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Composting of the Urban Garbage: Assessment of the Nutrient Elements for the Plants, Case of Niamey in Niger

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Abstract— *Composting is a process of natural decomposition of biodegradable waste. It represents one of the waste management techniques that is consistent with sanitation and whose resulting product can serve as a soil remediation agent. The objective of this work was on the one hand to compost the biodegradable urban waste of the city of Niamey and on the other hand to analyze the physic-chemical parameters characteristic of the nutrients of the final product. Thus, three types of composts C_1 (waste), C_2 (waste + natural phosphate from Tahoua, PNT) and C_3 (waste, phosphate rock from Tahoua and manure) were developed using the aerobic composting technique (in pit). The process lasted five months during which we periodically carried out control measures of the physicochemical parameters (T °, pH and C / N). The analysis of the physical parameters of the composts obtained C_1, C_2 and C_3 are respectively for the pH: 9.5, 9.1 and 8.1 and for the temperature about 33 ° C and the chemical analysis revealed carbon contents (10.99%; 11.89% and 14.07% for C_1, C_2 and C_3 respectively); in nitrogen (1.12%, 1.40% and 1.57% for C_1, C_2 and C_3 respectively), the C / N ratios are: 9.81; 8.49 and 8.96 for C_1, C_2 and C_3 respectively; fertilizer elements: total phosphorus (1110, 7220, 14665 ppm for C_1, C_2 and C_3 respectively), available phosphorus (322, 458.5, 686 in ppm for C_1, C_2 and C_3, respectively), potassium (34,000, 18,000; 10000 ppm for C_1, C_2 and C_3 respectively); Calcium (48.00, 123.5, 98.00 ppm for C_1, C_2 and C_3 respectively); magnesium (65.57, 627.87, 609.83 ppm for C_1, C_2 and C_3 respectively); chlorine(221.87 ; 207.67 ; 136.67 ppm for C_1, C_2 and C_3 respectively) and sodium (11600, 5200, 1840 ppm).*

Keywords— *Composting, urban waste, nutrients, PNT.*

I. INTRODUCTION

The accumulation of the urban garbage is not in general without consequence on the environment and on the human's health in particular. This garbage spread in disorder and uncontrolled way in nature are sources of much sanitary, ecological, economic, legal and ethical unrest of which damages are considerable and impact on the conditions of life of the poorest populations. Whereas, one can locally, in his house, district, citie, find ecological solutions, economically and socially viable. Thus, for a better lasting management of the garbage, the valorization of the latter would be the method recommended by researchers. The valorization of the garbage is one useful method contributing to limit the use of the non extendable raw materials and products merely chemical (Sanonka., 2011). several methods of valorization or treatment of the garbage exist: (1) the recuperation or reuse; recycled; (2) the energizing valorization that appears either by the incineration of the garbage with production of energy and for public works or either the methane production that is an anaerobic fermentation with production of the biogas (methane, ammonia); (3) the biological valorization (composting). Composting is a natural process by which biodegradable materials are put together to be transformed by micro-organisms under controlled conditions in a consolidated amendment, named compost (Zanguina 2011,2018) because the urban loss is composed largely by humid degradable matters, this one can be used to elaborate a compost.

The objective of this work is to mineralize the biodegradable urban garbage around Niamey and assess some physico-chemical features of the plant nutrient elements from composts produced.

II. MATERIAL AND METHODS

Three composts have been elaborated: (1) compost C_0 produced with garbage; (2) compost C_1 produced with garbage plus Tahoua rock phosphate (TRP); (3) compost C_2 produced with garbage, manure from cow dung and TRP. After the drying, the garbage has been sorted out in order to minimize presence of undesirable matter for composting (plastic, glasses).

The set of pits used are constructed in cement under a shelter to protect the compost from rain and the sun in order to avoid all disruption of vital conditions of the presence of organisms in the medium. Pits are 104 cm of length, 67 cm of width and 68 cm of height.

The garbage has been placed in the pits by layer of 20 cm thick. The dry garbage is placed first in order to avoid plugging of the bottom of the pit and is assured a homogeneous ventilation of the medium during the process. Every pit has been filled with 150 kg of the garbage then watered with a volume of tap water equal to the volume of the residue

TABLE I. Distribution and proportion of materials used in composting pits.

