Characterization of a compost made from hen manure and wood ash and its effect on soil properties, production and nutritional quality of tomato (*Lycopersicon esculentum* Mill.)

Abstract

The effect of a compost based on chicken manure and wood ash on the production and nutritional quality of tomatoes was evaluated. The mixtures of the constituents of each compost were made at variable m/m proportions: 25/75 (C1); 50/50 (C2); 75/25 (C3) and 100/0 (C4). Tomato cultivation in pots was done in completely randomized random blocks with 5 repetitions, and 3 compost/soil m/m proportions (5%, 10% and 15%). The physicochemical and biochemical parameters of the compost and the amended soil, as well as the production and nutritional quality of the fruits, were evaluated.

The compost showed higher pH values than the unamended soil. The C3 variant exhibited the highest pH (9.97±0.00). The C/N ratio varied from 14.78±0.67 to 15.30±0.35 values higher than that of the unamended soil (11.86±0.27); exchangeable ion concentrations were higher in the compost. The microbial biomass and the enzyme activities of the compost were significantly higher than those of the unamended soil, the greatest values were obtained with the C3 variant. pH, EC, C/N ratio, and exchangeable ion concentrations were higher in all treated soils than in soils amended with chemical fertilizer.

Tomato production was higher with the variant (15% C3) with a value of 156.00 ± 1.00 fruits, the soil amended with chemical fertilizer having given 14.00 ± 1.00 fruits. Biological tomatoes obtained with compost were richer in lycopene, vitamin C, phenolic compounds and minerals than those obtained with chemical inputs (Chemical tomatoes). The compost has improved the production and nutritional quality of the tomato, which is an efficient alternative for sustainable agriculture.

Keywords: Compost, Soil, Chicken droppings, Biological Tomato, Production, Nutritional quality.

1. Introduction

Market gardening plays an important role in agriculture. Among vegetable crops, tomato (*Lycopersicon esculentum* Mill.) is the most demanded vegetable in the world, after potato (**Tuyen et *al.*, 2016**). The consumption of tomatoes is an asset in households, because of their richness in proteins, vitamins A, C and E (**Nacro, 2018**). It remains an important cash

crop for smallholders and commercial farmers as it provides income and allows people to combat food insecurity. Lycopene, a vital antioxidant responsible for the red color of tomatoes, has anticancer activity, helps in the prevention of cardiovascular diseases and improves immune system responses. Dietitians frequently recommend tomatoes for cholesterol control and for weight loss programs. Present in many dishes, it can be consumed in different ways, raw, dried, transformed into juice or combined with other ingredients to make sauces, for example. World tomato production was 18,230,135 tonnes with a yield of 188t/h (**FAOSTAT, 2020**). Production in Cameroon amounts to 1,279,853 tonnes with a yield of 12.1t/h (**FAOSTAT, 2020**).

Despite its economic importance, tomato cultivation faces many constraints, including diseases (bacterial and fungal) and pests **(Konje et *al.*, 2019)**. It is also threatened by a low level of soil fertility and agricultural productivity **(Saïdou et *al.*, 2012)**. Faced with these constraints, farmers massively use synthetic chemical substances, the excessive cost of which is sometimes inaccessible to producers **(Ettien et *al.*, 2016)**. In addition to the problem of high cost, their misuse has repercussions on the health of users and consumers and also the environment **(Zinkakuba et *al.*, 2019)**. To overcome this problem, alternative methods oriented towards the use of organic fertilizers including plant extracts, manures and composts are used. Biofertilizers are environmentally friendly and pose less of a health risk to consumers. Moreover, they have the advantage of improving the physicochemical and biochemical qualities of the soil while preserving the environment with easy access to the raw material **(Kitabala et *al.*, 2016)**. **Zeba et *al.*, (2019)** showed that fly ash vermicompost improves soil quality, microbial biomass and enzyme activities, growth and yield of tomatoes; similarly, previous studies have shown that the use of composts based on green waste and ash from wood as biological inputs in soybean cultivation improves the physicochemical and microbiological parameters of the soil **(Bougnom et *al.*, 2020)**. It has also been proven that compost made from household waste improves tomato growth parameters and protects it against diseases **(Btissam et *al.*, 2010)**. Thus, the general objective of this work was to evaluate the effect of a compost based on chicken manure and wood ash on the production and nutritional quality of tomatoes.

2. Materials and methods

2.1 Materials

2.1.1 Biological and soil material

The chicken droppings used for the production of the Compost were collected from a farm in the Ngousso district (Yaoundé-Cameroon), the wood ash was collected from a roaster in the Efoulan district (Yaoundé-Cameroon). The soil samples used were collected in the Nkolbisson district (Yaoundé-Cameroon). Roma VF variety tomato seed was purchased at the Mfoundi market (Yaoundé-Cameroon). The chemical fertilizer NPK (10-11-18) serving as a positive control was purchased at the Mfoundi market (Yaoundé Cameroon).

2.2 Methods

2.2.1 Compost preparation

The chicken droppings were dried in the shade for 14 days in the laboratory and then crushed using a mill to obtain the powder; similarly, the wood ash was sieved using a 20 mm mesh sieve and then packaged in the laboratory. These different powders obtained were mixed in variable mass/mass (m/m) proportions and then homogenized with water leading to obtaining compost. Composting was carried out in closed containers in an aerobic environment for three months (90 days) inside the greenhouse covered with black plastic and white cloth. The experiment was conducted according to a completely randomized block random experimental design divided into two categories; the following proportions mass/mass were each carried out in 5 repetitions: 25% chicken droppings and 75% wood ash (C1), 50% chicken droppings and 50% wood (C2), 75% chicken droppings chicken and 25% wood ash (C3), 100% chicken droppings (C4). To follow the evolution of the composting process, the following activities were carried out at the compost site: visual observation and turning.

The compost variants were subdivided into two parts, the major part of which was used for soil amendment and the rest was sieved and then dried in the open air for the physicochemical characterization and kept at 4°C for the biological characterization.

2.2.2 Characterization of composts produced and compost/soil mixtures

2.2.2.1 Determination of physicochemical parameters

• Determination of pH and electrical conductivity

The pH was measured after dissolving 5g of the sample in 25 ml of distilled water. The method used consisted of preparing a suspension the dried substrate, diluted in 5 times its

volume of water (1/5), leaving it to stir for 5 minutes and then letting it rest for at least two hours. The pH reading is made using a pH meter.

• Measurement of electrical conductivity

20g of each sample was taken to which 100 ml of distilled water was added. The solutions were stirred for 30 minutes and then filtered. The specific electrical conductivity of the filtered extract was measured using an HQ 14d brand conductivity meter (HACH).

2.2.2.2 Determination of total organic matter (TOM), total organic carbon (TOC) and total nitrogen (Total N)

• Determination of organic matter and carbon dosage

The determination of total organic matter (TOM) and ash were made according to the method of (**M'sadak, 2013**). 20g of each substrate were weighed and the samples were put in the oven for 24 hours at 70°C; the calcination of 3g of the sample, previously dried in an oven, at 900°C for at least 6 hours in a muffle furnace was carried out and the determination of the dry residue or mass after calcination was carried out. The TOM content was determined according to the following equation:

$$TOM\ (\%) = ((M1 - M2) / M1) \times 100$$

With M1: Mass before calcination (mg); M2: Mass after calcination (mg).

From the OM, a deduction of the Total Organic Carbon (TOC) content was made by applying the following relationship:

$$TOC\ (\%) = (MO\ (\%) / 1.8) \times 100$$

• Determination of total nitrogen content (Total N)

The total nitrogen was determined by the Kjeldahl method by mineralization of the sample of mass equal to 5g by concentrated sulfuric acid in the presence of a catalyst (selenium) at 400°C for 2 hours; alkalization of the reaction products was then carried out with a NaOH solution with a concentration of 400 g/l; distillation and titration of the ammonia released were carried out in the last step using a sulfuric acid solution with a concentration equal to 0.05M.

