IOSR Journal of Applied Chemistry (IOSR-JAC)
e-ISSN: 2278-5736.Volume 19, Issue 4 Ser. I (April. 2026), PP 11-17
www.iosrjournals.org

Valorization Through Composting Of Rice Straw, Water Hyacinth, And Rumen Residues: Assessment Of Nutrient Substances

Balla Ado Oumarou, Ousmane Mahamane Sani, Mamane Souley Abdoul Aziz, Alio Halidou Sani, Zanguina Adamou, Natatou Ibrahim
Université D'agadez, Ecole Nationale D'ingénierie Et Des Sciences D'energies, Bp 199 Agadez, Niger
Université Abdou Moumouni De Niamey, Faculté Des Sciences Et Technique, Laboratoire De Physico-Chimie Des Matériaux, Bp 11662 Niamey, Niger

Abstract
This study aims to improve agricultural productivity by valorizing agricultural waste through composting, particularly water hyacinth and rumen residues. Two formulations were developed: compost C1 composed of 30% rice straw, 26% water hyacinth, 16% rumen residues, 28% cow dung; and compost C2 made of 100% organic matter containing 39% rice straw, 33% cow dung, 28% rumen residues. The technique used was pit composting, with regular monitoring of temperature and pH. The resulting composts were characterized by physicochemical parameters: total organic carbon, total nitrogen, total and available phosphorus, and organic matter. The maximum temperatures reached were 44°C and 52.7°C for C1 and C2 respectively, before stabilizing around 28°C at the end of incubation. The initial pH values of 8.95 (C1) and 9.6 (C2) evolved to 8.81 and 8.4 respectively at the end of incubation. The final C/N ratios were 28.25 for C1 and 20.27 for C2. The total phosphorus content in mg/kg was 409.25 and 113.68 for C1 and C2 respectively. The available phosphorus content in mg/kg was 143.24 and 39.79 for C1 and C2 respectively.

Keywords: *composting, valorization, rice straw, water hyacinth, rumen residues, nutrient substances*

Date of Submission: 04-04-2026 Date of Acceptance: 14-04-2026

I. Introduction

Niger, like other Sahelian countries, faces increasing degradation of its natural resources. Among these resources, soils are the most affected, notably due to the impact of human activities [1]. The continuous exploitation of agricultural land without adequate restitution measures, combined with phenomena such as erosion and desertification, contributes to the decrease in organic matter quantities, leading to a decline in soil fertility. In addition, the poor temporal and spatial distribution of rainfall has detrimental consequences on agricultural yields. Furthermore, when crop water conditions are satisfactory, farmers due to soil deficiencies in nitrogen, phosphorus, and potassium see yields of crops (millet, peanut, sorghum, and cowpea) stagnate or even decline, whereas they expected better results given the rainfall distribution. In urban areas, demographic pressure increasingly places considerable strain on soils. Consequently, the issue of cultivable space is becoming acute [2]. Small plots of land are overexploited, leading to a decline in soil fertility. Yet, the quantities of nutrients present in soils determine the quality of mineral nutrition for plants [3]. Faced with this problem, Nigerien farmers tend to use synthetic fertilizers to improve soil productive potential in the short term. However, these fertilizers are not accessible to farmers with very limited incomes [4]. Moreover, the exclusive use of mineral fertilization (conventional fertilizers) leads in the long term to soil acidification and reduced yields [5]. This degradation of agricultural soils is one of the main causes of the food self-sufficiency problem.in Niger. In this context, soil amendment must be considered. To this end, the valorization of organic matter is an important technique for the amendment of arable land, thereby ensuring the sustainability of productive potential. The presence of organic matter greatly contributes to the process of restoring and improving the biological and physicochemical properties of soils [6]. Likewise, it effectively contributes to increasing agricultural yields as well as to the stability and sustainability of pastoral agrosylvo systems. This study is a contribution to the technique of improving agricultural productivity through the valorization of crop residues via composting, particularly water hyacinth and rumen residues. During this work, three compost formulations were developed.

