Evaluation of Thermally Treated Faecal Sludge As A Potential Source of Organic Fertilizer

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***Abstract:* - This study was aimed at assessing the effect of heat on the efficacy of thermally treated faecal sludge as organic fertilizer, going by the fact that some farmers use untreated faecal sludge with its attendant health risk as organic fertilizer.Uuntreated faecal sludge were collected from two major collection points. A portion of the untreated faecal sludge was subjected to thermal treatment using oven drying method at 100^0C for 1hour. Seventy Kilograms of soil sample was collected. The untreated faecal sludge, treated faecal sludge and soil were analysed for their physico-chemical properties. Six planting groups each with five replicates were set up, two kilograms of soil was weighed into each pot and used for planting cowpea (*Vignaunguiculata*) for ten weeks. Agronomic parameters such as number of leaf, stem diameter, plant height weremonitored during the experiment.Analysis using descriptive statistics and ANOVA at p=0.05 was conducted on data obtained. Significant difference was observed in the agronomic parameters measured among the treatment groups with the soil amended with treated faecal sludge sample having the highest yield. Therefore, the use of thermally treated faecal sludge should be explored to improve the safety of farm produce grown with it.**

***Keywords:* organic fertilizer, pre-treatment, agronomic parameters, faecal sludge**

I. INTRODUCTION

Human excreta consist of faeces and urine, which are the waste products of body metabolism. A person's health as well as on the quality and quantity of food and liquid consumed usually influence the appearance, physical and chemical characteristics of urine and faeces (Lentner *et al*., 1981; Feachem *et al*., 1983). According to Guyton, urine is the excreta fraction that is filtered from the blood by the kidneys (Guyton, 1992). It is employed as a balancing medium for liquids and salts by the body and the amount of urine excreted by a person therefore varies (Jönsson *et al*., 2004). Urine is largely made up of approximately 93-96% water (Vinnerås *et al*., 2006), and large quantities of plant nutrients that are mainly in water-soluble form (Jönsson *et al*., 2004).

Faeces consist of material which remains undigested as it passes through the intestines, which may be mixed with mucus and material extracted from the blood stream or shed from glands and the intestines (Guyton, 1992). The characteristic brown colour of faeces is imparted bybile (Featherstone, 1999). Pathogenic viruses, cysts of protozoa, bacteria and eggs of helminths may often be found in large concentrations in faeces (Faechem *et al*., 1983; WHO, 2006).

Globally an average of about 2.6 billion people do not have access to basic sanitation and in most developing countries more than 90% of the sewage and sludge produced are discharged untreated (Esrey, 2001; WHO, 2004a; Langergraber and Muellegger, 2005)]. This leads to the accumulation of human excreta around homes, in nearby drains and in garbage dumps which consequently leads to environmental pollution together with its adverse effect to the society (Kulabako *et al*., 2007).

The use of excreta-based nutrients in plant production is a way of recycling excreta thereby closing the nutrient loop and is one way of decreasing the environmental pollution caused by untreated excreta in the environment, thus decreasing the negative impacts on the society[(Vinnerås and Jönsson, 2002). In order to use the nutrients present in excreta safely, the different fractions of the excreta can be collected separately, treated and applied safely in plant production.

Faecal sludge contains plant nutrients including nitrogen and phosphorus and is low in chemical impurities; it tends to be suitable for agricultural purposes. Report has shown that some Nigerian farmers use faecal sludge as organic fertilizer without any form of pre-treatment nor taking preventive measures against its health risks. Fresh faeces should always be considered unsafe as a result of the likely presence of high concentrations of pathogens (WHO, 2006) and therefore needs to be subjected to one form of treatment or the other in order to sanitise it. This study was therefore structured to assessthe effect of heat on the efficacy of thermally treated faecal sludge as organic fertilizer.

II. MATERIALS AND METHODS

2.1 Administration of questionnaire

Questionnaires were administered to some desludgers and some farmers in order to ascertain that faecal sludge were actually used either in its raw or treated form as organic fertilizer.