	C_0	C_1	C_2
Dry matter/ DM	20%	20%	18.5%
Fresh matter/ FM	80%	75%	63%
Manure	-	-	13.3%
TRP	-	5%	5%
Tap water (l)	90	90	90
C/N	29	29.5	29.5

Methods of Analyses

The elaborated composts underwent physico-chemical analyses following suitable methods of analyses in soils and plants laboratories of National institute of the Agronomic Research of Niger (INRAN) of Niamey.

Mixing is an important stage in composting process. It allows providing oxygen in the medium as well as triggering microorganisms' activities. At the time of this study, a session of mixing has been applied at two weeks interval during the whole process of composting.

The evolution of the temperatures has been followed with a probe digital EUROLAB brand thermometer. The mean temperature of each pit is determined by taking average of temperature collected in the five parts of the composting pits.

Indeed, the temperature has been collected every day during one month and half, and then operated every three days during the remaining days of the process.

To measure the acidity or basicity of compost, a pH-meter of HANNA type connected to a glass electrode and containing a saturated solution of KCl has been used.

The content in total C has been determined according to WALKLEY-BLACK method (1934). The content in total organic matter is determined from the results of content in Total -C found. Org Matter =% TOC x 1,724

The content in total nitrogen is determined by the macro-Kjeldahl method.

The content in Total P is determined with the help of modified colorimetric method. The content in availavle-P is determined by the method of Bray I

III. Results and Discussions

3.1 Physico-Chemical Characterization of the Garbage Used

The physico-chemical analyses have been achieved to determine the compositions of the different garbage. The results obtained at the time of these analyses are consigned in Table II.

TABLE II. Physico-chemical characteristics of the garbage used at composting.

Samples	**% total C**	**% total N**	**C/N**	**pH-water**	**K_2O_5 ppm**
Dry garbage	20,12	0,8	25,15	9,2	74000
Manure	17,55	2,3	7,6	8,5	68000

According to these results, these residues can be valorized in compost. It is evident from the latter that manure is richer in nitrogen than the residue with a coefficient of 2, 87 in relation to that starting material. On the other hand the content in carbon is more raised in the garbage. The C/N ratio of the loss is 3, 30 times higher than that of manure. It is due to the relative importance of the content in total carbon and the weak quantity of nitrogen of the residue compared to the manure richer in nitrogen. The garbage is richer in potassium than manure.

The hydrogen potential (pH) is an important parameter of the composting process and for the quality of compost produces. The pH of the substratum used is alkaline. Therefore it is susceptible to give an alkaline product that can be applied in one acidic soil.

3.2 Evolution of the Temperature

The figures (1a, 1b, and 1c) show the evolution of temperature observed at the time of the process of composting. One could note, after the beginning of composting of the garbage in the pits, a fast elevation of the temperature since the 1st day of experience and until the 50th day for all composts with maximal temperatures of 54°C and 60°C attacks on the 3rd day of composting for C_1 composts and C_2 and of 55°C attack on the 7th day for the C_3 compost. This value of the temperature is going to decrease progressively from 50th day to stabilize around 33°C from 80th day of composting. This elevation of the temperature at the beginning of the composting could be explained by a strong microbial activity due to the presence of biodegradable organic matters. Also, as reported by Godden (1986), the production of heat by the micro-organisms is proportional to the mass of the heap however the volume of the heap of elaborated composts is important. So, the heaps lower progressively during the process. Indeed, this decrease of the heap is explained by the consumption of the organic matter by the presence of organisms in the medium that explains therefore the decrease of the temperature. The figures (1a, b, and c) show besides, that the temperature nearly evolved in the same way in the three composts during the process. It can be explained by the composition of the garbage used. One also notes a brief elevation of temperature the first day of active composting with above pit ambient temperature of 48°C in all pits. That corresponded to the mesophilic phase during which a class of the micro organismes as the fungi, that multiply, thus provoking an increase of the temperature.

A variation of temperature between 48°C and 60°C about has been observed in all composts of the first day until the 50ième day of composting, what corresponds to the phase thermophile. This phase is characterized by thermophilic organisms as the actinomycètes and bacteria capable to live in a medium of whose temperature is consisted between 50°C and 70°C maximal.

