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Development of Compost from Agro-food Residues: Analysis of the Crop Nutrients and Trace Elements

Zanguina Adamou[a*], Mella M. Tchicama[b], Addam kiari Saidou[c], Ousmane Garba[d]

[a,b]Faculty of Science Université Abdou Moumouni, BP: 656 Niamey

[c]Institut National de la Recherche Agronomique du Niger, BP : 429Niamey

[d]Faculty of Science University of Zinder BP: 237Zinder

[a]Email: adazangui@yahoo.fr

[b]Email: marouma2009@yahoo.fr

[c]Email: kaddam2001@yahoo.fr

[d]Email: ousmgb@yahoo.fr

Abstract

A composting study of agro-food residues was conducted to evaluate the nutrient content of plants. Three types of composts were made: compost C_1 based on organic matter; compost C_2 based on organic matter and Tahoua rock phosphate and compost C_3 based on organic matter, cow manure and Tahoua rock phosphate. During composting, the pH reached 9.60; 8.93 and 8.88 respectively for composts C_1, C_2 and C_3 before falling respectively to 9.15; 7.90 and 7.83 at the end of composting. The temperature reached 57 ° C for all composts during composting before stabilizing at 31 ° C after composting. The analysis of the physicochemical parameters of the composts obtained reveals that they contain carbon contents (23.01%, 14.625% and 16.575% for C_1, C_2 and C_3 respectively) and nitrogen (2.63%; 34% and 1.62% for C_1, C_2 and C_3 respectively) and C / N ratios (8.74, 10.91 and 10.83 for C_1, C_2 and C_3 respectively) and nutrients: available phosphorus (186.2, 399.70, 695.8 mg / kg for C_1, C_2 and C_3 respectively), potassium (3389.97, 1127; 1313.30 for C_1, C_2 and C_3 respectively), calcium (12000, 42800, 64000 mg / kg for C_1, C_2 and C_3 respectively) and magnesium (18936.77, 15946.62, 16346.47 mg / kg for C_1, C_2 and C_3 respectively).

Keywords: composting; agro-food residues; crop nutrients.

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* Corresponding author.

1. Introduction

Nowadays, the cities of Niger, like the other African cities, are confronted to a problem of purification due to an important stock of strong garbage. This garbage is produced daily by the populations whose quantity passes the capacities of hold currently in charge of the townships. It proves to be then necessary to think about a method of sustainable management of this garbage.

An ecological, economic and beneficial solution yet exists for the man and for the environment, a mineralization process called composting. An adequate solution that allows to overcome the environmental problems with a non costly and yet valorizing the garbage.

Composting presents some interests as the improvement of fertility and the quality of soil, health by hygiene and the increase of the agricultural production [1] encouraging an increase of the agricultural productivity, a better biodiversity of soil, a reduction of the ecological risks and a more favorable environment [2]. Composting allows adding value to garbage while manufacturing from these organic manure.

In substitution to the manures of synthesis, many researchers recommended the use of compost produces especially by composting of the strong garbage, the agro-food residues. This work appears in the setting of a thematic of research developed in our laboratory on the treatment of the urban strong garbage by composting. The objective of this work is to elaborate composts, from the agro-food residues. It adds value to crop nutrient elements in the soil. Work is aimed at the valorization of this garbage in compost added value to fertilizing improved material by addition of manure and Tahoua rock phosphate.

2. Materials and methods

2.1. Materials

The agro-food garbage: the residues of agro-food cut in small pieces as source of nitrogen; dried millet stems and ground as source of carbon; dry cow manure as source of nitrogen and potassium; Tahoua rock phosphate as source of phosphorus; used domestic garbage are largely from the kitchen activities of the university restaurant of Niamey. Before loading the composting pit, a sorting of the garbage as well as a reduction must be to operate. The sorting will permit to isolate the non biodegradable matirials as the plastic bags, the tins of canned food etc and the reduction will permit to refine the granulometry of the garbage to make them more accessible to the micro-organisms responsible for the mineralization of the organic matter.

2.2. Experimental Site

Works are conducted at botanical garden of the faculty of sciences of the Abdoul-Moumouni University in Niamey during the period of August 2017 to December 2017.