2.2 Faecal sludge samples collection

Faecal sludge were collected from two major sludge collection facility following the methods described by Osibote *et al.*(2016), and transported immediately to the laboratory where physico-chemical analysis was performed on it to determine its proximate and mineral contents. The faecal sludge was then subjected to thermal treatment as described by Osibote *et al.*(2016). After treatment, it was subjected to another round of analysis in order to compare the physico-chemical parameters of the untreated and treated faecal samples.

2.3 Planting/pot experiment

Soil used for planting was collected from the top soil of a crop garden, subjected to chemical analysis to determine its physical properties, heavy metal content and mineral content after which it was sieved and weighed (5 kg each) into each of the plastic pots used. After which Ife brown variety of cowpea species (*Vigna unguiculata* L. Walp) was planted in a screen house experiment.

2.4 Experimental Design

Completely Randomized Design (CRD) having six treatment groups each with 5 replicates was used. The treatments were:

Group A: Soil with untreated faecal sludge sample from location A

Group A^{o}: Soil with treated faecal sludge sample from location A

Group B: Soil with untreated faecal sludge sample from location B

Group B^{o}: Soil with treated faecal sludge sample from location B

Group C: Soil with NPK

Group D: Control (soil with no amendment)

The total number of pots used was thirty;each pot was seeded with three cowpea seeds and was later thinned to one plant per pot after a week. Data were collected starting from two weeks after planting on the following parameters: plant height, stem girth, leaf width, number of leaves, number of pods per plant, leaf length, length of pod, mean weight of the harvested cowpea(Elings, 2000) till the experiment was terminated.

2.5 Data analysis

Data obtained were reported as mean ± standard deviation of five measurements and analyzed using one-way analysis of variance (ANOVA) with Least Significant Difference (LSD) and post hoc test was used to determine significant differences (p<0.05) between treatments using Statistical Package for Social Science Research version 17 (SPSS).

III. RESULTS

The result of the physico-chemical analysis comprising of heavy metal analysis and proximate mineral analysis carried out on the faecal sludge samples before and after treatment is as shown in Table 1. Faecal sludge collected from location A had higher concentration of heavy metals and proximate minerals present in it compared to the sample collected from location B. The chemical composition of the soil sample used for the planting experiment comprising of its physical parameters, heavy metal content and mineral content is as shown in table 2.

Table 1: Physico-chemical properties of faecal sludge samples

Physical parameters	**Before treatment**		**After treatment**	
	A	**B**	**A**	**B**
pH	6.6	6.76	6.88	7.13
% Sand	80.96	84.96	78.21	82.87
% Silt	8.77	7.24	7.10	6.18
% Clay	7.9	7.8	9.80	10.95
Mineral content				
% Organic Carbon	36.79	26.7	31.38	19.75
% Nitrogen	3.18	3.75	2.69	2.86
Average Phosphorus	1126	987	993	886
% Calcium	1.23	2.4	0.79	1.34
% Sodium	0.31	0.18	0.24	0.25
% Magnesium	0.29	0.64	0.21	0.75
% Potassium	0.78	0.43	0.65	0.51
Proximate matter				
% Crude protein	18.38	12.60	12.76	9.67
% Crude fat	2.94	1.80	3.11	2.10
% Crude fibre	31.86	25.44	25.91	18.11
% Ash	6.28	3.33	7.13	2.43

Table 2: Chemical composition of soil sample used for planting experiment

Physical parameters	Soil sample
pH	6.94
% Sand	80.96
% Silt	8.77
% Clay	7.9
Mineral content	
% Organic Carbon	1.15
% Nitrogen	0.12
Average Phosphorus (ppm)	4.96
% Calcium	2.18
% Sodium	0.27
% Magnesium	0.59
% Potassium	0.41

3.1 Plant height

From week 3 to the tenth week when the experiment was terminated, it was observed that the plant on the soil amended with treated faecal sludge from location A (i.e. group A^{o}) and those from the soil amended with untreated faecal sludge from location B (i.e. group B) had the highest plant height compared to all the other treatment groups as seen in Figure 1. No significant difference was observed in the plant height among the treatment groups at $p \leq 0.05$ except during the seventh week of planting.