II. Materials And Methods

Plant Material

- Dried and crushed rice straw: it is the main source of carbon;
- Fresh water hyacinth, cut into small pieces, harvested from the banks of the Niger River as a source of nitrogen;
- Dry cow dung as a source of nitrogen and potassium;
- Rumen residues from the Gamkallé slaughterhouse (Niamey) as a source of nitrogen and carbon.

Compost Preparation Methods

In order to respect the C/N ratio in each windrow, the compost was prepared by mixing materials as follows:
- Compost C1: 100% organic matter containing 30% rice straw + 26% water hyacinth + 16% rumen residues + 28% cow dung.
- Compost C2: 100% organic matter containing 39% rice straw + 33% cow dung + 28% rumen residues.

The composition of the mixture in kg of material used is given in Table 1.

Table 1: Composition of the mixtures used during composting

Composition	Rice Straw	Water Hyacinth	Rumen Residues	Cow Dung
Compost C1	30 kg	26 kg	16 kg	28 kg
Compost C2	39 kg	-	28 kg	33 kg

To obtain the different composts, the materials were arranged in alternating watered layers (18 L per layer) at the bottom of the basin, then turned with a pitchfork every 15 days for 4 months while maintaining moisture between 50% and 60%.

Analysis of Physicochemical Parameters

Equipment

The equipment used during this work includes:
- A molecular absorption spectrophotometer for the determination of total phosphorus and available phosphorus.
- A Swiss quality analytical balance for mass measurement.
- A flame photometer for K^+ ions.
- A flame spectrophotometer for Ca^{2+} ions.

Their specifications are indicated in Table 2.

Table 2: Characteristics of Equipment Used

Equipment	Model	Producer	Country of Origin
Balance	Precisa 205 A	SWISS Quality	Switzerland
Spectrophotometer	Jenway 6300	IMLAB	France
Calcination Furnace	Carbolite	Carbolite Gero	Germany

pH and Temperature Measurement

A compost suspension was prepared in a 75 ml beaker by mixing 5 g of compost with 25 ml of distilled water. pH measurement was performed after ten (10) minutes of agitation and thirty minutes of rest at ambient temperature using a WTW-type pH meter [4]. Temperature measurement was carried out throughout the composting process using a digital display metal probe thermometer until stabilization.

Organic Matter (OM)

The decomposition rate of organic matter was determined by calcination of 5 g of dry compost at 550°C in a Carbolite furnace for 4 hours (NF ISO 14235, NF U 44-160) [7].

Total Organic Carbon (TOC)

The method used for determining total organic carbon is that of Walkley and Black [8]. It is based on the hot oxidation of organic carbon by potassium dichromate in a sulfuric acid medium. The excess dichromate is then titrated with a standardized solution of Mohr's salt (0.5 N) in the presence of ferroin.

Total Kjeldahl Nitrogen (TKN)

The method used is the Kjeldahl method [8]. The nitrogenous organic matter of the sample is mineralized under the oxidizing action of concentrated hot sulfuric acid in the presence of Kjeldahl catalyst. The nitrogen from organic and mineral compounds is transformed into ammonium sulfate. In a nitrogen distiller, the ammonium ion is then displaced by 45% sodium hydroxide, carried by steam, fixed by 2% boric acid, and finally titrated with 0.025 N sulfuric acid in the presence of a colored indicator.

Total Phosphorus and Available Phosphorus

The determination of phosphorus first involves its solubilization, the formation and reduction of the phosphomolybdate complex, and then its colorimetric dosage. The reduction of the complex is carried out by ascorbic acid and is accompanied by a blue coloration whose intensity is proportional to the concentration of phosphate ions in the solution. Under the action of concentrated mineral acids, mineralization is performed for total phosphorus determination and extraction by chemical solutions for available phosphorus. For total phosphorus determination, the modified Dabin method was used at a wavelength of 882 nm using a spectrophotometer (JENWAY 6300) [8]. For available phosphorus, the chemical extraction solution used was a mixture of 1 mL of ammonium fluoride (1 N) and 25 mL of hydrochloric acid (0.5 N) dissolved in 500 mL of demineralized water. Dosage was performed by measuring the percentage of transmittance at a wavelength of 660 nm using a spectrophotometer (JENWAY 6300) [8].