After 50 days of composting, one notes that the temperature lowered to 50,4°C, 48,80°C and 47,3°C respectively for the C_1 compost, C_2 and C_3 to the ambient temperature (33°C) for all elaborate composts corresponding to the phase of cooling and announce the beginning of the maturation phase thus until the end of the process. One noticed an elevation of the temperature after every mixing, then again a reduction of temperature.

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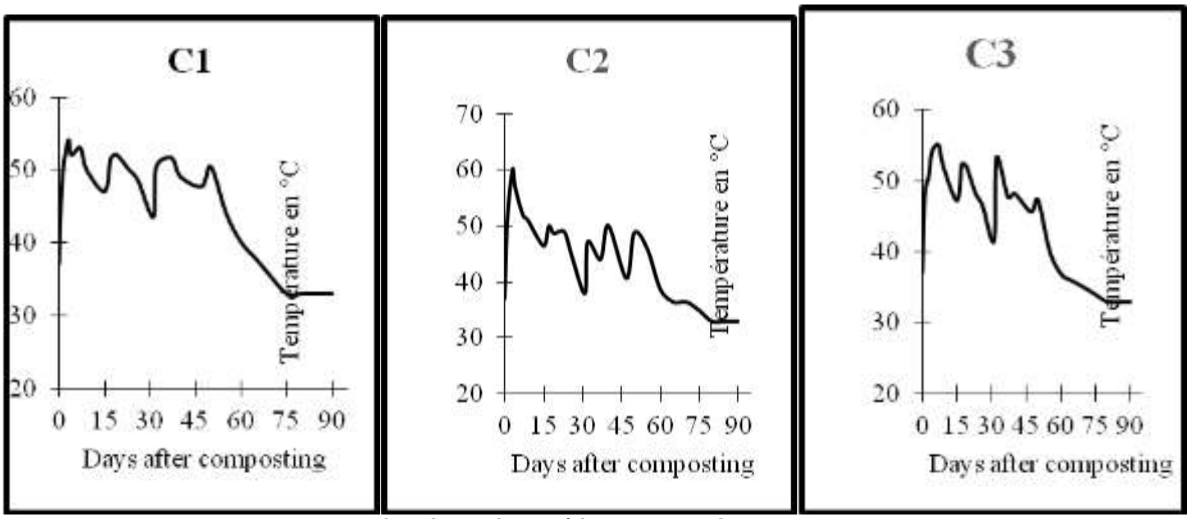

Fig. 1a, b, and c. Evolution of the temperature during composting

3.3 Evolution of Carbon

The carbon is a source of energy for the micro organismes to grow. The figures 2a, b and c show the evolution of the content below respectively in carbon in composts C_1, C_2 and C_3 during composting.

The figures show that the content in carbon fell in all elaborated composts. It passed from 47, 97% at day15th to 10, and 99% at the end of the process for the compost C_1. It decreased from 45, 24% on the day 15th to 11, and 89% at the end of composting for the compost C_2. And finally it decreases from 62, 77% at day15th to 14, and 07% at the end of the process in the compost C_3. This decrease of content in carbon is on one hand due to the decomposition of the organic matter and of the consumption of this same matter by the micro organismes in the medium on the other hand to have the energy in order to really carry on their activities.

It is necessary to note otherwise that the content in organic carbon in the compost C_1 is slightly important than in composts C_2 and C_3. It is due to the addition of TRP in composts C_2 and C_3, product capable to react with the elements content and mineralize the organic matter. This decomposition of the organic matter can be translated according to the following oxidization reaction:

$$\text{Organic matter} + O_2 \rightarrow CO_2 + H_2O$$

Besides, similar reductions of the content in organic carbon, during the composting, have been returned and have been assimilated to the mineralization of the organic matters by the micro-organisms by Zanguina., (2011) and Sonanka., (2011).