2.3. Methods of compost development

The method in an aerobic pit has been used for the development of composts. Composts are elaborated in vats pit that measures 1, 04 x m 0, 67 x m 0, 68 m, covered by a plastic material, under a shelter in order to protect composts against the strong rains, the excess of sun and waters flooding**.** In order to respect the C/N ratio in every pit, compost has been prepared through a mixture of raw materials as follows: C1 compost, 100% of the organic matter containing 72% of the agro-food garbage plus 28% dried millet stems. C2 compost, 95% of the organic matter (70% of the agro-food garbage plus 25% dried millet stems) and 5% of the Tahoua rock phosphate. C3 compost, 95% of the organic matter (50% of the agro-food garbage plus 25% dried millet stems plus 20% of the cow dung manure) and 5% of the Tahoua rock phosphate. To assure a good aeration of the watered mixture, some agitations have been done every two (2) weeks with the help of a fuck. The first agitation intervened after 15 days of experimentation, and then the agitation continued every week and during the whole time of the experimentation that lasted 5 months. We also controlled humidity in order to check and maintain the content of water in the proportions of 50 to 60% of the weight of the mixture; The main physico-chemical features have been determined appropriately on samples of compost after 2, 3, 4 and 5 months of incubation. The chemical content of different composts has been determined at the end of the composting process. In the first month of composting, the temperature is taken every day with a digital thermometer, EUROLAB to probe then every 3 day after the 50th day of the process.

In a biker, 10 g of compost ground and sieved to 2 mm are mixed to 100 ml of distilled water. The measure of the pH is done after ten (10) minutes of homogenization and after thirty (30) minutes of rest to ambient temperature with the help of a pH meter HANNA type.

The total organic carbon is determined by the Walkley and Black method [3].

The total organic carbon, expressed in percentage of dry matter, is given by the following relation: $\%\mathbf{COT} = \frac{\mathbf{NFe^{2+}\times(Vt-Ve)}}{\mathbf{P}}\,\mathbf{x\ 0,39}$

COT : carbone organique total en percentage of dry matter.

Vt : titration volume of the check in ml.

Ve : titration volume of the sample in ml.

P : weight of the sample in g.

NFe^{2+} : ions normality Fe^{2+} du sel de Mohr

Total nitroge is determined by Kjeldahl method de

Total nitrogen Kjeldahl is given by :

$$\%\boldsymbol{NTK} = \frac{(\boldsymbol{V}-\boldsymbol{V0})\times\boldsymbol{N}\times\mathbf{0,014x100}}{\boldsymbol{P}}$$

V : volume of H_2SO_4 that serve for sample titration ;

V_0 : volume of H_2SO_4 that serve for blank titration;

N : H_2SO_4 normality for ammonia titration ;

P : sample weight in g.

Available phosphorus is determined by Bray 1method.

Exchangeable cations (K+, Ca2+, Mg2+, Na+) have been determined on the elaborated composts. End product served to measure out exchangeable K+ and Na+ by flame absorption spectrophotometry in flame and Ca2+ and Mg2+ by flame atomic absorption spectrophotométry.

3. Results and discussions

The raw materials constitute the source of mineral elements of the prepared composts.

The results show that manure is a lot of richer in total nitrogen (2.30%) than the milet dry stems **(0.99%) that, them, are richer in total carbon (40.73) against (17.55%) for manure. The PNT is source of the Phosphorus, P_2O_5.**

One notices an increase of the temperature until maximal values being located between 50 and 57°C(fig.4a, b, c).. These values are reached after 2 days of composting for compost 3 (55,2°C), 5 days of composting for compost 2 (50,4°C) and 15 days of composting for compost 1 (57°C). This tendency is maintained until the 50th day of dating. The elevation of the temperature in the beginning of the process explains itself by a microbial activity (Thermopile) due to the presence of organic matters easily biodegradable. These elevated temperatures could lead to the reduction of the pathogenic agents and the elimination of the seeds of adventitious plant [4].

One notes that the temperature evolved practically in the same way in all composts studied from the 15th day of composting process.

After 50 days of composting, the temperature begins to lower and come closer of the ambient temperature (30°C). This decrease of temperature can be explained easily by a slowing of the activity of the micro-organisms due to the weariness of the organic matters degradable. The evolution of the temperature is characterized by four phases.

