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Research Article
Operation Parameters Impact on Fertilizer NPK Produced by Anaerobic Co-digestion of Plantain Extract and Cow Dung

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Abstract
Background and Objective: The annual wastes generated from rearing of cow and plantain plantation have been on the increase as a result of their higher demand. Hence, there is need to manage these wastes for human benefit. This study examined the contact time and mixing ratio effects of co-digestion of plantain pseudostem extract and cow dung on NPK value of produced organic fertilizer. **Materials and Methods:** Each of the samples was analyzed for nitrogen, phosphorus and potassium which were the major constituents of an organic fertilizer. Calibration curve was used to generate correlation between the absorbance obtained using UV spectrophotometer and concentration of potassium and phosphorus. **Results:** The results revealed presence of nitrogen, phosphorus and potassium with decrease in their respective concentrations as the pseudostem extract volume increases. However, each of them exhibited maximum value at specified contact time and plantain extract-cow dung mixing ratio. Nitrogen content decreased as contact time increased while concentrations of phosphorus and potassium increased with increasing contact time. **Conclusion:** Varying the values of plantain pseudostem extract-cow dung mixing ratio and contact time had significant effect on anaerobic micro-organisms' activeness which thus affected the NPK value of produced fertilizer. Optimum NPK value could be obtained at specified contact time and mixing ratio. Digestate from anaerobic co-digestion digestate from plantain pseudostem sap and cow dung had revealed potential to be used as organic fertilizer as it contained some level of NPK.

Key words: Plantain pseudostem extract, cow dung, contact time, mixing ratio, NPK value

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Competing Interest: The authors have declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

Organic fertilizers are sources of soil nutrients derived from animal or vegetable matter applied to the soil to supply needed plant nutrients that contains major important quantities of nitrogen (N), phosphorus (P) and potassium (K)[1]. Researchers have shown organically produced crops to be healthier for consumption and safer for the environment and hence, high demand for organic fertilizers over chemical fertilizers[2-4]. Unbalanced and prolonged use of chemical fertilizers such as ammonium sulphate decline soil fertility and may also increase the soluble salt content of the soil solution by increasing the osmotic pressure of the solution beyond that of the plant sap[5]. However, organic fertilizers keep soil friable; promote beneficial soil life; increase crop yield and grow larger plant; benefit environment by recycling and reducing waste; minimize green house gas emission; protect certain crops from disease and cheaper than chemical fertilizers as they can be locally prepared on farm at a low cost using crop residues, animal dung and other plant material such as banana stems, leguminous leaves and green grasses[6].

Anaerobic digestion (AD) is a process by which organic matter is broken down to simpler chemical components in the absence of oxygen[7] and consists of four stages (hydrolysis, acidogenesis, acetogenesis and methanogenesis) in which each stage is carried out by a different group of anaerobic bacteria[8]. Co-digestion is the simultaneous digestion of a homogenous mixture of two or more substrates in the same unit. Traditionally, anaerobic digestion was a single substrate, single purpose treatment. Recently, it has been realized that anaerobic digestion as such became more stable when the variety of substrates applied at the same time is increased[9]. The use of co-substrates usually improves the biogas yields from anaerobic digester due to positive synergisms established in the digestion medium and the supply of missing nutrients by the co-substrates[10]. The digestate from an anaerobic digestion process can be used as organic fertilizer[11].