• Determination of the C/N ratio

C/N ratio was calculated from the organic carbon and nitrogen values according to the formula:

$$\frac{C}{N} = \frac{\text{Organic Carbon \%}}{\text{Total Nitrogen \%}}$$

2.2.2.3. Determination of phosphorus (P) and potassium (K) concentrations

• Phosphorus concentration

The total phosphorus content was determined by the so-called "molybdovanadate" method (**Eaton et *al*., 2005**). 1 ml of molybdovanadate reagent was added to 25 ml of each previously digested sample. A control consisting of distilled water followed the same treatment. When orthophosphate molecules are present, they react with molybdate in an acidic medium to form the phosphomolybdate complex. In the presence of vanadium, vanadomolybdophosphoric acid which has a yellow colour is formed. The intensity of the colour is proportional to the concentration of phosphates present in the medium. The reading of the optical density was made with a spectrophotometer at the wavelength of 650 nm. The values were presented in the form of orthophosphate (PO_4^{3-}) and expressed in mg/l.

• Potassium concentration

To 25 ml of sample contained in a test tube, were successively added the contents of a capsule of reagent potassium 1 and potassium 2. The mixture was stoppered and homogenized. To the clear solution was added the content of one capsule of potassium reagent 3. After 30 seconds of stirring, the solution obtained was transferred to a 25 ml cell. Another cuvette (the blank) was filled with 25 ml of sample. The reading of the optical density was made with the DR/3900 spectrophotometer at the wavelength of 650 nm. The result was expressed in mg/l.

2.2.2.4. Assay of exchangeable cations (Mg^{2+}, Ca^{2+}, K^+, Na^+) and heavy metals

The determination of the content of macroelements and microelements of the different variants of the compost in the soil was made after the mineralization of the samples. The solutions were prepared by mixing 0.2 g of sample with 4 ml of sulfuric acid (H_2SO_4) 95%. These solutions were then incubated for 5 minutes in a HACH brand digestahl mineralizer, first at low temperature, then by gradually increasing the temperature to 440°C until the mixture cleared. During the incubation, between the 3rd and 4th minute (after boiling), 10 ml of hydrogen peroxide (H_2O_2) was gradually added using a syringe. The mineralized material thus obtained (5 ml) was reduced to 70 ml in a volumetric flask with distilled water. The Ca^{2+}, Mg^{2+}, Na^+, K^+, Pb, Zn, and Cu concentrations were then determined according to standard protocols using a DR 3900 brand spectrophotometer.

2.2.2.5. Determination of fungal and bacterial biomass

• Enumeration of fungal flora

Analysis of the microflora was carried out using the suspension-dilution technique on agar medium, Sabouraud dextrose agar (SDA) medium supplemented with an antibiotic (gentamicin). In a 250 mL Erlenmeyer flask containing 90 mL of sterile distilled water was aseptically added 10 g of dry compost (after drying at 30°C overnight). This mixture was agitated for 30 minutes to suspend the particles of Compost as well as the spores which were attached to it. The suspension obtained corresponds to the 10^{-1} dilution. Then decimal and successive dilutions were made up to 10^{-8}. 0.1 mL of each dilution was inoculated onto the culture media contained in Petri dishes and incubated at 26° C. for three days.

• Enumeration of bacterial flora

The determination of the total bacterial flora was carried out using the suspension-dilution technique on nutrient agar added to an antifungal (0.5% nystatin). 5g of each sample were placed in a 100 mL Erlenmeyer flask containing 45 mL of sterile physiological water (9g of NaCl/L in 1000 mL of distilled water) and suspended using a magnetic stirrer for 30 minutes. The suspension was then decanted for 20 minutes, then the supernatant was removed, and it constituted the 10^{-1} dilution. From this suspension, decimal dilutions were made up to 10^{-8}. 0.1 mL of each dilution was inoculated onto the culture media contained in Petri dishes and incubated at 26° C. for three days.

The determination of the microbial load was made by counting the colonies and the results expressed in CFU/g of soil according to the formula:

$$N = \frac{\Sigma \text{ colonies } \times Fd1}{Vml \times (n1 + 0{,}1n2)}$$

N: Number of CFU per gram of soil; Σcolonies: Sum of the colonies of the interpretable boxes; V: Volume of deposited solution (1ml); n1: Number of boxes considered at the first dilution retained; n2: Number of boxes considered at the second dilution used; Fd1: Factor of the first dilution retained.

2.2.2.5. Determination of enzymatic activities

• Cellulase activity

The cellulase activity was determined by the method described by **Tabatabaï (1994)**. The enzymatic unit (U) was expressed in g of reducing sugars released per hour. The enzymatic activity (A) corresponds to U/g of compost-soil.

• Protease activity

Protease activity was determined using the method described by **Tabatabaï (1994)**. The enzyme unit (U) is expressed in mg of amino acid released over 2 hours. The enzymatic activity (A) corresponds to U/mg of compost.

• The activity of β-glucosidase

The activity of β-glucosidase was evaluated respectively according to the method developed by **Eivazi and Tabatabai (1988)**. A sample of compost (1 g) was placed in a 50 ml Erlenmeyer flask and treated with 0.25 ml of toluene, 4 ml of MUB (pH 6.0) and 1 ml of the glucoside solution. The flask was shaken for a few seconds to mix the contents, capped and incubated at 37°C. After 1 h the stopper was removed and 1 ml of 0.5 M $CaCl_2$ was added, mixed and treated with 4 ml of 0.1 M THAM, pH 12. The flask was shaken and the compost suspension was filtered through a Whatman No. 2 folded filter paper. The absorbance of the solution was measured using a Klett-Summerson photoelectric calorimeter equipped with a No. 4 filter. The maximum absorbance of the measured colour is located at 400 nm.

• Dehydrogenase activity

Dehydrogenase activity was determined by the method described by **Tabatabaï (1994)**.

• Alkaline and acid phosphatases

The phosphatase activities were evaluated by the method developed by **Eivazi and Tabatabai (1988).** Enzyme activity was measured using 1 g of compost and 5 mL of pH 5 or pH 9 buffer containing 10 mM p-nitrophenyl phosphate. After incubation for one hour at 37°C, 1 mL of a 0.5 M $CaCl_2$ solution and 4 mL of 0.5 M NaOH solution was added to the reaction medium. Reading of the optical density at 405 nm of the released p-nitrophenol ($\varepsilon M=1.9\times104\ M^{-1}\ cm^{-1}$) was performed after centrifugation for 10 min at 10,000 rpm. The results were expressed in units per gram of dry matter ($U.g^{-1}$ DM), one unit corresponding to the number of μmoles of p-nitrophenol released per minute. A standard range of p-nitrophenol was produced in each of the two buffers.

2.2.2.6. Evaluation of the effect of composts on production and nutritional quality of tomato.

2.2.2.6.1. Tomato cultivation

• Creation of the nursery

The nursery was carried out in four containers each containing 15 kg of soil (earth + sand) for 30 days with a watering frequency of twice a day (morning/evening). She was covered with black plastic for the first five days to promote germination.

• Soil amendment

Each component of the compost was mixed with the soil in the proportions compost/soil 5%, 10% and 15% (m/m). In addition to these treatments, two controls were carried out: positive control (soil + NPK synthetic fertilizer) and negative control (simple soil).

• Transplanting the tomato

After soil amendment, the pots were watered and left to rest for 24 hours. The tomato plants were then transplanted individually into the pots and the latter were randomly arranged in completely randomized blocks. The frequency of watering the pots was twice a day (morning and evening) and the harvesting of fruits took place according to maturity.

2.2.2.6.2. Evaluation of fruit production.

During tomato cultivation, the number of flowers and fruits was determined by counting 70, 90, and 110 days after transplantation (DAT). The number of ripe fruits was evaluated and their average masses were determined 90 and 110 DAT.

2.2.2.6.3. Evaluation of nutritional quality

Three batches of tomatoes (Biological tomato, Chemical tomato, and Market-bought tomato) were washed with distilled water. They were cut into small dice, and a part was reduced to a puree using a blender and stored at -80°C for the analyses of the content of total sugars, vitamin C and lycopene. The other part was dried and then reduced to powder using a mortar and stored in a polyethylene tube at room temperature for the analyses of the other parameters (ash, phenolic compounds, total lipids, crude fibres and minerals**• Determination of water content**

The dry porcelain capsule was weighed (Po) using a balance as well as 5g of fresh sample (P1). They were dried in a "Memmert" brand oven at a temperature of 105°C. Weighing was done regularly until a constant weight was obtained. The dry residue was cooled in the atmosphere of a desiccator containing P_2O_5 as a desiccant for 1 hour and weighed (P2). The water content is the average of the contents of the three tests determined according to the following formula:

$$\text{Water content} = \frac{P_1 - P_2}{P_1 - P_0} \times 100$$

The results were expressed in g per 100 g of fresh material.