One notes a brief evolution of the active temperature of the ambient temperature to 45°C for all active studied composts of the 1st on the 2nd day of composting for composts 2 and 3 and of the 1st on the 13rd day of dating for compost 1. What corresponds to the mesophile phase provoked by the bacteria of this group raising the temperature of 25-45° C. To this phase mésophile a phase thermophile follows for a length of 48 days for composts 2 and 3. And of 37 days for compost 1 characterized by elevated temperatures with a maximum of 57°C.

After 50 days of composting, one notes that the temperature lowered 47°C to the ambient temperature for all studied composts corresponding to the phase of cooling and the beginning of the maturation phase. One noticed an elevation of the temperature after every agitation, then again a fall of temperature.

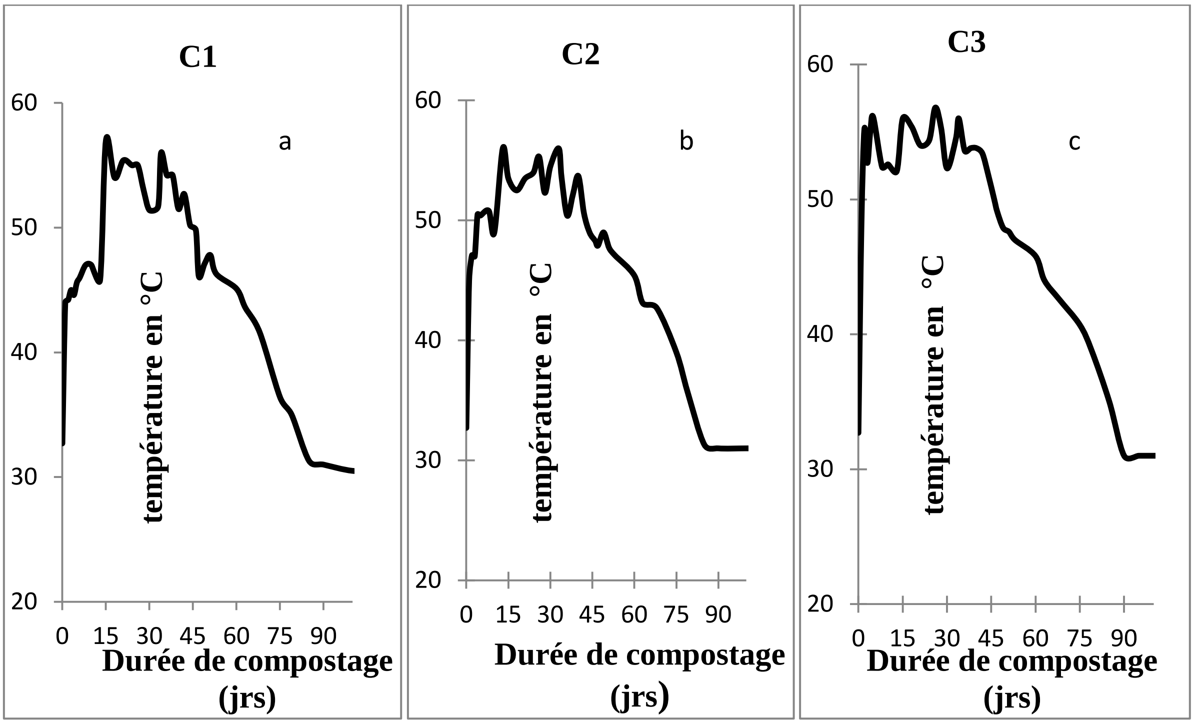

Figure 4a, b, c : Courbe d'évolution des Thermophiles et Mésophiles au cours du compostage

The evolution of the pH during the process is represented on the face 5. The pH of C1 composts, C2 and C3 constantly remained basic during the composting. This increase of the pH would be due to the nature of the garbage used composed largely of oranges rich in potassium (151 mg/100g) [5]. The addition of the powder of the Tahoua rock phosphate in C2 and C3 decreased the pH of these composts. This reduction would be due to the complex binding power of metallic cation of the phosphate ore by the carboxyliques groupings and hydroxyles of the acidic present humiques in the middle with liberation of the H+ protons [6]. Some similar results have been returned by [7].