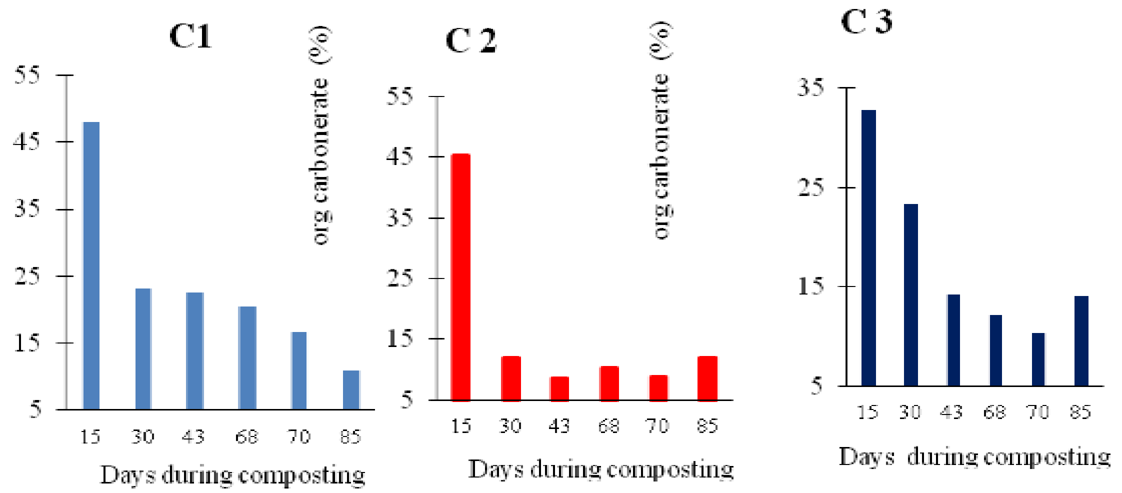

Fig. 2a, b and c. Evolution of carbon rate during composting.

3.4 Evolution of the Content in Nitrogen

Nitrogen is the most important nutriment for the plants. It is an essential constituent of the cytoplasm and its inclusions, it encourages in more the cellular multiplication and therefore the increase of the micro organisms. Its presence in big quantity in the organic garbage often means a rate considered of other nourishing elements.

The figures 3a, b and c show the evolution of the content below in total nitrogen during the process of the composting.

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These faces show that C_1 composts, C_2 and C_3 leave respectively from a percentage of total nitrogen of 2, 1%, 1, 85% and 1, 31% for the three composts after 15 days of dating in order to give the percentages of 1, 12%, 1, 4% and 1, 54% respectively to the term of the process for C_1 composts, C_2 and C_3. One also notes that the percentages in total nitrogen vary considerably during composting in C_2 composts and C_3 in relation to the C_1 compost whose variation is weak.

This variation of nitrogen is on one hand due to the decomposition of the organic matter and of the use of this species by the microorganisms for their cellular multiplications in order to lead its activities of carbon oxidization. Thus, the retiring nitrogen is as NH_3 ammonia. The decomposition of the nitrogenous organic matter can result in the following reaction:

$$\text{Organic matter} + \text{Micro} - \text{organisms} \rightarrow NH_4^+$$

$$NH_4^+ + H_2O \rightarrow NH_{3(g)} + H_3O^+$$

It is necessary to notice in more that the percentages in nitrogen in the C_1 compost are from afar more important than in C_2 composts and C_3. It can explain itself by the addition of the natural phosphate in these last that could react with the ion ammonium of the reaction (2) to turn into phosphate of ammonium. But before, the P_2O_5 shape here of natural phosphate turns into phosphoric acid in the middle according to the following reaction:

$$P_2O_5 + 3H_2O \rightarrow 2H_3PO_4$$

The phosphoric acid in solution frees on its turn ions as follow:

$$H_2PO_4^-,\ HPO_4^{2-}\ \text{et}\ PO_4^{3-}$$

These respective ions are going to react with the ions NH_4^+ ammonium produces the mineralization of the organic matter to form the phosphates of formula ammonium $(NH_4)_3PO_4$, $(NH4)_2HPO_4$ and $NH_4H_2PO_4$

Similar reductions of the content in total nitrogen, during the dating, have been returned and have been assimilated to the oxidization of the organic carbon by the micro-organisms by Zanguina, (2011) and by Sonanka, (2011).

