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Environmental Impacts of Farm Waste Treatment Methods and Perspectives of Valorization by Composting: The Case of the Farm "Société de Provenderies du Cameroun (SPC)" of Foumbot

Alvine Larissa Meyabeme Elono[1,2]*, Alida Londji Meli[2], Henri Gabriel Tsila[3]

[1]Department of Forestry, Dschang School of Agriculture and Environmental Sciences, Faculty of Agronomy and Agricultural Sciences, University of Dschang, Dschang, Cameroon
[2]Regional Training Centre Specialized in Agriculture, Dschang School of Agriculture and Environmental Sciences, Faculty of Agronomy and Agricultural Sciences, University of Dschang, Yaounde, Cameroon
[3]Biology and Applied Ecology Unit Researches, Department of Animal Biology, Faculty of Science, University of Dschang, Dschang, Cameroon
Email: *meyabemealvine@yahoo.fr

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Abstract

Waste recovery is an environmental, agronomic and economic asset. The farm "Société de Provenderies du Cameroun" (SPC) processes its wastes by incineration and landfill. During this study, environmental impacts of these two treatment methods were assessed in this farm and a composting experiment was also conducted. For the experiment, chicken carcasses and droppings mixed with wood shavings, straw, incineration ash, egg shells and cattle dung were distributed differently in four experimental composters C1, C2, C3 and C4 with the same starting weight. C1 consisted of the first three waste types, for C2, C3 and C4 a new waste was added in the order they are listed above. The results show that the major impacts associated with the incineration and landfilling of SPC waste are the degradation of the health of workers and surrounding populations, the occurrence of conflicts, and the pollution of the air, soil and groundwater of the site. As far as composting is concerned, the characteristics of three of the four composts obtained are usable as soil fertilisers. Indeed, at the end of the experiment, the pH of the four composters was basic (8), the temperature values were between 24˚C and 34˚C and the humidity values were between 37% and 41%. However, the last parameter, the C/N ratio, was not satisfactory for C1 (13.42), which eliminated it from mature and ready-to-use composts according to FAO standards. The C/N ratios of C2 (15.71), C3 (16.30), and C4 (18) composters were found to be good for mature and ready-to-use compost.

Keywords

Farm Wastes, Treatment Methods, Environmental Impacts, Composting Experiment

1. Introduction

In the face of demographic, industrial and urban development, the problem of waste is becoming increasingly acute. Phenomena such as the globalisation of trade, the emergence of a new consumer society and the development of production techniques for various products, contribute to the qualitative and quantitative increase of the waste. In African countries in general, and in Cameroon in particular, the quantity of waste has been increasing steadily from 1960 to the present (Kapepula, 1996). Environmental waste management policies, developed since the 1970s, are favourable to the recycling of materials and the recovery of organic waste. Solano et al. (2001) show for example that composting livestock substances reduces environmental nuisances (nitrogenous gas emissions after spreading, nitrate leaching or odour nuisances) linked to the direct use of these substances. Compost improves the physical, chemical, biological and textural properties of the soil (Sérémé & Phal, 2007); hence its contribution to increased yields of crops such as tomatoes (Maynard, 1995).

The Société de Provenderie du Cameroun (SPC) is a major company specialising, among other things, in the production of eggs, chicks, food and animal health products in Cameroon. These activities result in various types of waste such as chicken carcasses, eggshells, droppings and poultry feathers. SPC usually incinerates its waste or buries it.

However, the incineration process is accompanied by the release of a wide variety of pollutants contained in fly and bottom ashes, as well as toxic gaseous substances (dioxins, furans, nitrogen and sulphur oxides, HCl, etc.); these pollutants represent a real risk to public health and the environment (Miquel & Poignant, 1999). Some of the health problems identified and linked to waste incineration include cancers (both in children and adults), adverse impacts on the respiratory system, heart disease, immune system disturbances, amplified allergies and birth defects (Calvez, 2016; Sané, 1999).

The landfill process is a kind of pit dug to receive all kinds of waste. In this kind of pit, water tightness is not guaranteed and rainwater easily infiltrates the waste mass; biological activities take place and generally lead to environmental pollution by producing leachate and greenhouse gases (carbon dioxide and methane). These contribute to global warming (Quintus, 2007).