Studies have shown organic fertilizers produced from organic wastes to be very rich in N-P-K. Liquid organic fertilizers like poultry manure tea and compost tea have been found to contain Nitrogen mainly in inorganic form like ammonia[12]. Kasim *et al.*[3] examined the effectiveness of organic-Nitrogen fertilizer with different sources of humic molecules and treatments in enhancing nutrients uptake and use efficiency in corn (*Zea mays*). Organic fertilizer produced from seaweed extract has been found to contain negligible amounts of N and P but high levels of all trace elements and plant hormones cytokinins, gibberellins and vitamins[13]. In India, an organic fertilizers called panchagavya was made from a manure tea by fermenting cow dung in water with NPK content of 0.03-0.02-0.04 but a high iron content of 0.84% while Jeevamrut and Beejamrut, contain plant growth hormones[14]. Govere *et al.*[15] investigated the nutrient content of three organic liquid fertilizers made from Water Hyacinth (*Eichhornia Crassipes*), Russian Comfrey (*Symphytum officinale)* and Pig Weed red-root *(Amaranthus retroflexus)* plants. Water Hyacinth liquid manure had significantly high N (3.72%) and P (2.86%) contents indicating its suitability as a macronutrient fertilizer. Russian Comfrey had high K content (3.90%) while Pig weed had high levels of Ca, Zn and Mg suggesting its suitability as a sufficient micronutrient fertilizer. Mohiuddin *et al.*[16] has also shown sap extracts from banana pseudostem to be very rich in nitrogen (N), phosphorus (P) and potassium (K). Plantain powder had been shown to contain 0.297 mg phosphorus and 435.200 mg potassium per 100 g of sample analysed[17]. Dickson[18] also revealed 100 g of dried plantain to contain 400 and 28 mg of potassium and phosphorus respectively. Cow dung has also been analyzed to contain nitrogen, phosphorus and potassium[19].

The expensive cost of conventional fertilizers sold to farmers coupled with the wastes generated from cow dung and plantain pseudostem after harvest have called for global attention as these wastes are needed to be properly managed before they go out of control. Thus, this study executed anaerobic co-digestion to produce organic fertilizer from plantain pseudostem extract and cow dung because of their potentials for N-P-K content. Plantain pseudostem waste has been considered as useful in the production of organic fertilizers as it contains appreciable amount of nitrogen, phosphorus and potassium which are major macronutrients needed by plant for growth[20]. In current research study, the effects of contact time and mixing ratio of plantain pseudostem extract and cow dung were examined using a digester.

MATERIALS AND METHODS

This research study was executed inside the Material Science Laboratory of Chemical and Petroleum Engineering Department, Afe Babalola University, Ado-Ekiti, Ekiti State, Nigeria between January 2018 and May 2018.

Collection of samples: The plantain pseudostem was taken after harvest from Afe Babalola University Farm, Ado-Ekiti, Ekiti State Nigeria located on longitudes 5°18'05.78"E and latitudes 7°36'09.59"N. The cow dung used was obtained from an abattoir located inside Bodija International Market, Ibadan, Oyo State, Nigeria on longitudes 3°55'2.3268"E and latitudes 7°24'7.0632"N.

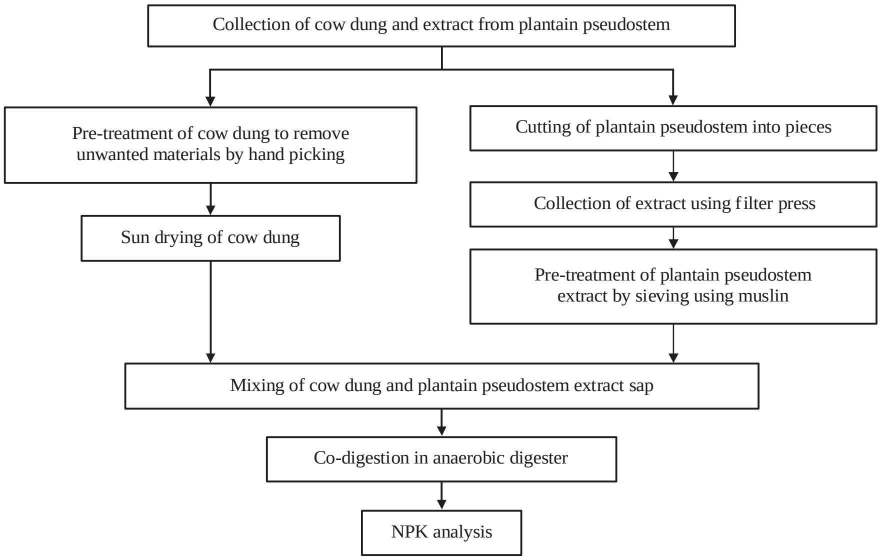

Fig. 1: Schematic diagram of the steps involved in the organic fertilizer production by anaerobic digestion process

