfills polluting both surface and groundwater with even heavy metals and other poisons. It is therefore, important to consider composting the organic portion of municipal solid waste to mitigate the various challenges and also, enjoy the numinous benefits of the compost to protect the environment, boost agricultural life towards the improvement of socio-economic and sustainable developments. Since leguminous plant used for replenishing soil nutrients and its seeds are of high protein, it was hypothesized in the current study that combining the velvet beans (*mucuna pruriens*) with kitchen wastes in co-compost could produce rich composts to serve as soil conditioner for crop plant growth. The mixing ratios and the turning frequency for producing the composts were key parameters noted to establish which mixing ratio and turning frequency facilitated the production of quality composts for the recommendation for industrial and sector-specific practices.

CONCEPTUAL FRAMEWORK

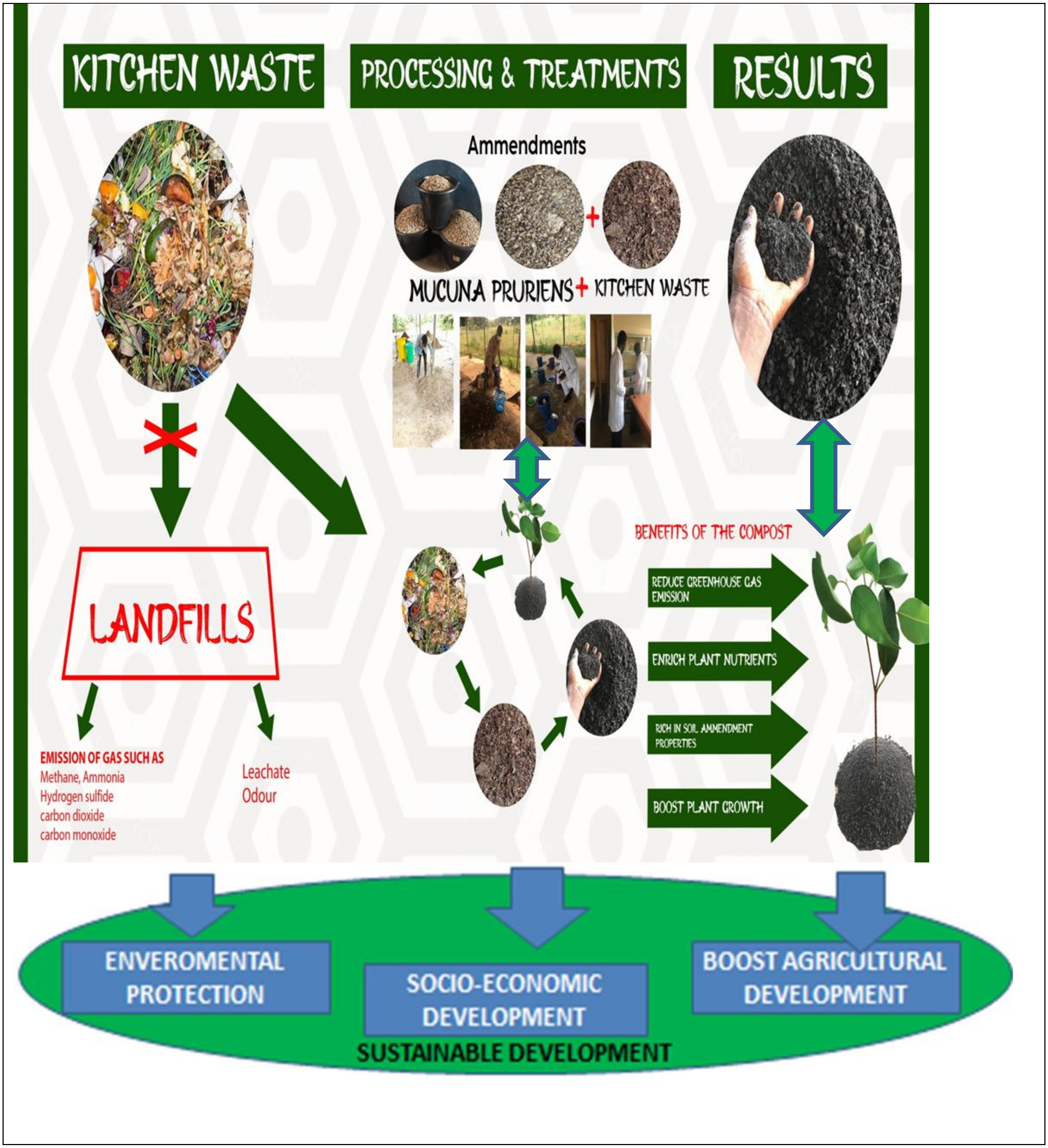


Figure 2.1 Conceptual Framework

CHAPTER THREE

MATERIALS AND METHODS

3.1 Study Area

3.1.1 Location of the Study Area

The University of Skill Training and Entrepreneurial Development (AAMUSTED) Mampong campus was the place of study. The composting site where the study took place is located at the Mampong-Ashanti campus of AAMUSTED. Mampong-Ashanti is 57.6 km of Kumasi on the latitude 1.024 west of the equator and it is 457.5 m above sea level. It is bounded to the South by Sekyere south district, to the east by Sekyere Central, and to the North by Ejura Sekye Dumasi districts. Ashanti Mampong is the capital of the Mampong-Ashanti Municipality which covers a land in area of about 23.9 km^2(Ghana Statistical Service) (GSS, 2014).

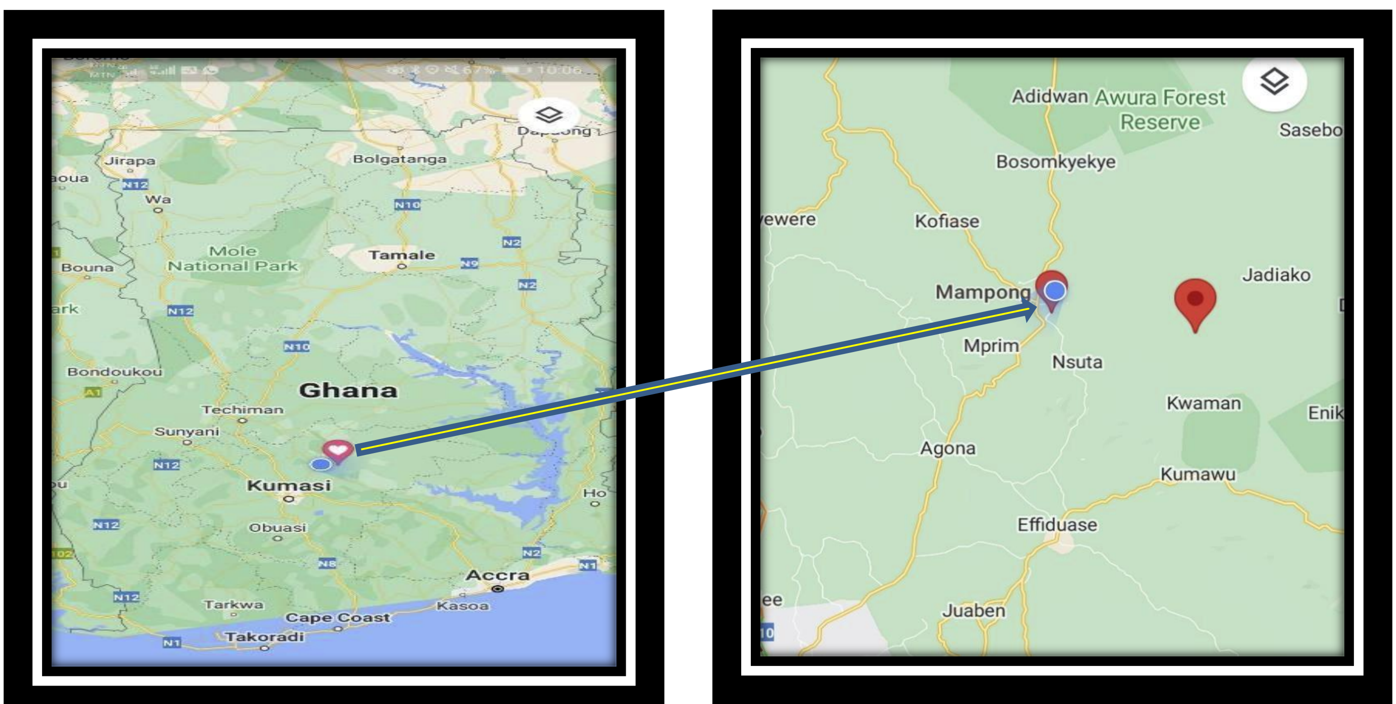


Figure 3.1 showing map of Mampong-Ashanti

3.1.2 Climate of the study area

Mampong-Ashanti has a bimodal rainfall pattern with annual rainfall between 1094.4 mm and 1200 mm and monthly mean rainfall of about 91.2 mm. The major rainy season occurs from March to July while the minor rainy season occurs from September to November (Ghana Meteorological Department, 2008). Between the two seasons is a short drought spell in August (Meteorological Services Department, Ghana, 2005). The daily temperature ranges around 29°C during the day and 21°C in the night (Mampong Meteorological Station, 2008).

3.1.3 Demography of the study area

Mampong is the largest town in the Mampong Municipal of Ashanti and serves as the administrative capital of Mampong Municipal. The municipality has a population of 116,632 people according to the year 2021 population census. One important characteristic of the Municipality is its ethnic diversity. Each group has a unique culture in terms of building styles, physical appearances, and the type of food. The people engage in the tuber, cereal, vegetable such as carrot and leguminous crops production (GSS, 2014).

3.2.0 Data Collection

The materials for the co-compost were kitchen waste and *Mucuna pruriens*. The kitchen waste materials were collected from Mampong township and the schools within the town whiles the *Mucuna pruriens* were bought from local farmers in Mampong and the AAMUSTED Mampong campus farm.

3.2.1 Composting experiment design

Aerated in-vessel composting method was used to compost the degradable portion of kitchen waste (Gill *et al.*, 2020). In-vessel aerated composting technique was used for the experiment where four different baskets were setup in triplicate on the composting site, using a bench scale. A Completely Randomized Design (CRD) was used to determine the interaction between mixing levels, moistening, and turning frequencies of the compost (Zhu *et al.*, 2019; Nkodi et al., 2020). The CRD was made up of a mixing composition of kitchen waste material and *Mucuna pruriens* seed labelled (C, T1, T2, T3) with three replicates as shown in (Figure 3.1)

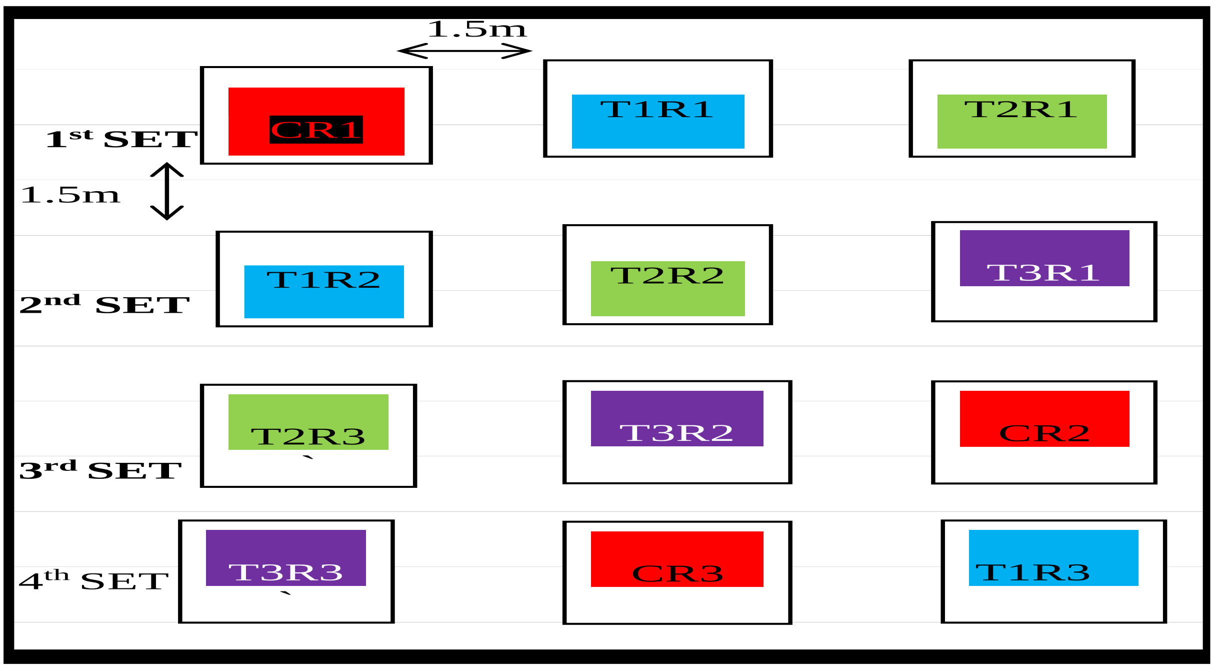


Figure 3.2 The composting experiment in a Completely Randomized Designed (CRD)

1ST SET (CR1, T1R1, T2R1)

2ND SET (T1R2, T2R2, T3R1)

3RD SET (T2R3, T3R2, CR2)

4TH SET (T3R3, CR3, T1R3)

(Where C is the control, T means treatment of the mixing composition of *Mucuna pruriens* and kitchen waste whereas R stands for the replicates).