III. Results And Discussion

Physicochemical Parameters

Temperature Evolution During Composting

Figure 1 shows the temperature evolution of the two composts C1 and C2 during the process. A sharp increase in temperature is observed during the first three days of incubation. The maximum values reached are 44°C for C1 and 52.7°C for C2. Subsequently, the temperature gradually decreases until stabilizing around 28°C, indicating the end of active organic matter degradation. This evolution corresponds to the classical decomposition phases: heating, cooling, and maturation. The maximum temperatures obtained are comparable to those reported by [4, 9, 10], ranging between 53 and 55°C.

After turning, the temperature varies slightly, which can be explained by the decrease in the amount of available organic matter. Turning is performed when the temperature drops or approaches ambient temperature. The literature indicates that optimal conditions for hygienizing compost are a temperature above 55°C, that the range 45-55°C favors biodegradation, and 35-40°C improves microorganism diversity [11].

The temperature rises after turning, observed until day 19 for C1 and until day 18 for C2, indicates persistent microbial activity. These microorganisms oxidize organic matter and thus release energy contained in the chemical bonds of molecules. Part of this energy is recovered for their metabolism, but a significant portion is lost and dissipated into the atmosphere.

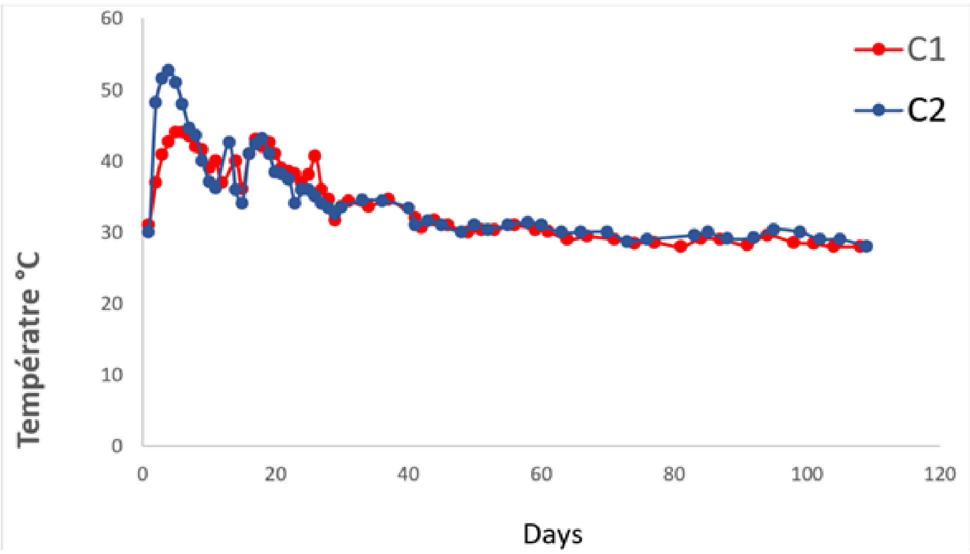

Figure 1: Temperature Evolution During Composting

pH Evolution During Composting

Figure 2 shows the pH evolution of the two composts C1 and C2 during the process. Initially, the two studied composts C1 and C2 have basic pH values of 8.95 and 9.6, respectively. These pH values are higher than those typically found in the literature, which range between 7.8 and 8.9 [12, 13, 14] (Toundou, 2016; Clairon et al., 1982; Temgoua et al., 2014; and Francou, 2003). This could be due to the nature of the materials being composted. On the 20th day of incubation, the pH of compost C2 drops sharply to 6.15. This characterizes the acidification phase. According to Mustin (1987) [11], this pH decrease can be explained by the production of organic acids following the degradation of carbohydrates, lipids, and other substances. Then, the pH returns to basic levels until the end of the process, demonstrating the alkalinity of the obtained composts. These pH levels remained basic due to the production of ammoniacal gas [15] (Bernal et al., 1998) associated with protein degradation releasing amines and the decomposition of organic acids.