• Determination of ash content

A porcelain capsule, carefully washed and rinsed with distilled water and 1% nitric acid, was dried in an oven at 65°C for 1 hour. It was then placed in a "VECSTAR" brand oven at 550° C. for 3 hours to destroy all traces of organic matter. On leaving the oven, it was left to cool in a desiccator for 1 hour. Its weight (P1) was determined. Exactly 3 g of dry matter (P0) of the sample was placed in the dish. The whole was put in the oven at 550°C for 48 hours. On leaving the oven, the capsule containing the ash was left to cool in a desiccator and its weight P2 was determined. The ash content is the average of three determinations and is given by the following relationship:

$$\text{Ash content} = \frac{P_2 - P_1}{P_0} \times 100$$

The results were expressed in g per 100 g of dry matter.

• Determination of the hydrogen potential "pH"

The fruits were cut into small pieces and then mashed in a mortar. The pH meter was calibrated successively with buffer solutions of pH 4, 7 and 10. The pH was read at 20° C by immersing the electrode in the sample solution.

• Density determination

According to **James (1980)**, the density is obtained by calculating the quotient of the density of a solution of the same density of distilled water at 20°C. The pycnometer was weighed empty (m0). It is then filled with distilled water. Before weighing, the water level was adjusted to the gauge line after plugging the pycnometer. After this operation, a solution of the powder obtained was prepared and after filtration, the solution obtained was replaced by distilled water and then weighed.

The density was calculated by the following formula:

$$\text{Density} = \frac{m2 - m0}{m1 - m0} \times 100$$

m0: mass in grams, of the empty pycnometer, m1: mass in grams, of the pycnometer filled with distilled water, m2: mass in grams, of the pycnometer filled with tomato solution

• Dosage of total sugars

In a beaker containing 100mg of sample powder, 10ml of a hydro-alcoholic mixture (1/10 v/v) was introduced; the whole was homogenized for 10 minutes then filtered and evaporated at room temperature. The filtrate obtained was used for the assay. From a standard solution of glucose 1mg/ml, volumes of 0.07; 0.14; 0.21 and 0.28 ml were pipetted and introduced into 10 ml tubes. Then, 0.3 ml of 5% phenol was added as well as 1.8 ml of sulfuric acid; the volumes were then completed with distilled water. The optical densities of the solutions thus obtained were read on a spectrophotometer at 490 nm against blank.

In the test tube, 1 ml of hydro-alcoholic extract was then added to 0.4 ml of distilled water and 0.3 ml of phenol 5% (w/w) then the whole was mixed with 1.8 ml of sulfuric acid. In the white tube, was introduced 0.4 ml of distilled water, 0.3 ml of 5% phenol and 1.8 ml of concentrated sulfuric acid. The optical densities were immediately read on a spectrophotometer at 490 nm.

$$\text{Sugar mass} = \text{Sugar content} \times \text{Material fresh mass}$$

• Dosage of total lipids

The total lipids were extracted with a Soxhlet using the method described by **Goodon (1997)**. The filter papers were dried in an oven at 105°C for 3 hours, and then the weights (PF) were recorded. 2 g of dry samples were weighed and placed in the filter papers, and then the whole was left to dry in an oven for 24 hours. At the end of the drying, the whole was weighed and the weight (PA) was noted. The filter papers containing the samples were then placed in the Soxhlet for 12 hours for the extraction of oils. 12 hours later, the samples were removed from the extractor and dried in an oven at 105°C for 3 hours and the weight (PE) was noted. The results are expressed in g per 100 g of dry matter (DM). The amount of total lipids was determined according to the formula:

$$\%\ \text{Total lipids} = \frac{P_A - P_E}{P_A - P_F} \times 100$$

$$\text{Total lipids mass} = \text{Total lipids content} \times \text{Dry mater mass}$$

• Dosage of total polyphenols

The phenol contents of each sample were determined with a reference antioxidant (gallic acid). The content of phenolic compounds in our extracts was calculated from a linear

calibration curve (y = ax + b) established with accurate concentrations of gallic acids as a reference standard, under the same conditions as the sample. The phenolic compound content of each sample was obtained by projecting its absorbance on the calibration line produced with gallic acid.

• Dosage of lycopene

15 g of fresh samples were introduced into 25 ml of solution (hexane-acetone-ethanol, (50/50/1). After stirring for 10 min, centrifugation at 10,000 revolutions per min for 30 min was carried out. 1 ml of the organic phase was then extracted and diluted in 10 ml of hexane. In a cell, a sample of the organic phase was introduced and the absorbance was measured at 472 nm. The lycopene content was calculated according to the formula:

$$C(\mu g/g) = \frac{\text{Abs } 472 \times \text{Fd} \times 106 \times V}{3450 \times 100 \times P}$$

Fd: Dilution factor, V: Volume of extraction solvent, 3450: Extinction coefficient of hexane, P: Weight of test sample.

• Dosage of crude fibres

1 g of delipidated dry matter (P1) was introduced into a 200 ml beaker and 100 ml of 0.26 N sulfuric acid was added. The mixture was heated at 100°C for 30 min, then filtered and washed 3 times with distilled water. Then, 100 ml of 0.23 N KOH was added and the whole was heated for 30 min, then the contents were filtered and washed 3 times with distilled water and 2 times with acetone. The contents of the beaker were dried in a porcelain dish at 105°C for 8 h, then left to cool in the desiccator and weighed (P2). The capsule was then placed in an oven at 500° C. for 3 hours then cooled in a desiccator and weighed (P3). The results were expressed in g per 100 of dry matter (DM) according to the formula:

$$\text{Crude fibres content} = \frac{P_2 - P_3}{P_1} \times 100$$

The amount of crude fibre was determined according to the formula:

- $\text{Crude fibres mass} = \text{Crude fibres content} \times \text{Dry material mass}$

s added to it. The mixture obtained was homogenized and then centrifuged at 6000 rpm for 10 minutes.

The filtrate was collected in a tube. For the test, 1 ml of filtrate was pipetted into a 10 ml tube followed by 0.2 ml of 10% hydrochloric acid and the volume was made up of deionized water. For the blank, 2 ml of distilled water and 0.6 ml of the 1 M sodium hydroxide solution were added to a 10 ml tube. 12 minutes after shaking, 0.6 ml of 10% hydrochloric acid was added and the volume made up of deionized water. The vitamin C concentration of each sample was obtained by projecting its absorbance onto the calibration line. The concentration was expressed in mg per 100 g of fresh sample.

• Determination of Ca, Mg, K, Na, Fe, Mn and Zn content

The determination of the calcium, magnesium, potassium, sodium, iron, manganese and zinc content was done by flame atomic absorption spectrophotometry **(Benakmoun et *al*., 2008)**. For the determination of the macroelements (Ca, Mg, K, Na), 0.5 ml of each supernatant was diluted in 19.5 ml of strontium chloride solution. For the determination of trace elements (Fe, Mn, Zn), the supernatant was not diluted, approximately 10 ml were used. 2 tubes containing the same quantities of products as all the other tubes were filled with deionized water for each dosing series. Standards, samples and blanks were then passed through a flame atomic absorption spectrophotometer. The calibration line of each standard made it possible to determine the concentration (mg/100g DM) of each mineral by a projection of the absorbances on the corresponding curves.

• Determination of phosphorus content

Phosphorus content was determined by colourimetric spectrophotometry **(Murphy and Riley, 1962)**

• Determination of heavy metal content

The copper (Cu), lead (Pb), and zinc (Zn) content was determined by atomic absorption spectrophotometry according to standard protocols.

2.2.2.6.3. Statistical analysis of results

The results obtained were subjected to statistical analysis for the calculation of means, standard deviations and the search for significant differences using SPSS 23.0 software. The one-way ANOVA test coupled with the Student-Newman-Keuls test was used to assess the Least Significant Difference (LSD) at $P < 0.05$.

3. Results and discussion

3.1. Results

3.1.1. Physicochemical, biological and biochemical characteristics of compost and compost/soil mixtures

3.1.1.1. Physicochemical, biological and biochemical characteristics of the composts produced

3.1.1.1.1. pH, EC, organic C, total N, C/N ratio, total P, the concentration of exchangeable ions (Mg^{2+}, Ca^{2+}, K^{+}, Na+) and heavy metals (Pb, Zn, Cu) of compost variants

The **Table I** below presents the results obtained after physicochemical analysis of the C1, C2, C3 and C4 variants of the compost.