Fig. 2: Anaerobic digester containing samples undergoing co-digestion

Extraction of plantain pseudostem sap: The plantain pseudostem was cut into pieces with diameter of 10 cm and thickness 3 cm after which a filter press was used to extract the sap. The liquid extract was then filtered to remove uncrushed plantain pseudostem and suspended particles using a thin piece of cloth (Muslin). Figure 1 was the schematic diagram of the steps involved in the organic fertilizer production by anaerobic digestion process.

Anaerobic digestion process for mixing ratio effect: This step was carried out to determine which mixing ratio of cow dung and plantain pseudostem sap gave the optimum NPK (Nitrogen, Phosphorus and Potassium) values. About 50 g of the fresh cow dung was put in separate beakers and a different volume of sap was added to each of the beakers to acquire the various mixing ratios. Beakers 1, 2, 3, 4 and 5 contained 100, 150, 200, 250 and 300 mL of sap, respectively. The mixtures were stirred continuously in 500 mL beaker and placed in the anaerobic digester for 2 weeks (14 days) at room temperature. After the digestion time was completed, the five samples were examined for laboratory analysis for the determination of the NPK (Nitrogen, Phosphorus and Potassium) values.

Anaerobic digestion process for contact time effect: This process was carried out to determine the effect of time on the sample with the optimum NPK concentrations obtained. About 100 mL of sap was put in a beaker and 50 g of fresh cow dung was added to it. The mixture was stirred continuously to ensure thorough mixing. The sample was placed in the anaerobic digester for one week (7 days) after which it was retrieved. The procedure was repeated for 21 days and samples were analyzed for NPK concentrations. Figure 2 presented a mixture of cow dung and sap from plantain pseudostem undergoing anaerobic digestion in a digester.

Determination of nitrogen (N): Nitrogen determination process involved three stages which were digestion, distillation and titration.

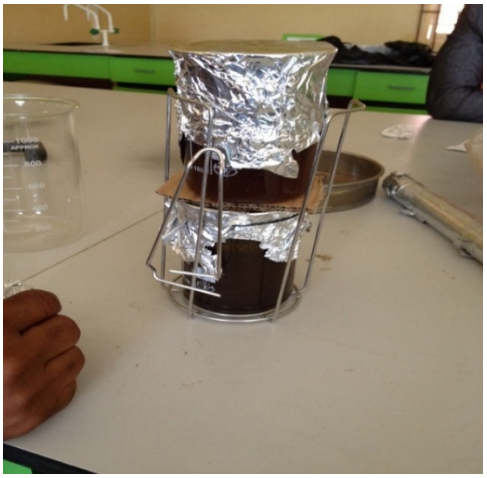

Fig. 3: Anaerobic digestion of pure liquid extract of plantain pseudostem

Digestion process: About 10 mL of the sample was measured into a digestion tube. About 3 g of catalyst mixture and 10 mL of concentrated H_2SO_4 were added to the tube. Anti-bumping was added and the tube was placed on the digestion rack and the exhaust manifold was turned on and was allowed to digest at a temperature of 400°C until the sample became clear. The digestion was continued for an hour after the mixture was clear. The digestion was allowed to cool for an hour and the content was then diluted to 100 mL with distilled water and then allowed to cool to room temperature. As Fig. 3 was the anaerobic digestion of pure liquid extract of plantain pseudostem.