One notes that the quantity of the organic carbon decreased in the elaborated composts (figure. 6) passer-by of 51,87% to the 2nd month to 23,01% at the end of the dating for the C1 compost. She/it decreases from 40, 56% to the 2nd month to 14,62% at the end of the composting for the C2 compost. And finally it decreases from 36, 27% to the 2nd month to 16, and 57% at the end of the process for the C3 compost. One also notices that the quantity of the organic carbon is raised more in the C1 compost where there was not addition of the Tahoua rock phosphate.

This decrease of the content in organic carbon explains itself by a fast decomposition of the biodegradable compounds as sugar. This decomposition of the organic matter can be translated by the following oxidization reaction:

$$\textbf{Matière organique} + O_2 \rightarrow CO_2 + H_2O \quad (1)$$

Indeed, similar reductions of the content in organic carbon, during the composting process, have been returned and have been assimilated to the mineralization of the organic matters by the micro-organisms by [1].

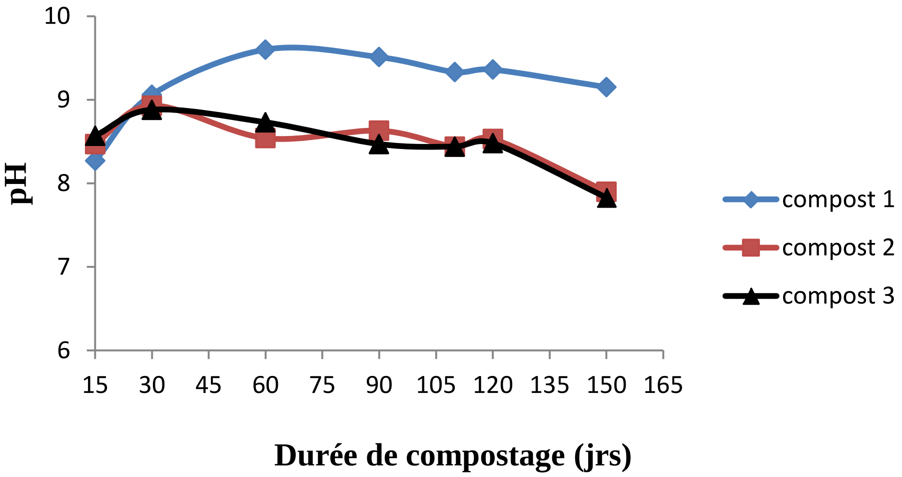

Figure 5: pH status during composting

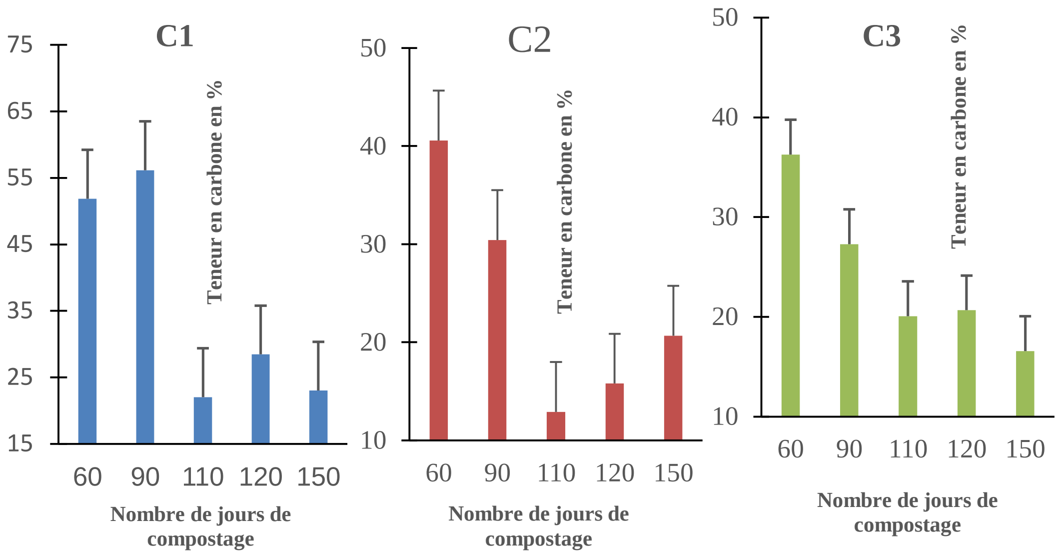

Figure 6: Carbone fate during composting, C1, C2 and C3

One notices that the quantity of total nitrogen decreased in the prepared composts (figure. 7). This effect is due to the immobilization of nitrogen by the micro-organisms to oxidize the carbon. The nitrogen that disappears in this case is the most often free as NH_3. The decomposition of the nitrogenous organic matter can be translated by the following reaction:

$$\textbf{Matière organique azotée} + \textbf{Micro} - \textbf{organismes} \rightarrow NH_4^+ \quad (2)$$

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

One also notices that the content in nitrogen decreases when one adds the natural phosphate in the mixture (figures 7b and 7c). The decrease of the content in nitrogen with the addition of the phosphate is to the reduction of the quantity of the organic matter in the C2 miscellanies and C3. This reduction of the content in nitrogen could also be explained by the formation of the ammonium phosphates in the medium. Indeed the phosphorus of P_2O_5 formula coming from the Tahoua rock P turns in the medium into phosphoric acid according to the following reaction:

$$\mathbf{P_2O_5 + 3H_2O \rightarrow 2H_3PO_4} \ \mathbf{(4)}$$

Then next gave $H_2\,PO_4^-$, HPO_4^{2-} and PO_4^{3-} as follows :

$$\mathbf{H_3PO_4 + H_2O \rightarrow H_3O^+ + H_2\,PO_4^-} \ \mathbf{(5)}$$

$$\mathbf{H_2\,PO_4^- + H_2O \rightarrow H_3O^+ + HPO_4^{2-}} \ \mathbf{(6)}$$

$$\mathbf{HPO_4^{2-} + H_2O \rightarrow H_3O^+ + PO_4^{3-}} \quad \mathbf{(7)}$$

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

$$\mathbf{3NH_4^+ + PO_4^{3-} \rightarrow (NH_4)_3PO_4} \qquad \mathbf{(8)}$$

$$\mathbf{2NH_4^+ + HPO_4^{2-} \rightarrow (NH_4)_2HPO_4} \qquad \mathbf{(9)}$$

$$\mathbf{NH_4^+ + H_2\,PO_4^- \rightarrow NH_4H_2PO_4} \qquad \mathbf{(10)}$$

Similar reductions of the content in total nitrogen, during the composting process, have been returned and have been assimilated to the oxidization of the organic carbon by the micro-organisms by [8] and by [1].

C/N report is the most commonly parameter measured to determine the maturity of a compost. According to [9], the optimum for a C/N of departure must be located between 25 and 30. For [10], the optimum is located between 30 and 35.

One notes that the C/N report decreased in the elaborated composts (figure. 8) passer-by of 30,4 at the beginning of the process to 8,74 at the end of the process for the C1 compost; of 29,47 at the beginning of the process to 10,91 at the end of the composting for the C2 compost and 30,5 in the beginning of the dating to 10,23 at the end of the dating for the C3 compost. Because of the consumption of nitrogen and the mineralization of the carbon, the C/N report decreases during the dating.

At the end of the process of the composting the C/N reports of the different composts products are in between 8 and 11 that according to [10] characterize a mature compost.