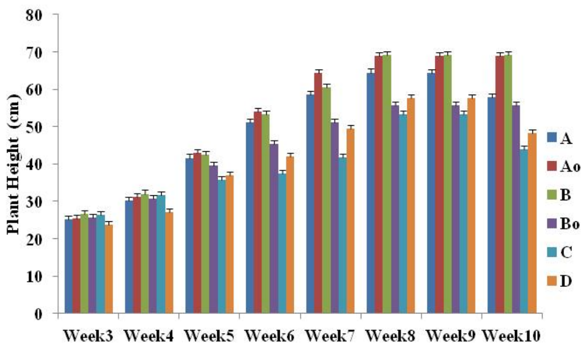

Fig 1: Plant height of the cowpea plant

Key: A - plant harvested from soil with untreated faecal sludge from location A, A^o - plant harvested from soil with treated faecal sludge from location A, B - plant harvested from soil with untreated faecal sludge from location B, B^o - plant harvested from soil with treated faecal sludge from location B, C - plant harvested from soil with NPK, D - plant harvested from soil with no amendment (Control)

3.2 Stem diameter

It was observed that from week 3 to 10, plants on soil amended with treated faecal sludge sample from location A (Group A^o) appeared to have the largest stem diameter compared to the other treatment groups but by the eighth week, those on soil amended with untreated faecal sludge sample from location A (Group A) had the largest stem girth. It was observed that all through the experiment, plants growing on soil amended with NPK (Group C) had the smallest stem girth as observed in Figure 2. Significant difference was observed in the stem girth of the cowpea plants among the treatment groups ($p \leq 0.05$) starting from week 3 till the end of the experiment.

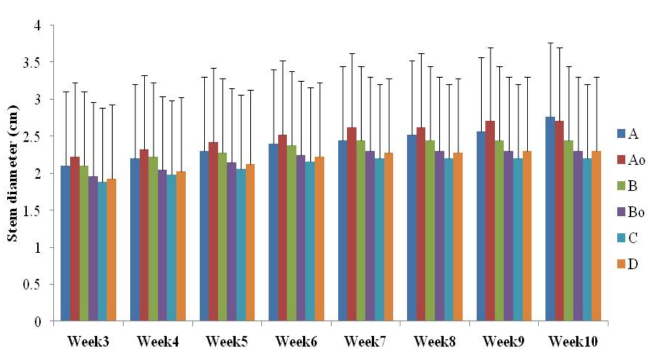

Fig 2: Stem diameter of the cowpea plant

Key: A - plant harvested from soil with untreated faecal sludge from location A, A^o - plant harvested from soil with treated faecal sludge from location A, B - plant harvested from soil with untreated faecal sludge from location B, B^o - plant harvested from soil with treated faecal sludge from location B, C - plant harvested from soil with NPK, D - plant harvested from soil with no amendment (Control)

3.3 Leaf width

Observation of the plant growth on a weekly basis revealed that plant growing on soil amended with treated faecal sludge sample from location A (Group A^o) had the widest leaf width when compared to the other treatment groups except on the third and fifth weeks of the planting exercise as observed in Figure 3. Significant difference was observed in the width of the leaf of the cowpea plants ($p \leq 0.05$) among the treatment groups starting from week 3 till the end of the experiment.

