



The Potential of Cassava (*Manihot esculenta Crantz*) Peels as an Organic Fertilizer



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ABSTRACT

Cassava peels are in large quantity and practically of no economic value in many developing nations such as Cameroon, where cassava is widely consumed and processed far beyond other crops. Cassava peels might be used in those countries to face declining soil fertility and soil erosion. This study aimed to evaluate the composting of cassava peels and the effect of the increasing quantity of cassava peels in the bin during the process of composting and to assess some physico-chemical qualities, biological properties and the phytotoxicity of the produced composts. After three months of composting the produced composts (C1; C2; C3 and C4) had a dark brown color, relatively dry, uniform structure and its texture were similar to the soil's texture. The electrical conductivity of the various composts was in between 1499 and 1924 $\mu\text{S}\cdot\text{cm}^{-1}$. The pH (6.50-6.73), was slightly acid, favorable for the cultivation of sweet pepper. The composts were rich in minerals (Mg^{2+} ; Ca^{2+} ; K^{+} ; and Na^{+}) and poor in heavy metals such as (Cu, Zn and Mn). The composts C/N ratios were between 13.15 to 13.42. The produced composts showed a germination index and the rate of germination higher than 80% at all amounts, indicating the absence of phytotoxicity. The increased amounts of cassava peels did not alter the process of composting and increased the fungal and bacterial populations. In conclusion, cassava peels are good substrates that can be used to produce stable and inclusive organic fertilizers, with high nutrient content, and less hazardous material which could be used in farms to remediate declining soil fertility and to promote sustainable agriculture.

Keywords : Cassava peels, compost, phytotoxicity, sustainable agriculture.

1 Introduction

Cassava (*Manihot esculenta Crantz*, *Euphorbiaceae*) is the sixth most important food crop globally, in terms of annual production, and is a staple food for approximately 800 million people [1]. This perennial root crop is grown in the tropics, including sub-Saharan Africa, Asia, the Pacific Islands, and Central and South America [1]. Cassava is cultivated in more than 100 countries worldwide [2]. It holds the position of the strategic crop in many tropical countries, [2] such as Cameroon. In Cameroon, it is a leading crop in terms of annual yield both for cash and food

crop categories. It is widely consumed and processed far beyond other crops such as maize and rice [2]. Cassava is cultivated for its starchy roots and is a staple food material in many developing countries, including Cameroon, where it is eaten as garri, fufu, or other products. According to the Central Bureau of Statistics in 2004-2008, the production of cassava peel tend to increase annually which means the production of cassava peel also increasing [3]. Cassava peel is the peeling of food product from cassava. The Chemical composition of cassava peel is identic with cassava which contains most of the polysaccharide and some of mineral and water.



The main component of polysaccharide is amylose, amylopectin, and cellulose [3]. Cassava peel represents about 5 to 15% of the root when peeled mechanically [4] and about 20 – 35% of the weight of the tuber with hand peeling [5]. The solid fibrous dry waste consists of 56 – 60% starch, 15 – 18% hemicellulose, 2 – 3% lignin, 1.5 – 2% protein, 2% pentosan and 0.4 – 5% reducing sugar [6] making it a good organic matter of composting. During the processing of cassava tubers, an enormous quantity of cassava peels (about 30% of processed cassava tubers) are generated as waste [7] and only an insignificant proportion is usually fed to livestock such as goats [8]. Very often, cassava peels are thrown away after removal from the edible part of the root during processing. The peel eventually decays in the soil [9].

However, The potential of these peels to be used in the production of other products such as biofertilizers can help most of the cassava processors and farmers to increase their source of income, to avoid the environmental nuisance released by cassava peels on dumping sites and the pollution of both water and land resources, which might increase rodents and insect vector diseases thereby creating public health nuisance. This study therefore aimed at assessing some physico-chemical qualities and biological properties of the produced composts from cassava peels, to determine if respectively, the composting of cassava peels without any additional material and the increased quantity of cassava peels in the bin during the process of composting might undermine the process of composting and finally to assess the phytotoxicity of the produced composts.

2 Materials and Methods

2.1 Compost Preparation

Fresh cassava peels were collected from various sources within the subregion of Yaounde (Cameroon). The obtained cassava was air-dried for one week. Then the dried cassava peels were mechanically ground in a local mill to particles ranging 0.1 – 1.5mm. Figure 1 and 2 respectively below present cassava peels before and after shredding.



