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STUDY OF PHOSPHORUS AVAILABILITY IN PHOSPHO-COMPOSTS MADE FROM POULTRY MANURE AND PHOSPHATE WASTE

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Abstract

To evaluate phosphorus availability in phospho-composts produced from poultry manure (PM) and phosphate waste (Phosphate Sludge – PS and Screening Residue – SR), six composts (A1: 75% PM + 25% PS; A2: 80% PM + 20% PS; A3: 89% PM + 11% PS; B1: 75% PM + 25% SR; B2: 80% PM + 20% SR; B3: 89% PM + 11% SR) were prepared. The results showed that the initial levels of available phosphorus were low, ranging from 0.101 to 0.114% P_2O_5, indicating that microorganisms were not yet active at the beginning of the composting process. By the end of the process, the concentration of available phosphorus increased significantly, reaching 0.395 to 1.195% P_2O_5, representing an increase of 290 to 1071%. Overall, the composts enriched with phosphate sludge (series A) showed higher levels of available phosphorus than those containing screening residues (series B). These phospho-composts therefore represent promising organo-mineral amendments suitable for direct application in soil fertilization.

Key words*: phosphorus availability, phosphate waste, poultry manure, compost.*

INTRODUCTION

Considered one of the essential nutrients for plant growth (Ochwoh et al., 2005; Wang et al., 2012), phosphorus (P) plays a central role in biochemical processes such as photosynthesis, cellular respiration, and energy transfer (Hinsinger, 2001). However, the availability of this element in agricultural soils is very low in West African countries due to its strong binding to iron and aluminium oxides found in ferralitic soils (Nziguheba et al., 2016). In sub-Saharan Africa, phosphorus deficiency in arable soils remains one of the major constraints limiting the productivity of food crops (Vanlauwe et al., 2015). Limited phosphorus availability, resulting in nutrient deficiencies, frequently compels farmers to rely on phosphate-based fertilizers.

However, previous studies have demonstrated that excessive application of chemical fertilizers can contaminate groundwater, increase soil acidity, degrade soil physical structure, and reduce soil organic matter (Konaté et al., 2020; Afanou et al., 2025a). Other studies have shown significant accumulations of heavy metals in crops after the application of chemical fertilizers to the soil (Afanou et al., 2025b). Given the limited phosphorus availability in agricultural soils, along with the environmental and food security concerns associated with the use of mineral fertilizers, advancing the adoption of organic and biological fertilizers, especially compost, is imperative. Numerous studies have shown that composting enhances phosphorus availability in composts (Ablede et al., 2019; Bustamante et al., 2016; Wei et al., 2015; Christel et al., 2014) and substantially reduces the formation and release of greenhouse gases emissions into the atmosphere (Sema et al., 2021a).

Compost, the final product of the composting process, improves soil organic matter content (Afanou et al., 2025a). It is also important to note that these amendments, through their organic matter content, contribute to the

immobilization of heavy metals within the soil (Wang et al., 2012). Togo is one of the West African countries suffering from a lack of assimilable phosphorus in its agricultural soils. However, the country possesses a large phosphorus deposit, the exploitation of which generates two main waste products (phosphate sludge and screenings) that create major environmental problems due to their discharge into seawater or their accumulation at the washing site (Afanou et al., 2025c). These wastes are frequently poorly managed, despite containing approximately 14-20% P_2O_5, which could be utilised locally in agricultural production (Koriko et al., 2021). Additionally, livestock waste, particularly poultry manure produced in large quantities during modern poultry farming (laying and broiler hens), is often stored on-site or applied directly to crops without prior treatment, thereby contributing to various environmental problems (Lekefack, 2015). Therefore, this study aims to investigate the availability of phosphorus in composts made from poultry manure and this phosphate-rich waste. This research aligns with the promotion of organic farming and the development of the Circular Economy (CE).