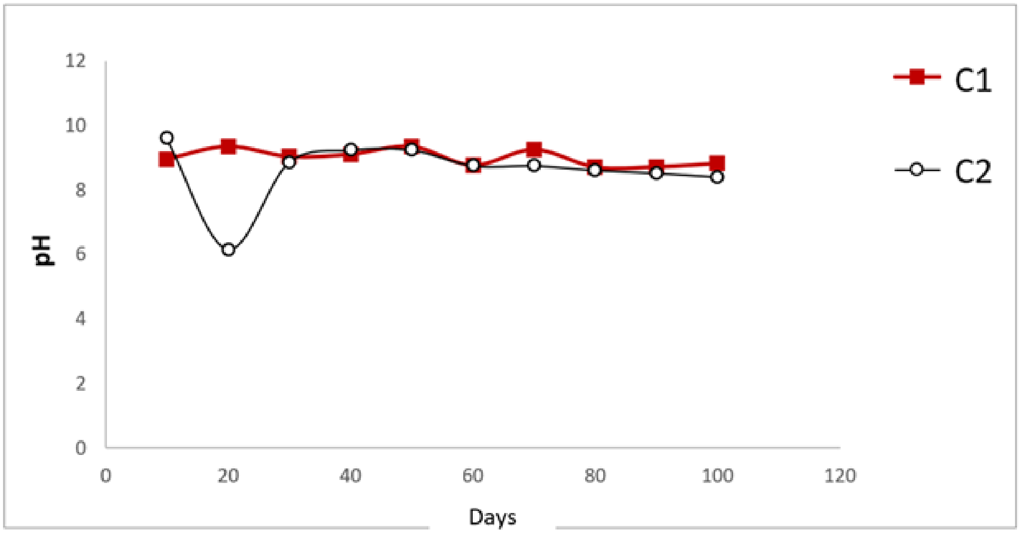

Figure 2: pH Evolution During Composting

Total Organic Carbon Content

Figure 3 below indicates the organic carbon content of composts C1 and C2 obtained at the end of the composting process. The low organic carbon content found in composts C1 and C2 can be explained by rapid decomposition of biodegradable compounds. According to Ousmane (2018) [2], this decomposition can be represented by the following oxidation reaction:

$$Matière\ organique\ +O_2\ \rightarrow CO_2\ +H_2O$$

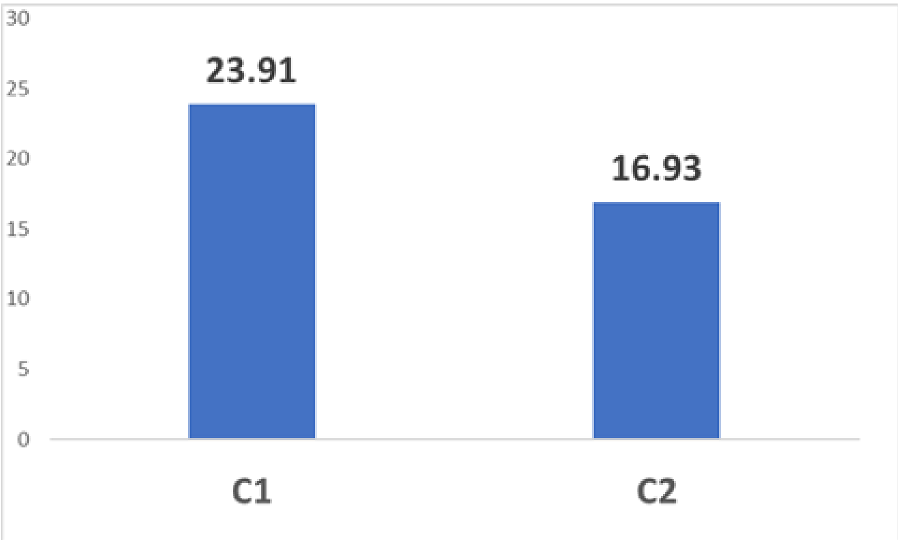

Figure 3: Organic Carbon Content at the End of Composting

Total Organic Matter Content

Figure 4 shows the organic matter content of composts C1 and C2 obtained at the end of composting. The decomposition rate of organic matter for compost C1 is 62.69% compared to 54.67% for compost C2. These results are comparable to those obtained by Toundou (2016) [12] and Koledzi et al. (2011) [9] during composting of household waste, restaurant waste (fruit peels and draff), poultry and cattle manure, and natural phosphate, ranging between 26.9% and 75%. The total organic matter content is higher for compost C1 than for compost C2. This could be explained by the nature and quantity of substrates used in composting.