Figure 1: *Dried Cassava peels.*



Figure 2: *Cassava peels after shredded.*

2.2 Properties of input materials

For comparative purposes, four (4) types of compost in a different weight of 50kg, 70kg, 90kg and 110kg of cassava peels were produced, labelled C1, C2, C3 and C4 respectively. Table 1 shows the nutrient composition of cassava peels.

2.3 Study area

Field experiments were carried out at the University of Yaounde I. The average air temperature varies from 20 to 23°C. It is governed by a "Cameroonian" climate, which is very hot and humid.

2.4 Online monitoring of the composting

The process of composting was carried out in composting bins (barrels) of 120 litres for 3 months. The experiment was a randomized block design with three replicates. The temperature was measured weekly for the whole composting period [10]. To prevent excessive heat loss during composting, the barrels were wrapped with plastic tilt. Additional holes were cut around the barrels to provide improved aeration and were

turned once after two weeks to ensure adequate O₂ levels inside the barrels. The temperature was monitored at a depth of 65 cm inside the piles at 9:00 h twice every two weeks. The water content of barrels was maintained at 60% of their water holding capacity throughout the 3-months experiment and water was added depending on the level of humidity, after barrels were turned. The compost was matured by the end of the 12th weeks and the temperature dropped and remained unchanged with the compost having no peculiar smell. At the end of the composting process, three subsamples were taken randomly from within each barrel, they were bulked and homogenised, air-dried and stored for some physico chemicals, biological properties, and phytotoxicity analysis.

2.5 Physical and chemical analysis

The determination of moisture content of cassava peels was run according to the method of [11]. Cassava peels were dried at 105°C for 4 hours until constant weight. The emptied Petri dishes have been heated and weighted then 10g of samples was introduced in each petri dish and the whole was also weighted. The next step consisted of putting the petri dishes containing cassava peels in the oven at 105°C during 4 hours, then after 4 hours, they have been transferred into a desiccator. After 05 minutes of cooling the whole has been weighted and the moisture content was calculated as the following formula:

$$\text{Moisture content} = (A-B / B-C) \times 100$$

A : Weight of petri dishes and sample before drying.

B: Weight of the petri dishes and the sample after drying.

C: Weight of the emptied petri dishes

Nutrients (P, K, Ca, Mg, and Na) and heavy metal (Mn, Cu, and Zn) contents were determined after wet digestion by inductively coupled plasma atomic emission spectroscopy (ICP-AES). The pH measurement was carried out according to the international standard ISO 10390 (1994). 10 g of compost was weighed and introduced into an Erlenmeyer flask containing 50 ml of distilled

water; then the mixture was stirred for 5 minutes and then allowed to stand for 2 hours. After standing, the pH was then measured using a HQ 11D brand pH meter.

To measure electrical conductivity, 20 g of compost were introduced into 100 ml of distilled water, stirred for 30 minutes and then filtered. The specific electrical conductivity of the filtered extract was measured using a Hach HQ conductivity meter 14d. (NF ISO 11265, 2005). The methods below were used to determine an Organic C (Corg) and total N.

50 g of compost were dried in an oven at 105 °C and then calcined at 550 °C for 2 hours in an oven. The percentage of total organic matter (% MOT) or of volatile solid was obtained by the difference in weighing between the mass of the sample dried at 105 °C and the mass of the sample after calcination [12] according to this formula:

$$\% \text{ MOT} = \frac{(M1-M2)}{M1} \times 100$$

M 1: a mass of the sample after heating in the oven (g);

M 2: a mass of the sample after calcination (g);

-% MOT: percentage of dry matter content in the sample.

Total organic carbon was determined according to the formula below:

$$\% \text{ C} = \frac{(\% \text{ MOT})}{2}$$

The total organic nitrogen content was determined by the Kjeldahl method. The mineralized sample is distilled with 40% sodium hydroxide in a BUCHI K-350 nitrogen distiller. The nitrogen vapours obtained are collected in an Erlenmeyer flask containing a pinkish color mixture composed of 20 ml of 3% boric acid and 3 drops of Tashiro reagent. This mixture gradually turns yellowish-green in the case where the distilled sample contains nitrogen, as the sample drops from the distillation column are added. The solution obtained was assayed by titrimetry with 0.1 N sulfuric acid.