MATERIALS AND METHODS

The raw materials and their origin

The poultry manure used in the composting process came from the Regional Centre of Excellence on Avian Sciences (CERSA) at the University of Lomé, while the phosphate waste was obtained from the Société Nouvelle des Phosphates du Togo, a phosphate washing plant located approximately 40 km southeast of Lomé (Figure 1).

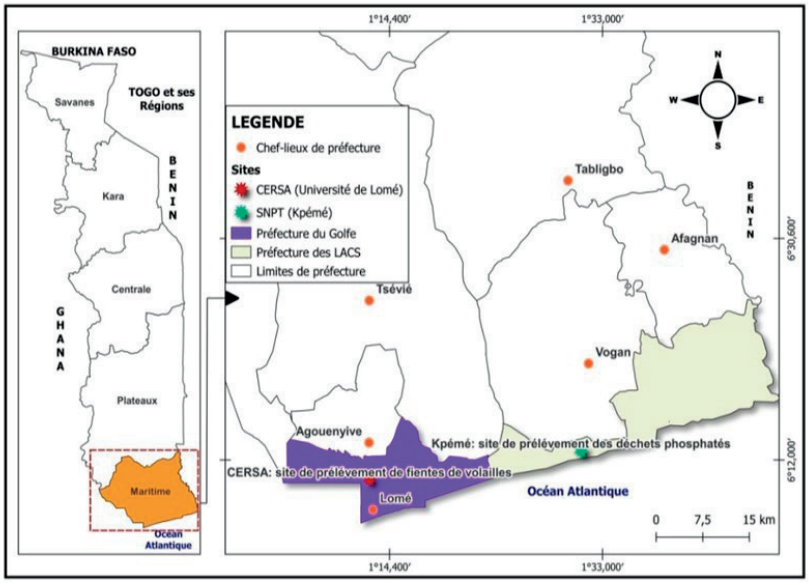

Figure 1. Map of Togo showing the origin of raw materials used for composting

Composting trial for poultry manure and phosphate waste

The composting experiment was carried out from May to July 2025 in plastic containers (pots) at the Laboratory of Applied Sciences for Agriculture and the Environment of the University of Agronomic Sciences and Veterinary Medicine (USAMV) of Bucharest, Romania. Prior to composting, several physicochemical parameters of the raw materials (poultry manure and phosphate waste) were analysed, including pH, total phosphorus, assimilable phosphorus, and carbon and nitrogen contents (only for poultry manure). In total, two series (A and B) of three composts each were produced. Series A composts were prepared using poultry manure (PM) and phosphate sludge (PS), while series B composts were produced using poultry manure and screen refuse (SC). The composition of each compost, based on the proportion of the various

wastes used, is provided in Table 1. Photo 1 presents: the weighing of the waste (a), mixing of the waste in a bin (b), placement of the mixtures introduced into the composting pots (c) and the phospho-composts during their evolution (d). Throughout the composting process, pH was regularly monitored at two-week intervals, as this parameter plays a critical role in determining phosphorus availability during compost maturation.

Table 1. Substrate composition of each compost

Series	Composts	PM		PS		SC	
		m (g)	P (%)	m (g)	P (%)	m (g)	P (%)
A	A_1	500	75	166.67	25	0	0
	A_2	500	80	125	20	0	0
	A_3	500	89	62.5	11	0	0
B	B_1	500	75	0	0	166.67	25
	B_2	500	80	0	0	125	20
	B_3	500	89	0	0	62.5	11

Photo 1. Stages preceding and during the composting process: weighing (a) and mixing of waste (b); filling of the composting boxes (c); phospho-composts during their evolution (d)

Physico-chemical analysis methods during composting

The pH was determined using a potentiometric method, following the methodology of the Research Institute for Pedology and Agrochemistry (ICPA) of Bucharest (1983), Chapter 3, PT 126, which is specifically applied to residual products. Total organic carbon (TOC) content was quantified using the Walkley and Black (1934) method. Total nitrogen was determined by the Kjeldahl method in accordance with ICPA (1983), Chapter 8 (2), PT 129. Total phosphorus (Ptot) was determined following the ICPA methodology (1983), Chapter 9 (2.1 and 3), PT 132. Assimilable phosphorus (Pass) was assessed through ammonium acetate–lactate extraction according to the Romanian STAS method 7184/19-82; PTL 19; ed.3, rev. 0.

