Indian Journal of
Advances in Chemical Science

Article

Evaluation of Some Nutrient Elements Contained in Composts of Certain Biodegradable Household Waste

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ABSTRACT

The aim of our study was to find an alternative to the use of chemical fertilizers which not only degrade the soil but cause global warming. To achieve this, seven composts were made from three domestic waste (plantain peelings, cassava peelings, and yam peelings at 100% and also their mixtures two to two at 50% then at three 1/3). These different composts were characterized and their chemical properties were determined and then compared to those of the six others, to the ENPRO compost (made in Togo) and also to those of the soil from the Akouédo landfill. The analysis of the results of the mineral composition of the composts showed that the C7 compost is the richest in minerals and has the same amount of nitrogen as the ENPRO compost. It has also been demonstrated that the compost of crushed plantain peels (C3) used alone or in mixtures with the compost of yam and/or cassava peels (C5, C6 and C7) mineralizes and rapidly releases nutrients to make them available to plants. These organic fertilizers (elaborated composts C3, C5, C6, and C7) could, therefore, constitute an alternative to the use of chemical fertilizers and be recommended to farmers, because they are rich in minerals, accessible, cheap, and easy to produce.

Key words: Peelings, Peels, Compost, Chemical fertilizers, Organic fertilizers.

1. INTRODUCTION

Pollution of the environment, in general, and aquatic environments, in particular, by household waste and chemical fertilizers is increasingly the subject of particular attention from researchers and decision-makers. This particular attention is a consequence of the persistence and increases of household waste due to the precarious conditions of its collection and population growth [1,2]. Furthermore, the excessive and exclusive use of chemical fertilizers causes greenhouse gas emissions and soil degradation [3,4]. Added to this are poor land management practices that subsequently lead to soil nutrient depletion, causing a drop in crop yield [5]. The essential components of soils are organic matter (OM) and the C/N ratio, which play a very decisive role in improving land productivity [6]. Indeed, OM feeds soil organisms and must be at least between 3 and 7% to have a good yield [6]. The C/N ratio, for its part, conditions the process of mineralization of OM [6]. From the analysis of the above, efficient technologies accessible to low-income producers, already highlighted, can be used, in particular composts or organic fertilizers. Their contributions increase the levels of OM in the soil as well as the biomass of microorganisms and their activities [7]. The use of organic fertilizers prepared from less expensive materials (waste) is increasingly widespread. Thus, many studies have focused on organic fertilizers prepared from waste [8-11]. The work of Bomisso *et al*. (2018) [8] showed that dried and crushed plantain peel used alone or in a mixture is an optimal source of nutrients for plants. Indeed, plantain banana peels, cassava peels, and yam peels constitute abundant easily biodegradable waste in tropical countries and particularly in Côte d'Ivoire. However, their chemical characteristics remain unknown and countries continue to import chemical fertilizers for various applications, particularly with regard to soil fertilization in the field of agriculture. According to studies conducted by the FAO, (2010) [12] and by Mulaji (2011) [7], chemical fertilizers have polluting and degrading effects on the soil, hence the need to seek other sources of nutrients for plants. Their use is one of the major causes of global warming [12-14].

The general objective of this study is to evaluate the nutrients contained in the composts of plantain peels, cassava peels, and yams. It is not only a question of producing and determining the chemical characteristics of organic fertilizers (composts) from waste, but also and above all of identifying the compost(s) richer in nutrients.

2. MATERIALS AND METHODS

2.1. Reagents

96% sulfuric acid and 37% hydrochloric acid were used to carry out the characterization of the composts. They were provided to us by the Panreac company.

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ISSN NO: 2320-0898 (p); 2320-0928 (e)
DOI: 10.22607/IJACS.2022.1003005

Received: 23th March 2022;
Revised: 13th June 2022;
Accepted: 30th June 2022

2.2. Collection of waste and preparation of compost

Three varieties of waste [Figure 1] were collected directly from market vendors in the city of Kounahiri (Côte d'Ivoire). They are plantain peels, cassava, and yam peels.