The experiment was set up using four (4) different coloured and labelled polystyrene compost baskets of (length × width × height= 480 × 390 × 310mm) shown in (plate 3.1). The compost baskets were well aerated to enable free passage of oxygen and also well enclosed to keep the compost materials together to build up the required temperature for microbial activities (Cautereels & Vanderlinden, 2017). The experiment used kitchen waste material as a control for the composting and three other mixing compositions in triplicate. In total 12 setups were raised which were then subjected to seven day turning frequency and water was sprinkled on the composting materials frequently to ensure moisture in the compost materials. Samples at the time (T=0 before treatment, T=28 days & T=56 days) were taken for laboratory analysis, then the best mixing ratio in terms of physicochemical, biological, and nutrition availability in compost was subjected to different turning frequencies (that is turn every (3) three days, (5) every five days and every (7) seven). The replicates were needed so that the extraneous factors affecting the composting treatment processes such as the air circulation, sunlight, and other environmental conditions were fairly distributed, thus any minor error was taken care of by the replicates so that any significant difference between conditions was attributed to the independent variables.

Plate 3.1 Experimental set-up using different coloured composts baskets

3.2.2 Composite Treatment and composting process

The composition of the co-compost was kitchen waste materials that were collected from Mampong Township and the schools within the town, the *Mucuna pruriens* were bought from local farmers in Mampong and the AAMUSTED Mampong campus farm. About 200kg of both samples were transported to the composting site. Proximate analysis was done on both the kitchen waste and the *Mucuna pruriens* seeds to determine their physicochemical properties.

3.2.3 Shredding

The materials of the kitchen waste such as peels of cassava, yam, plantain, and banana were chopped into smaller pieces with a machete about 20 mm in diameter (Lin *et al.*, 2021).

. The seeds of the *Mucuna pruriens* were broken to the size of 2mm to 3mm in diameter using a milling machine (plate 3.2). This was to increase the surface area available for microbial action, provided better aeration, and sped up the decomposition process (Wang *et al.*, 2015 & Schneider, 2019).

A = ***Mucuna pruiens s*****eeds** → B = 1-3mm

Plate 3. 2 The seeds of *Mucuna pruriens* (A) and the shredded sizes of the *Mucuna pruriens* seeds (B).

3.2.4 Phase 1: Mixing ratio

The key feature that influenced the compost quality was the mixing ratio using kitchen waste and *Mucuna pruriens*. The mixing ratio was the mixture of kitchen waste and *Mucuna pruriens* by the weight of their dry matter. The kitchen waste was the control (100% of kitchen waste), 70% kitchen waste to 30% *Mucuna pruriens* (T1), 60% kitchen waste to 40% *Mucuna pruriens* (T2), 50% of kitchen waste to 50% of *Mucuna pruriens* (T3) (Table 3.2) (Long *et al.*, 2017; Nguyen *et al.*, 2020). A turning frequency of seven days' intervals was used to run the mixing ratios (Manu, et al, 2019).

Table 3.1 The table below shows the mixing ratio (%)

TREATMENTS	PILE A	PILE B	PILE C	PILE D
Mixing ratio (%)	3:0 (**100%KW**	3:1 **70%:30%** As in 3 part of KW to 1 part *MP*	3:2 **60%:40%** As in 3 part of KW to 2 part *MP*	3:3 **50%:50%** As in 3 part of KW to 3 part *MP*
Turning rate	Every seven (7) days (Manu, *et al*, 2019)			

Where: KW=Kitchen Waste
MP=*Mucuna Pruriens*

3.2.4 Phase 2: Turning frequency

To determine the turning rate that produced the quality compost, three (3) days, five (5) days and seven (7) days turning intervals were considered because it was observed in the first phase that after seven days the pile dried up and solidify because of the windy nature of the composting site (Nguyen *et al*., 2020). It was therefore decided that the turning interval should not go beyond seven (7) days.

Table 3.2 Turning rate of the co-compost

TYPE	TREATMENT 1	TREATMENT 2	TREATMENT 3
Mixing	3:2 60%:40% As in 3 part of KW to 2 part *MP*	3:2 60%:40% As in 3 part of KW to 2 part *MP*	3:2 60%:40% As in 3 part of KW to 2 part *MP*
Turning rate	**3-days**	**5 days**	**7 days**
References	Soto-Paz, *et al*, 2019)	Cai *et al*., 2007)	Manu, *et al*, 2019)

Where: KW=Kitchen Waste
MP=*Mucuna Pruriens*

3.2.5 Moisturizing

The moisture in the compost affected the microbial activities, thus the compost was watered to about 40-60 percent of compost volume before turning, following the turning sequence (Thomas *et al.,* 2020). About 2 litres of water was sprinkled on each setup to moisten the compost before turning based on the set day and time for turning to maintain its optimum moisture content for the first month. The volume of the water to moisten the pile kept reducing after the first month to the level of the pile size which was between 1-1.5 litres.

3.3 Composting Monitoring

3.3.1 Temperature measurement

The temperature was monitored and recorded daily until the compost became more stable (Hemidat *et al.,* 2018). The thermocouple thermometer was used for temperature measurement (plate 3.2).

Plate 3. 3 Recording temperature of the compost.

3.3.2 Maturity Determination

To determine the maturity stages, samples of compost were taken from each of the different compost treatments from both the mixing ratio phase and turning frequency phases. The sample was picked at the start of composting (time, t=0), the 28th day of composting (time, t=28), and the 56th day of composting (time, t=56). Composite samples were picked from each compost basket (bottom, centre and surface) and mixed in a sterilized container to get the composite which were kept within the temperature of 4 °C before taking to the laboratory for analysis (Harvey *et al*., 2019). The ratio of NH_4^+-N to NO_3^--N was used to determine the stability of the compost produced. Which was use when the C:N was comparatively low, a stable compost has a NH_4^+-N/NO_3^--N ratio of 0.16 which gives a sense of the compost maturity (Bazrafshan *et al.,* 2016).

3.3.3 Laboratory analyses

The laboratory analysis was done at Akenten Appiah-Menka University of Skills Training and Entrepreneurial Development (AAMUSTED) Mampong campus science laboratory and Kwame Nkrumah University of Science and Technology (KNUST) laboratory.

3.3.4 Physicochemical composition of *Mucuna pruriens* seeds and kitchen waste

A sample of both kitchen waste and *Mucuna pruriens* seeds were taken to the lab for physicochemical analysis. They were first dried up thoroughly. The pods were shelled to remove the seeds. The seeds were ground and sieved using wire meshed of 0.002 mm in size to a fine powder before taking to the laboratory for physicochemical analysis (Balogun & Olatidoye, 2012). Proximate analysis of both the kitchen waste and *Mucuna pruriens* seeds was done before the composting started. The following physicochemical parameters were determined; Electrical Conductivity (EC), Organic carbon (OC), Moisture content (MC), Nitrogen (N), Potassium (K), Phosphorus (P), pH, Temperature, and C/N ratio. The N% was determine using the Dry Ash method, P% was determined using the colorimetric method, the K% was determined using the flame photometric method, and the Walkley-black method was used to determine the OC% of the compost (Hunter *et al.,* 1984 & Benton Jones*, et al.,* 1990). pH was also determined using the pH meter and moisture content (%) was determined using standard testing methods 2540D and 2540E (APHA, 2017).

3.3.5 Determination of the nutritional availability in the compost

The available phosphorus content was determined using the Bray-1 method, which involves fluoride extraction for assessing available P (Bray and Kurtz, 1945). To prepare the extraction solution, 87 ml of concentrated HCl (sp. gr. 1.18, 36%) was measured and made up to 1000 ml in a volumetric flask. In this solution, 2.22 g of NH_4F and 5.0 ml of concentrated HCl were dissolved in deionized water, making it a 0.025 N HCl + 0.03 N NH_4F solutions, which was then made up to 2 L in a volumetric flask. For the ammonium molybdate solution, 37.652 g of ammonium molybdate ($(NH_4)\ O_{24}.H_2O$) was dissolved in about 245 ml of distilled water and heated to 60°C. After cooling, it was added to 781.5 ml of concentrated HCl and made up to the 1000 ml mark in a volumetric flask with deionized water. The solution was stored in a brown glass stoppered bottle containing 50 g of boric acid (H_3PO_3). The resulting solution had a concentration of 1.76 g per 100 ml of distilled water.

To prepare the stock standard of 2500 µg P/ml, 15 g of KH_2PO_4 (AR grade, M.W. = 136.09, 99.5%) was oven dried at 80°C for 2 hours. Then, 10.9825 g of the dried KH_2PO_4 was weighed out, dissolved, and made up to 1 litre with distilled water. From this stock solution, 25 ml was pipetted into a clean 250 ml volumetric flask and made up to volume using the Bray-1 extract. To determine the available potassium, ammonium acetate (1.0 N NH_4OAc)

was used as an extracting solution in the compost. To prepare this solution, 57 ml of glacial acetic acid was diluted to 800 ml with distilled water, and the pH was neutralized to 7.0 using concentrated NH_4OH. The solution was then made up to one litre in a volumetric flask. For the stock solution of 1000 ppm K, 1.907 g of KCl (dried at 105°C for 4 hours) was dissolved in about 200 ml of deionized water and made up to 1000 ml. This stock solution yielded a concentration of 100 ppm K. To extract the compost, 10 g of compost was measured in an extraction bottle, and 100 ml of 1.0 N NH_4OAc solution was added. The bottle was placed in a mechanical shaker and shaken for 2 hours. The supernatant solution was then filtered through No. 42 Whatman filter paper. A 10 ml aliquot of the filtered solution was read for K on a flame photometer after calibrating the instrument with prepared standards. By determining the flame photometer reading for the soil sample and using the meter reading standard curve, the concentration of K in the soil extract could be determined.

3.3.6 Biological analyses

Total coliform within the compost was determined using the Most Probable Number (MPN) technique. (Soobhany, 2018). It was done by preparing a Serial dilution of 10-1 to 10-4 by picking 1ml of the sample into 9ml sterile distilled water. 1ml aliquots from each of the dilutions were inoculated into 5ml of MacConkey Broth and incubated at 37°C for total coliforms for 18-24 hours. Tubes showing the colour change from purple to yellow after 24 hours were identified as positive for the total coliforms. Counts per 100ml were calculated from the MPN tables

3.3.7 Data Processing and Analysis

The data collected were analysed using the one-way analysis of variance (ANOVA) with the aid of Excel version 2019 embedded with the XLTS statistical application. The least significant difference was used to determine the significance of the variables. For quality and standard facts, the findings were compared with another source of information and the benchmark of compost.