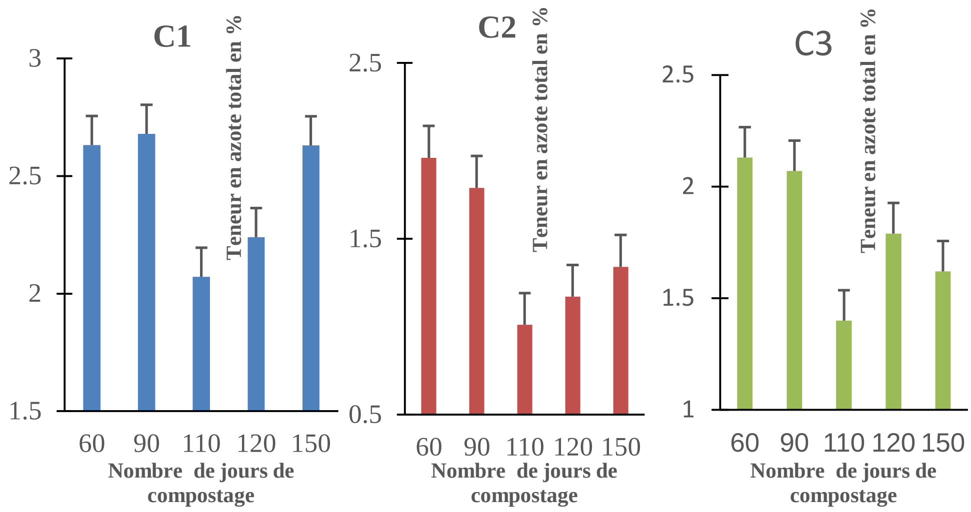

Figure 7: Fate of nitrogen during composting C1, C2 et C3.

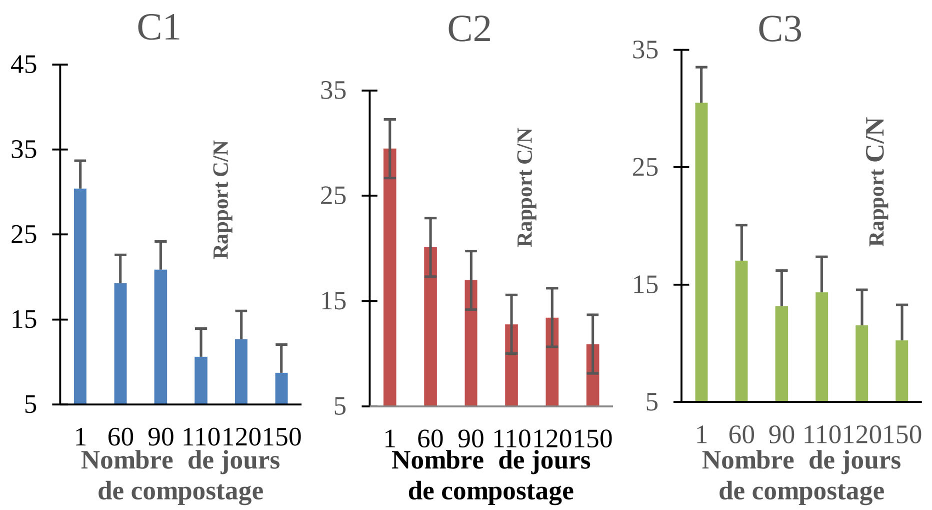

Figure 8: Ratio C/N during composting C1, C2 et C3.

4. Fertilizing elements

The dosage of the different fertilizing elements in composts at the end of the process of composting allowed us to get results consigned in table 1.

The aP has been multiplied by 3, 73 in the C3 compost in relation to the Compost C1 and by 2,14 in the C2 compost in relation to the Compost C1. This increase of the content in phosphorus is due to the presence of the P from manure of cow and the dissolution of Tahoua rock phosphate. Indeed the availability of the P would be assigned to the mcrobiological oxidization of the organic matter and the process of humification that encourage the dissolution of the natural phosphates [11]. Of works achieved on the composting of lawn mowing in presence of Tahoua rock phosphate by [8] showed that the addition of the phosphate in the mixture permitted to improve the content of composts in phosphorus. One notice that the content in total potassium (figure 9) is raised more in the C1 compost than in C2 composts and C3. Indeed the content of potassium in the C1 compost is equal to 3 times the one in the C2 compost and 2,6 times the one in the C3 compost. It is due to the nature of the garbage used that are composed largely of oranges rich in potassium [5] (151 mg/100g, www.lesfruitsetlégumesfrais.com). The reduction of the content in potassium with the addition of the phosphate could be explained by the formation of the phosphates of K_(3 potassium) PO_4, KH_2 PO_4 and K_2 resulting in HPO_4 of the attack of the potassium hydroxide (KOH) by the phosphoric acid following these reactions:

$$\mathbf{3K^{+} + PO_4^{3-} \rightarrow K_3\,PO_4} \qquad \textbf{(11)}$$

$$\mathbf{2K^{+} + HPO_4^{2-} \rightarrow K_2HPO_4} \qquad \textbf{(12)}$$

$$\mathbf{K^{+} + H_2PO_4^{-} \rightarrow KH_2PO_4} \qquad \textbf{(13)}$$

Table 1: Chemical composition of C1, C2 and C3

Compost	pH	C	N	C/N	aP	K	Ca	Mg	Na	Cl
		%					mg/kg			
1	9,15	23,01	2,63	8,74	186,2	3389,97	12000	18936,77	62,1	207,67
2	7,90	14,62	1,34	10,91	399,70	1127	42800	15946,62	34,5	138,45
3	7,83	16,57	1,62	10,83	695,8	1313,30	64000	16346,47	110,4	108,27

aP = available P

So the main source of potassium in our miscellanies is the organic matter.