These three types of waste were crushed using a laboratory mortar and its pestle then mixed intimately with the soil taken from Kounahiri before undergoing composting in different proportions: 100% for compost made up of a single waste; 50% for compost made up of two different types of waste; and to 1/3 for the compost made up of the three different types of waste. The composting technique used was aerobic composting in a windrow on the soil surface and in a closed container. At the end of this composting, three composts each made up of a single waste, namely, cassava (C1), yam (C2), and banana (C3) compost, were developed as well as three other composts made up each of the mixture of two wastes, these are cassava peel and yam mixture compost (C4), yam peel and plantain mixture compost (C5), and cassava and plantain peels (C6) as well as a compost from the mixture of the three wastes (C7). Table 1 shows the composition of the various composts prepared.

2.3. Characterization of composts

The physical characteristics (pH, salinity, and conductivity) of the composts produced were carried out using a multi-parameter (HANNA brand pH-meter).

The total nitrogen (NT) content was determined by the Kjeldhal method according to the French standard AFNOR ISO 11–261 following a mineralization of 0.5 g of a sample of dried compost and sieved to 2 mm [15]. Equation 1 below is used to determine the total nitrogen content of compost samples:

$$NT(\%) = \frac{(V' - V) * N * 14 * 100}{m} \quad (1)$$

With, V' and V the volumes of sodium hydroxide required to neutralize the blank and the sample, respectively; C, the concentration of sodium hydroxide (0.1 N) and m, the mass of the test sample (g).

The total phosphorus content was determined by HACER brand UV-visible spectrophotometry at λ=760 nm after mineralization at 550°C [16]. The phosphorus content expressed as a percentage was obtained from equation 2:

$$P\ (\%) = \frac{C_s * V}{m} \quad (2)$$

With, C_s, the concentration read on the spectrophotometer (mg/L); V the volume of the filtrate (mL) and m, the mass of mineralized compost in kg.

The potassium (K), calcium (Ca), and magnesium (Mg) contents were determined using an atomic absorption spectrophotometer (SAA Flamme VARIAN SpectrAA) after mineralization by incineration with hydrochloric acid.

The potassium (K), calcium (Ca), and magnesium contents, expressed in %, were calculated using equation 3:

$$C\ (\%) = \frac{C_s * V}{m} \quad (3)$$

With, C_s, the concentration read on the spectrophotometer (mg/L); V the volume of the filtrate (mL) and m, the mass of mineralized compost in kg.

The determination of the OM content was carried out by the modified Walkley-Black potassium dichromate chemical method [17]. In the principle of this method, it is considered that the majority of total organic carbon is oxidized. The calculation of the organic carbon content in the composts (TOC in % of mass of compost) was made from equation 4:

$$COT = \frac{0.39 * V * N}{m} \quad (4)$$

Where, v is the volume of titrant; N, the normality of the titrant and m, the mass of compost used (g).

The OM content (OM in % of sediment mass) is calculated using the following equation:

$$OM = 1.73 * COT \quad (5)$$

The statistical analysis of the results obtained was carried out using the XLSTAT software.

3. RESULTS AND DISCUSSION

3.1. Characteristics of Composts

The results obtained concerning the physical and chemical characteristics of the various composts are recorded in Table 2. The analysis of the average pH values showed that they are between 6.2 and

Table 1: Composition of the different composts.

Composts	Composition of each compost
C_0	Land without input (control)
C1	C_0+EMB
C2	C_0+EIB
C3	C_0+PBB
C4	C_0+EMB+EIB
C5	C_0+EIB+PBB
C6	C_0+EMB+PBB
C7	C_0+EMB+EIB+PBB
C8	SDA

Co: Land from Kounahiri, EMB: Crushed cassava peelings, EIB: Crushed yam peelings, PBB: Crushed plantain peels, SDA: Soil from the Akouedo waste dump (Ivory Coast)

Figure 1: Banana peel (a); cassava peel (b); and yam peel (c).

Table 2: Physical, chemical, mineral, and organic composition of the composts obtained.