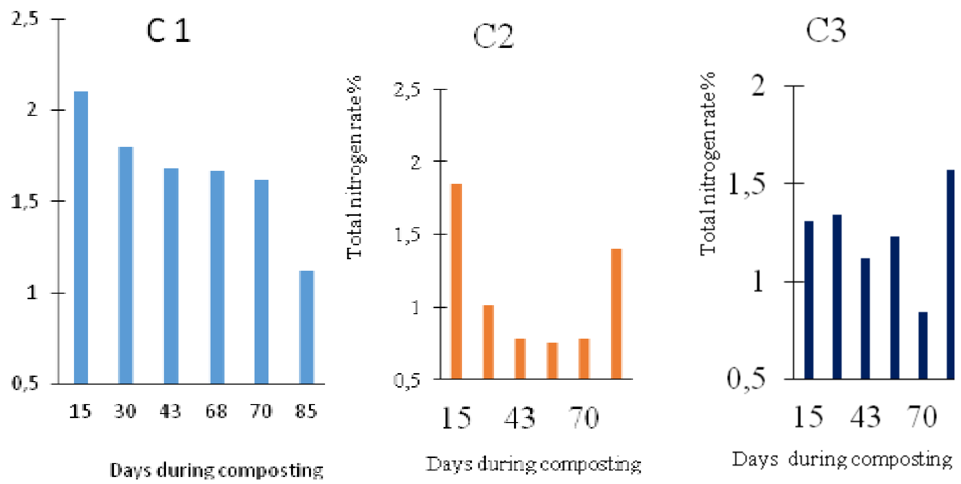

Fig. 3a, b and c. Evolution of the rate of nitrogen during composting.

3.5 Evolution of the C/N Report

The process of composting depends on the activity of the micro-organisms that needs carbon to multiply and nitrogen to elaborate their proteins. This activity is substantial when the C/N report of garbage to mineralize is fairly weak, 25 and 30 according to Godden, (1995) and 30 to 35 recommend Mustin, (1987). It is one of the factors to use in order to observe the phase of compost maturation. So a matured compost is characterized in general by it weak C/N ratio between 15 and 8 as reported by Mustin, (1987).

The evolution of C/N ratio of composts elaborated during this study is given in the figures 4a, b and c. One notices that the C/N ratio decreased in all elaborated composts ranging from 22, 5 at the beginning of composting to 9, 81 at the end of the composting for the compost C_1; of 24.7 at the beginning of the dating to 8, 49 at the end of the composting for the compost C_2 and 21.8,7 at the beginning of the composting to 8, 96 at the end of the composting for the compost C_3.

This reduction is especially explained by the nature of the loss but also to the microbial activities. Huang et al. (2006) returned that the modifications of the C/N ratio reflect the decomposition and the stabilization of the organic matters. It is necessary to note otherwise that the urban garbage of Niamey is composed in big quantity of matters putrescibles organic. It is why one got at the end of the process of the weak C/N ratio (9, 81; 8, 49 and 8, 96 for composts C_1, C_2 and C_3 respectively) that according to Mustin, (1987), it is about the composts walls.

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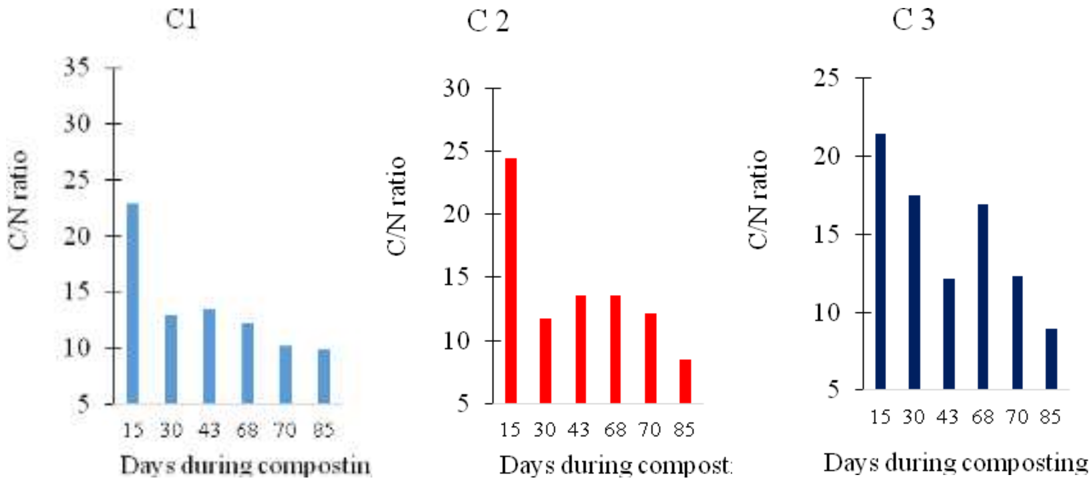

Fig. 4a, b and c. Evolution of ratio C/N during composting.