CHAPTER FOUR

RESULTS

4.1 Proximate Analyses of Kitchen Waste and *Mucuna pruriens*

The proximate composition was determined for the dry seeds of *Mucuna pruriens* and the kitchen waste. The results indicated that the *Mucuna pruriens* contains a percentage moisture content (%MC) of 41.65, a percentage organic matter (%OM) of 90.59, a percentage organic carbon (%OC) of 24.21, a percentage total nitrogen (%N) of 4.203, a percentage phosphorous (%P) 0.733 and percentage potassium (% K) as 1.376. It also had pH 5.7 and electrical conductivities (EC) of 3040 dS/m. The kitchen waste was noted to contain percentage moisture content (%MC) of 92.4, a percentage of organic matter (%OM) of 95.66, and percentage of organic carbon (%OC) of 55.62. percentage total nitrogen (%N) of 1.751, percentage phosphorous (%P) of 0.598, and percentage potassium (% K) of 2.053. It also had pH of 7.5, and 4970 dS/m electrical conductivities.

The characteristics of kitchen waste and the seeds of *Mucuna pruriens* showed that the kitchen waste had a high organic matter. The *Mucuna pruriens* seeds were found to contain comparatively high nitrogen. *Mucuna pruriens* had low pH as compared to kitchen waste (Table 4.1).

Table 4. 1 Proximate composition of kitchen waste and *Mucuna pruriens* seeds

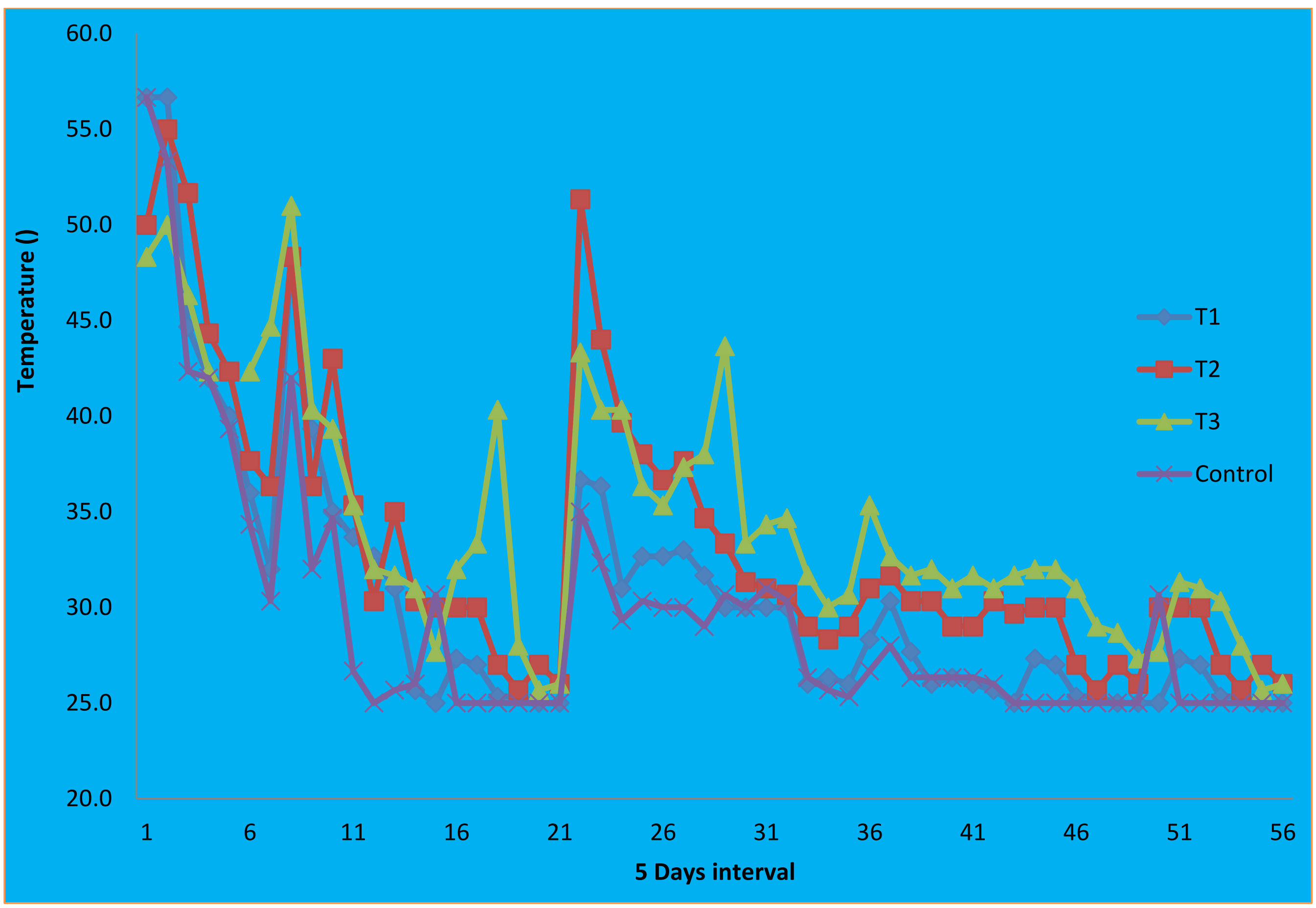
RAW SAMPLE	MC	OM	OC	% N	% P	% K	pH	EC
Kitchen Waste	92.42	95.66	55.62	1.751	0.598	2.053	7.5	4970
Mucuna pruriens	41.65	90.59	24.21	4.203	0.733	1.376	5.7	3040

(Source: field experiment, 2023).

4.2.0 Mixing Ratio

4.2.1 Temperature

The Temperature for T1 ranged between 25.0 ℃ to 56.7℃, T2 ranged from 25.7℃ to 55.0℃, and T3 ranged from 25.7℃ to 51.0℃ from day 1 to 56th day of the composting (Figure 4.1). The pile started heating up after the first day but reached its maximum temperature within the first week of the treatment. The temperature started dropping after the third week except for T2 which showed some inconsistency as shown in (Figure 4.1) where (T=Treatment & C=Control). The temperature was therefore consistent throughout all the treatments during the seventh week and beyond of composting processes.



(Source: field experiment, 2023), Fig. 4. 1 Mean daily temperature for the treatments.

4.2.0 Physicochemical properties of mixing ratios

4.2.1 pH

At the start of the composting, pH was weakly acidic for T1, T2, and T3 but alkaline for the control treatment (Table 4.2). Between day 28 to day 56, PH remained weakly alkaline (PH>7) with no correlation between T1, and T2 (Table 4.3).

4.2.2 Electrical conductivity (EC)

Electrical conductivity (EC) measures the ions and salts in the compost. The EC was greater than 7.0 dS/m for T1, T2, and T3 at t=0 (Table 4.2). The EC generally decreased from t=0 to t=56 in all the treatments. The treatments,T1 (5.81± 1.14 dS/m), T2 (4.64±2.47 dS/m) and T3 (5.16±0.53 dS/m) with significant relationship among all treatments (r^2>0.50) (Table 4.2).

4.2.3. Moisture Content (MC) and Organic Matter (OM) of *Mucuna pruriens* and kitchen waste co-compost

The percentage of moisture content and the percentage of organic matter content were noted at time zero (0), 28, and 56 days of the composting processes for the four treatments. The treatments had the mixing ratio of T1- 30:70, T2- 40:60, T3-50:50 and C-0:100 (T means treatment whiles C means control which was only kitchen waste. The treatment was a mixture of *Mucuna pruriens* seeds and kitchen wastes concerning the mixing ratio with weekly turning rate. The MC at time zero was 36.08%, 36.10%, 36.50%, and 36.17% for T1, T2, T3, and control respectively (Table 4.2). There was an increase in MC for all the treatments from the experiment to day 28 (Table 4.2).

At the end day 56, a further increase in MC was observed. These were 59.64±2.95 %, 65.85±0.68%, 65.47±1.94%, and 61.63±4.66% for control, T1, T2, and T3 at day 28 respectively, and 65.18±1.07%, 55.89±24.13%, 68.61±4.88% and 66.19±1.04% for control, T1, T2, and T3 respectively at day 56 but a slight decline in T1 from day 28 to day 56.

The percentage of organic matter (OM) at the start (t=0), %OM was 50.99%, 50.50%, 50.70%,37.33% for T1, T2, T3 and control respectively. This increased to 58.60±2.43 %, 69.51±2.68%, 76.38±1.69%, and 52.14±2.18 for T1, T2, T3, and control respectively at day 28, but declined at the end of the experiment (56 days) in all the treatments as follows: 52.43±4.58%, 59.34±2.10%, 62.40±3.18% and 48.14±5.82% indicating about 10.5%, 14.63%, 18.30%,7.67% decline from day 28 to day 56 of the composting processes for T1, T2, T3, and control respectively (Table 4.2).

4.2.5. Phosphorus (P) and potassium (K)

Phosphorus and potassium are very important to determine the quality of composts for soil nutrient improvement and amendment. There was an increase in the %P from the start of the composting to the end of composting (day 56) for T1, T2, and T3 but all treatments were less than <2% (Table 4.2). There was increase in %K from time (t=0) to t=56 days) for T1, T2, and T3 but below 3% for all treatments (Table 4.2). There was no relationship between T1, T2, and T3 sampled on 28^{th} day and T1, T2, and T3 sampled on 56^{th} day for %P (p=0.05).

Table 4.2 Mean physicochemical properties at day 0, 28 and day 56 for the various treatment

Period	Treatments	% MC	% OM	% OC	% N	% P	% K	pH	EC (ds/m)
0	Control	36.17±2.43^{a}	37.33±0.98^{d}	21.70±1.26^{c}	1.82±0.09^{a}	0.26. ±0.32^{a}	1.59 ±0.45^{c}	9.20 ±0.27^{a}	5.95. ±0.17^{a}
	T1	36.08±2.95^{c}	50.99±2.43^{a}	29.65±1.26^{c}	2.10±0.20^{d}	0.30. ±0.17^{c}	1.59 ±0.27^{b}	6.30.±2.25^{c}	7.04. ±0.16^{a}
	T2	36.10±0.27^{d}	50.50±4.58^{b,c}	30.35±0.98^{d}	2.50. ±0.17^{c}	0.36. ±0.47^{e}	1.40. ±0.17^{c}	6.60 ±0.15^{c}	7.07. ±01.17^{c}
	T3	36.50±1.22^{d}	50.70±2.43^{a}	32.50±0.09^{d}	2.5±0.09^{d}	0.30. ±0.17^{c}	1.45 ±0.56^{c}	6.35 ±0.16^{c}	7.07. ±0.57^{d}
28th DAY	Control	59.64±2.95^{c}	52.14±2.18^{c}	30.32±1.26^{c}	1.96±0.24c	0.55±0.03^{c}	2.47±0.07^{c}	8.16.±0.17^{c}	7.12. ±0.17^{c}
	T1	65.85±0.68^{a}	58.60±2.43^{a}	34.08±1.42^{a}	2.52±0.28^{a}	0.66±0.18^{a}	2.09±0.17^{a}	8.13±0.15^{a}	5.81±1.14^{a}
	T2	65.47±1.94^{b}	69.51±2.68^{b}	40.41±1.56^{b}	3.18±0.08^{b}	0.59±0.18^{b}	2.09±0.17^{b}	7.5±0.1^{b}	4.64±2.47^{c}
	T3	61.63±4.66^{d}	76.377±1.69^{d}	44.40±0.98^{d}	3.18±0.09^{d}	0.58±0.08^{d}	2.20±0.13^{d}	7.13±0.06^{d}	5.16±0.53^{d}
	CV (%)	3.77	3.33	3.33	3.18±0.10	24.04	7.37	1.36	26.52
56th DAY	Control	65.18±1.07^{c}	48.143±5.82^{c}	27.99±3.39^{c}	1.96±0.11^{c}	1.00±0.1^{4b,c}	2.39±0.41^{c}	8.57±0.06^{c}	7.13±0.067^{c}
	T1	55.89±24.13^{a}	52.43±4.58^{b,c}	30.48±2.67^{c}	3.18±0.12^{c}	1.43±0.02^{c}	2.32±0.07^{c}	8.56±0.29^{c}	6.85±0.91^{c}
	T2	68.61±4.88^{d}	59.34±2.10^{d}	34.50±1.22^{d}	3.18±0.13^{d}	1.16±0.27^{d}	2.62±0.20^{d}	8.27±0.15^{d}	5.62±0.41^{e}
	T3	66.19±1.04^{a}	62.40±3.18^{b}	36.28±1.85^{b}	3.18±0.14^{b}	1.76±0.11^{c,b}	2.88±0.17^{b}	7.87±0.06^{b}	5.83±0.57^{b}
	CV (%)	17.29	5.79	5.80	3.18±0.15	10.37	5.42	2.22	10.09

(Source: field experiment, 2023).