Composts composition	C_0	C1	C2	C3	C4	C5	C6	C7	C8	ENPRO	Reference values
pH	6.24	6.71	6.95	8.74	7.17	8.07	7.76	5.82	8.28	8.25	5–8.5 [19,20]
Conductivity (mS/cm)	0.08	0.11	0.15	0.23	0.19	0.41	0.19	1.01	0.116	3.30	
Salinity (%)	0.10	0.20	0.30	0.50	0.40	0.80	0.40	2.00	0.20	Notcalculated	
TP (%)	0.03	0.16	0.23	0.27	0.06	0.21	0.43	2.61	0.55	0.03±0.00	
TN (%)	0.14	0.204	0.209	0.221	0.213	0.229	0.227	0.460	0.224	0.50±0.02	0.5
PO_4^{3-} (%)	0.09	0.49	0.68	0.83	0.18	0.64	1.31	7.97	1.69	Non calculé	
Mg (%)	0.59	1.18	0.85	1.19	1.29	1.31	1.36	1.69	1.47	0.21±0.02	>1.46 [21]
Ca (%)	0.61	0.70	0.77	0.78	0.80	0.82	0.79	1.32	0.76	2.91±0.07	>11.21 [21]
K (%)	1.10	2.29	2.33	2.41	2.39	2.45	2.42	2.82	2.34	0.40±0.00	>5.06 [21]
COT (%)	5.91	6.54	6.63	6.26	6.73	6.57	6.44	7.85	6.16	12.00±2 0.00	
OM (%)	10.22	11.32	11.46	10.83	11.65	11.37	11.14	13.58	10.66	26.10±0.70	>20 [22]
C/N	42.21	32.06	31.72	28.32	31.59	28.68	28.37	17.08	27.50	24.70±0.00	<25 [21]

ENPRO: Ecosystème Naturel Propre (urban waste compost produced and marketed by a Togolese non-governmental organization)

8.2. Taking the pH scale into account, three groups of composts can be distinguished: acid, including C0 (6.91), C1 (6.96) and C7 (6.92), basic (C3, C4, C5, C6, and C8) and neutral C2 (7.01). We noted that with the exception of composts C1, C7, and C2, all the other composts have pH which is of the same order of magnitude as the pH of ENPPRO compost. This variation could be explained by the composition of the inputs and the intensity of nitrification of these organic products during storage [18].

Composts C3, C5, and C7 are the richest in nutrients among composts consisting, respectively, of a single type of waste (plantain peels); mixtures of two wastes (yam peels and banana peels); and mixtures of three wastes. The results also revealed that the C3, C5, and C7 composts are richer in potassium. This great richness in this mineral is due to their high proportion of banana peel. In fact, potassium essentially emanates from the veins of the mature plantain peels [23].