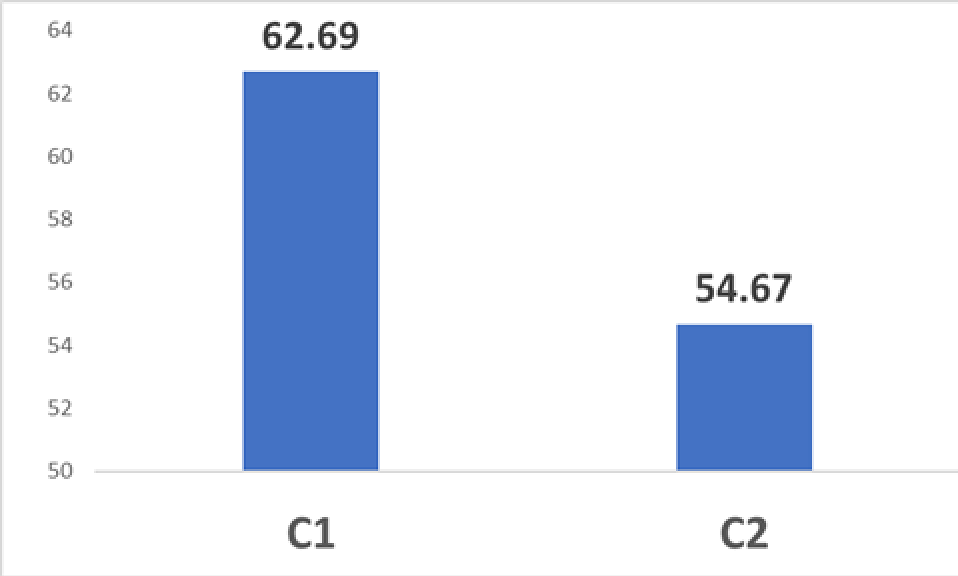

Figure 4: Total Organic Matter Content at the End of Composting

Total Nitrogen Content

Figure 5 presents the total nitrogen content at the end of composting. The total nitrogen contents obtained at the end of the composting process are 0.85% and 0.84% for composts C1 and C2, respectively. These values are low despite nitrogen being the second most important element in organic matter. This is due to nitrogen being mineralized into ammonium and nitrate ions during composting. This mineral nitrogen is reincorporated into microbial metabolism during composting and also into the organic matter of composts during their humification and released into the matrix as mineral nitrogen.