Table I: pH, EC, organic C, total N, C/N ratio, total P, the concentration of exchangeable ions (Mg^{2+}, Ca^{2+}, K^{+}, Na^{+}) and heavy metals (Pb, Zn, Cu) of the compost variants.

Parameters	Compost variants				
	Soil T	C1	C2	C3	C4
pH	5.40±0.14^{a}	9.83±0.02^{b}	9.93±0.00^{b}	9.97±0.00^{b}	9.94±0.00^{b}
EC (mS/cm)	0.19±0.01^{a}	0.62±0.02^{c}	0.68±0.00^{d}	0.59±0.02^{bc}	0.56±0.01^{b}
C (g/kg)	10.55±0.19^{a}	32.60±0.81^{b}	39.26±0.20^{d}	35.26±0.62^{c}	31.76±1.02^{b}
Total N (g/kg)	0.89±0.02^{a}	2.20±0.04^{bc}	2.56±0.04^{d}	2.30±0.04^{c}	2.10±0.04^{b}
C/N	11.86±0.27^{a}	14.78±0.67^{b}	15.30±0.35^{b}	15.29±0.37^{b}	15.07±0.29^{b}
P (g/kg)	0.10±0.00^{a}	0.55±0.00^{a}	0.67±0.01^{b}	0.62±0.00^{b}	0.53±0,00^{a}
Mg^{2+} (g/kg)	0.05±0.00^{a}	0.09±0.00^{a}	1.07±0.09^{b}	0.07±0.00^{a}	0.06±0.00^{a}
Ca^{2+} (g/kg)	0.02±0.00^{a}	0.05±0.01^{a}	0.48±0.01^{c}	0.26±0.00^{b}	0.25±0.01^{b}
K^{+} (g/kg)	0.02±0.00^{a}	0.08±0.00^{c}	0.10±0.00^{d}	0.04±0.00^{b}	0.03±0.00^{ab}
Na^{+} (g/kg)	1.33±0.00^{a}	8.00±0.16^{b}	13.96±1.24^{d}	10.06±0.04^{c}	7.93±0.09^{b}
Pb (mg/kg)	0.40±0.04^{a}	0.43±0.04^{a}	0.68±0.02^{b}	0.79±0.00^{b}	0.46±0.09^{a}
Zn (mg/kg)	0.05±0.00^{b}	0.02±0.00^{a}	0.21±0.00^{c}	0.02±0.00^{a}	0.05±0.00^{b}
Cu (mg/kg)	0.05±0.01^{a}	2.03±0.01^{d}	2.13±0.01^{e}	1.69±0.01^{c}	1.46±0.01^{b}

Results are presented as means ± standard deviations of 5 replicates. The values assigned by different letters on the same row are significantly different at the threshold (P < 0.05). C1 = 25% chicken droppings + 75% wood ash, C2 = 50% chicken droppings + 50% wood ash, C3 = 75% chicken droppings + 25% wood ash, C4 = 100% chicken droppings, Soil T= control soil.

From this table, it appears that all the parameters have varied according to the variants of the Compost. There is an increase in pH in the compost variants, the greatest value was obtained with the C3 variant (9.97 ± 0.00^{b}) value significantly higher than that of the control soil (5.40 ± 0.14^{a}). The electrical conductivity (EC) increased significantly and the greatest value was obtained with the C2 variant (0.68±0.00^{d} mS/cm) of the control soil having given a value of 0.19±0.01^{a} mS/ cm. C2 presented the highest values in total nitrogen (Ntotal) (2.56±0.04^{d} g/kg), in Carbon (C) (39.26±0.20^{d} g/kg) and the C/N ratio (15.30±0.35^{b}), compared to the control soil. The phosphorus (P) concentration increased significantly in the compost variants and the greatest value was obtained with the C2 variant (0.67±0.01^{b}g/kg) compared to the Soil T (0.10±0.00^{a}g/kg). The concentrations of exchangeable ions (Mg^{2+}, Ca^{2+}, K^{+}, Na^{+}) significantly increased in the Compost variants with the highest values obtained by the C2 variant compared to the Soil T.

3.1.1.1.2. Microbial biomass and enzymatic activities of compost variants

The **Table II** below presents the analysis of the microbial biomass and the enzymatic activities of the C1, C2, C3 and C4 variants of the compost.

Table II: Microbial biomass and enzymatic activities of compost variants.

Parameters	Compost variants				
	T soil	C1	C2	C3	C4
Total bacteria (10^5 CFU/g)	401.67±0.94^{a}	611.00±1.41^{c}	452.67±1.25^{b}	742.67±1.25^{e}	680.67±7.36^{d}
Total fungi (10^5 CFU/g)	371.67±8.50^{a}	580.00±7.07^{b}	587.00±1.63^{b}	914.67±1.89^{d}	783.33±1.89^{c}
Cellulase activity (U/mg/h)	13.67±0.47^{a}	21.67±0.94^{c}	17.67±1.25^{b}	30.67±1.25^{d}	24.67±0.94^{c}
Protease activity (U/mg/h)	1.17± 0.01^{a}	2.37±0.02^{b}	2.26±0.02^{b}	3.54±0.07^{d}	2.61±0.03^{c}
Deshydrogenase activity (mgTFP/kg sol sec/24h)	40.67±0.47^{a}	45.67±0.94^{b}	54.33±0.47^{c}	80.67±0.94^{e}	68.67±0.94^{d}
β-glucosidase activity (mg PNP/kg sol sec/h)	44.67±0.47^{a}	49.33±0.94^{b}	60.67±0.47^{c}	99.33±0.47^{e}	78.67±0.94^{d}
Acid phosphatase activity (mg PNP/kg sol sec/h)	263.33±2.36^{a}	299.00±1.41^{b}	448.67±1.25^{c}	698.67±1.25^{e}	598.67±1.25^{d}
Alkaline phosphatase activity (mg PNP/kg sol sec/h)	346.67±2.36^{a}	498.67±0.94^{b}	599.33±0.94^{c}	898.67±1.25^{e}	748.67±0.94^{d}

Results are presented as means ± standard deviations of 5 replicates. The values assigned by different letters on the same row are significantly different at the threshold (P < 0.05). C1 = 25% chicken droppings + 75% wood ash, C2 = 50% chicken droppings + 50% wood ash, C3 = 75% chicken droppings + 25% wood ash, C4 = 100% chicken droppings, Soil T= control soil.

This table shows that the bacterial biomass varied from 452.67±1.25 x 10^5 CFU/g (C2) to 742.67±1.25 x 10^5 CFU/g (C3), values significantly higher than that of the control soil (401.67±0.94 x 10^5 CFU/g). The fungal biomass varied from 580.00±7.07 x 10^5 CFU/g (C1) to 914.67±1.89 x 10^5 CFU/g (C3), values significantly higher than the control soil (371.67 ±8.50 x 10^5 CFU/g).

The C3 compost variant presented the highest values in cellulase activities (30.67±1.25 U/mg/h), protease (3.54±0.07 U/mg/h), and dehydrogenase (80. 67±0.94 mgTFP/kg soil dry/24h), β-glucosidase (99.33±0.47 mg PNP/kg dry soil/h), acid phosphatase (698.67±1.25 mg PNP/kg dry soil/h) and alkaline phosphatase (898 .67±1.25 mg PNP/kg dry soil/h) compared to the control soil.

3.1.1.2. Physicochemical characteristics of the proportions of compost/soil mixtures

3.1.1.2.1. pH, EC, total N, Corg, C/N and P of the proportions of compost/soil mixtures

The **Table III** below presents the results obtained after analysis of the proportions of Compost/soil mixtures.

Table III: pH, EC, total N, Corg, C/N and P of the proportions of compost/soil mixtures.