Compost C7 contains the highest values of electrical conductivity (1.01 mS/cm) and salinity (2 %) compared to other composts, a consequence of a strong dissolution of the conductive ions under the effect of the acidity of the medium (pH = 5.82). This compost is the richest in salt compared to Akouedo dump compost whose salt content is 0.2% and electrical conductivity (0.116 mS/cm). Furthermore, note that with the exception of compost C1, the other composts produced C2, C3, C4, C5, and C6 have electrical conductivity values (0.15; 0.23; 0.194; 0.41; and 0.196) mS/cm, respectively, and salinity (0.3; 0.5; 0.4; 0.8; 0.4) % higher than those of Akouedo dump compost. There is also a great variability in the mineral composition of the composts produced. This could be explained by their heterogeneity. The analysis of the results of the mineral composition of the composts [Table 2] shows that the C7 compost is the richest in minerals (nitrogen (N), phosphorus (P), potassium (K), phosphate ion, and calcium (Ca)). As the latter is composed of a mixture of three waste products (EMB; EIB; and PBB), this difference could be explained by the additional effect of cassava and yam peelings on plantain peel. Indeed, it revealed that cassava and yam peelings contain minerals such as nitrogen, phosphorus, and calcium [24]. The C/N ratio also confirms that the C7 compost is the best, because this ratio is between 15 and 20 [25]. In addition, this compost has practically the same amount of nitrogen as ENPRO compost (made in Togo). However, it is richer in phosphorus, potassium, phosphate ion, and magnesium than this one. The results of the organic chemical characterization reveal that the C3, C6, C0, and C8 composts have relatively low OM contents and that those of the C1, C2, C4, C5, C6, and C7 composts are greater than 10%. This variability of OM could be attributed to the nature of the inputs and the degree of mineralization of these composts during the analysis. C3 compost has a low OM content. This low content is also due to its high mineralization and its lack of ligneous compounds [26]. Regarding the C/N ratio, the results of the analysis showed that the C1, C2, C4, and C0 composts have high ratios (C/N >30) and lower ratios (C/N <30) for the C3, C5, C6, C7, and C8 composts. This difference could be due to their nitrogen content. Since the process of mineralization of OM is evaluated by the C/N ratio, the mineralization of composts C1, C2, C4, and C0 will, therefore, be very slow [27]. This could cause a slow release of the nutrients they possess. On the other hand, it is important to note that the C3, C5, C6, and C7 composts which have C/N ratios between 10 and 30 will mineralize and quickly release the nutrients to make them available to the plant. They are therefore mature, quality composts [21]. Thus, the comparison of the composts made with the ENPRO commercial fertilizer through the C/N ratio and the mineral

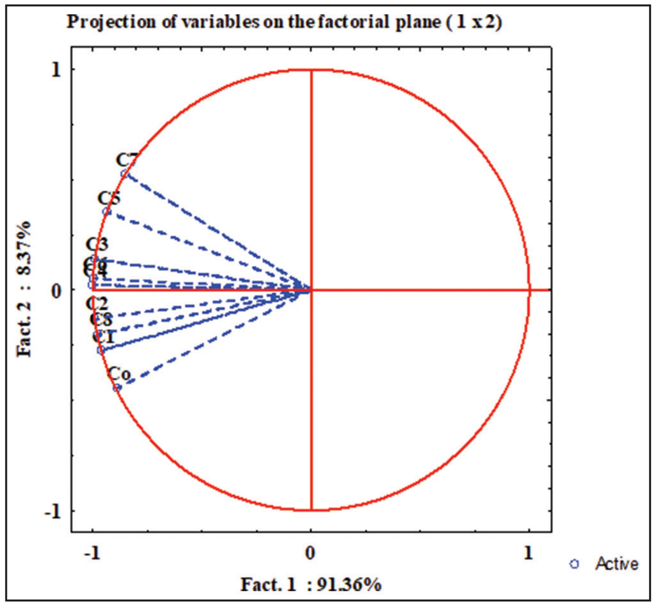

Figure 2: Distribution of composts and mineral composition characterization parameters in planes 1 and 2 of a component analysis.

composition shows that the household waste compost (C7) is much richer and more mature.

3.2. Principal component analysis (PCA)

The quality of compost is determined by the percentage of minerals that it contains [28]. PCA made it possible to characterize the composts on the basis of their mineral content [Figure 2]. The correlation circle shows that axes 1 and 2 contribute 99.73% to the total variation observed and that all the minerals are positively correlated with axis 1. The dispersion of composts in planes 1 and 2 allowed to obtain two groups of composts, the rich (C3, C5, C6, and C7), and the poor (C8, C4, C2, C1, and C0) in minerals.

3.3. Distribution of the Different Composts on the Factors

The factors F1 and F2 with respective values of 8.95 and 1.89 then percentages of total variances of 74.6 and 15.7% better express the information contained in the original data set [Table 3]. A correlation is significant in this study when it is greater than or equal to 0.70 [29,30]. With regard to the correlations, all the variables, with the exception of the pH, are correlated with the factor 1. As a result, all the composts are better described by the factor F1 [Table 3]. As for the components of these composts, only the pH with a correlation coefficient −0.04 cannot be explained by this axis [Table 3].

Table 3: Spatial distribution of physical and chemical parameters.