Statistical analysis of data

To assess the normality of the data and the significance of the difference for the results on assimilable phosphorus between the beginning and end of the composting process, statistical analyses (Shapiro Wilk test, t-test and Wilcoxon test) were performed using R software, version 4.5.0.

RESULTS AND DISCUSSIONS

Some physicochemical characteristics of poultry manure and phosphate waste

The pH, organic carbon (%TOC), total nitrogen (%N), total phosphorus (Ptot expressed as $\%P_2O_5$) and assimilable phosphorus (Pass expressed as $\%P_2O_5$) of the raw materials used in the composting process are presented in Table 2. The pH of these materials is slightly alkaline,

ranging from 7.53 to 7.77. This alkalinity can be attributed, on the one hand to the high nitrogen content of poultry manure (3.09%), and on the other hand, to the abundance of carbonate (CO_3^{2-}), sodium (Na_2O), calcium (CaO) and magnesium (Mg) in the natural phosphates from which the phosphate waste was generated (Tchangbedji et al., 2003). The high carbon (33.09%) and nitrogen (3.09%) contents of these poultry manure are normal and are expected to be beneficial during the composting process. The phosphate waste exhibits high total phosphorus concentrations, ranging from 10 to 13% of P_2O_5, which can be attributed to its apatite content. However, its assimilable phosphorus (Pass) levels are very low, indicating the need for processing to enhance phosphorus availability before this material can be used as fertilizer in agriculture.

Table 2. Some characteristics of the materials used in the composting process

Raw material	pH	%TOC	%N	Ptot (%P_2O_5)	Pass (%P_2O_5)
Poultry manure	7.59	33.39	3.09	4.56	0.1
Phosphate sludge	7.77	-	-	10.68	0.09
Screening residue	7.53	-	-	13.54	0.1

The evolution of pH during the composting process

The pH is one of the important parameters during the composting process (Hellal et al., 2012). The evolution of the pH during the composting process is shown in Figure 2. At the initiation of composting, the pH of the different composts ranged between 7.33 and 7.73, reflecting the comparable pH values of the raw materials (poultry manure and phosphate waste) used. During the first fifteen (15) days of composting, the pH increased considerably, reaching values between 7.86 and 8.64 in both compost series. This rise can be attributed to the release of ammonia or amines resulting from the degradation of nitrogenous organic matter, as well as to the breakdown of organic acids accompanied by CO_2 release (Pan et al., 2011; Kim et al., 2018; Azis et al., 2023). In series A composts, the highest pH value (8.39) was recorded in compost A3 (compost from 89%PM and 20%PS), whereas in series B, the maximum pH value (8.64) was observed in compost B3 (compost at 89%PM and 20%PS). The high pH values occurring around the 15th day of composting are likely attributable to the high proportions of poultry manure, which is rich in nitrogen. Similar increases in pH have also been reported in several composting studies (Gao et al., 2010; Mengistu et al., 2017). The decline in pH after the 15th day of composting, reaching values around 7, can be attributed to the volatilization of ammoniacal nitrogen (N-NH_4^+) and the release of hydronium ions (H_3O^+) through bacterial nitrification (Huang et al., 2004; Wang et al., 2016; Onwosi et al., 2017).