Compost-soil mixtures		Parameters					
		pH	EC (mS/cm)	C (g/kg)	Total N (g/kg)	C/N	P (g/kg)
C1	5%	5.80±0.08^{b}	0.21±0.00^{a}	33.93±1.24^{bcd}	1.94±0.08^{b}	17.63±0.34^{cd}	10.91±0.94^{bcd}
	10%	6.33±0.04^{c}	0.26±0.00^{a}	38.26±1.24^{d}	1.94±0.08^{b}	19.68±0.61^{cd}	14.58±1.24^{efg}
	15%	7.36±0.04^{de}	0.30±0.00^{a}	54.26±0.94^{e}	2.90±0.04^{c}	18.67±0.31^{cd}	16.91±1.24^{g}
C2	5%	6.43±0.04^{c}	0.21±0.00^{a}	34.93±1.88^{bcd}	1.97±0.09^{b}	17.72±0.89^{cd}	9.75±0.40^{bc}
	10%	7.36±0.04^{de}	0.25±0.00^{a}	37.26±1.70^{d}	1.97±0.12^{b}	18.91±0.69^{cd}	13.15±0.14^{de}
	15%	7.60±0.08^{e}	0.30±0.00^{a}	52.26±1.88^{e}	2.84±0.08^{c}	18.40±0.34^{cd}	16.91±1.24^{g}
C3	5%	5.40±0.08^{a}	0.18±0.00^{a}	29.60±0.81^{b}	1.97±0.09^{b}	15.05±1.14^{ab}	9.68±0.41^{bc}
	10%	6.26±0.04^{c}	0.26±0.00^{a}	37.26±1.70^{d}	1.97±0.12^{b}	18.99±1.86^{cd}	13.41±0.62^{def}

	15%	7.26±0.09^{d}	0.30±0.00^{a}	52.26±1.88^{e}	2.90±0.04^{c}	17.97±0.36^{cd}	16.58±0.94^{fg}
	5%	5.36±0.04^{a}	0.21±0.00^{a}	31.26±0.94^{bc}	1.97±0.09^{b}	15.90±1.28^{cd}	8.91±0.94^{b}
C4	**10%**	6.26±0.04^{c}	0.26±0.00^{a}	36.26±1.24^{cd}	1.97±0.12^{b}	18.48±1.65^{cd}	14.58±0.94^{efg}
	15%	7.23±0.04^{d}	0.30±0.00^{a}	51.60±1.41^{e}	2.87±0.04^{c}	17.96±0.44^{cd}	13.58±1.24^{def}
T+		6.33±0.04^{c}	0.55±0.46^{a}	34.93±2.62^{bcd}	2.64±0.08^{c}	13.26±1.36^{ab}	12.41±0.62^{cde}
T-		5.40±0.14^{a}	0.19±0.01^{a}	10.55±0.19^{a}	0.89±0.02^{a}	11.86±0.27^{a}	0.10±0.00^{a}

Results are presented as means ± standard deviations of 5 replicates. The values assigned by different letters on the same column are significantly different at the threshold (P < 0.05). C1= 25% chicken droppings + 75% wood ash, C2 = 50% chicken droppings + 50% wood ash, C3 = 75% chicken droppings + 25% wood ash, C4 = 100% chicken droppings, T^{+} = positive control, T^{-} = negative control, 5%, 10%, 15% = compost-soil proportion (m/m).

From this table, it appears that all the parameters evaluated varied according to the compost-soil proportions. Except for the C3 and C4 mixtures (5%), the pH increased significantly in the amended soils and the greatest value was obtained with the 15%C2 compost (7.60±0.08) compared to the untreated soil. amended T^{-} (5.40±0.14).

A significant increase in the concentration of organic carbon (C) was noted in all the soils amended with the composts and the greatest value was obtained with the 15%C1 variant (54.26±0.94g/kg) compared to the T^{+} (34.93±2.62g/kg) and T^{-} (10.55±0.19g/kg). The total N concentration increased significantly in the soils amended with the composts and the greatest value was obtained with the 15%C1 and 15%C3 variants compared to the positive control (T^{+}) and the negative control (T^{-}). A significant increase in the C/N ratio was noted in soils amended with compost compared to control soils. This ratio varied from 11.86±0.27 (T^{-} soil) to 19.68±0.61 (10%C1).

The total phosphorus (P) concentration increased significantly in the amended soils and the highest values were obtained with the 15% C1 and 15% C2 variants (16.91±1.24g/kg) compared to the unamended T^{-} soil (0.10±0.00g/kg).

3.1.2.2.2. Concentrations of exchangeable ions (Mg^{2+}, Ca^{2+}, K^{+}, Na^{+}) and heavy metals (Pb, Zn, Cu) of the proportions of compost/soil mixtures.

The concentrations of exchangeable ions (Mg^{2+}, Ca^{2+}, K^{+}, Na^{+}) and in heavy metals (Pb, Zn, Cu) are presented in **Table IV** below.

Table IV: Concentrations of exchangeable ions and heavy metals in the proportions of compost-soil mixtures.

Compost-soil mixtures		Parameters						
		Mg^{2+} (g/kg)	Ca^{2+} (g/kg)	K^{+} (g/kg)	Na^{+} (g/kg)	Pb (mg/kg)	Zn (mg/kg)	Cu (mg/kg)
C1	5%	1.06 ± 0.04^{cd}	12.68 ± 0.94^{cde}	0.68 ± 0.09^{b}	2.99 ± 0.15^{b}	0.090 ± 0.01^{a}	$0.01\pm0,00^{a}$	$0.03\pm0,00^{b}$
	10%	1.46 ± 0.04^{f}	14.68 ± 0.94^{efg}	1.08 ± 0.04^{de}	3.39 ± 0.00^{d}	0.28 ± 0.02^{a}	0.02 ± 0.00^{b}	0.057 ± 0.00^{cd}
	15%	0.95 ± 0.04^{c}	14.01 ± 1.41^{defg}	1.35 ± 0.12^{def}	3.86 ± 0.09^{e}	0.46 ± 0.09^{a}	0.02 ± 0.00^{bcd}	0.06 ± 0.00^{d}
C2	5%	0.93 ± 0.04^{c}	10.68 ± 0.94^{bc}	0.75 ± 0.04^{bc}	3.11 ± 0.02^{bcd}	0.66 ± 0.80^{a}	0.01 ± 0.00^{a}	0.04 ± 0.00^{b}
	10%	1.31 ± 0.06^{def}	12.68 ± 0.94^{cde}	1.12 ± 0.08^{de}	3.33 ± 0.04^{cd}	0.26 ± 0.02^{a}	0.02 ± 0.00^{b}	0.05 ± 0.00^{cd}
	15%	1.46 ± 0.04^{f}	16.51 ± 1.08^{fg}	1.38 ± 0.09^{ef}	3.86 ± 0.09^{e}	0.37 ± 0.02^{a}	0.02 ± 0.00^{d}	0.06 ± 10.00^{d}
C3	5%	0.95 ± 0.04^{c}	11.34 ± 0.94^{bcd}	0.68 ± 0.09^{b}	3.05 ± 0.07^{bc}	0.09 ± 0.00^{a}	0.00 ± 0.00^{a}	0.04 ± 0.00^{b}
	10%	1.40 ± 0.07^{ef}	13.34 ± 0.47^{cdef}	1.12 ± 0.08^{de}	3.43 ± 0.12^{d}	0.27 ± 0.02^{a}	0.02 ± 0.00^{b}	0.05 ± 0.00^{cd}
	15%	1.83 ± 0.11^{g}	16.68 ± 0.94^{g}	1.32 ± 0.14^{def}	3.86 ± 0.09^{e}	0.26 ± 0.09^{a}	0.02 ± 0.00^{cd}	0.06 ± 0.00^{d}
C4	5%	0.96 ± 0.04^{c}	10.68 ± 0.94^{bc}	0.68 ± 0.09^{b}	3.06 ± 0.06^{bc}	0.08 ± 0.01^{a}	0.01 ± 0.00^{a}	0.04 ± 0.00^{b}
	10%	1.16 ± 0.11^{cde}	13.28 ± 0.52^{cdef}	1.05 ± 0.04^{cd}	3.33 ± 0.04^{cd}	0.28 ± 0.01^{a}	0.02 ± 0.00^{bc}	0.05 ± 0.00^{cd}
	15%	1.83 ± 0.11^{g}	16.01 ± 0.81^{fg}	1.58 ± 0.09^{f}	3.90 ± 0.14^{e}	0.33 ± 0.04^{a}	0.02 ± 0.00^{bcd}	0.06 ± 0.00^{d}
T+		0.40 ± 0.04^{b}	8.68 ± 0.94^{b}	1.15 ± 0.04^{de}	2.96 ± 0.09^{b}	0.26 ± 0.01^{a}	0.04 ± 0.00^{e}	0.01 ± 0.00^{a}
T-		0.05 ± 0.00^{a}	0.02 ± 0.00^{a}	0.02 ± 0.00^{a}	1.33 ± 0.00^{a}	0.40 ± 0.04^{a}	0.05 ± 0.300^{ab}	0.05 ± 0.00^{a}

Results are presented as means ± standard deviations of 5 replicates. The values assigned by different letters on the same column are significantly different at the threshold (P < 0.05). C1 = 25% chicken droppings + 75% wood ash, C2 = 50% chicken droppings + 50% wood ash, C3 = 75% chicken droppings + 25% wood ash, C4 = 100% chicken droppings, T^{+} = positive control, T^{-} = negative control, 5%, 10%, 15% = compost-soil proportion (m/m).