The mean values in Colum's with different letters are not significant at p=0.05 in a column-by-column analysis of the physicochemical properties of the various treatments for the compost from day 0 to day 56 of the composting processes. T1, T2, and T3 represent treatment 1, treatment 2, and treatment 3 respectively. CV is the covariance.

4 .2.5. Organic Carbon and Nitrogen of the composting

The organic carbon (OC) and nitrogen (N) were determined during the composting processes. The percentage OC at t=0 was 29.65%, 30.35%, 32.50%, and 21.70% for T1, T2, T3, and control respectively. After 28 days of composting, the increment was recorded in the %OC in the T1 (34.08±1.42%), T2 (40.41±1.56%), T3 (44.40±0.98%), and C (30.32±1.26%). By day 56 of the composting processes, the %OC dwindled as follows: T1 (30.48±2.67%), T2 (34.50±1.22%), T3 (36.28±1.85%) and C (27.99±3.39%). A similar trend of results was observed for %N. At the start of the composting processes %N was T1 (2.10%), T2 (2.50%), T3 (2.55%), and C (1.82%) increasing to T1 (2.52±0.28%), T2 (3.18±0.08%), T3 (3.18±0.09%) and C (1.96±0.24%) by the 28th day of composting (Table 4.3). The %N from day 28 to day 56 is as follows: T1 (3.18±0.12%), T2 (3.18±0.13%), T3 (3.18±0.14%), and C (1.96±0.11%) depicting slight increment in T1 and no change in T2 and T3 (Table 4.2).

Table 4.3. C: N ratio for treatments

Treatments	%OC			%N			C: N Ratio		
	(days)			(days)			(days)		
	0	28	56	0	28	56	0	28	56
T1	29.65	34.08	30.48	2.10	2.52	3.18	14.11	13.52	9.58
T2	30.35	40.41	34.5	2.50	3.18	3.18	12.14	12.71	10.85
T3	32.50	44.4	36.28	2.55	3.18	3.18	12.75	13.96	11.41

(Source: field experiment, 2023).

4.3.1 Nutritional characteristics of the mixing ratios

The assessment of the nutrients of the kitchen wastes and *Mucuna pruriens* for the compost presented nutritional values in terms of NO_3^--N, NH_4^+-N, K, and P measured in mg/kg (Table 4.5). T3 had the highest value of NO_3^--N (4116.33±188.22 mg/kg) compared to T1

(2925±325mg/kg) and T2 (3683±93.53mg/kg) after the 28 days of composting (Table 4.5). There was a significant difference between T1 and T2 in terms of NO_3^--N ($p<0.05$) but T2 and T3 were not significantly different ($p>0.05$). The NO_3^--N, NH_4^+-N, saw an increase from the beginning of the composting to day 28 for T1, T2, and T3 (Table 4.5). The NH_4^+-N among the three treatments were significantly different ($p<0.05$). However, K and P decreased from t=0 days to t=28 days in T1 (4245mg/kg), T2 (4686mg/kg), T3 (4518mg/kg) for K at t=0 days to T1 (4184.67±350.68mg/kg), T2 (4556.67±450.00mg/kg), T3 (4407.33±260.96mg/kg) at t=28 days and T1 (310.3mg/kg), T2 (321.90mg/kg), T3 (505.10mg/kg) to T1(291.17±98.03mg/kg), T2 (274.54±74.64mg/kg) and T3 (238.92±31.87mg/kg) for t=0 days to t=28 days respectively for P but slightly increased to the end at t=56 (Table 4.5).

Similar nutrient analyses after 56 days showed that T2 remained the same between t=28 days to t=56 days for NO_3^--N, NH_4^+-N, and K whiles phosphorus remained the same (T2=274.54±74.64mg/kg) from the start of composting to the end (t=56 days) for T2 (Table 4.5). T1 increased for NO_3^--N, NH_4^+-N, K, and P by day 56 of composting (Table 4.5). The NO_3^--N and NH_4^+-N between t=28 days and t=56 days also increase as well as K and P increased for T3 (Table 4.5).

Table 4.4 Nutrient analyses of the Kitchen wastes and *Mucuna pruriens* co-compost before (T=0) during treatment (T=28) and after (T=56) days of composting

Treatments Day 0	NO_3^--N (mg/kg)	NH_4^+-N (mg/kg)	Potassium (K) (mg/kg)	Phosphorus (P) (mg/kg)
C-100	2464±201.50a	3024±418.50b	4505±118.30a	185.5±318.10c
T1-30%:70%	2022±216.51b	1845±210.40c	4245±218.50b	310.2±418.50b
T2-40%:60%	2380±513.00a	2076±418.50b	4686±518.10c	321.9±218.20a
T3-50%:50%	1797±318.50a	1476±218.00a	4518±318.50a	505.1±218.50a
		Day 28		
T1	2925±325a	1966.67±218.50a	4184.67±350.68a	291.17±98.03a
T2	3683±93.53a	2476.33±63.51a	4556.67±450.00b	274.54±74.64b
T3	4116.33±188.22b	2804.33±167.05a	4407.33±260.96a	238.92±31.87a
Control	2275±282.32	1529.67±189.37	4934.67±130.48	223.29±11.61
CV (%)	15.58	16.22	8.06	25.24
P (0.05)	0.00	0.00	0.49	0.69
LSD	446.44	325.60	723.65	146.80
Absolute mean T1, T2	758.00	509.67	372.00	16.62
Absolute mean T2, T3	433.33	328.00	149.33	35.63
		DAY 56		
T1	2708.33±845.56b	1820.67±568.70c	4633.33±130.48a	594.75±10.07a
T2	3683±93.53b	2476.33±63.51c	4556.67±450.00b	274.54±74.64b
T3	4469±0.00a	3096±157.62a	5821±444.16c	730.94±45.18b
Control	2437.33±703.79	1638.33±473.43	4783.33±814.02	582.84±289.45
CV (%)	26.75	25.28	11.41	20.57
P (0.05)	0.02	0.01	0.06	0.01
LSD	1281.66	698.32	698.44	139.83
Absolute mean T1, T2	1967	482.00	601.33	113.04
Absolute mean T2, T3	1741	793.33	586.33	249.23

(Source: field experiment, 2023).

The significant difference when LSD<abs mean between treatments. The same letters between mean treatments in a column are significantly different at p=0.05. LSD =Least Significance Difference

4.4 Estimation of Optimum Mixing Ratios for the Co-composting

Analyses of variance and correlation were used to determine the performance of the mixing ratios for the composting. The mixing ratios were 30:70 for T1, 40:60 for T2, and 50:50 for T3. From (Table 4.6), there was a strong correlation between T1 (30:70) and T2 (40:60) for %MC, %N, %P, %K, total coliforms, pH, and EC. There was a strong correlation between T2 (40:60) and T3 (50:50) for %MC, %OM, %OC, total coliforms, and EC (Table 4.2). Between T1(30:70) and T3 (50:50), there was a strong correlation between the two mixing ratios in terms of %OM, %OC, %N, total coliforms, pH, and EC. For the nutrients, T1 (30:70) and T2 (40:60) correlated strongly for NH_4^+-N, K, and P (Table 4.5). The mixing ratio, T1 (30:70) and T3 (50:50) correlated strongly for only NH_4^+-N and the ratio T2 (40:60) and T3 (50:50) correlated strongly for only NO_3^--N (Table 4.6). The analyses of variance and correlation between the mixing ratios in terms of the physicochemical, microbial, and nutritional values in the results above indicated that the mixing, irrespective of the ratio produced the same/similar results.

However, the mixing ratio 40:60 of *Mucuna pruriens* and kitchen waste was considered for the turning frequencies since the analysis variance above shows no significant difference meaning any of the mixing ratios will produce similar results for both the physicochemical and nutritional values (Table 4.2).

It was also advantageous to consider mixing a ratio of 40% *Mucuna pruriens* to 60% of kitchen waste because it seems to have increased the nutritional composition slightly above the other treatments, especially in nitrate (NO3-N) and potassium (K) at the end of the treatment whiles ((NH4-N) decreases these nutrients are readily available to plant on application (Table 4.5). Therefore, this was used for the turning frequencies in phase two.

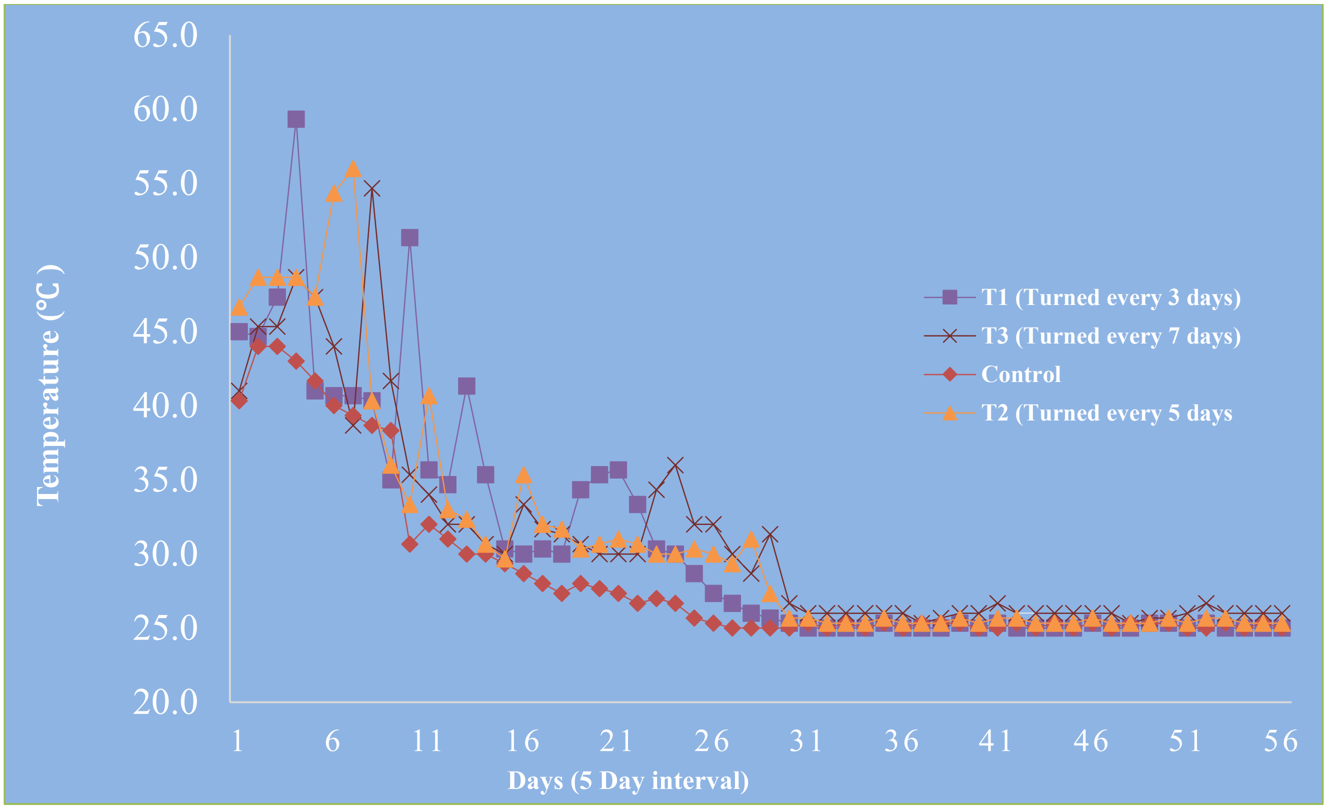
Mixing ratio	NO_3^--N	NH_4^+-N	Potassium (K)	Phosphorus (P)
T1 (30:70)				
T2 (40:60)	0.00	0.50	-1.00	0.85
T3 (50:50)	0.00	-0.69	-0.26	-0.20
T2 (40:60)				
T3 (50:50)	0.98	0.28	0.26	0.34

(Source: field experiment, 2023).