The C / N ratio of the composts was calculated from the organic carbon and nitrogen values obtained. It was determined according to the formula below:

$$C/N = \frac{\text{percentage of organic carbon}}{\text{percentage of total nitrogen}}$$

2.6 Phytotoxicity test

To evaluate the compost maturity and their phytotoxicity, a germination index and germination test were conducted with sweet pepper seeds (yelo wonder) according to respectively [13] and the method using soil (compost) of [14]

2.6.1 Germination Index

Compost extracts were prepared by shaking compost samples with distilled water at three different dilutions (10%, 30% and 50 %) in a wrist-action shaker for 20 min at 416 rpm, followed by filtering the slurry through filter paper (Whatman). The germination test was carried out (in triplicate) on filter paper in petri dishes. Sweet pepper seeds were placed onto filter paper, ten millilitres of aqueous extract from composts were added to dishes and the dishes were placed in the dark at 25 °C. Petri dishes with sweet pepper seeds and sterile distilled water (10 mL) was the control. The germination percentages with respect to control and relative root lengths were determined after 14 days. The GI was calculated as $GI = \%G \times Le/Lc$, where %G is the percentage of germinated seeds in each extract with respect to control, Le is the mean total root length of the germinated seeds in each extract and Lc is the mean root length of the control. The control GI value is considered as 100%. Seeds were considered to be germinated if the radicle was 5 mm long [15].

2.6.2 Germination test

For comparative purposes and to estimate the value of the composts, four types of composts, sampled from the produced composts, in proportion of 1kg, 2kg, 4Kg and 6kg were introduced respectively in four buckets of 10 litres labelled B1, B2, B3 and B4 with three replications. The bottoms of each bucket was aerated with five holes. Then, 400 seeds of sweet

pepper in replicates of 100 were randomly counted from the well-mixt pure seed. Afterward, replicates were divided into split replicates of 50 seeds to ensure adequate spacing and were sown concentrically in each bucket. After that, all the treatments were placed in direct sunlight (temperature: 25°C). The buckets were continuously watered with distilled water (pH: 6.5), in accordance to the moisture content of the composts, during the test period to avoid composts to be dried out. The first count of the germination seed started after 7 days and the final count after 14 days. The rate of the germination test was calculated as the average of 400 seeds replicates and the below formula was used:

$$\begin{aligned} &\text{rate of the germination} \\ &= \frac{\text{number of germinated seeds}}{\text{number of seeds sown}} \times 100 \end{aligned}$$

2.7 Microbiological analysis

The analysis of mycoflora was carried out according to the suspensions-dilutions technique [16], on medium agar Potato dextrose agar (PDA) added to an antibiotic (Gentamicin). In a 250 ml Erlenmeyer flask containing 90 ml of distilled water sterile, 10 g of dry compost was added aseptically (after drying at 30 °C overnight). This mixture was stirred mechanically with magnetic bars for 30 minutes to suspend the compost particles and the spores and mycelia attached thereto. The suspension obtained corresponds to the 10⁻¹ dilution. 1 ml of the 10⁻¹ dilution was removed aseptically and put in 9 ml of sterile distilled water thus giving the 10⁻² dilution which was stirred for two minutes before taking 1 ml which was added to 9 ml of water sterile distilled and so on until dilution 10⁻⁸. 0.1 ml was taken from each dilution, operating from 10⁻⁸ dilution to the 10⁻¹ dilution, and seeded onto the culture media, using a sterile glass bent pipette. Petri dishes were incubated at 26 ° C for 3 days. The fungal load was determined by colony counting and the results were expressed in CFU (Colony Forming Units) / g of compost according to the mathematical formula below.

$$N = \frac{\Sigma \text{ colonies}}{2V \text{ml} \times (n_1 + 0.1 n_2)} \times d_1$$

N: Number of CFU per gram of compost; Σ colonies: Sum of colonies of interpretable petri dishes; V: Volume of solution deposited (1ml); n1: Number of petri dishes considered at the first dilution retained; n2: Number of petri dishes considered at the second dilution retained; d1: Factor of the first dilution retained. Only Petri dishes counting between 15 and 150 colonies at two successive dilutions were selected for enumeration [17] [18].