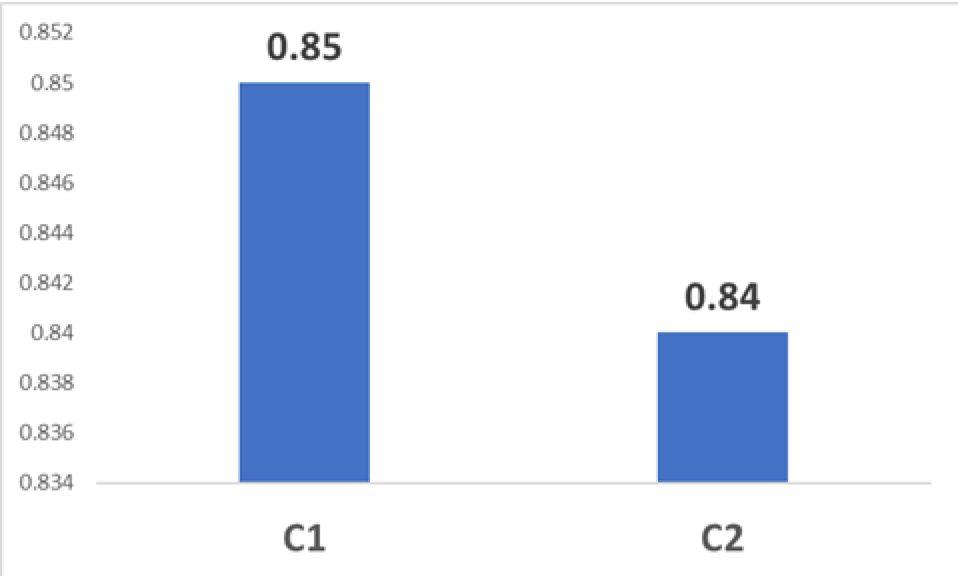

Figure 5: Total Nitrogen Content at the End of Composting

C/N Ratio

The total organic carbon content and total Kjeldahl nitrogen (TKN) content allowed calculation of the carbon/nitrogen (C/N) ratio, which is a criterion for evaluating compost maturity [15]. The results are given in Table 3.

Table 3: C/N Ratio of Different Composts

Sample	C1	C2
C/N Ratio	28.25	20.27

Theoretically, these values could indicate that these composts are mature.

Total and Available Phosphorus

Figure 6 presents the total and available phosphorus contents of composts C1 and C2. The total phosphorus values (expressed in mg/kg of P_2O_5) are 409.25 for C1 and 113.68 for C2. For available phosphorus, they reach 143.24 mg/kg for C1 and 39.79 mg/kg for C2. Compost C1 shows the highest concentrations of total and available phosphorus, ahead of C2. The high levels observed in C1 would be related to the quality of the different substrates used, which are likely rich in these elements. The application of this compost as a base fertilizer to the soil would help meet the needs of cultivated plants and stimulate soil biological activity.

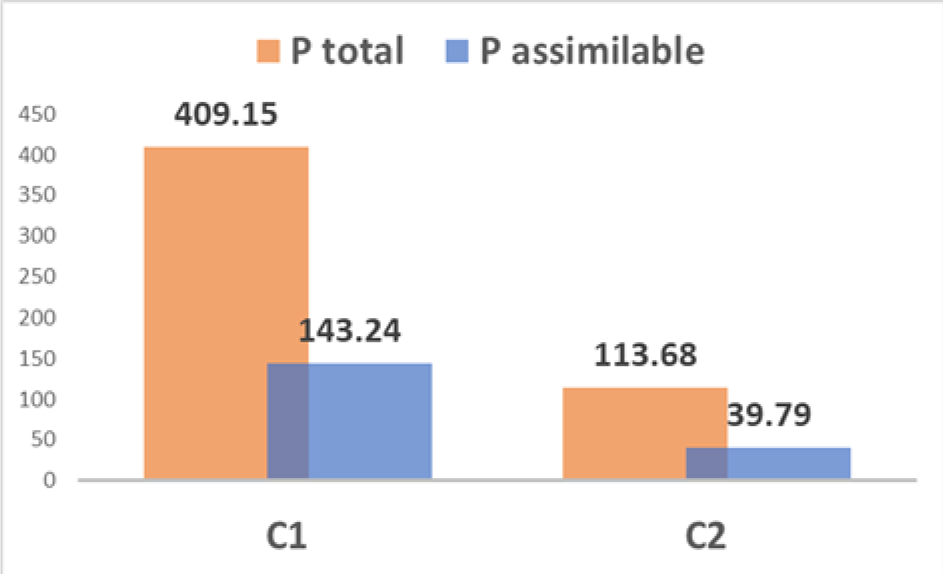

Figure 6: Total and Available Phosphorus Content at the End of Incubation

IV. Conclusion

The physicochemical analyses show that composts C1 and C2 contain the following fertilizing elements, respectively: nitrogen (0.85% and 0.84%), total phosphorus in mg/kg (409.25 and 113.68), and available phosphorus in mg/kg (143.24 and 39.79). Their organic matter contents are 62.69% and 54.67%. The composts are basic with pH values of 8.81 (C1) and 8.4 (C2). The C/N ratios could indicate maturity. These results attest to the quality of these composts, which are usable as agricultural amendments and fertilizers, particularly on acidic soils. This work demonstrates that crop residues, water hyacinth, and animal rumen residues can be valorized into compost, which serves as an excellent organic fertilizer for agricultural soil. These results could be leveraged to valorize animal rumen residues and reduce environmental pollution, as these residues, discarded daily along the banks of the Niger River, pose an environmental threat.