4.4.0 Impact of Different Turning Frequency on Compost Quality

4.4.1 Temperature

The Temperature for the turning frequencies was monitored daily for all the treatments from the beginning to the end of the treatment. T1 recorded 45℃ a day after composting reached maximum temperature on the 4th day, T2 recorded 46℃ from the beginning, T3 recorded 42℃ from day 1 and C recorded 41℃ after day 1 of the composting. The pile reached maximum temperature on the fourth day of the treatment with the following range T1-60℃, T2- 50℃, T3- 50℃, and C-43℃, The temperature dropping after the third week and was consistent with all the treatments from that period to the end of the composting process, recording 25℃ as the minimum temperature for all the treatment (figure 4.3).



(Source: field experiment, 2023).

Figure 4.2: Daily temperature of the turning frequencies.

4.42. Effect of the Turning Frequencies on the physicochemical properties

Within the 56 days of the composting period, each of the treatments was turned at a different turning rate. T1 was turned every (3) three days, T2 was turned every (5) days and T3 was turned every (7) days.

The turning impacted significantly the physicochemical properties of the compost ($p<0.05$) for %MC, %OM, %OC, %P, %K, pH, and EC for T1-T3 from day 28 to day 56 of the processes (Table 4.8). From day 0-28, the physicochemical properties increased due to the turning rate. However, from day 28 to day 56, the %MC, %OM, and %OC remained unchanged (Table 4.8). There was increment in %N, %P, and %K for T1, T2, and T3 but decrease in pH and EC for the treatments (Table 4.8). The turning rates did not have a significant impact on the compost nutritional composition but on the compost quality at the end of the treatment ($p>0.05$).

The turning further reduced the C: N ratio from 14.11 to 7.96 for T1 turned every 3 days, 7.06 for T2 turned every 5 days, and 6.96 for T3 turned every 7 days as shown in (Table 4.9).

Table 4.6 Impact of turning frequencies on compost quality

Treatments	Physicochemical properties from day 0- 28-56 days of composting								
	Day Zero								
Treatments		**% MC**	**% OM**	**% OC**	**(%) N**	**(%) P**	**(%) K**	**pH**	**E C (dS/m)**
C-100% Kw		36.17±0.55	37.33±3.05	21.70±1.12	1.82±0.10	0.26±0.05	1.59±0.12	9.20±0.12	5.93±132.05
T-60%:40% (Kw+Mp)		36.50±0.30	50.70±5.55	32.50±6.05	2.55±0.36	0.30±0.07	1.45±0.14	6.35±0.30	7.08±333.05
	Within 28 Days								
T1	3	54.96±5.55	44.76±6.52	26.02±3.79	3.5±0.64	0.7±0.08	2.29±0.14	8.4±0.10	6553.33±85.05
T2	5	68.38±0.29	48.23±1.69	28.04±0.98	3.50±0.14	0.75±0.06	2.55±0.17	7.6±0.20	7346.67±362.26
T3	7	56±10.88	44.3±40.62	25.75±23.61	2.85±0.32	0.78±0.05	2.57±0.09	7.33±0.15	7263.33±126.62
C		44.60±0.35	34.53±2.30	20.08±0.55	1.54±0.01	0.58±0.05	3.12±0.08	8.60±0.13	3950.00±122.15
Min (T1-T3)		46.94	3.66	2.13	2.66	0.63	2.16	7.20	6490.00
Max (T1-T3)		68.65	84.89	49.35	4.20	0.85	2.72	8.50	7660.00
	Within 56 days								
T1	3	54.96±5.55	44.76±6.52	26.02±3.79	3.27±0.93	0.68±0.12	2.44±0.20	7.97±0.25	4910±295.13
T2	5	68.38±0.29	48.23±1.69	28.04±0.98	3.97±1.18	0.72±0.11	2.44±0.20	7.17±0.15	5116.67±133.17
T3	7	56±10.88	44.3±40.62	25.75±23.61	3.70±1.16	0.71±0.20	2.53±0.03	7.3±0.36	5326.67±395.01
C		47.05±0.20	37.29±0.20	21.68±0.40	1.82±0.11	0.55±0.10	2.61±0.05	6.90±0.15	5100.00±400.05
Min (T1-T3)		46.94	3.66	2.13	0.48	2.21	2.21	8.40	4620.00
Max (T1-T3)		68.65	84.89	49.35	0.86	2.66	2.66	8.20	5720.00
CV(%)		14.43	43.82	43.81	22.62	14.41	6.52	6.31	17.42
P (0.05)		0.03	0.00	0.00	0.00	0.00	0.00	0.00	
P (0.05) @ t=0-28-56 days		0.03	0.00	0.00	0.00	0.00	0.00		0.00

(Source: field experiment, 2023).

The significant difference when LSD<abs mean between treatments, significantly different at p=0.05. LSD =Least Significance Difference **(**Mp= Mucuna pruriens, Kw=Kitchen waste)

Table 4.7: C: N ratio for the treatments when compost is turned every 3,5 and 7 days

Treatments/Turned	%OC (days)			%N (days)			C: N Ratio (days)		
	0	**28**	**56**	**0**	**28**	**56**	**0**	**28**	**56**
T1-3 Days	29.65	26.02	26.02	2.10	3.5	3.27	14.11	7.43	7.96
T2-5Days	30.35	28.04	28.04	2.5	3.5	3.97	12.14	8.011	7.06
T3-7Days	32.5	25.75	25.75	2.55	2.85	3.7	12.75	9.04	6.96

4.4.3 Turning Frequency and microbial content

From the start of the composting, it was determined that the total coliforms were higher in numbers, (8.53E+01) for control and (7.70E+01) for T1, T2, and T3. Comparatively, there was much decline in total coliforms at the end of the composting period (56 days) which meant that although turning allows aeration and enhances microbial activities, at the maturation and stabilization stage this is expected. The total coliforms decreased from T2 (3.27E+08cfu/100ml) to (2.93E+07cfu/100ml) and T3 (2.56E+08cfu/100ml) to (1.25E+08 cfu/100ml) but unchanged for T1 (5.03E+08cfu/100ml) of day 28 sampling and day 56 sampling respectively (table 4.10).

Table 4.8 Total coliforms in the composting treatments within the 28th days and 56th day of the composting processes. C represents control

Day zero		**28 days**		**Microbial**	**56 days**		
Mixing ratio		**Turning Frequency**	**Treatment**	**Tot Coliform (cfu/100ml)**	**Treatment**	**Turning Frequency**	**Total Coliform (cfu/100ml)**
60:40	7.70E+01 (cfu/100ml	3days	T1	5.03E+08	3	T1	5.03E+08
		5days	T2	3.27E+08	5	T2	2.93E+07
		7days	T3	2.56E+08	7	T3	1.25E+08
Control	8.53E+01 (cfu/100ml)		C	4.30E+08		C	5.10E+08

4.6 Influences of Turning Frequency on the Nutritional Characteristics

There was a nutrient improvement in the compost for all the turning frequencies. For T1 turned every 3 days there was a decrease in NO_3^--N, NH_4^+-N, and phosphorus (P) while K increased. T2 which was turned every 5 days also improved each nutrient above the 3 days turned interval. T3 was turned every week (7 days) and increased in the nutrient concentration of NO_3^{-}N, K but NH_4^+-N and P concentration were reduced. From day one to the end on the 56th day of composting, the NO_3^--N, NH_4^+-N, K, and P increased in nutrient concentration for *Mucuna pruriens* and kitchen waste co-compost as compared to the control (Table 4.11).

Table 4.9 Effects of turning rate on the nutrients

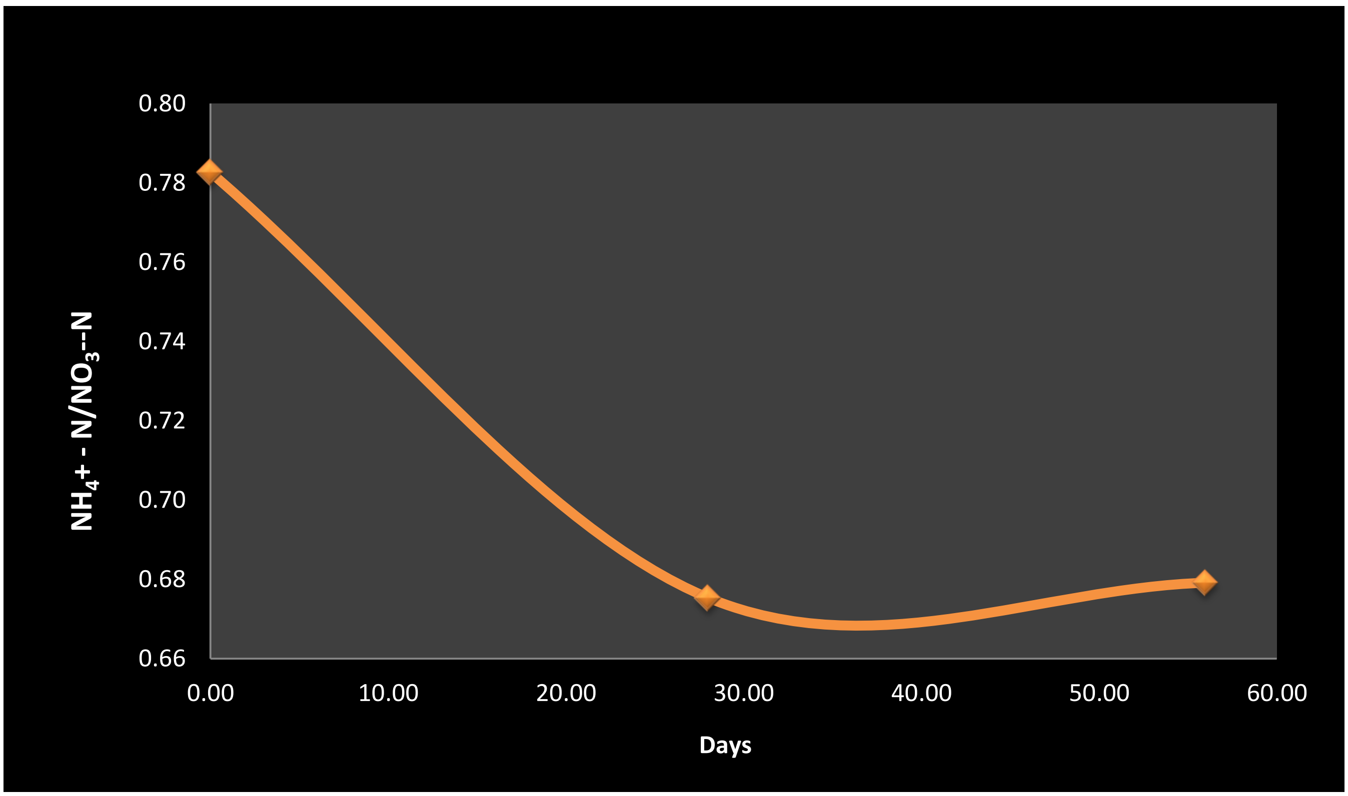
Treatments Day 0	[redacted] (mg/kg)	[redacted] (mg/kg)	Potassium (K)	Phosphorus (P)(mg/kg)
C-100 kitchen waste	2464±201.50a	3024±418.50b	4505±118.30a	185.5±318.10c
T-60%:40%	2380±513.00a	2076±418.50b	4686±518.10c	321.9±218.20a
		Day 28		
T1	2925±325a	1966.67±218.50a	4184.67±350.68a	291.17±98.03a
T2	3683±93.53a	2476.33±63.51a	4556.67±450.00b	274.54±74.64b
T3	4116.33±188.22b	2804.33±167.05a	4407.33±260.96a	238.92±31.87a
Control	2275±282.32	1529.67±189.37	4934.67±130.48	223.29±11.61
CV (%)	15.58	16.22	8.06	25.24
P (0.05)	0.00	0.00	0.49	0.69
LSD	446.44	325.60	723.65	146.80
Absolute mean T1, T2	758.00	509.67	372.00	16.62
Absolute mean T2, T3	433.33	328.00	149.33	35.63
		DAY 56		
T1	2708.33±845.56b	1820.67±568.70c	4633.33±130.48a	594.75±10.07a
T2	3683±93.53b	2476.33±63.51c	4556.67±450.00b	274.54±74.64b
T3	4469±0.00a	3096±157.62a	5821±444.16c	730.94±45.18b
Control	2437.33±703.79	1638.33±473.43	4783.33±814.02	582.84±289.45
CV (%)	26.75	25.28	11.41	20.57
P (0.05)	0.02	0.01	0.06	0.01
LSD	1281.66	698.32	698.44	139.83
Absolute mean T1, T2	1967	482.00	601.33	113.04
Absolute mean T2, T3	1741	793.33	586.33	249.23

(Source: field experiment, 2023). The significant difference when LSD<abs mean between treatments, significantly different at p=0.05. LSD =Least Significance Difference.