The determination of the total bacterial flora was carried out according to the technique of suspensions-dilutions on solid medium, nutrient agar added to an antifungal agent: 0.5% nystatin. 5 g of each compost was placed in a 100 ml Erlenmeyer flask containing 45 ml of sterile physiological saline (9 g of NaCl / L of distilled water) and suspended with a magnetic stirrer for 30 minutes. The suspension was then decanted for 20 minutes, then the supernatant was removed, and it constitutes the 10^{-1} dilution. From this suspension, decimal dilutions were made up to 10^{-8} . 0.1 ml was taken from each dilution, operating from 10^{-8} dilution to 10^{-1} dilution, and seeded onto the culture media, using a sterile glass bent pipette. The petri dishes were incubated at 30 °C for 24 hours [17].

2.8 Statistical analyses

The data obtained were subjected to a two-way analysis of variance (ANOVA) followed by a Tukey's B-test at 5% level. The data were analysed using SPSS Software Package 16.

3 Results

3.1 Produced composts

The composting of the above different treatments lasted 3 months. The produced composts (C1, C2, C3, and C4) were odourless during the composting process and presented the same odour (they did not have a smell of ammonia) at the end of composting. They had a dark brown color, relatively dry and uniform structure and its texture was similar to the soil's texture. Their temperature was 25 °C. Figure 3 below presents the obtained composts.



Figure 3: Composts produced from the different weights of cassava peels.

3.2 Material characteristics

The physical, chemical properties and the micronutrients content of the Cassava peels are reported in Table 1.

Table 1: Physical and chemical properties of cassava peels

Parameters	Cassava peels
pH	5.7
Organic carbon (%)	44.3
Total nitrogen (%)	1.47
Total phosphorus (g/kg)	7.9
Total potassium (g/kg)	1.1
total calcium (g/kg)	18.9
Total magnesium (g/kg)	8.1
total sodium (g/kg)	0.12
Moisture (%)	2.43
C/N	30.13

3.3 Physical and chemical properties

The physical and chemical properties and the micronutrients content of the produced composts are reported in Table 2 and 3.

At the end of the composting, the pH of C1, C2, C3 and C4 was in between 6.50 to 6.73, which slightly increased compare to the pH (5.7) of cassava peels. There was not a significant difference between the pH of the obtained composts. The total nitrogen (2.68%) of the first compost (C1) was not significantly higher than

the total nitrogen of the initial substrates. Also, the total nitrogen (respectively 5.30%, 8.1%, and 10.50%) of the last three compost significantly increased at the end of the process. The same fashion is reflected concerning the percentage of the organic carbon, in which the organic carbon of C2 (70.5%), C3 (105.75%) and C4 (141%) dramatically increased. There was respectively a significant difference between the percentage of organic carbon of cassava peels (44.3%), C1 (35.25%), and the last three compost (C2, C3 and C4). On the other hand, the proportion of the total potassium of each produced composts increased significantly and was respectively 5.63 mg.kg⁻¹, 11.25 mg.kg⁻¹, 16.23 mg.kg⁻¹, and 22.49 mg.kg⁻¹; while the percentage of the total phosphorus of the each produced compost, which was respectively C1 (130 mg.kg⁻¹), C2 (240 mg.kg⁻¹), C3 (380 mg.kg⁻¹), and C4 (500), gradually decreased with the increase among of cassava peels. The ratio C/N Of the four cassava peels manure has significantly decreased. The

value of those ratios was between 13.15 and 13.4, and there was not a great difference in between the ratio C/N of the produced composts. However, the EC slightly increased with the among of cassava peels that was composted and the difference was not significant. The concentration of Mg, Ca, K, Na, Mn and Cu gradually increased with the increase among of cassava peels. The concentration of the four composts in terms of Zn fluctuated in between 0.025 and 0.03 g.kg⁻¹.

3.4 Phytotoxicity

3.4.1 Germination Index (GI)

Figure 2 shows that cassava peels-based composts were not toxic to the sweet pepper seeds and seedlings at the concentration of 10% 30% and 50%. All extracts, C1, C2, C3, and C4, had a germination index between 80% to 84.4%, and the difference was not significantly different.