From this table, it appears that the concentrations of exchangeable ions (Mg^{2+}, Ca^{2+}, K^{+}, Na^{+}) increased significantly in all the amended soils compared to the unamended soil. The highest Mg^{2+} concentration was obtained with the 15%C3 and C4 variants (1.83±0.11) compared to the T^{+} (0.40±0.04g/kg) and T^{-} (0.05±0. 00^{a}g/kg). The highest Ca^{2+} concentration was obtained with the 15%C2 variant (16.51±1.08g/kg) compared to T^{+} (8.68±0.94g/kg) and T^{-} (0.02±0.00g/kg) soils. The highest K^{+} value was obtained with the 15%C4 variant (1.58±0.09g/kg) compared to T^{+} (1.15±0.04g/kg) and T^{-} (0.02±0.00g/kg) soils. The most

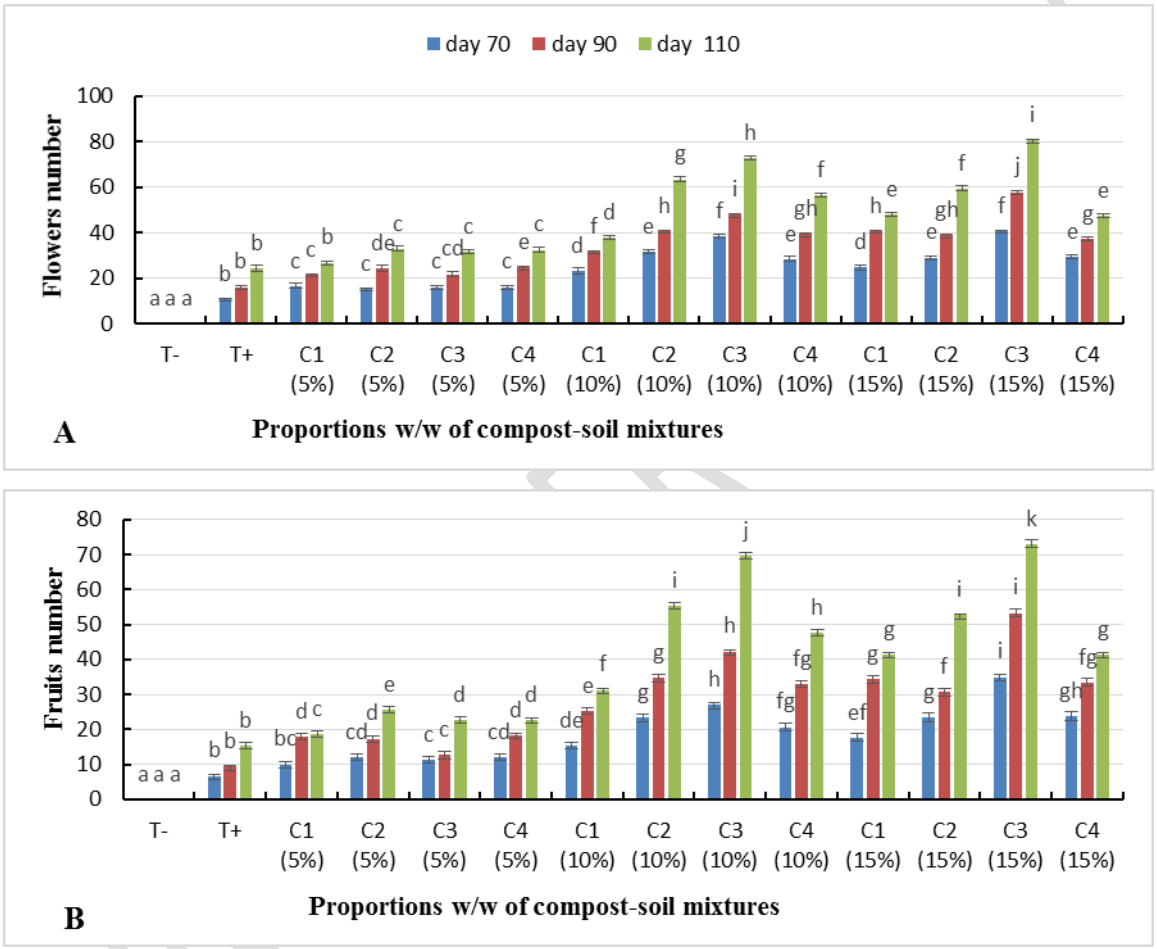
significant Na^+ concentration was obtained with the 15%C4 variant (3.90±0.14g/kg) compared to T^+ (2.96±0.09g/kg) and T^- (1.33±0.00g/kg) soils.

3.1.2. Effect of different composts on production and nutritional quality of tomato.

3.1.2.1. Effect on production of tomato

• Number of flowers and the total number of fruits

The **Figure1** below presents the variations of the number of flowers and the total number of fruits according to the proportion of compost-soil mixtures and time.



Results are presented as means ± standard deviations of 5 replicates. The values assigned by different letters on the same column are significantly different at the threshold (P < 0.05). C1 = 25% chicken droppings + 75% wood ash, C2 = 50% chicken droppings + 50% wood ash, C3 = 75% chicken droppings + 25% wood ash, C4 = 100% chicken droppings, T^+ = positive control, T^- = negative control, 5%, 10%, 15% = compost-soil proportion (m/m).

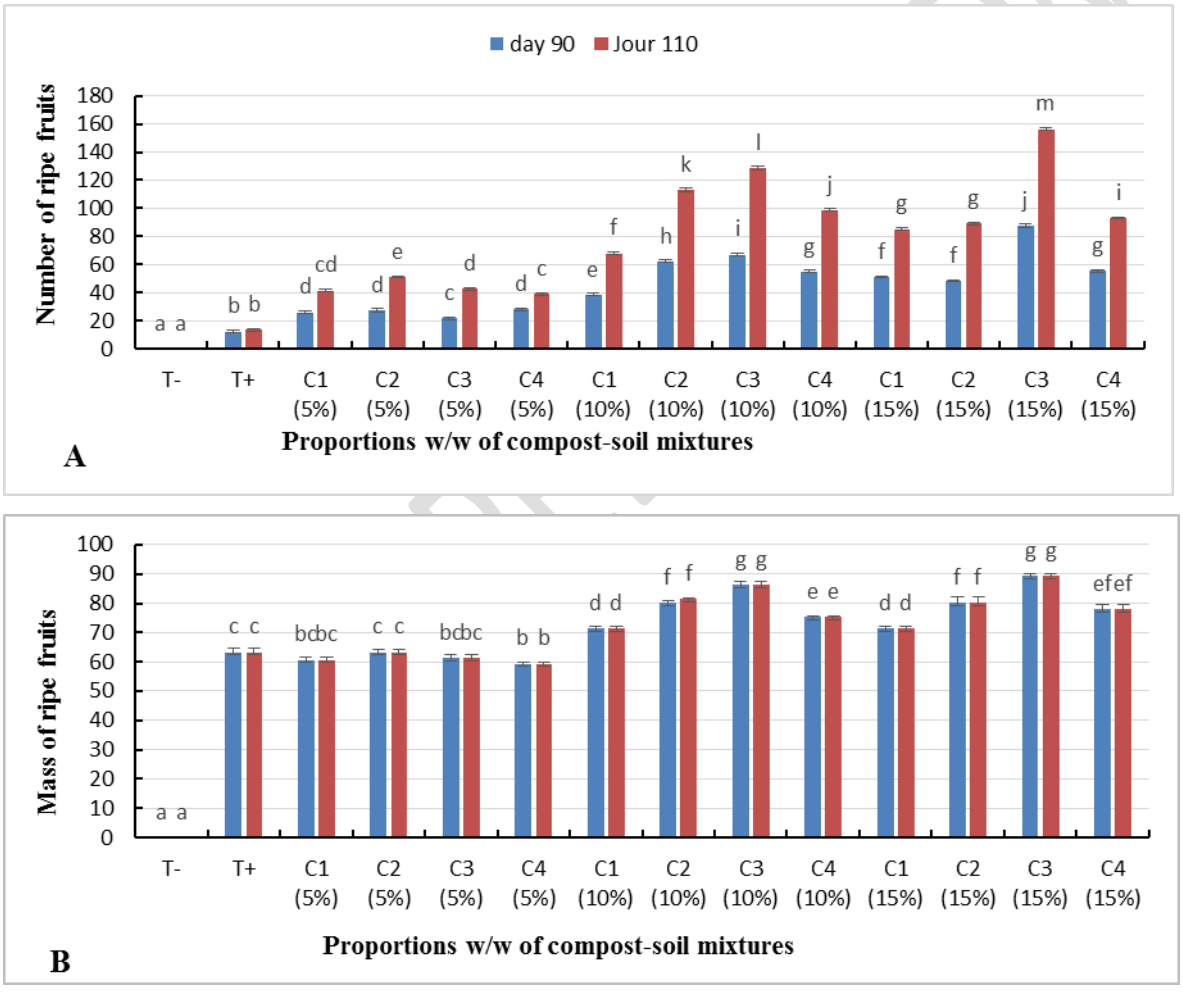
Figure 1: variation of the number of flowers (A) and the total number of fruits (B) as a function of the proportion of compost/soil mixtures and time.