The phosphate is not a good source of potassium (% K_2O = 0,12, [12]. Of works achieved on the dating of lawn mowing in presence of the phosphate natural of Tahoua by [8] showed that the content in potassium of composts decreases with the addition of the phosphate in the mixture. One notices that the content in total calcium (figure. 9b) is raised more in C2 composts and C3 that in the C1 compost. The content of the calcium in the C3 compost is equal to 5,3 times the one in the C1 compost and the content in calcium , C2 compost is equal to 3,56 times the one in the C1 compost. It explains itself at a time by the contribution of the calcium by the garbage used composed largely of oranges that are rich in calcium [5](29,7 mg/g, www.lesfruitsetlégumesfrais.com), of the manure of cow and the phosphate natural of Tahoua rich in calcium. (% CaO = 43,12) [12].

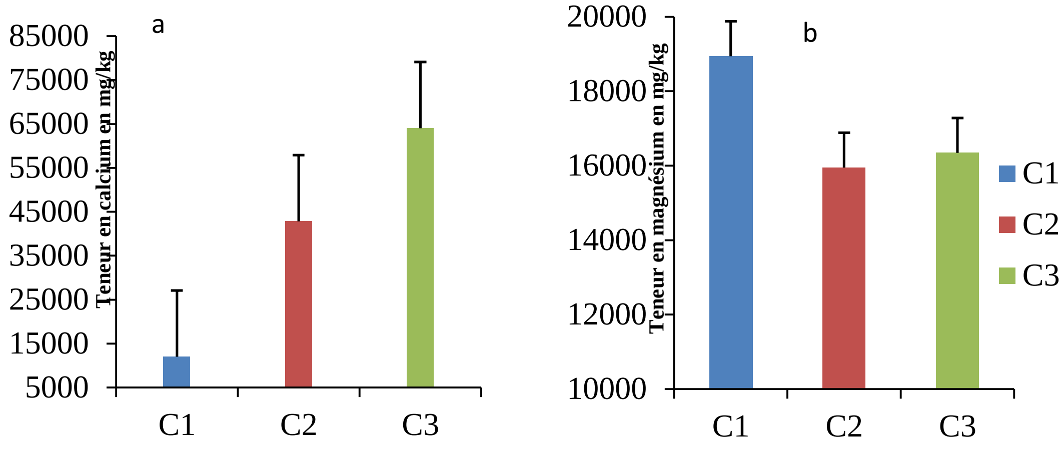

Figure 9ab: Content in calcium(a) and in magnesium(b) in the composts

One notices that the content in total magnesium is raised more (figure.12) in C1 composts and C3 that in the C2 compost. It is due to the nature of the garbage used that is composed largely of oranges rich in magnesium [5] (12,4 mg/100g, www.lesfruitsetlégumesfrais.com) and of the cow manure. The reduction of the content in magnesium with the addition of the phosphate natural of Tahoua in C2 and C3 could be explained by the formation of the magnesium phosphates in the middle according to the reactions:

$$\mathbf{3Mg^{2+} + 2PO_4^{3-} \rightarrow Mg_3(PO_4)_2} \quad \textbf{(14)}$$

$$\mathbf{Mg^{2+} + HPO_4^{2-} \rightarrow MgHPO_4} \quad \textbf{(15)}$$

$$\mathbf{Mg^{2+} + 2\ H_2PO_4^{-} \rightarrow Mg(H_2PO_4)_2} \quad \textbf{(16)}$$

These results show that the main source of magnesium in our miscellanies is the organic matter and that the phosphate natural of Tahoua is poor in magnesium. (% MgO = 0, 20), [12]. The results gotten after analysis of composts showed that the elaborate composts have contents raised in P, K, That and Mg. These contents can explain themselves between other by the nature of the garbage used. Indeed, the fertilizing value of the compost of the agro-food residues depends on the initial content in major elements of the garbage. The composts of studied garbage are therefore rich in fertilizing elements can be used then like fertilizing.