Table 2: pH, C, N, P, C and C/N of the produced composts made with increasing Kg of cassava peel.

composts	Parameters					
	pH	Total nitrogen (%)	Total phosphorus (mg.kg ⁻¹)	Total potassium (mg.kg ⁻¹)	Organic carbon (%)	C/N
C1	6.50±0.12 ^a	2.68 ± 0.34 ^a	130 ± 0.09 ^a	5.63 ± 1.34 ^a	35.25 ± 2.62 ^a	13.15 ^a
C2	6.61±0.20 ^a	5.30 ± 0.99 ^b	240 ± 0.16 ^b	11.25 ± 2.67 ^b	70.5 ± 4.24 ^b	13.30 ^a
C3	6.68±0.14 ^a	8.01 ± 0.03 ^c	380 ± 0.26 ^c	16.23 ± 3.85 ^c	105.75 ± 3.86 ^c	13.20 ^a
C4	6.73±0.11 ^a	10.50 ± 0.05 ^d	500 ± 0.20 ^d	22.49 ± 5.33 ^d	141 ± 5.48 ^d	13.42 ^a

Means followed by the same letter in a column are not significantly different at $P \leq 0.05$

Table 3: EC, extractable nutrients and heavy metal content of the produced composts made with increasing Kg of cassava peel.

composts	Parameters							
	EC (µS.cm ⁻¹)	Mg (mg.kg ⁻¹)	Ca (mg.kg ⁻¹)	K (mg.kg ⁻¹)	Na (mg.kg ⁻¹)	Mn (g.kg ⁻¹)	Cu (g.kg ⁻¹)	Zin (g.kg ⁻¹)
C1	1499±210.86 ^a	0.04±0.01 ^a	0.24±0.12 ^a	5.63±1.23 ^a	2.38±0.50 ^a	0,10 ± 1,11 ^a	5.53±1.16 ^a	0,028 ± 0,01 ^a
C2	1737±211.70 ^b	0.07±0.03 ^b	0.48±0.19 ^b	11.26±1.30 ^b	3.58±0.29 ^b	0,11 ± 1,01 ^b	8.20±0.30 ^b	0,026 ± 0,014 ^a
C3	1830±187.74 ^c	0.11±0.04 ^c	0.73±0.23 ^c	16.80±2.01 ^c	7.58±2.21 ^c	0,12 ± 1,21 ^c	12.56±0.23 ^b	0,025 ± 0,011 ^a
C4	1924±199.84 ^d	0.15±0.02 ^d	0.94±0.29 ^d	22.49±0.54 ^d	8.59±0.40 ^d	0,14 ± 1,15 ^d	20.32±2.35 ^d	0,03 ± 0,012 ^b

Means followed by the same letter in a column are not significantly different at $P \leq 0.05$

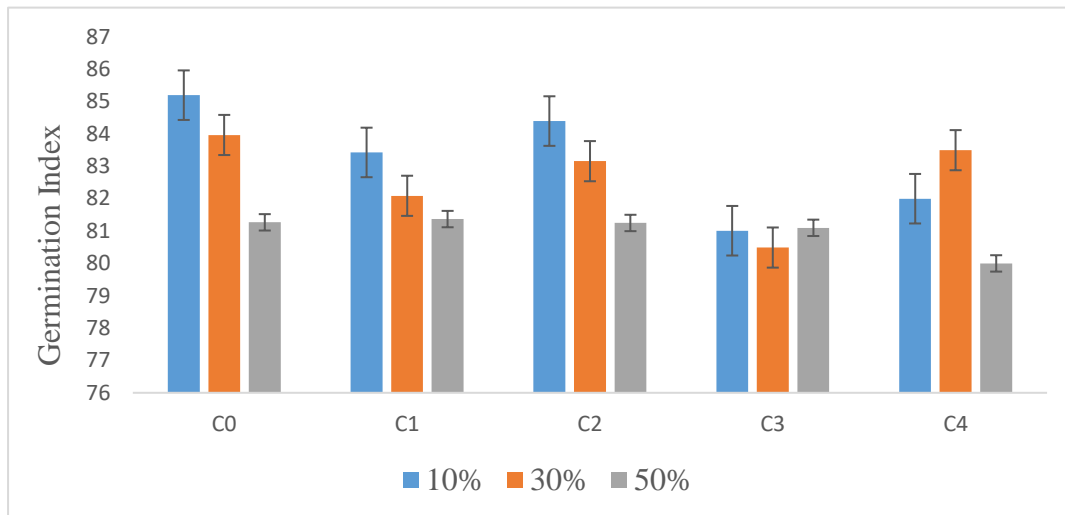


Figure 2: Germination index in cassava peels-based composts made with increasing percentages of the quantity of cassava peels.