Distillation and titration: Distillation was carried out using the Kjeldahl apparatus (or the steam distillation unit) previously applied elsewhere[21]. About 10 mL of the digestate plus 10 mL of 40% NaOH was measured and placed in the reaction chamber of the Kjeldahl apparatus. About 15 mL of 2% boric acid was placed into 250 mL conical flask (The boric acid receives and traps down free ammonia vapour liberated from the digestate into the flask). Two drops of indicator was added to the 250 mL flask. Distillation took place and 200 mL of the distillate was collected into the receiving flask. The distillate was titrated with 0.01 m HCl. Blank distillation and titration was also carried out. The percentage nitrogen was calculated thus[22]:

$$\text{Nitrogen (\%)} = \frac{(V_2 - V_1)\times 0.014\times C_a \times 100}{\text{Vol. of sample used}\times V_d} \qquad (1)$$

Where:

V_2 = Titre value (volume of acid used for titration of the digest)
V_1 = Volume of acid used for the titration of the blank
V_d = Volume of digestate distilled
C_a = Concentration of acid used

Determination of phosphorus (P): Five milliliters of sample was measured into a crucible and ashed in the muffle furnace at 650°C for 4 h. The ash was digested with 6N HCl and a drop of conc. The HNO_3 and heated until it was completely dissolved. The dissolved ash was cooled, transferred into a 100 mL volumetric flask and diluted to volume with distilled water. About 1 mL of the solution was prepared with 20 mL molybdovanadate reagent and put in a 50 mL volumetric flask. Colour was allowed to develop for 10 min. The absorbance was read at wavelength of 400-450 nm using UV spectrophotometer (Spectrumlab 752s, England). The concentration of phosphorus from absorbance is calculated using a linear expression (Eq. 2) generated from the calibration curve thus[23]:

$$y = 0.006x+0.003 \qquad (2)$$

Where:

y = Absorbance
x = Concentration (ppm)

Determination of potassium (K): The plantain pseudostem sap samples were filtered using Whatman filter paper to remove suspended particles. One milliliter each of the filtrate was pipette into 50 mL standard flask and diluted to volume with distilled water. Samples were analyzed using flame photometer.

RESULTS AND DISCUSSION

Mixing ratio effect: The data in Figure 4 presented a graph of nitrogen content (%) against varying volume of plantain pseudostem extract at constant 50 g cow dung. Optimum nitrogen content of 0.170% was obtained at cow dung and plantain pseudostem sap mixing ratio of 50 g/100 mL. The plot revealed decrease in nitrogen content as plantain pseudostem sap volume increased. A similar trend was obtained for the plot of phosphorus concentration against plantain pseudostem extract volume at 50 g cow dung as shown in Fig. 5. Optimum phosphorus concentration of

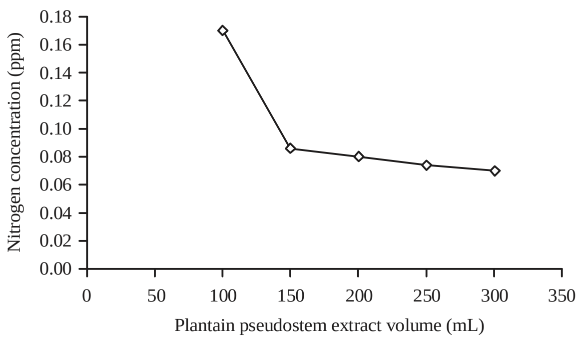

Fig. 4: Nitrogen content against plantain pseudostem extract volume at 50 g cow dung

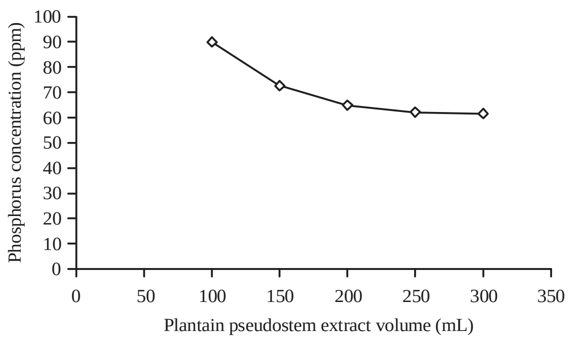

Fig. 5: Phosphorus conc. against plantain pseudostem extract volume at 50 g cow dung