4.8 Determination of compost stability

There are several indicators for compost maturity. In this study, temperature was one of the indicators used. The temperature dropped and became stable within the fifth and sixth week and was consistent with all the treatments from that period to the end of the composting process, recording 25℃ as the minimum temperature for all the treatment (figure 4.2).

The ratio of NH_4^+-N to NO_3^--N was also used to determine the stability of the compost produced. The study showed that the ratio of NH_4^+-N/NO_3^--N at the end of the composting (day 56) was 0.68 above the recommended ratio of 0.16 for stable composts, but it dropped low at 0.67 close to 0.16 at the fifth week so therefore by the sixth week co-compost was considered mature as shown in (figure 4.3). These was used because of the low C/N ratios.



(Source: field experiment, 2023).

Figures 4. 3 Ratio of NH_4 + - N/NO_3--N for determination of compost stability

CHAPTER FIVE

5.0 DISCUSSIONS

5.1 Physicochemical Properties of *Mucuna Pruriens* and Kitchen Waste Co-compost

The composting involved a mixture in different proportions (T1- 30:70, T2-40:60, T3: 50:50) of kitchen wastes and *Mucuna pruriens*. Physicochemical parameters such as, moisture content (MC), organic carbon (OC), organic matter (OM), potassium (K), nitrogen (N), electrical conductivity (EC), and phosphorus (P) were measured in percentages. Nutrients such as NO_3^--N, NH_4^+-N, K, and P were determined for the co-compost.

The pH was in the range of weakly acidic to alkaline (PH =5.3-6.4 at t=0 and 8.56 at t=56 days) for T1-T3. pH is a major determinant of compost quality and controls the composting processes (Sundberg, & Jönsson, (2008); Ge *et al.*, 2022). Usually during the biodegradation of kitchen wastes, there is the production and accumulation of acids which can inhibit microbial activities if not controlled (Gao *et al.*, 2022). The addition of lime has been a practice to balance the pH for effective microbial performances in the composting processes; however, the kitchen waste and *Mucuna pruriens* co-compost had the natural tendency to balance the pH of the compost. The recommended range of pH for effective composting is 7.0-8.0 for conventional composting processes. The pH for this study was within the range reported by other authors with a slight increase above the maximum value (the highest pH recorded for the treatments were 8.56). The mixing of *Mucuna pruriens* seeds with the kitchen wastes might have controlled the acids production from the biodegradation of kitchen wastes putting the pH in the range recorded.

This implied efficient microbial activity. Furthermore, the result of this study agrees with other findings that showed that safe composts pH standards ranged from 7.0-8.5 (Hwang *et al.*, 2020). There was a high %OC from the beginning of the composting time to the end of the 8th week of composting the %OC decreased. Though the %OC at the end of the composting (56th day) decreased, it was still higher than the raw kitchen waste compost without amendments. This meant that the overall amount of %OC increased. The *Mucuna Pruriens* contained high organic carbon (Monge *et al.,* 2022). The organic matter from the *Mucuna pruriens* and that of the kitchen wastes contributed to the production of OC. The *Mucuna pruriens* also improves the biological activities of the compost which in turn elevates OC production which corroborates with studies reported elsewhere which was considered to be the reason for the increased in the OC (Oliver & Feller, 2004); Ziblim *et al*., 2013).

The %N was constant across all the treatments (3.18%), meaning the % N witnessed an increase in the compost with the *Mucuna pruriens* amendment as compared to 1.96% of the nitrogen in the raw kitchen waste compost in this study. The *Mucuna pruriens* is considered to have high protein (Ayilara *et al.,* 2020). The protein-rich *Mucuna pruriens* provides a source of nitrogen that supports the growth and development of microorganisms involved in composting. Nitrogen mineralisation is facilitated by microorganisms present in the composting system, such as bacteria and fungi. These microorganisms mineralize the organic nitrogen present in *Mucuna pruriens,* converting it into inorganic forms such as ammonium (NH_4+) and nitrate (NO_3-). These inorganic forms of nitrogen can be readily utilized by plants for their growth and nutrient uptake. (Tuleun *et al.,* 2008; Kouakour *et al.*, 2022). This discovery contradicts previous findings where nitrogen losses occurred during aerobic composting, resulting in a lower nitrogen percentage in the final compost compared to the initial stage (Goyal *et al.*, 2005). It is documented that when the carbon-to-nitrogen (C: N) ratio is low, there are higher losses of nitrogen in the form of ammonia (Goyal et al., 2005). The quality of compost is typically influenced by the C: N ratio. A preferred range is 30:1 at the start and 20:1 at the end for high-quality compost (Ouédraogo *et al*., 2001; Gabhane *et al.,* 2012; Jiang-Ming, 2017; Nguyen *et al.,* 2020). However, in the current study, the average C: N ratio was as low as 14.11 at the beginning and decreased to 11.41 by the end. It is important to note that the C: N ratio can vary based on several factors, including feedstocks, substrate, experimental conditions, and location (Bazrafshan et al., 2016). In this particular study, kitchen waste and *Mucuna pruriens* which were used as feedstock are all nitrogen-rich components. A low C: N ratio reduces competition between crop plants and microorganisms, promoting plant growth (Bazrafshan *et al*., 2016). According to Bazrafshan *et al.* (2016), a C: N ratio as low as 15.64 represents compost that is safe for agricultural application, which aligns with the findings of the current study's C: N ratio of 11.41.

The %MC recorded in the study reflects an increment in the moisture content of the compost from the initial as a result of the watering but reduced toward the end. The composting method used was aerobic composting which involved turning. The biodegradation of the wastes produced moisture and the addition of water contributed to the moisture content. Whiles moisture is important for microbial functions; its excess blocks the air spaces/voids to create anaerobic pockets/conditions that can kill the microorganisms leading to poor compost. Various literature reports moisture content for composting in the range of 40-60% (Hwang *et al.,* 2002; Goyal *et al.,* 2005; Mawussi *et al.*, 2019). In this study, the % MC was in the range of 36.5-68.6% which was kept for the effective decomposition of the waste materials. During the turning, the moisture content was maintained from 54.96±5.55% -68.38±0.29% which was within the maximum performing range for composting (Hwang *et al.,* 2002). The increase in MC was possible because of regular watering and rainfall compared to reduced evaporation and drying. However, the moisture did not impede the inflow of oxygen to enhance microbial activities of degradation of the composting material. For effective composting MC is recommended at 40%-60 or 64% which is not far from the range compared to the current study (Hwang *et al.,* 2020).

The % OM represents a clear idea of the value of the compost that will be produced. The %OM decreased by the 56th day of composting, which meant that during this period there was the breakdown of the OM which reduced the content (Hwang *et al.,* 2002). Whiles turning impacted significantly the OM content ($p<0.05$), there was no significant difference between the treatments. This mean that during the period of composting, the breakdown of OM by microorganisms was taking place in all the treatments but is reduced to the end due to the compost nearing maturity (Barthod *et al.*, 2018).

There was an increase in the %P from the initial to the 56th day of the composting. There was no significant difference in the %P of mixing ratios though the addition of *the Mucuna pruriens* had an influence upon the compost the impact on the %P in the composting was not significant ($p<0.05$). The %P recorded in this study was similar to that reported by Mawussi et al. (2019). In their composting experiment, the %P was between 1.35±0.3% - 2.70±0.4% comparative to the current study which recorded as high as 1.43±0.02% - 1.76±0.11%. Though there was an increase in the %P with the amendment, it was relatively low. In a study conducted by Soto *et al.* (2020) in Spain, it was found that co-composting high nitrogen-based materials resulted in compost with a low level of phosphorus. This is because nitrogen and phosphorus are mutually antagonistic, competing for binding sites in the compost medium. Consequently, when there is a high level of nitrogen, phosphorus is less likely to be bound and more likely to leach out. The study analysed compost made from chicken manure and sewage sludge after 12 months of composting and found a low phosphorus content (0.15%), despite the initial high phosphorus levels in the input materials (1.5% and 1.0%, respectively).

The composting from t=0 days to t=56 days gave an increased %K with a significant impact ($p<0.05$) from the mixing ratios. Whiles there is no specific value set for potassium content in quality composts, the %K corroborated with other studies that involved composting of organic wastes (Gautam *et al.*, 2010; Jiang-ming, 2017). The loss in carbon from the mineralization of organic matter into either CO_2 or CH_4 could explain the rise in %K in this study. In the mixing ratios, there was a strong correlation between T1 (30:70) and T2 (40:60) for %MC, %N, %P, %K, total coliforms, pH, and EC. There was a strong correlation between T2 (40:60) and T3 (50:50) for %MC, %OM, %OC, total coliforms, and EC. Between T1(30:70) and T3 (50:50), there was a strong correlation between the two mixing ratios in terms of %OM, %OC, %N, total coliforms, pH, and EC.

The study showed much decline in total coliforms at the end of the composting period (t=56 days) which meant that the temperature at the thermophilic stage of the composting eliminated most of the organisms leading to a reduction in microbial activities at the maturation/curing of the composts (Jurado *et al*., 2014; González *et al.,* 2015). The decline meant that the microbial activities had reduced due maturation of the compost, at the maturation/curing stage of the composting microbial activities reduced producing a stabilized compost (Palaniveloo *et al.*, 2020).

The microbial levels showed that there was an on-going activity which is evident in the compost stabilization determination which had 0.68>0.16. This means that if the composting period was extended a little beyond 56 days, microbial activities could have ceased completely for compost stabilization.

5.2 Available Nutrients in *Mucuna Pruriens* and Kitchen Waste Co-Compost

Nutrients measured in the composts accessible to crop plants included NO_3^--N, K, and P. The mixing ratio 50:50 had the highest value (4116.33±188.22 mg/kg) of NO_3^--N when sampling was done on the day-28 (i.e., from t=0 day to the 28th day) of the composting but by the end of the composting at the day-56, there was a further increase of NO_3^--N to (4469±0.00mg/kg) with no significance difference between the treatments. This meant a general increase in nitrate from the beginning of composting to the end with no differences amoung the treatments. This implied that the degradation of the kitchen wastes and the *Mucuna pruriens* added nitrate which provides an enhancement for soil fertility in agricultural production. To determine the significant of the mixing ratios T1 (30:70) and T2 (40:60) correlated strongly for NH_4^+-N, K, and P. The mixing ratio, T1 (30:70) and T3 (50:50) correlated strongly for only NH_4^+-N, and the T2 (40:60) and T3 (50:50) correlated strongly for only NO_3^--N. The correlation implies that the substrates used for the mixing produced outputs that were statistically the same in terms of assessment. From these results, it is therefore scientifically logical that mixing the composts materials (kitchen wastes and *Mucuna pruriens*) mixing ratios of 70:30 60:40 and 50:50 produced similar physicochemical, nutrient quality and microbial quality of the composts. However, based on the nominal value the mixing ratio of 60:40 of kitchen waste and *Mucuna pruriens* was considered the best and was used for further studies.