3.6 Evolution of the pH

The figure 5 shows the evolution of the pH below during composting. One notes that all composts have to the departure a basic pH closed to 8,8. This basic pH encourages the development of the actinomycètes and the alkali bacteria (Mustin, 1987). The pH decreases to reach a minimal value of 8, 2; 7, 1 and 6, 1 for C_1 composts, C_2 and C_3 respectively until the 15th day of composting. This reduction of the pH is due to the production of the organic acids contained in the matter derived from the microbial activity (metabolism of glucides, lipids and other substances), acidifying the middle thus according to the following reaction:

$$\text{Organique Substrat} \rightarrow R-COOH \rightarrow R-COO^- + H^+$$

Thus, the production of CO_2 at the time of the aerobic decomposition also contributes to the acidification of the middle by his/her/its dissolution in water, what generates the carbonic acid according to the reaction:

$$CO_2 + H_2O \rightarrow H^+ + HCO_3^-$$

One also notices that compost present C1 in the same day an acidic enough pH that the other. It is due to the composition of the loss. The loss used in the C_1 compost is largely descended of the garbage collected to the garbage dump of the university that is rich in orange peel, the fresh tomato and vector onions of acids.

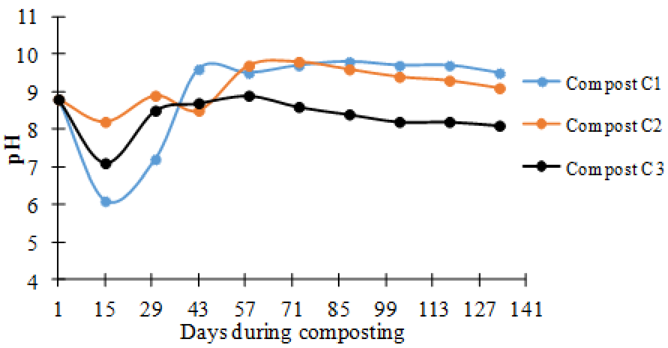

Fig. 5. Evolution of pH during composting

The pH increases from the 15th day to stabilize to 9, 5; 9, 1 and 8, 1 at the end of the composting for C_1 composts, C_2 and C_3 respectively. This increase of the pH results either of ammonia production from the metabolism of the amino (proteins, bases nitrogenous), either of the liberation of the integrated bases from the organic matter.

3.7 Content in Phosphorus

The phosphorus is a useful element for the plants; its deficiency provokes some damages at the cultures. The plants assimilate it as the available phosphorus ($H_2PO_4^-$ and HPO_4^{2-}). The figures 6a and b show the contents in Total-P and in Assimilated-P in the different elaborated composts. The content in Total P and in available P is very weak in the C_1 compost, average in C_2, and elevated in C_3. It explains itself by the fact that in compost C_1 y'a had not the addition of the P-Natural contrary to compost C_2 and C_3. The content in Total P and/or in Available P is a lot more important in the compost C_3 because this medium also contains the manure of cows in which it has been added phosphorus according to the analyses. Indeed, this availability of the phosphorus is assigned to the biologic oxidization of the organic matter and the process of humification that encourage the dissolution of the natural phosphates according to authors. Zanguina, (2011) showed that the addition of the natural rock phosphate in the mixture of loss to regulate permits to improve the content of composts in phosphorus. So that it solubilize during the process of composting and improve compost in available phosphorus, and must be used in small quantity according to Sonanka, (2011).

3.7 Content in Potassium and Calcium

Potassium plays an important role at the plants. It is consumed in big quantity by the plants and contributes to the growth of the plants. The Figure 7 shows the content in potassium of the elaborate composts. According to this face the compost C_1 contains the a lot more important content than in the compost C_2 of which his/her/its content is superior to the one of the compost C_3. This tendency is due to the

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composition and the nature of substratum. Indeed, the urban garbage from the discharges are largely composed of the garbage of the household in which ash and others element rich in potassium. The weak contents noticed in C_2 composts and C_3 are due to the addition of the natural rock P at the beginning of the composting process. The latter reacts on the available potassium in order to give the formation of the following products: K_3PO_4, KH_2PO_4 and K_2HPO_4. These molecules present the answer of the reaction of the potassium hydroxide on the phosphoric acids.