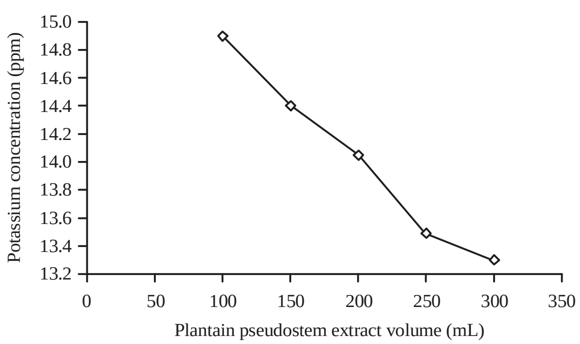

Fig. 6: Potassium conc. against plantain pseudostem extract volume at 50 g cow dung

89.95 ppm was obtained at plantain pseudostem extract volume of 100 mL with decrease in concentration as extract volume increases. As shown in Fig. 6, the concentration of potassium also decreased as the plantain pseudostem extract volume increased while optimum concentration of 14.9 ppm was obtained at 100 mL extract of plantain pseudostem. This was evident that increasing extract's concentration at fixed cow dung mass of 50 g was not favourable for increasing N-P-K content of the produced fertilizer. This could be linked to the chemical content and structure of the extract weakening the N-P-K content of the fertilizer as its volume increases. In a similar result, Minale and Worku[24] obtained N-P-K value of 0.19%, 47.16 and 67.52 mg kg^{-1}, respectively at sanitary wastewater and kitchen solid waste mixing ratio of 25:75. Kuo *et al.*[25] presented 0.1-0.3%, 40-110 mg kg^{-1} and 60-120 mg kg^{-1} ranges for N-P-K, respectively at optimum cow dung and corn cob mixing ratio of 4:1. Tampio *et al.*[26] also presented similar result while Opurum *et al.*[27] obtained optimum biogas yield of 5.51 dm^3 at 65 g/6 g corns health:NPK mixing ratio. A digestate having total nitrogen, phosphorus and potassium content of 0.1-0.3%, 40-90 and 10-20 ppm, respectively has fertilizing efficiency in agriculture[28].

Contact time effect: As Figure 7 presented a plot of nitrogen content against contact time with optimum nitrogen content of 14.44% obtained at 7 days of anaerobic co-digestion of plantain pseudostem extract and cow dung. A decrease in nitrogen content from 14.44-0.17% between 7-21 days of digestion was due to the inactiveness of anaerobic micro-organisms enhancing the nitrogen production when transforming from nitrogen into nitrates. However, the nitrogen content started increasing again after 14 days of co-digestion while nitrogen content of 0.87% was obtained at 21 days. Phosphorus concentration increased linearly from 81.67-93.25 ppm when the anaerobic co-digestion contact time was extended from 7-21 days as shown in Fig. 8. This was an indication that increasing time contact for the anaerobic co-digestion of plantain pseudostem extract and cow dung was favourable for phosphorus formation in the fertilizer production. Nevertheless, an increase in potassium concentration started manifesting after 14 days of co-digestion contact time as presented in Fig. 9. An optimum concentration of 27.5 ppm was obtained at 21 days. In previous studies, Escobar *et al.*[29] obtained optimum NPK at 75 days during a 90 days vegetable and date palm residues composting while Minale *et al.*[24] obtained maximum NPK at 20th day when subjecting sanitary wastewater and kitchen solid waste to co-digestion for 30 days. Aragaw *et al.*[30] produced optimum N-P-K content of 0.24%, 73 and 14 ppm, respectively at contact time of 21 days during 45 days retention time of cow manure and organic kitchen waste co-digestion. Many studies had obtained optimum NPK value at different anaerobic co-digestion contact time of 21 days[26], 31 days[27,31] and 41 days[32,33]. However, of all the literatures consulted, many obtained optimum NPK value at 21st day of anaerobic co-digestion retention period.