5.3 Impact of Turning Rates on *Mucuna Pruriens* and Kitchen Waste Co-Compost

Turning allows heat loss, prevents anaerobic pockets, allows for aeration, and facilitate the decomposition of the composting (Zhou *et al.,* 2018). The temperature of the turning rates using the mixing ratio of 60:40 of kitchen waste and *Mucuna pruriens* ranged from 25.0 ℃ to 60℃. At temperatures within the 25 ℃ - 40℃ mesophilic range organisms dominated to break down the wastes materials because the temperature favoured their functioning. When the temperature was >40 ℃, the mesophilic organisms died giving rise to the thermophilic organisms to function (Giełżecki, & Jakubowski, 2020; Wang *et al.* 2021). Usually at maturation of compost, the temperature drops to ambient temperature. In the current work, the temperature on the 56th day of sampling was 25.3℃ within recommended temperature at the maturation of composts (Shen *et al.,* 2015).

pH is a major determinant of compost quality and controls the composting processes (Sundberg, & Jönsson, (2008); Ge *et al.,* 2022). During the turning frequencies stage of composting, the pH levels go through significant changes due to microbial activities. Bacteria and fungi break down organic materials, causing a shift in pH. Initially, the pH may be slightly acidic due to the release of organic acids during decomposition. However, as microbial activity intensifies, the pH gradually rises towards alkaline levels, around 8. This rise is due to factors like the release of alkaline ammonia and the reactivity of certain organic compounds.

The EC decreased from t=0 day to t=28 days and slightly increased between t=28 days and t=56 days with a significant correlation between all treatments (r^2>0.50). The correlation among all the treatments indicated common sources of EC in the different treatments. The

EC is a measure of ions and salts in waste mixtures (Gondek *et al.,* 2020). When EC decreased from the start of composting to the 28th day of sampling, it meant a flushing of ions and salts from the wastes. However, the decomposition and mineralization, as well as the addition of water during the composting, increased the EC on the 56th-day of sampling slightly but was still lower than the initial (Smith & Hughes, 2002; Soto et al., 2020). The composition of the Kitchen wastes was most possibly saline resulting in the high EC values (Hwang *et al*., 2020).

Potassium (K) and Phosphorus (P) concentration increased between t=0 day to t=56 days. There was a slight decrease in phosphorus which might be associated with the leaching of the phosphorus from the beginning of the experiment which is also reported elsewhere (Soto *et al*., 2020).

However, K and P increased for T3 by the 56th day of composting. The increases in P and K resulted from the concentration effect arising from a higher rate of carbon loss that occurred when organic matter (OM) was decomposed or mineralized into CO_2 or CH_4 (Jiang-ming, 2017). Phosphorus increased at this stage because of the mineralization of the organic carbon (OC). From day 28 to the 56th day of composting with turning rates of 3, 5, and 7 days, the K and P decreased in nutrient concentration for all the treatments but was still higher than the K and P concentration at the start of composting, t=0. This indicates that higher microbial activities existed in the turning treatments, resulting in increased mineralization (Jiang-ming, 2017). There was a strong positive correlation between turning frequency and K (r=0.88, p=0.00), turning frequency and P (r=0.99, p=0.00) within the 28 days of composting. At the end of composting (t=56 days), the frequency of turning impacted effectively on the nutrient's concentration for K (r=0.87, p=0.00), and P (r=0.68, p=0.00). The turning was accompanied by watering which might have increased the moisture content (MC) which might have also caused leaching to reduce the concentration of the phosphorus.

Again, the C/N ratio was low which promotes a higher loss of phosphorus. According to Soto *et al.* (2020), a lower C/N ratio together with leaching caused a decline in phosphorus concentration during the co-composting of bio-waste and sugarcane. It is important to indicate that from t=0 days to t=56 days, the increase in P and K was 54.88% and 40.07% respectively.

There was also a strong negative correlation between turning rates and the concentration of NO_3^--N in the compost signifying a strong effect of the turning on the availability of the nitrate in the composts ($r=-0.87$, $p<0.05$). T1 also increased for NH_4^+-N, by day 56 of composting. This phenomenon can be explained in the concept of nitrification. At temperatures less than 40℃ and aeration, nitrification is best (Wang *et al.*, 2021). This is evident by the strong correlation and the significant effect ($r=-0.87$, $p<0.05$) the turning had on the concentration of the NH_4^+-N concentration. When nitrogen conversion happens during composting, it also reflects in the concentration of the NH_4^+-N. The reduction of NH_4^+-N in T3 could be that there was volatilization of NH_3 (Hwang *et al*., 2020).

Several study, suggest that compost is considered mature when its temperature had stabilized below 40°C, over two weeks of the co-composting. The composting process was considered to be matured when the temperature of the compost pile had stabilized for more than a week at temperature below 40°C (Venelampi, *et al.,* (2010)., Meng, *et al.,* 2018). In this study, temperature dropped and became stable during the fifth and sixth week of co-composting, remaining consistent across all treatments until the end of the process. The minimum temperature recorded during these periods was 25°C. The co-compost was successfully matured by the sixth week and it was the same for both the mixing ratios and the turning frequencies treatments. The ratio of NH_4^+-N to NO_3^--N was determined to provide the perspective of the compost maturity. Stable compost has a NH_4^+-N/NO_3^--N ratio of 0.16 which gives a sense of the compost maturity depending on the feedstock (Bazrafshan *at el.,* 2016). In the current study, the NH_4^+-N to NO_3^-—N ratio was 0.68 (Figure 4.6). There was a steep decline in NH_4^+-N/ NO_3^--N from the start of composting experiment then approaching the end there was a little rise. Although a value of 0.16 has been reported for compost stability many other factors come into the determination of compost stability (Gómez-Brandón *et al.*, 2008). The ratio recorded in this study could be dependent on the source materials for the composting. Again, the NH_4^+-N/ NO_3^--N ratio greatly decreased during the active phase due to the high levels of NO_3^--N detected at the end of the study.

CHAPTER SIX

CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

The following are the conclusions and recommendations of the kitchen waste and *Mucuna pruriens* co-compost:

- The proximate analysis of both kitchen waste and the *Mucuna pruriens* indicated that kitchen waste had high organic matter content of 95.66%, a high potassium (%K) of 2.053% and a pH of 7.5 but had a low nitrogen of 1.75% whiles *Mucuna pruriens* seeds had an organic matter (%OM) of 90.59%, a comparatively high total nitrogen (%N) of 4.203%, and a pH of 5.7 but their co-compost produced high quality compost.
- The study demonstrated that the co-compost of kitchen waste and *Mucuna pruriens* has significant improvement in terms of physicochemical and nutritional content as compare with the raw kitchen waste compost. The co-compost of kitchen waste and *Mucuna pruriens* exhibited higher nitrogen levels of (3.18±0.14%) as compared to the raw kitchen waste of (1.96±0.11%), indicating its potentials as a nitrogen-rich additive. Additionally, the phosphorus content increased to (1.76±0.11%) in the co-compost, compared to (1.00±0.14%) in the control. The potassium levels were found to be (2.62±0.20%) in the raw kitchen waste and (2.88±0.17%) in the co-compost. Throughout the composting process, there was a general increase in available nutrients such as phosphorus (P), potassium (K), and nitrate (NO3--N), with no significant differences observed between the mixing ratios. However, based on the nominal factors of the mixing ratios tested, the 60:40 ratio showed a slight improvement above the other treatments.
- This study evaluated the effect of turning frequency on *Mucuna pruriens* and kitchen waste co-compost quality using a 40:60 mixing ratio and found out that co-compost turned every week (7 days) slightly improved the compost quality concerning the physicochemical, biological, and nutritional concentration such as NO_3^--N, K, and P as compared to the three (3) days and five (5) days turning.

- In this study, the co-compost was considered matured when its temperature had stabilized below 40°C during the fifth and the sixth week of the co-composting. The temperature dropped and became stable during the fifth and sixth week of co-composting, remaining consistent across all treatments until the end of the process. The minimum temperature recorded during these periods was 25°C. The co-compost was successfully matured by the sixth week and it was the same for both the mixing ratios and the turning frequencies treatments.

Generally, *Mucuna pruriens* seeds have the capacity to enrich the nutritional value and improve the quality of kitchen waste compost in its totality. This implies that the co-composting of the kitchen wastes and the *Mucuna pruriens* contained soil enhancement potentials therefore have the potential to improve soil quality, boost crop plant life, and increase agriculture production.

6.2.1 Recommendation

I. **Farmers**:

- Farmers and compost producers should be educated on the need to consider *Mucuna pruriens* as a reagent for compost amendment. Since there is no significant difference between the treatments any reasonable parts of *Mucuna pruriens* can be used to enrich compost to produce maximum results. Mixing ratio 60:40 can be considered since it slightly improved the co-compost's nutrition and quality.
- Also, Farmers and compost producers should be enlightened on the need to consider seven day turning interval for compost turning since it allowed time for microbial activities and the mineralization of organic matter which increased the percentage levels of N, K, and P and the nutritional properties with a significant impact.

II. **Government and Policy Makers:**

- ❖ There should be an enlightenment program as a means to improve the knowledge of people especial farmers on the advantages of organically produced crops and the use of compost by farmers to shift their focus from over-dependence on synthetic fertilizer to compost use. This should be done to create a ready market for compost production to aid the willingness of others to venture into composting as a business and there promote composting of kitchen waste as means of increasing waste utilization, managing municipal solid waste and protecting the environment. This is possible if compost producers incorporate the use of *Mucuna pruriens* as an enrichment factor to produce rich compost.

III. **Gaps for Further Study:**

- ❖ Further research should be conducted to determine the rate of growth and performance of kitchen waste and *Mucuna Pruriens* co-compost application on specific crops to help farmers know the optimum usage. This study should not neglect information on the current soil characteristic and the impact of the compost on the soil.
- ❖ Further study is needed to look at the microbial dynamic in the composting process and how it can be enhanced to improve the quality of the compost to replenish other losses.
- ❖ Observing the nature and behavior of the *Mucuna pruriens* throughout the composting process it suggests that it had the ability to aid compost pelleting and darkling hence its study should be considered. The study should not neglect to assess the chemical properties that cause both the coloration and the pelleting.

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APPENDIX

PROTOCOL FOR DETERMINATION OF NUTRIENTS IN COMPOST

Available Phosphorus Determination (Bray-1 Method) in Compost. Accurate determination of available phosphorus is essential for evaluating the nutrient status of compost and ensuring optimal plant growth. The following procedures outline the step-by-step process for conducting the Bray-1 method to assess phosphorus availability in compost samples.

Introduction:

The determination of available phosphorus is crucial in understanding the nutrient content of compost. The Bray-1 method, based on fluoride extraction, provides an effective means to assess the availability of phosphorus in compost samples.

Reagents:

1. 1.0 N HCl: To prepare this solution, measure 87 ml of concentrated HCl (sp. gr. 1.18, 36%) and make up the volume to 1000 ml in a volumetric flask.

2. Bray 1 Extractant: In a volumetric flask, dissolve 2.22 g of NH_4F and 5.0 ml of concentrated HCl in deionized water. Make up the volume to 2 L with deionized water. This solution consists of 0.025 N HCl and 0.03 N NH_4F.

3. Ammonium Molybdate-HCl, Boric Acid Saturated Solution:

a. Dissolve 37.652 g of ammonium molybdate, $(NH_4)6Mo7O_{24}\cdot 4H_2O$, in approximately 245 ml of distilled water and heat it to 60°C.

b. After cooling, add the solution to 781.5 ml of concentrated HCl.

c. Make up the volume to 1000 ml in a volumetric flask with deionized water.

d. Store the solution in a brown glass stoppered bottle containing 50 g of boric acid (H_3BO_3).