3.4.2 Germination test

Table 4 illustrated and confirmed that all the samples of the composts were not toxic to the sweet pepper seeds and seedlings respectively at the proportion of 1kg, 2kg, 4kg, and 6kg, which had the rate of germination in between 96 and 99 %.

Table 4: The rate of germination (%) of sweet peppers seeds

Samples of the composts	The rate of germination (%)
B1	97 ± 4.2 ^a
B2	96 ± 4.8 ^a
B3	99 ± 4.7 ^a
B4	97 ± 4.9 ^a

Means followed by the same letter in a column are not significantly different at $P \leq 0.05$

3.5 Biological properties

The increased of the amount of cassava peels did not negatively impair the concentration of fungal and bacterial population. There was not a significant difference respectively in between the concentration of bacterial and fungal biomass from C1, C2, C3, and C4 (Table 5). However, the proportion of fungi biomass was greater than the proportion of bacterial, which was respectively in between 88.2 to 89.3 x 10⁵ UFC.g-1 compost for fungi population and 71.9 to 74.1 x 10⁵ UFC.g-1 compost for the bacterial population.

Table 5: Microbial biomass counted in compost samples.

Treatment	Microbial biomass (.10 ⁵ UFC.g-1 compost)	
	Fungi	Bacteria
C1	88.6 ± 1.49 ^a	71.9 ± 6.27 ^a
C2	89.1 ± 6.41 ^a	72.4 ± 0.15 ^a
C3	88.2 ± 0.75 ^a	72.9 ± 5.50 ^a
C4	89.3 ± 7.42 ^a	74.1 ± 1.04 ^a

Means followed by the same letter in a column are not significantly different at $P \leq 0.05$

4 Discussion

4.1 Composting process

The dark brown colour, the relatively dry and uniform structure, the lack of odours, the ambient temperature (25 °C) observed from the produced composts and its texture (soil's texture) reflect respectively the degree of stability or maturity of those composts. This is in accordance with the results obtained by [15], who found that, the above characteristics of the compost generally indicate that the composts obtained at the end of the composting process are stable and mature.

The lack of odours noticed respectively during the composting process and at the end of the process might be due to the absence of some volatile compounds such as NH₃ [19] organic acids, and some of the sulfur-containing compounds and the increased aeration that took place during the composting process. [19].

Besides, it may be the result of the absence of those intermediate compounds that had been decomposed during the thermophile phase of composting [19]. Moreover, that lack of odour should be also explained by the acidity of the compost piles pH, which was (5.7). It could also be explained by the initial value of cassava peels C/N ration (30.13), which did not allow the underutilization of N, during which the excess is usually lost to the atmosphere as ammonia or nitrous oxide. That is in accordance with the [11] and [20] who showed that a C: N ratio of less than 20:1 leads to underutilization of N and the excess may be lost to the atmosphere as ammonia or nitrous oxide.

4.2 Physical and chemical properties

The salinity of a compost is measured by its electrical conductivity, which greatly depends on the nutrient content of the compost and determines the phytotoxicity of a compost. Therefore, the increase of EC regarding the amount of cassava peels, which was composted, could be explained by the process of organic matter mineralisation, which always takes place during the composting process [21] [22]. That increase might also be the result of the maturation phase, which is the last phase of the process of composting, during which there is a production of organic acids and soluble salt. Moreover, it could also be explained by the slight amount of Mg^{2+} ; Ca^{2+} ; K^+ and Na^+ in the produced composts. [22] [23] [24]. As a result, a great amount of cassava peels might increase the salinity of the final product that might cause osmotic problems and affects water intake ability [22]. However, the value of the electrical conductivity of each produced compost was below the value that might cause a toxic effect on plants (3,7 à 8,8 mS/cm) [25]. The few concentration of Cu from the produced composts could be explained by their absence from the composted cassava peels.

The slight increase of pH from the obtained composts (C1, C2, C3, and C4) should be explained by the presence of a thermophilic phase in which there is the degradation of organic acids, produced during the acidophilic phase,

which allows a phenomenon of alkalization of the compost, which is increased by the mineralization of the soil's nitrogen [22] [26] [27] [28]. That increase in pH may be also attributed to the lack of production of some organic acids [22]. It could also be the lack of CO_2 mineralization of organic material [29].