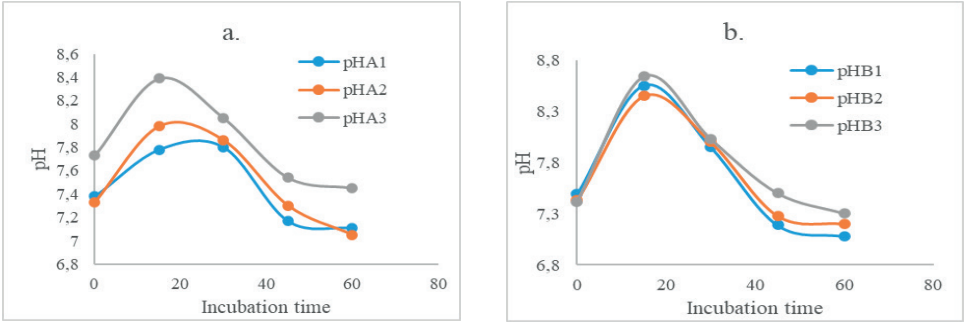

Figure 2. Evolution of compost pH (a. - series A; b. - series B) during composting

Total phosphorus in the different composts

The total phosphorus contents of the phospho-composts are presented in Figure 3. Analysis of the data shows that the composts in series A contain lower levels of total phosphorus (ranging from 5.27 to 6.60% of P_2O_5) compared

with those in series B, whose values range from 7.90 to 12.55% P_2O_5. The reduced Ptot levels in series A composts are likely attributable to the use of phosphate sludge, which contains less total phosphorus than the screen refuse used in the series B composts.

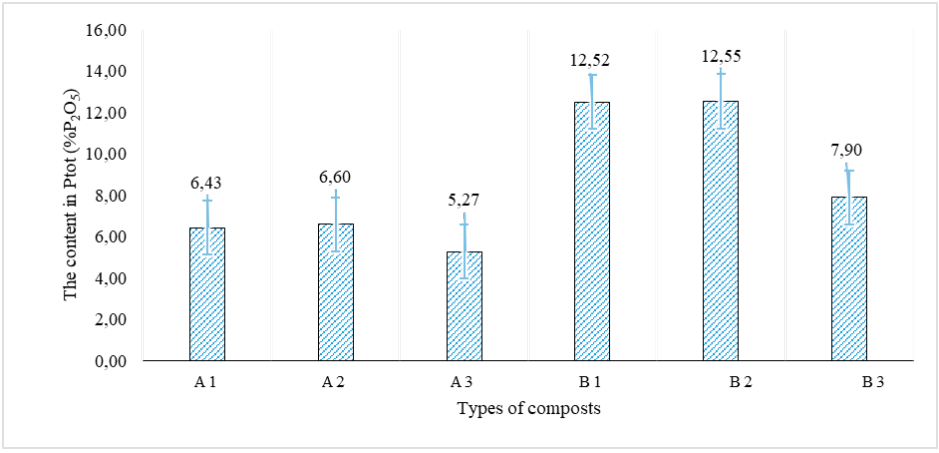

Figure 3: Total phosphorus content in the different phospho-composts

Study of assimilable phosphorus in different composts

Composts that contain high levels of total phosphorus but very low contents of assimilable phosphorus provide limited benefit as plant phosphorus sources, since most of the element remains immobilized in unavailable forms. The Pass contents of the 6 composts are presented in Figure 4. At the initiation of composting, these values were low, ranging from 0.102 to 0.111%P_2O_5, indicating that phosphatase-producing decomposer microorganisms were not yet fully active. After two months of composting, Pass increased substantially, reaching values between 0.394 and 1.195% P_2O_5, an increase between 290 and 1071% compared to the initial levels. Similar observations have been made by other authors (Amarasinghe, 2022; Debicka et al., 2023; Kutu et al., 2018; Lee, 2016). We also observed that, throughout the composting process, phosphorus tends to be more available in the series A composts (Pass between 0.74 and 1.195% P_2O_5) than in the series B (Pass between 0.394 and 0.973% P_2O_5). The nature of phosphate waste largely determines this difference. Specifically, phosphate sludge promoted greater phosphorus availability in the composts compared to the screening refusals.