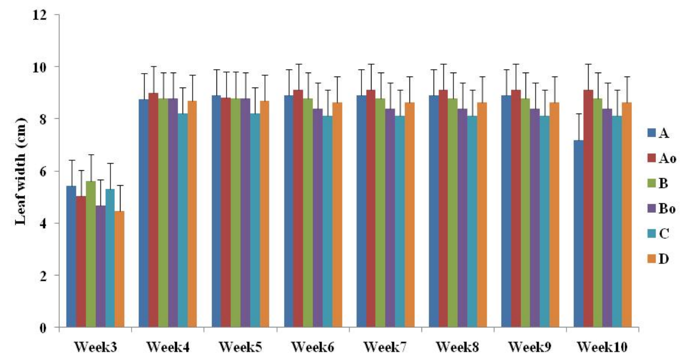

Fig 3: Leaf width of the cowpea plant

Key: A - plant harvested from soil with untreated faecal sludge from location A, A^o - plant harvested from soil with treated faecal sludge from location A, B - plant harvested from soil with untreated faecal sludge from location B, B^o - plant harvested from soil with treated faecal sludge from location B, C - plant harvested from soil with NPK, D - plant harvested from soil with no amendment (Control)

3.4 Number of leaves

Significant difference was observed in the number of leaves of the cowpea plants among the treatment groups ($p \leq 0.05$) starting from week 4 till the end of the experiment as shown in Figure 4. However, no significant difference was observed in the number of leaves among treatment groups ($p \leq 0.05$) in the third week of the planting exercise.

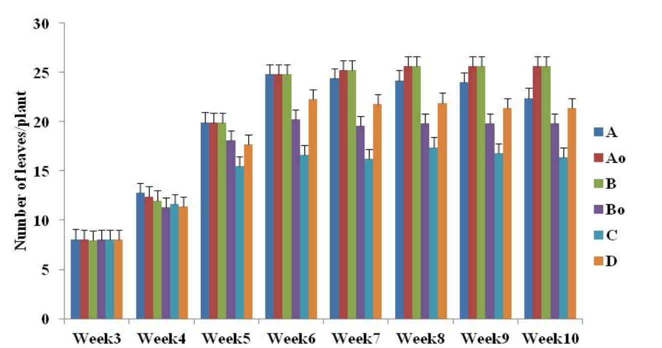

Fig 4: Number of leaves of the cowpea plant

Key: A - plant harvested from soil with untreated faecal sludge from location A, A^o - plant harvested from soil with treated faecal sludge from location A, B - plant harvested from soil with untreated faecal sludge from location B, B^o - plant harvested from soil with treated faecal sludge from location B, C - plant harvested from soil with NPK, D - plant harvested from soil with no amendment (Control)

3.5 Number of pods per plant

Significant difference was observed in the number of pods on the cowpea plants among treatment groups ($p \leq 0.05$) starting from week 3 till the end of the experiment as shown in Figure 5. Among all the treatment groups, plants growing on soil with treated faecal sludge sample from location A i.e. Group A^o had the highest number of pods per cowpea plant. All through the experiment, group C (soil amended with NPK) had the lowest number of pods per cowpea plant compared to the other treatment groups.

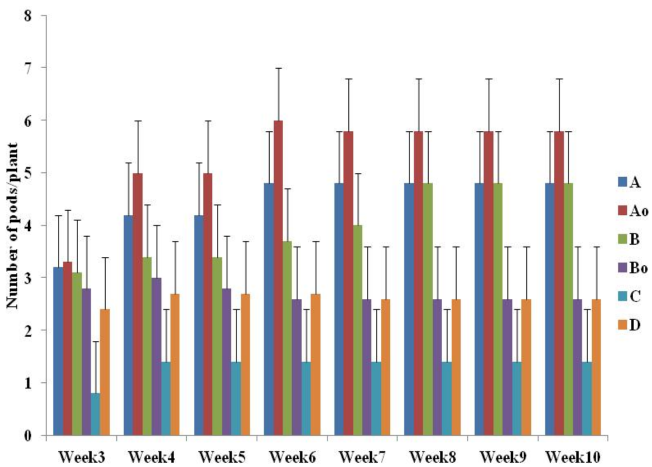

Fig 5: Number of pods per plant of the cowpea plant

Key: A - plant harvested from soil with untreated faecal sludge from location A, A^o - plant harvested from soil with treated faecal sludge from location A, B - plant harvested from soil with untreated faecal sludge from location B, B^o - plant harvested from soil with treated faecal sludge from location B, C - plant harvested from soil with NPK, D - plant harvested from soil with no amendment (Control)

3.6 Leaf length

Significant difference was noticed in the leaf length of the cowpea plants among treatment groups ($p \leq 0.05$) starting from week 3 till week 10 of the experiment, however no significant difference ($p \leq 0.05$)was observed in the leaf length of the cowpea plant among treatment groupsat the 10^{th}week of the experiment as shown in Figure 6. From week 3 to 10, plant harvested from soil amended with treated faecal sludge from location A i.e. group A^o had longer leaves compared to the other treatment groups.