Variables	F1	F2
Total nitrogen	0.97	0.04
Total phosphore	0.94	0.15
Potassium	0.73	−0.55
Magnesium	0.77	−0.55
Calcium	0.99	0.07
TOM	0.89	0.26
TOC	0.88	0.26
C/N	0.84	0.39
pH	−0.04	−0.95
Conductivity	0.95	0.16
Salinity	0.95	0.13
Phosphate (PO_4^{3-})	0.94	0.15
Clean value	8.95	1.89
% Total variance	74.61	15.77
Accumul of clean value	8.95	10.84
Cumul %	74.61	90.38

3.4. Correlation between Physical and Chemical Components of Composts

The statistical study of the physical and chemical parameters of the different composts made it possible to obtain the correlation table [Table 4]. This table shows that total nitrogen is strongly correlated with total phosphorus, calcium, conductivity, salinity, and phosphate with respective correlations of 0.98; 0.98; 0.94; 0.94; and 0.98. In addition to these components, magnesium, total OM, and total organic carbon with respective correlations of 0.74; 0.82; and 0.82 are also correlated with nitrogen. Apart from total nitrogen, total phosphorus is strongly correlated with calcium, salinity, phosphate, and conductivity with respective correlations of 0.95; 0.91; 1; and 0.92. However, phosphate is moderately correlated with OM and total organic carbon. Potassium is only correlated with magnesium at 0.84. Conductivity, salinity, and phosphate are close to calcium with respective correlations of 0.96, 0.95, and 0.97. These three components are also correlated to OM and total organic carbon.

In view of the different correlations between most physical and chemical parameters and total nitrogen, a good compost would be one that necessarily contains nitrogen. The strong correlations of 0.96 and 0.99 observed, respectively, between conductivity and calcium then salinity and calcium corroborate the assertions of [31]. Calcium salts are largely responsible for conductivity in water and soils. Indeed, calcium salts contribute to salinity which positively impacts conductivity. In addition, the different correlations between conductivity, salinity, and phosphates and other parameters also imply that a compost will have good properties if its conductivity, salinity, and phosphate content are proportional.

4. CONCLUSION

This study has made it possible to highlight the richness in minerals (N, P, K, Mg, and Ca) of the composts made from banana peels, yam,

Table 4: Correlation between the different compost parameters.

Parameters	NT	PT	K	Mg	Ca	TOM	TOC	C/N	pH	Cond	Salinity	PO_4^{3-}
NT	1											
PT	0.98	1										
K	0.65	0.51	1									
Mg	0.74	0.64	0.84	1								
Ca	0.98	0.95	0.67	0.71	1							
TOM	0.82	0.76	0.64	0.55	0.88	1						
TOC	0.82	0.76	0.64	0.54	0.88	1.00	1					
C/N	−0.85	−0.77	−0.81	−0.88	−0.79	−0.59	−0.59	1				
pH	−0.07	−0.16	0.46	0.44	−0.07	−0.31	−0.31	−0.25	1			
Cond	0.94	0.92	0.56	0.63	0.96	0.85	0.85	−0.67	−0.11	1		
Salinity	0.94	0.91	0.58	0.64	0.97	0.85	0.85	−0.68	−0.08	0.99	1	
PO_4^{3-}	0.98	1.00	0.51	0.64	0.95	0.77	0.77	−0.78	−0.17	0.92	0.92	1

$P<0.05$

and cassava peels and also mixtures from these three wastes. The best formulations obtained were C3, C5, C6, and C7. Crushed plantain peels (C3) used alone or mixed with the compost of yam peels and/or cassava (C5, C6, and C7) mineralize and quickly release nutrients to make them available to plants. The C7 compost (mixture of plantain peels, yam peels, and cassava peels) presented the best characteristics. It clearly appears from this study that composts from crushed banana peels (C3) or mixed with yam and/or cassava peels (C5, C6, and C7) can be recommended to farmers, because they are rich in minerals, accessible, cheap, and easy to produce. Their popularization could contribute to the practice of organic farming and to cleaning up the urban environment.

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