The results of the statistical tests assessing the significance of the differences in assimilable phosphorus between the beginning and end of composting are presented in Table 3. The Shapiro-Wilk test ($W = 0.896$; $p = 0.351$) indicates that the differences between initial and final values are normally distributed ($p > 0.05$). This normality justified the use of a parametric test, namely the paired *t*-test ($t = 6.82$; $p = 0.001$), which revealed a highly significant difference between the initial and final means of assimilable phosphorus (P_{ass}), indicating a clear increase in this parameter by the end of the composting process. The non-parametric Wilcoxon test ($W = 0$; $p = 0.031$) further confirmed the *t*-test results, reinforcing the conclusion that assimilable phosphorus increased significantly from the start to the end of the process. Thus, the statistical analyses consistently demonstrate that the composting process promotes a significant increase in assimilable phosphorus, likely associated with the progressive mineralization of organic matter and the consequent release of nutrients within the compost matrix.

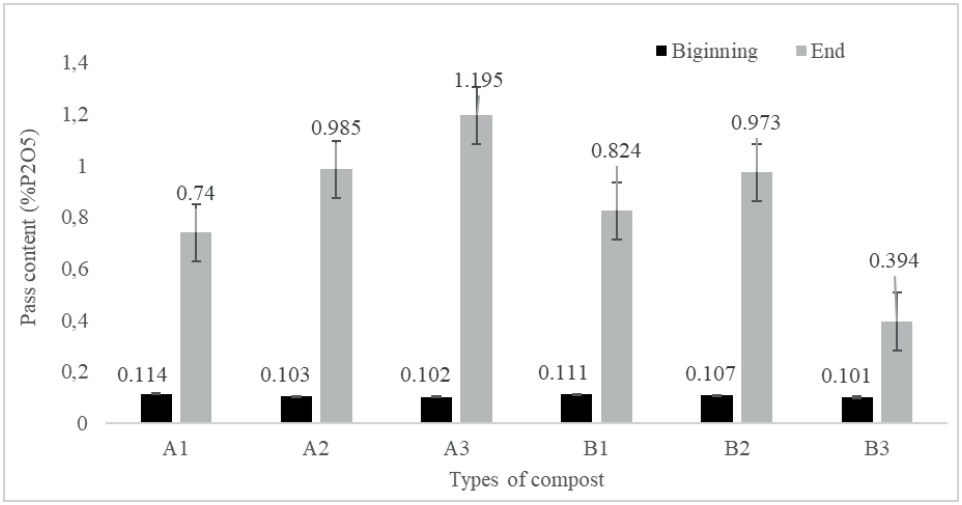

Figure 4: Assimilable phosphorus content of different phospho-composts at the beginning and at the end of composting

Table 3: Results of statistical tests applied to the assimilable phosphorus values of composts

Statistical test	Objectives of the test	Statistic	p-value	Threshold (α= 0.05)	Interpretation
Shapiro-wilk	Verify the normality of the distribution of differences (End – Beginning)	W = 0.896	0.351	$p > 0.05$	The distribution of differences does not deviate significantly from normality.
Paired t-test (parametric)	Compare the mean available phosphorus at the beginning and at the end of composting	t = 6.82	0.001	$p < 0.05$	Highly significant difference: increase in available phosphorus between the beginning and at the end of composting.
Wilcoxon (non-parametric test)	Confirm the difference without assuming normality (comparison of medians)	W = 0	0.031	$p < 0.05$	This result is also significant, confirming the increase in assimilable phosphorus after composting.

CONCLUSIONS

The study of phosphorus availability in phospho-composts produced from poultry manure and phosphate waste over a 60-day period revealed a pronounced increase in assimilable phosphorus (Pass). Initial Pass levels, ranging from 0.101 to 0.114% P_2O_5, were relatively low at the beginning of composting. During the composting process, and especially around day 60, Pass levels reached values between 0.394 and 1.195% P_2O_5, corresponding to an increase of 290 to 1071% compared to the initial values. In conclusion, the combined management of poultry manure and phosphate waste through a controlled composting process results in a product enriched in available phosphorus (Pass).

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