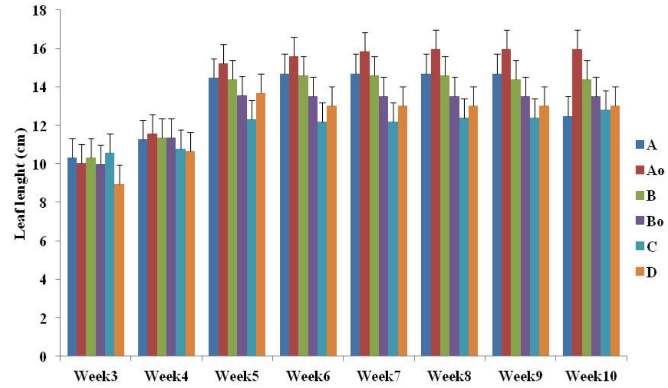

Fig 6: Leaf lenght of the cowpea plant

Key: A - plant harvested from soil with untreated faecal sludge from location A, A^o - plant harvested from soil with treated faecal sludge from location A, B - plant harvested from soil with untreated faecal sludge from location B, B^o - plant harvested from soil with treated faecal sludge from location B, C - plant harvested from soil with NPK, D - plant harvested from soil with no amendment (Control)

3.7 Length of pods

Significant difference was observed in the length of the pods of the cowpea plants among the treatment groups from week 3 till the end of the experiment ($p \leq 0.05$) as shown in Figure 7.Plant harvested from soil with treated faecal sludge from location A i.e. Group A^ohad longer pods while group C had shorter pods compared to other treatment groups.

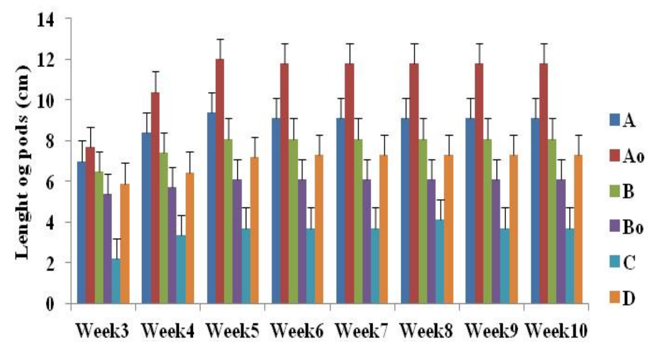

Fig 7: Lenght of pods per plant of the cowpea plant

Key: A - plant harvested from soil with untreated faecal sludge from location A, A^o - plant harvested from soil with treated faecal sludge from location A, B - plant harvested from soil with untreated faecal sludge from location B, B^o - plant harvested from soil with treated faecal sludge from location B, C - plant harvested from soil with NPK, D - plant harvested from soil with no amendment (Control)

3.8 Mean weight of the harvested cowpea

It was observed that there was significant difference in mean weight of pods of the harvested cowpea plants among the treatment groups ($p \leq 0.05$) as shown in Figure 8. The pods harvested from soil amended with treated faecal sludge from location Ai.e. Group A^o had the highest mean weight when compared with the other treatment groups.