References:

[1]. Lall, D.; Prasad, T. (1989). Compositional Quality Of Certain Unconventional Calcium And Phosphorus Sources In India For Use As Mineral Supplements For Livestock. Animal Feed Science And Technology, 23(4): 343-348.

[2]. Ousmane, M. S. (2018). Physico-Chemical Characterizations And Improvement Of Agronomic Efficiency Through Phospho-Composting Of Natural Phosphates From Niger [Doctoral Dissertation, Abdou Moumouni University].

[3]. Bacyé, B. (1993). Influence Of Cropping Systems On The Evolution Of Organic And Mineral Status Of Ferruginous And Hydromorphic Soils In The Sudan-Sahelian Zone (Yatenga Province, Burkina Faso). University Of Aix-Marseille Iii, Marseille.

[4]. Mahamane Sani Ousmane, Adamou Zanguina, Sanonka Tchegueni, Sidi Laouali, Nomao Dan Lamso, & Ibrahim Natatou (2017).

[5]. N'dayegamiye, A., Royer, R., & Audesse, P. (1997). Nitrogen Mineralization And Availability In Manure Composts From Quebec Biological Farms. Canadian Journal Of Soil Science, 77, 345-350. Https://Doi.Org/10.4141/S96-004.

[6]. Lavigne-Delville, P. (1996). Managing Soil Fertility In Sahelian Countries: Diagnosis And Farmer Advice. 397 P. Https://Agritrop.Cirad.Fr/306169/

[7]. French Standard Nf U 44-160 (1985). Organic Amendments And Growing Media - Determination Of Total Organic Matter - Calcination Method.

[8]. Mathieu, C., & Piettain, F. (2003). *Soil Chemical Analysis: Selected Methods. Tec & Doc, Paris, France.

[9]. Koledzi, K. E. (2011). Valorization Of Urban Household Waste In Lomé Neighborhoods (Togo): Methodological Approach For Sustainable Compost Production* [Doctoral Dissertation, University Of Lomé, Togo]. 210 Pages.

[10]. Tchegeni, S. (2011). Contribution To The Valorization Of Agro-Food Waste Into Compost: Physico-Chemical Characterization Of Composts And Study Of Their Mineralization In Two Agricultural Soils Of Togo [Doctoral Dissertation, University Of Lomé, Togo]. 117 Pages.

[11]. Mustin, M. (1987). Compost: Management Of Organic Matter*. Éditions François Dubusc, Paris. 954 Pages.

[12]. Toundou, O. (2016). Evaluation Of The Chemical And Agronomic Characteristics Of Five Waste Composts And Study Of Their Effects On Soil Chemical Properties, Physiology, And Yield Of Maize (Zea Mays L. Var. Ikenne) And Tomato (Lycopersicum

Esculentum L. Var. Tropimech) Under Two Water Regimes In Togo* [Doctoral Dissertation, University Of Limoges; University Of Lomé, Togo].

[13]. Temgoua, E., Djoukouo, J., Likeng, J. D. H., & Tematio, P. (2014). Structural Stability Of Andisols And Andic Ferralsols From Mount Bambouto, West Cameroon Highlands. *Cameroon Journal Of Experimental Biology, 10, 26-34.

[14]. Francou, C. (2003). Stabilization Of Organic Matter During The Composting Of Urban Waste: Influence Of Waste Nature And Composting Process. Search For Relevant Indicators [Doctoral Dissertation, Institut National Agronomique Paris-Grignon]. 286 Pages.

[15]. Bernal, M. P., Paredes, C., Cegarra, J., Roig, A., & Sánchez-Monedero, M. A. (1998). Maturity And Stability Parameters Of Composts Prepared With A Wide Range Of Organic Wastes. Bioresource Technology, 63(1), 91–99.