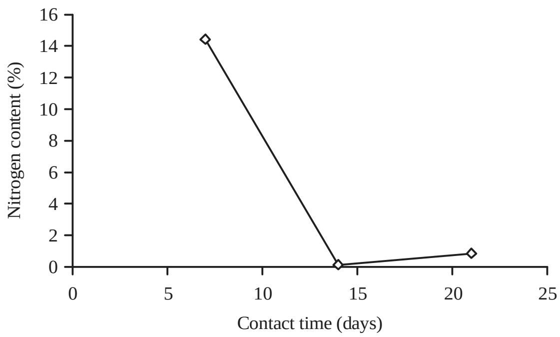

Fig. 7: Nitrogen content (%) against contact time (days)

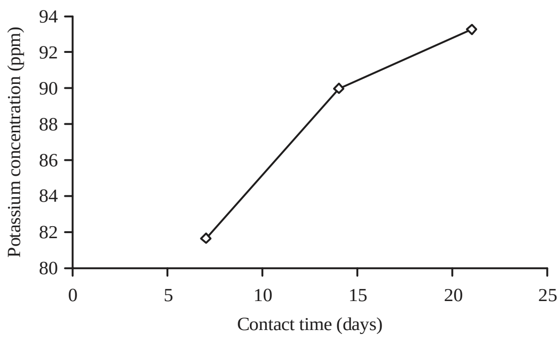

Fig. 8: Phosphorus concentration (ppm) against contact time (days)

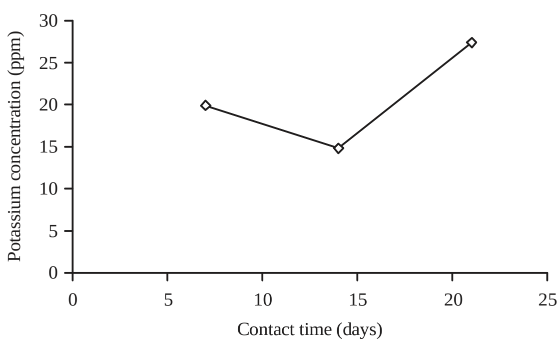

Fig. 9: Potassium concentration (ppm) against contact time (days)

CONCLUSION AND RECOMMENDATION

Digestate from anaerobic co-digestion of plantain pseudostem sap and cow dung can be used as liquid organic fertilizer as it contains some level of NPK. However, the organic fertilizer exhibited highest values of 0.170%, 89.950 ppm and 14.900 ppm for N-P-K, respectively cow dung-plantain pseudostem sap mixing proportion of 50 g:100 mL. The concentration of each constituents decreases with increasing pseudostem extract volume. However, nitrogen exhibited highest value of 14.438% at 7 days while phosphorus and potassium revealed highest concentrations of 93.250 and 27.500 ppm, respectively after 21 days contact time. The NPK concentrations increase with contact time, i.e., the longer the digestion period, the greater the concentrations of NPK that will be present in the digestate (or fertilizer). In conclusion, the results have revealed the potential of cow dung and plantain pseudostem wastes to be used as substitutes to expensive conventional fertilizers. Also, optimum mixing ratio and digestion contact time at which optimum NPK can be obtained from the wastes have been revealed.

For future research work, catalyst can be developed from organic waste also in order to enhance the process. Further laboratory analysis can be done on samples to determine other nutrients present besides NPK. Also, determination of the effects of pH, temperature, nutrients and inhibitors concentrations on micro and macronutrients of the samples can also be carried out. There is also need to test the produced fertilizer on a soil sample and crop. The effects of pre-treatments processes such as physical (comminution, solid-liquid separation, ultrasonic), biological and physical-chemical processes and thermal on the NPK yield for both the substrates can be checked in future research work.

SIGNIFICANCE STATEMENT

This study unveils the effects of contact time and mixing ratio as operational parameters on N-P-K value of produced fertilizer by anaerobic co-digestion of plantain pseudostem extracts which could be beneficial to farmers as alternative to highly expensive fertilizers. This will be helpful to prospective researchers to critically look into application of material science to production of useful finished products for vegetation purposes such that new theories and innovations can be developed in this area of research.

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