From this figure, it appears that the number of flowers and the total number of fruits varied according to the proportion of compost-soil mixtures and time. The negative control produced no flower; on the other hand, the number of flowers increased significantly with the

plants amended with compost and the greatest value was obtained on the 110th day with the 15%C3 variant (80.33 ± 0.47) flowers compared to the positive control (24±1.41) flowers. The negative control did not produce any fruit, on the other hand, the total number of fruits increased significantly at the level of the other treatments and the greatest value was obtained with the 15%C3 variant respectively (73 ± 1.41) fruits compared to the positive control which produced (15.33±0.94) fruits on average.

• Number and mass of ripe fruits

The **Figure 2** below presents the variations in the number of ripe fruits and the mass of ripe fruits as a function of the proportions of the compost-soil mixtures and of time.



Results are presented as means ± standard deviations of 5 replicates. The values assigned by different letters on the same column are significantly different at the threshold ($P < 0.05$). C1 = 25% chicken droppings + 75% wood ash, C2 = 50% chicken droppings + 50% wood ash, C3 = 75% chicken droppings + 25% wood ash, C4 = 100% chicken droppings, T^+ = positive control, T^- = negative control, 5%, 10%, 15% = compost-soil proportion (m/m).

Figure 2: variations in the number of fruits (A) and the mass of ripe fruits (B) as a function of the proportion of compost/soil mixtures and time.

From this figure, it appears that the number of ripe fruits and the mass of ripe fruits varied according to the proportion of compost-soil mixtures and time. The negative control that did not flower did not produce any fruit; on the other hand, the other plants produced fruits significantly and the greatest value was obtained on the 110th day with the 15%C3 variant, 156.00±1.00 fruits compared to the positive control which produced 14.00±1.00 ripe fruits.

3.1.3. Effect of composts on the nutritional quality of tomato

• Physicochemical characteristics of the tomato obtained with the compost (Biological tomato)

Three batches of tomatoes: Biological tomatoes, Chemical tomatoes, and Market tomatoes) were used. The physicochemical and nutritional characteristics of the tomatoes analyzed have been summarized in Table V below.

Table V: Physicochemical and nutritional characteristics of tomatoes

Parameters	Tomatoes batches		
	Biological tomatoes	**Chimical tomatoes**	**Market tomatoes**
Water content (%)	93.99±0.23^{a}	97.13±0.12^{b}	97.96±0.05^{b}
Ash content (%)	14.30±0.14^{c}	10.87±0.02^{a}	11.27±0.04^{b}
pH	4.39±0.01^{b}	4.29±0.01^{a}	4.59±0.01^{c}
Density	1.10±0.00^{b}	1.05±0.01^{a}	1.06±0.01^{a}
Total sugars (g/100g FM)	3.57±0.12^{b}	2.77±0.05^{a}	2.71±0.07^{a}
Total lipids (%)	14.16±0.04^{a}	14.79±0.07^{b}	15.24±0.06^{c}
Crude fibres content (g)	0.16±0.01^{b}	0.10±0.00^{a}	0.11±0.00^{a}
Lycopene (mg/100g FM)	9.59±0.13^{c}	3.87±0.09^{b}	2.97±0.05^{a}
Vitamine C (mg/100g FM)	18.57±0.09^{c}	14.76±0.10^{b}	12.60±0.10^{a}
Total phenolics (mg d'EAG/ 100ml)	108.40±0.57^{c}	92.66±0.06^{b}	90.96±0.06^{a}

Results are presented in the form of means ± standard deviations of 5 repetitions. The values located on the same line and bearing the same superscript letters are not significantly different at P < 0.05.

From this table, it appears that these parameters varied significantly according to the different tomatoes batches. A low water content (93.99±0.23%) was observed in the Biological tomatoes batch compared to the other batches. The ash, total sugars, crude fibre, lycopene, vitamin C and total polyphenols content were significantly higher in the Biological tomatoes with respective values of 14.30±0.14%; 3.57±0.12 (g/100gFM); 0.16±0.01g;

9.59±0.13mg/100g FM; 18.57±0.09mg/100gFM; 108.40±0.57mg EAG/ 100ml. On the other hand, the pH content was higher in the tomatoes bought on the market. The total lipid content was lower in organic tomatoes compared to other tomato batches.

• Mineral composition of tomato batches

The **Table VI** below gives us the mineral content of the three tomato batches.

Table VI: Mineral composition of tomato batches

Parameters (mg/100g MS)	Tomatoes batches		
	Biological tomatoes	**Chemical tomatoes**	**Market tomatoes**
K	994.33±0.47^{c}	928.00±1.63^{b}	846.00±2.94^{a}
Mg	188.46±0.76^{c}	163.67±0.94^{b}	140.67±0.94^{a}
Ca	6133.33±47.14^{c}	4666.67±94.28^{b}	3233.33±47.14^{a}
Na	130.82±1.16^{b}	139.77±1.09^{c}	118.72±1.01^{a}
Cu	0.37±0.04^{a}	1.66±0.06^{b}	1.56±0.06^{b}
Fe	5.46±0.06^{c}	3.38±0.03^{b}	2.59±0.01^{a}
Zn	3.73±0.05^{c}	2.66±0.04^{b}	2.19±0.01^{a}
P	0.27±0.01^{b}	0.16±0.01^{a}	0.14±0.01^{a}
Mn	2.76±0.04^{a}	2.13±0.05^{a}	1.86±0.08^{a}

Results are presented in the form of means ± standard deviations of 5 repetitions. The values located on the same line and bearing the same superscript letters are not significantly different at P< 0.05.

From this table, it appears that apart from the manganese (Mn) concentration, all the other concentrations varied significantly according to the different tomato batches. The concentrations of K, Mg, Ca, Fe, Zn and P were higher in the organic tomato batches compared to the other batches. The concentration of Na was on the other hand higher at the level of the chemical tomato batch compared to the level of the batches of organic tomatoes and tomatoes purchased on the market. The Cu concentration was lower in organic tomatoes.

3.2. DISCUSSION

The objective of our work was to evaluate the effect of compost made from chicken manure and wood ash on the properties of the soil, the production and the nutritional quality of the tomato. The composts produced were of good quality given the physicochemical characteristics obtained in the different components.

The pH of the compost-amended soils was higher than those of the control soils and the increase in pH is explained by the fact that in the amended soils, there is a flow of protons from the soil towards the sites of organic matter. , which consequently increases the pH of the

soil, coupled with the proton consumption capacity of the compost **(Mokolobate and Hyanes, 2002; Wong and Swift, 2003)**.