The result of these reactions shows us indeed, the reduction of the content in potassium in the elaborate composts. Zanguina, (2011) showed that the content in potassium of composts decreases with the addition of the phosphate in the mixture in dating.

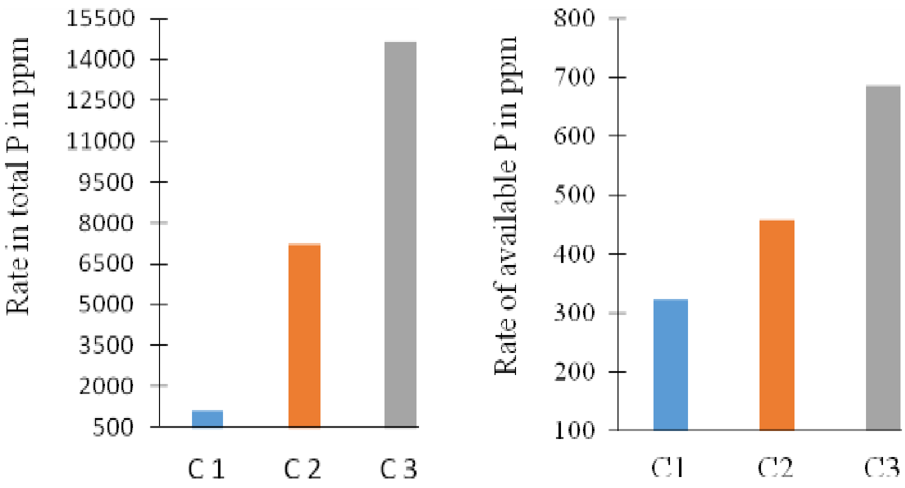

Fig. 6 a and b. Rate of total phosphorus and available P in the composts.

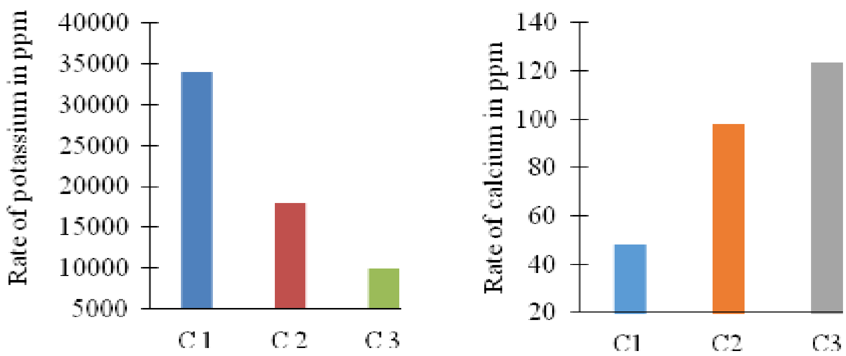

Fig. 7. Rate of potassium and calcium of elaborated composts.

3.8 Content in Calcium

The calcium makes leave from the major elements for the plants. The figure 7 shows the contents below in calcium in the elaborate composts. The figure shows that the compost C_1 is weak in calcium in relation to composts C_2 and C_3 that is richer in calcium than C_2. The results show that the used garbage contains calcium. In more C_2 composts and C_3 are richer in calcium because of the addition of the phosphate in the mixture and manure in the C_3 compost increasing its content more.

3.8 Content in Magnesium

One notices that the content in total magnesium is raised more in C_1 composts and C_2 that in the C_3 compost. It is due to the nature of the garbage used that are largely composed of the garbage descended of garbage dump of restaurant of the university of Niamey rich in skins of oranges and banana. Natatou and al, (2005) showed in their works that the Natural rock P from Tahoua is very weak in magnesium. Indeed, the C_3 compost contains two sources of the phosphorus at a time (P-Natural and from manure) capable to influence the content in magnesium of the medium according to the following reactions:

$$3Mg^{2+} + 2PO_4^{3-} \rightarrow Mg_3(PO_4)_2$$

$$Mg^{2+} + HPO_4^{2-} \rightarrow MgHPO_4$$

$$Mg^{2+} + 2\,H_2PO_4^{-} \rightarrow Mg(H_2PO_4)_2$$

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The products of these reactions show poverty in magnesium in the C_3 compost.