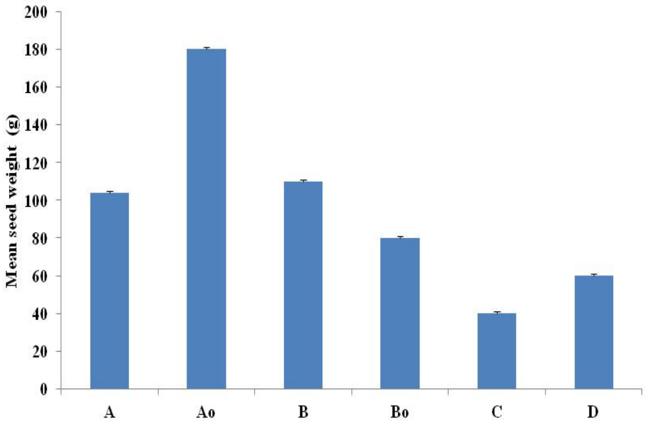

Fig 8: Mean seed weight of harvestedcowpea per treatment group

Key: A - plant harvested from soil with untreated faecal sludge from location A, A^o - plant harvested from soil with treated faecal sludge from location A, B - plant harvested from soil with untreated faecal sludge from location B, B^o - plant harvested from soil with treated faecal sludge from location B, C - plant harvested from soil with NPK, D - plant harvested from soil with no amendment (Control)

IV. DISCUSSION

In some agricultural settings in Nigeria, some farmers oftentimes demand for untreated faecal sludge which they in turn use on their farmlands, this is often sold to them either in the raw form i.e. directly from the emptied soakaways or after it had been dumped in holes, this is one way of turning waste into wealth for those who empty the soakaways (Ayeni, 2012).

Chemical analysis of untreated faecal sludge samples revealed that minerals such as sodium, magnesium, nitrogen, phosphorus, calcium etc were present in varying concentrations. After thermal treatment of the faecal sludge samples, reduction in the concentration of the proximate matter and mineral content of the faecal sludge samples was observed even though the treatment temperature was far less than the boiling points of these elements, Okibe *et al*. (2016) observed a relationship between application of heat and reduction in proximate matter and mineral contents of vegetables. In an earlier study, Osibote *et al.,* (2016) observed that when faecal sludge is treated using heat, it has the tendency of reducing the microbial load hence this guarantees its safety for use as there is no fear of introducing pathogenic organism via the faecal sludge.

In the course of the planting experiment, it was observed that groups amended with the treated faecal sludge performed better compared to the one amended with inorganic fertilizer (NPK). According to Gupta *et al.* (1977), the addition of municipal sewage sludge to soil improves the soils biological, chemical and physical properties. Although, addition of sludge to the soil can impact the properties of the amended soils however, these changes vary with the characteristics of the sludge and soil, but certainly the faunal and microfloral components of soils will be altered as a result of the addition of faecal sludge. The addition of relatively high rates of sludge can increase the cation exchange capacity (CEC) of soils (Soon, 1981; Kladivko and Nelson, 1979b; Epstein *et al.,* 1976).Increase in CEC makes room for additional cation binding sites which retain essential plant nutrients within the rooting zone. It could be that the CEC increase causes more complexing of heavy metals in an unavailable form for plant uptake (Kladivko and Nelson, 1979b). Most faecal sludge have about 50 percent of the solid fraction as organic matter, this improves the physical condition of soils (Khaleel *et al.,* 1981; Kladivko and Nelson, 1979b; Kelling *et al.,* 1977a; Epstein, 1975). An increase in organic matter content decreases bulk density (Kladivko and Nelson,1979b), increases aggregate stability (Kladivko and Nelson, 1979a, 1979b; Epstein, 1975), increases water holding capacity (Kladivko and Nelson, 1979b; Gupta *et al.,* 1977; Kelling *et al.,* 1977a; Epstein *et al.,* 1976; Epstein, 1975), and promotes greater water infiltration (Kladivko and Nelson,1979a,1979b; Kelling *et al.,* 1977a) which favors the overall health of the plant.

In conclusion, this study revealed that thermal treatment has the tendency to reduce heavy metal content of faecal sludge in addition to producing a better yield than inorganic fertilizer (NPK) when used as manure.

V. CONFLICT OF INTEREST

The authors declare that there is no conflict of interest.

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