The increase of the total nitrogen from C2, C3, and C4 at the end of the process of composting could be the result of two main reactions that took place during the process: the reaction of mineralization and nitrification [30], during which there is the production of NH_4^+ and NO_3^+ . It might also be due to respectively the lack of NH_3 volatilization and the absence of three other reactions (incomplete denitrification, complete denitrification) during which there is the formation of N_2O and N_2 that can be released into the atmosphere [30]. Moreover, the increase of the total nitrogen from C2, C3, and C4 could also be explained by the fact that, under the pH conditions (less than 8.4) [31], the NH_3 -N form is difficult to be volatilized to the gas form and lost [30].

The decrease of P in the different composts could be explained by the fact that the composting may affect the distribution of P fractions, and the lack of phosphate solubilizing microbes that might solubilize insoluble P composts [22]. It might also result in the lower presence of microbial activity related to organic acids production lead to the solubilization of precipitated inorganic P [22] [31].

The drop of C/N rations at the end of the composting process could be the result of the lack of nitrogen volatilisation (i.e. increasing nitrogen content) [22] [32]. It may be also due to the release of the carbon in the form of CO_2 , and it would imply the level of humification of the organic matter [32]. Studies done previously, have indicated that a C/N ratio between 10 and 21 at the end of composting is an indicator of compost maturity [22] [32]. In this study, the composts produced meet this criterion.

One of the most commonly used and sensitive biological indicators for assessing the

phytotoxicity and maturity of compost is the value of the GI [22] [33]. The results obtained from the phytotoxicity test demonstrated that the composts had GIs $\geq 80\%$. Those results showed that the produced composts were mature and devoid of any toxic effect. Those results are in accordance with the result obtained by [34] [35] [36] [37] [38] and [22], who showed that GI values of 80% are indicative of mature compost with no phytotoxic effect. On the other hand, the results of the GI are also in the same line with those obtained from the germination test where all the samples (B1, B2, B3 and B4) of the composts had the rate of germination greater than 80 %. This could be explained by the fact that the composts produced had a pH (6.5) and good EC that allow the normal germination of sweet pepper seeds and their richness in mineral nutrients. It may be also due to the absence of harmful microorganisms.

4.3 Microbial biomass

The increasing quantity of cassava peels had positive effects on bacterial and fungal populations because it did not impair or change the imbalance that is usually observed at the end of the composting process in which the proportion of fungi increases, while bacterial numbers decline. [39] That increase of fungi population and decrease of the bacterial population could be due to the fact that during the maturation phase, compounds that are not further degradable, such as lignin–humus complexes and cellulose, are formed and become predominant [38]-[39]. Such kind of compounds is much more degradable by the fungi population than bacterial population [38]. It may also be explained by the water potential decreases, which is an advantage for fungi. On the other hand, the lack of significant difference, respectively in between the proportion of fungi and bacterial biomass, observed from the produced composts could be due to the relative salt concentrations (EC) that have been noticed. [40] [41] [42]. Therefore the important presence of this total microflora would reflect the maturity and eco-compatibility of the composts [22].

5 Conclusion

This study showed that cassava peels are good substrate that can be used to produce a good quality compost. The electrical conductivities of 1.49 to 1.92 mS/cm that were recorded from various composts, respected the standards value (3,7 - 8,8 mS/cm) and were below the phytotoxic levels. The pH, was nearly neutral, favorable to the cultivation of fruits and vegetables. Composts were rich in minerals and poor in heavy metals. In addition, the produced composts showed a germination index and the rate of germination of sweet pepper seeds were greater than 80%, indicating the absence of phytotoxicity. The increased amounts of cassava peels did not modify the process of composting and increased the fungal and bacterial populations. The compost of cassava peels could be recommended as organic fertilizer to remediate soil fertility and base deficiency, increase the soil microbial biomass and reduce the environmental pollution. The implementation of cassava peels waste as compost is a contribution to waste valorization and also represent a suitable alternative to mineral fertilizers for poor resource farmers.

6 Declarations

6.1 Acknowledgements

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6.2 Competing Interests

The authors declared that no conflict of interest exist in this publication.

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