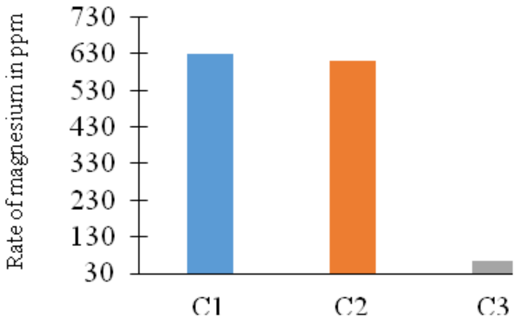

Fig. 8. Content in magnesium of the elaborate composts.

3.8 Content in Sodium and in Chlorine

Sodium and chlorine are part of the trace elements whose plant uses in small quantity. The figure 9 shows the rate in sodium and in chlorine of the elaborate composts respectively. One notices that the evolution is nearly identical in the two cases with a light difference for the case of chlorine that sodium or the difference is big. The C_1 compost is richer in sodium and chlorine than C_2 composts and C_3 or one notices a reduction in these elements. This reduction is due to the addition of the phosphate in the case of sodium forming the phosphates of sodium and the formation of the calcium chloride thus especially in C_2 composts and C_3 in which one noted the content raised in calcium.

$$3Na^+ + PO_4^{3-} \rightarrow Na_3PO_4$$
$$2Na^+ + HPO_4^{2-} \rightarrow Na_2HPO_4$$
$$Na^+ + H_2PO_4^- \rightarrow NaH_2PO_4$$
$$Ca^{2+} + 2Cl^- \rightarrow CaCl_2$$

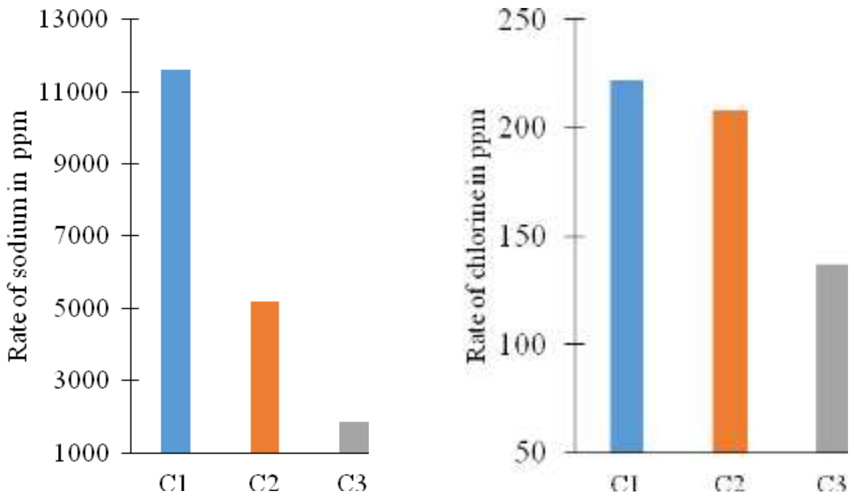

Fig. 9. Rate in sodium and chlorine of elaborated composts.

IV. Conclusion

According to results obtained, it is established that compost from the mixture of loss, the manure of cows and the TRP has a quality higher than one obtained from loss and natural phosphate itself more important than the one gotten on basis of only loss. It permits to conclude that the addition of natural phosphate during conducted composting to obtain an end product rich in plant nutrient elements in this case the Total P- and Available P of the plants.

It is necessary to note otherwise that the elaborate composts are basic with the pH: 9, 5; 9, 1 and 8, 1 respectively for composts C_1, C_2 and C_3. These results show that these composts can be applicable to acidic soil. Of their C/N report are consisted between 8 and 15 that indicate that composts are well mature containing a lot of nitrogen and the carbon. The gotten composts also present important contents in sodium and in chlorine. The results to which we arrived show the interest of the composting of the urban garbage to enrich soils and to produce more in farmers'field.

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