4. Ascorbic Acid: Prepare a fresh solution each day by dissolving 1.76 g of ascorbic acid in 100 ml of distilled water.

5. Stock Standard A (2500 µg P/ml): Oven dry 15 g of KH_4PO_4 (AR grade, MW = 136.09, 99.5%) at 80°C for 2 hours. Weigh out 10.9825 g of the dried compound and dissolve it in distilled water, making up the volume to 1 liter.

6. Working Stock Standard B in Bray 1 (250 µg P/ml): Pipette 25 ml of Stock A into a clean 250 ml volumetric flask and make up the volume using Bray 1 extractant.

7. Working Standards in Bray 1: Prepare five clean 250 ml volumetric flasks. Pipette 0, 2, 4, 8, 12, 16, and 20 ml of Stock B into each flask, respectively. Make up the volume to 250 ml using Bray 1 solution. These working standards contain 0, 1, 2, 4, 6, 8, and 10 µg P/ml in 250 ml volumetric flasks.

Procedure:

1. Weigh 3g of air-dry compost (2 mm sieved) and transfer it into centrifuge tubes. Add 15 ml of Bray 1 solution to each tube.
2. Place the tubes on a mechanical shaker and shake for 5 minutes to ensure thorough mixing.
3. Allow the mixture to settle for 2 minutes, then centrifuge for 5 minutes at 3000 rpm.
4. Pipette 2 ml of the clear supernatant solution (sample) and/or the standard solutions into separate clean centrifuge tubes.
5. Add 10 ml of distilled water to each tube and mix thoroughly.
6. Add 2 ml of the color reagent to each tube and mix well again.
7. Further, add 2 ml of the ascorbic acid solution to each tube and mix thoroughly once more.
8. After 15 minutes, measure the absorbance of the solutions at 650 nm using a colorimeter or visible range spectrophotometer.
9. Plot the absorbance versus ppm P on a graph. Read the unknown samples and obtain ppm P by interpolating on the plotted graph.
10. Calculate the ppm P (µg P/kg soil) using the formula: ppm P = c * 15/3, as described by Bray and Kurtz (1945).

Note: Ensure proper calibration of the instruments and follow all safety precautions during the procedure.

DETERMINATION OF AVAILABLE POTASSIUM IN COMPOST BY AMMONIUM ACETATE

1. Preparation of Extracting Solution (1.0 N NH_4OAc):
   - Dilute 57 ml of glacial acetic acid with distilled water to a total volume of 800 ml.
   - Neutralize the solution with concentrated NH_4OH to achieve a pH of 7.0.
   - Dilute the solution to one liter in a volumetric flask.
2. Preparation of Standard K Solution (1000 ppm (K)):
   - For the stock solution (1000 ppm K), dissolve 1.907 g of KCl (dried at 105°C for 4 hours) in approximately 200 ml of deionized water.
   - Make up the volume to 1000 ml with deionized water, resulting in a concentration of 100 ppm (K).
   - Dilute 50 ml of the 1000 ppm solution to 1000 ml to obtain a concentration of 50 ppm (K).
   - Dilute further as follows:
     - 0 ml of 50 ppm to 1000 ml = 0 ppm
     - 4 ml = 2 ppm
     - 8 ml = 4 ppm
     - 12 ml = 6 ppm
     - 16 ml = 8 ppm
     - 20 ml = 10 ppm

Preparation of Compost Extract:

1. Weigh 10 g of compost into an extraction bottle.
2. Add 100 ml of the 1.0 N NH_4F OAc solution.
3. Place the bottle with its contents on a mechanical shaker and shake for 2 hours.
4. Filter the supernatant solution through No. 42 Whatman filter paper.
5. Take a 10 ml aliquot and measure the potassium (K) concentration using a flame photometer after calibrating the photometer with the prepared standards.
6. Determine the flame photometer reading for the soil and, using the meter reading standard curve, determine the concentration of K in the compost extract.

PROTOCOL FOR DETERMINING THE PHYSICOCHEMICAL PROPERTIES OF COMPOST: PREPARATION AND DRY ASH DIGESTION OF COWPEA FOR ELEMENTAL ANALYSIS

To determine the physicochemical properties of the compost, the following steps were followed, based on the methods described by Hunter *et al.* (1984) and Benton Jones *et al.* (1990):

1. Sample Preparation and Dry Ash Digestion:

- The compost sample was milled into a powdered form. - One gram of the powdered sample was weighed into a clean ceramic crucible. An empty crucible was included as a blank for each batch of 5 samples.
- The crucibles with samples were arranged in a cool muffle furnace.
- The temperature was ramped up to 500°C over a period of 2 hours and then held at this temperature for an additional 2 hours.
- After the ashing process, the samples were allowed to cool down in the furnace.

2. Transfer and Mixing of Ashed Samples:

- The ashed samples were carefully removed from the furnace in a breeze-free environment.
- Each ashed sample was transferred into a pre-numbered 50 ml centrifuge tube.
- The crucibles were rinsed with 10 ml of distilled water, and the rinse was added to the respective centrifuge tubes.
- Additional rinsing of the crucible was done with 10 ml of aqua regia.
- The samples in the centrifuge tubes were mixed properly by shaking for 5 minutes on a mechanical reciprocating shaker.

3. Centrifugation and Transfer:

- After the shaking, the samples were centrifuged for 10 minutes at 3000 rpm.
- The clear supernatant digest was carefully decanted from each centrifuge tube into clean reagent bottles for phosphorus (P) and potassium (K) determinations.
- The samples were transferred into 100 ml volumetric flasks and made up to the 100 ml mark with distilled water.

By following this protocol, the physicochemical properties of the compost, including P and K concentrations, were determined.

Method of Determination of Phosphorus (P)

A vanadomolybdate reagent was prepared by dissolving 22.5 g of ammonium molybdate in 400 ml of distilled water and 1.25 g of ammonium vanadate in 300 ml of boiling distilled water. The vanadate solution was then added to the molybdate solution and cooled to room temperature. Next, 250 ml of analytical grade HNO3 was added to the solution mixture and diluted to 1 liter with deionized water.

To prepare the standard phosphate solution, 0.2195 g of analytical grade KH_4PO_4 was dissolved in 1000 ml of distilled water. This solution had a concentration of 50 µg P/ml. A standard curve was prepared by pipetting 1, 2, 3, 4, 5, and 10 ml of the standard solution (50 µg P/ml) into 50 ml volumetric flasks. Then, 10 ml of the vanadomolybdate reagent was added to each flask and the volume was made up to 50 ml. This resulted in P concentrations of 1, 2, 3, 4, 5, and 10 µg P/ml in the flasks. The absorbance measurements at a wavelength of 420 nm were obtained using a spectronic 20 spectrophotometer and used to create a calibration curve.

For the sample analysis, 10 ml of the sample solution was transferred into a 100 ml volumetric flask. Then, 10 ml of the vanadomolybdate reagent was added and the volume was made up to 100 ml. The sample was allowed to develop a stable yellow color for 30 minutes. The sample was then read on the spectronic 20 spectrophotometer at 420 nm, and the observed absorbance was used to determine the P content from the standard curve.

The % P was calculated using the formula:

P content (g) in 100 g sample (% P) = (c x df x 100) / 1,000,000 = (c x 1000 x 100) / 1,000,000 = c/10

where:

- c = concentration of P (µg/ml) as read from the standard curve
- df = dilution factor, which is 100 * 10 = 1000:
  - 1 g of sample made to 100 ml (100 times)
  - 5 ml of the sample made to 50 ml (10 times)

- 1,000,000 = factor for converting µg to g.

Method of Determination of Potassium (K) Using a Flame Photometer

A 1.908 g of analytical grade KCl, previously dried in an oven for 4 hours at 105°C, was dissolved in 200 ml of deionized water and the volume made up to 1000 ml. This resulted in a standard solution with a concentration of 1000 ppm for potassium (K). A calibration curve (standard curve) was prepared using solutions with concentrations of 200, 400, 600, and 800 ppm. The absorbance readings for all solutions were taken using a flame photometer.

The sample solution, obtained from the $HClO_4$ and HNO_3 treatment, was also read on the flame photometer. The concentration of potassium (K) in the sample was calculated using the corresponding absorbance value observed for the sample from the standard curve.

Calculation:

- K content (µg) in 1.0 g of plant sample = c x df
- K content (g) in 100 g of plant sample (% K) = c x df x 100 / 1000,000 = c / 100

Where:

- c = concentration of K (µg/ml) as read from the standard curve
- df = dilution factor, which is 100x1 = 100, calculated as follows:
  - 1.0 g of sample made up to 100 ml (100 times)
  - 1000,000 = factor for converting µg to g.

1. Total Nitrogen

Principle:

Nitrogen (N) is a major element found in living organisms, and it constitutes a significant portion of proteins. The total nitrogen content in a sample can be estimated using the micro Kjeldahl technique, which involves converting the nitrogen in the sample to ammonium sulfate through sulfuric acid digestion. The liberated ammonia is then collected and titrated against standard acid. By assuming that the nitrogen is derived from a protein containing 16% nitrogen, the approximate protein value can be calculated.

Apparatus:

i. Kjeldahl flasks: 30 ml hard glass flasks

ii. Digestion rack: Commercial heating apparatus

iii. Distillation apparatus

Reagents:

i. Sulfuric acid (specific gravity 1.84)

ii. Sodium sulfate

iii. Copper sulfate

iv. Sodium hydroxide-sodium thiosulfate solution: Dissolve 600 g NaOH and 50 g $Na2S_2O_2 \cdot 5H_2O$ in distilled water and make up to 1 liter.

v. Indicator solution: Methyl red 0.2 g / 100 ml ethanol, methylene blue 0.2 g / 100 ml ethanol. For the mixed indicator, add two parts of methyl red solution to one part of methylene blue solution.

vi. 4% boric acid solution

vii. Standard HCl, 0.1 N

viii. Boiling chips and/or glass beads.

Procedure

1. Weigh 2.0 g of the sample and transfer it to a 30 ml digestion flask.
2. Add one spatula full of Kjeldahl catalyst (mixture of sodium sulphate, copper sulphate, and selenium powder) and 20 ml concentrated H_2SO_4 to the digestion flask.
3. Add boiling chips and digest the sample until the solution becomes colorless.
4. After cooling the digest, dilute it with a small quantity of distilled ammonia-free water and transfer it to the distillation apparatus. Rinse the Kjeldahl flask with successive small quantities of water.

5. Place a 100 ml conical flask containing 5 ml of boric acid solution with a few drops of mixed indicator, ensuring that the tip of the condenser dips below the surface of the solution.
6. Add 10 ml of sodium hydroxide-sodium thiosulphate solution to the test solution in the apparatus.
7. Distill and collect the ammonia on boric acid. Collect at least 50 ml of distillate.
8. Rinse the tip of the condenser and titrate the solution against the standard acid until the first appearance of violet color, indicating the endpoint.
9. Run a reagent blank with an equal volume of distilled water and subtract the titration volume from that of the sample titration volume.

Calculation:

The nitrogen content of the sample can be calculated using the formula:

% N = (14 x (a - b) x n x 100) / (1000 x 0.2)

Where:

a = volume of standard HCl used in the sample titration

b = volume of standard HCl used in the blank titration

n = normality of standard HCl

Note: Adjust the weight of the sample used, considering the dilution and the aliquot taken for distillation.

Protocol for bacterial analysis

Sample Preparation:

1. Weigh 10.0g of the compost sample and add it to 90 ml of peptone water. Vortex the mixture for 15 seconds.

2. Take 1.0 ml of the supernatant for serial dilutions.

Total Coliforms:

The method used to determine total coliforms in the compost samples was the Most Probable Number (MPN) technique.

1. Prepare a serial dilution from 10-1 to 10-4 by adding 1 ml of the sample into 9 ml of sterile distilled water.

2. Inoculate 1 ml aliquots from each dilution into 5 ml of MacConkey broth.

3. Incubate the tubes at 37°C for 18-24 hours to detect total coliforms.

4. Identify tubes showing a color change from purple to yellow after 24 hours as positive for total coliforms.

5. Calculate the counts per 100 ml using the MPN tables.

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