A C/N ratio of less than 12 leads to leaching. If it is between 12 and 20, there is no leaching or immobilization and if it is greater than 20, there is nitrogen immobilization **(Springob and Kirchmann, 2003)**. The C/N value was between 14.78 and 15.30 for the composts and 15.05 and 19.68 for the amended soils, which implies that the compost and the amended soils do not present a risk of immobilization or nitrogen leaching.

The increase in concentrations of exchangeable cations observed in amended soils (Ca^{2+}, Mg^{2+}, K^{+}, Na^{+}) would be due to the addition of cations by organic amendments **(Smith, 2009)**. The high calcium concentration in these amended soils is of great interest because the buffering capacity of the soil depends on its quantity and availability, which reduces the potential for soil nutrient leaching **(Mokolobate and Hyanes, 2002).**

The increase in the concentration of phosphorus in the soil results in an improvement in the fertility of these soils because its increase is correlated with a decrease in aluminium toxicity **(Naramabiye et *al.*, 2008)**, which means improved conditions for plant growth. In addition, the superiority of the number of fruits in soils amended by compost is also due to the incorporation of chicken droppings known to be rich in phosphorus during composting. Our results are in line with those of **Okala (2020)** who showed that the addition of compost made from chicken droppings in tomato cultivation increases production.

The increase in the bacterial and fungal biomass of the compost is the consequence of the improvement of the physicochemical parameters of the soil, following the contribution of the compost. Since the microorganisms find the substrate necessary for their metabolism on site, the organic amendment will increase the nitrogen and carbon of the biomass as well as the microbial activity over several years **(Ros et *al.*, 2006).**

The increase in enzyme activities in composts follows the increase in fungal and bacterial biomass, soil enzymes are mainly of microbial origin. They are measurable and respond quickly to any change in soil management **(Dick et *al.*, 1996)**. In the same direction, **Caldwell (2005)** stipulated that enzymes are considered as potential indicators of soil quality and are closely linked to the activity and abundance of microorganisms. The increase in growth parameters and plant yield would be attributed to the improvement of physicochemical and biological soil parameters, which created favourable growth conditions for the plant, by providing the nutrients necessary for growth of the plant. Our results are conform to those of **Talimiroua (2010)** who showed that the contribution of organic matter

improves the physicochemical and biological properties of the soil favourable to the growth of the plant, and that the improvement of the microbial biodiversity of the rhizosphere can be used as an indicator of soil health, and is associated with improved productivity.

The water content obtained in organic tomatoes was lower compared to chemical tomatoes and tomatoes purchased from the market. This result is in agreement with that obtained by **Noumeni (2016)** who showed that tomatoes grown with organic inputs have a low water content, which gives them a fairly long shelf life compared to tomatoes grown with chemical inputs.

The ash content represents the total quantity of mineral salts present in a sample. The value obtained in the organic tomato is 14.30% while for the chemical tomato and the tomato bought on the market, it is respectively 10.87% and 11.27%. These values are much higher than those found by **Navarro et *al*., (2011)** which was 3.1%. According to these results, tomatoes grown with inputs of biological origin have a higher mineral salt content than those grown with inputs of chemical origin.

The levels of lycopene, vitamin C and total polyphenols obtained were higher in organic tomatoes than those purchased on the market. These results are in agreement with those obtained by **Vinha et *al*., (2014)** who showed that tomatoes grown with organic inputs have higher levels of lycopene, vitamin C and total polyphenols compared to those grown with synthetic chemical inputs.

The increase in total ash content of the tomato fruits harvested from pots amended with composts could be due to the application of compost that released organic and inorganic minerals in the soil (**Ihemeje et *al*., 2013 and Akinyemi et *al*., 2018**).This is in accordance with the result obtained by **Guilherme et *al*., (2020)** who reported that the ash content of the sweet pepper fruits obtained from the organic agriculture was found significantly greater that those obtained from the conventional agriculture.

The increase in total sugar content observed from of the tomato fruits harvested from the plants grown with compost might be due to the increase of the microorganisms in the soil that had a positive effect in converting the unavailable forms of nutrient elements to available forms. Those microorganisms produced growth-promoting substances resulting in more efficient absorption of nutrients, which are main components of photosynthetic pigments and consequently the carbohydrate (**Gomaa and Abou-Aly, 2001**; **Mohammed, 2013**). These results are in accordance with those obtained by **Mohammed, (2013) and Copetta et *al*., (2011)** who reported that compost application improved carbohydrate content.

The high fibre content obtained from the organic tomato fruits could be due to its greater organic or inorganic minerals content (**Ihemeje et *al*., 2013 and Akinyemi et *al*., 2018**), which makes them essential for little children, pregnant women and nursing mothers (**Ihemeje et *al*., 2013**). Minerals enhance the important functions of maintaining acid-base balance and proper osmotic pressure in the body **(Ihemeje et *al*., 2013**). Minerals are also required for normal functioning of the nerves and also muscular contraction and relaxation. Hence sweet pepper fruits could be a fair and cheap source of these essential minerals. (**Ihemeje et *al*., 2013**).

The high significant concentration of vitamin C found in fruits harvested from the plants grew with compost in pot experiments was in accordance with the findings of **Taiwo, et *al*., (2007)**, who reported that compost application improved vitamin C content of fruits. They are also in agreement with the work reported by **Abu-Zahra (2014) and Shahein et *al*., (2015)**, who obtained the highest amount of vitamin C from plots amended with the sheep manure and the lowest amount from the conventional agriculture. The increase in vitamin C observed could be due to the high amount of potassium contained in compost, which play a great role in plant metabolism and many important regulatory processes in the plant (**El-Bassiony et *al*., 2014**). Besides, tomato fruits have exceptionally high vitamin C content, the major water-soluble antioxidant in plant cells, which plays a major role in protecting cells against free radicals and oxidative damage (**Wang et *al*., 2003**). The role of Ascorbic acid in the human diet is thought to be significant in preventing common degenerative conditions (**Pascual et *al*., 2010**).

The significant high concentrations of Ca, Mg, K, Mn, Zn and Na, recorded in the fruits obtained from plants cultivated with compost may be attributed to the quick availability of Ca, Mg, K, Mn, Zn and Na elements and the slow release of minerals by compost during the crop growing cycle. According to **Suge et *al*., (2011)**, the high concentration in minerals could be due to the fact that organic matter improved the minerals cycling and availability to the plants especially, N and P, which improved root development and subsequently vegetative growth. Similar results were reported by **Elsadig et *al*., (2017) and Omar et *al*., (2018).** Moreover, that difference might be due to the presence of nitrogen and potassium in the compost, which may have increased the amount of Ca, Mg, K, Mn, Zn and Na in the tomato fruits. This is in accordance with the findings of **Elsadig et *al*., (2017)**, who reported that by increasing nitrogen levels, the values of microelements content increased in fruits. In addition, the higher concentration of Ca, Mg, K and Na in organic tomato fruits may be due to the

compost application, which could enhance soil fertility, resulting in increasing minerals availability and their uptake by plants. Furthermore, the application of compost might provide supplemental exchangeable cations such as potassium, calcium, magnesium and ammonium, mainly due to organic mineralization and release of these basic cations into the soils (**Al-Kahtani et *al*., 2012**). Similar results were also obtained by **Houndji et *al*., (2018)**.

4. Conclusion

Having reached the end of our study, the objective of which was to evaluate the effect of compost made from chicken droppings and wood ash on the properties of the soil, the production and the nutritional quality of the tomato, the compost made from chicken droppings and wood ash is rich in nitrogen, phosphorus, potassium with a C/N ratio ranging from 14.78 to 15.30. Compost and amended soils improved physicochemical (pH, nitrogen, phosphorus, Mg^{2+}, Ca^{2+}, K^{+} and Na^{+}), biological (fungal and bacterial biomass) and biochemical (cellulase, protease, dehydrogenase, β-glucosidase, acid and alkaline phosphatase) of the soil compared to the soil amended with synthetic chemical fertilizer. The use of compost improved tomato production with values of 156 fruits with the 15% C3 variant, i.e. 11 times more than the number of fruits obtained with chemical fertilizer (13 fruits). The tomatoes obtained with the compost were richer in lycopene, vitamin C, phenolic compounds and minerals. The compost improved the production and the nutritional quality of tomato, which constitutes an alternative for sustainable agriculture.

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