4. Trace elements

Two trace elements have been determined (Sodium and chlorine). Sodium (Na) and the chlorine (Cl) are present in all three elaborate composts with weak contents (Picture 4). One notices otherwise that the content in sodium is raised more in the C3 compost that in the C1 compost (fig. 10). One also notices that the addition of the phosphate natural of Tahoua decreased the content in sodium. This decrease of the content in sodium could be explained by the formation in the middle of the sodium phosphates according to the reactions:

$$\mathbf{3Na^+ + PO_4^{3-} \rightarrow Na_3PO_4} \quad \mathbf{(17)}$$

$$\mathbf{2Na^+ + HPO_4^{2-} \rightarrow Na_2HPO_4} \quad \mathbf{(18)}$$

$$\mathbf{Na^+ + H_2PO_4^- \rightarrow NaH_2PO_4} \quad \mathbf{(19)}$$

One also notes that the content in chlorine decreased with the addition of the phosphate in the middle. (fig14). This reduction could be explained by the formation of the calcium chloride according to the reaction:

$$\mathbf{Ca^{2+} + 2Cl^- \rightarrow CaCl_2} \quad \mathbf{(20)}$$

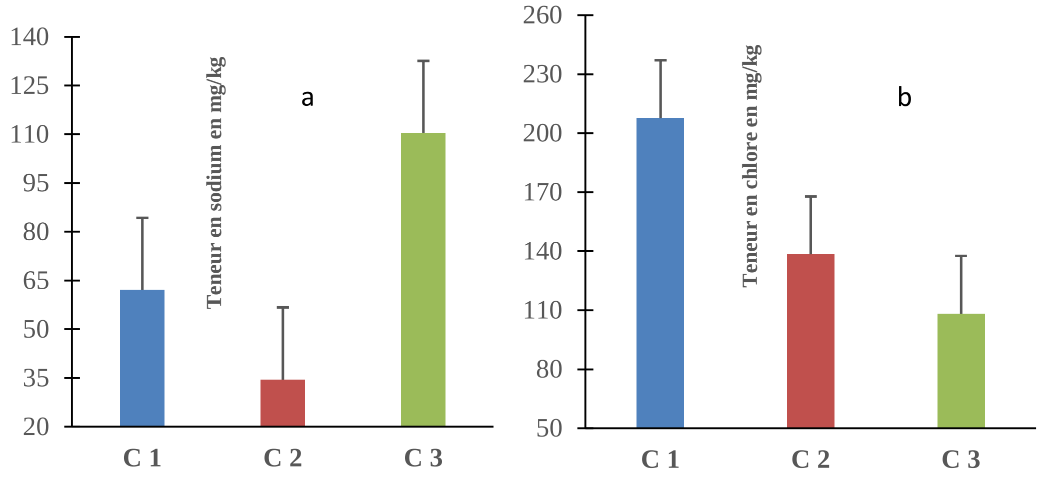

Figure 10a et b: Content in sodium and in chlorine in the composts

Other trace elements as iron, boron, manganese, the molybdenum, copper, zinc, silicon and cobalt…, that have not been measured out exist and contribute to crop growth.

5. Conclusion

Composting of agro-food garbage permits to get compost for the fertilization of soils. The sought-after nutriments notably nitrogen, potassium, phosphorus, calcium, magnesium and the trace elements (sodium and chlorine) are present in the prepared composts. The pH of elaborated composts is basic (9, 15; 7, 90 and 7, 83 respectively for C1, C2 and C3). C/N report of elaborated composts ranged between 8 and 11 (8, 74; 10,91 and 10,83 for C1, C2 and C3 respectively). It has been established that the incorporation of Tahoua rock phosphate in the development of compost allowed to improve the contents and in available phosphorus in composts. According to the results of this survey, it is established that compost gotten with a mixture of garbage, manure of cow and Tahoua rock phosphate (C3 compost) has content in major elements superior to the one gotten from garbage without or with Tahoua rock phosphate.

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