Therefore, the present study proposes to evaluate the environmental impacts of the current treatment methods of SPC waste and to experiment with recycling by composting of this waste as a more environmentally friendly method. In poultry farms around the world, the most common waste used as fertilizer in agriculture is chicken droppings, which represent only a part of the waste produced. However, this study suggests using all the other wastes from this type of farm to make compost and reduce the environmental cost of processing them.

2. Material and Methods

2.1. Study Site

The present study took place at the Société de Provenderies du Cameroun (SPC) farm in Baïgom located at 5˚33'48"North and 10˚40'06"East. Baïgom is a village located in the Foumbot subdivision, Noun Division, West Cameroon Region.

2.2. Data Collection

2.2.1. Impacts of Current Waste Treatment Methods of SPC

The impacts of the current waste treatment method at SPC were determined by the Fecteau grid (Fecteau, 1997). It is based on an integration of three parameters to assess the absolute significance of a determined impact on an environmental component. These three parameters are the duration, the extent and the intensity of an impact on the affected component.

- The duration of the impact specifies the period of time over which the changes to the environmental components will be experienced. It is measured using a scale of values. Therefore, the duration is:
- Short, when the impact is felt by the affected component at a given moment, especially when the impact is being carried out;
- Medium, when the impact is felt continuously by the affected component, but for a period of time after the activity has taken place;
- Long, when the impact is felt by the affected component at a given time and for a period of time equal to or greater than the life of the project.
- The extent of the impact, on the other hand, is punctual, local or regional. It expresses the scope or spatial extent of the effects generated by an intervention on the environment. The extend is:
- Punctual, when impacts are limited to any point on the project site;
- Local, when the impacts extend throughout the site and;
- Regional, when the impact extends beyond the site.
- The intensity or degree of disturbance caused is the extent to which the internal dynamics and function of the affected environmental feature are changed. Generally, three degrees are distinguished: strong, medium, weak.
- The disturbance is strong when the impact profoundly compromises the integrity of the affected element, very strongly alters its quality or restricts its use to a very large extent or cancels out any possibility of its use;
- It is medium when the impact somewhat compromises the use, quality or integrity of the affected element;
- The disturbance is low when the impact does not perceptibly alter the integr-

ity, quality or use of the affected item.

Once the three parameters (duration, extent, intensity) are assessed, they are aggregated into a summary indicator on the Fecteau grid to define the absolute significance of the impact (Fecteau, 1997).

2.2.2. Composting Experiment

For the experimentation on composting in order to valorise SPC's waste, the Indian indore method (Misra et al., 2005) in heaps was used. The Indore method is widely used to prepare compost in heaps during the rainy season or in areas with heavy rainfall. The compost is prepared in a heap, placed on the ground and protected by a shelter. A small protective wall is built around the heap to protect it from wind, which tends to dry out the mixture. This is a simple and easy method to do, as it requires very little turning and the compost is obtained in a short time (3 months).

Thus, an experimental trial consisting of four types of composters (C1, C2, C3, and C4), was conducted for three months. The composters were made up of chicken carcasses and droppings mixed with wood shavings, straw, incinerator ash, egg shells and cattle dung. C1 was constituted of the first three waste types; for C2, C3 and C4, a new waste was added in the order of appearance in which they are listed here. Therefore these composters differed in the quality and quantity of their constituents in terms of the waste produced by the SPC. **Table 1** shows the materials (waste) used in each of the four composters. The quantity used per waste type in each composter was based on their availability in the study site at the experimental time. In order to have the same final weight, and

Table 1. Quantitative and qualitative composition of experimental composters C1, C2, C3 and C4.

Waste type	Weight and proportion of different wastes in the composters							
	C1		C2		C3		C4	
	Weight (Kg)	% du TW	Weight (Kg)	% du TW	Weight (Kg)	% du TW	Weight (Kg)	% du TW
Chicken droppings + wood shavings	245	75 %	220	67 %	195	59 %	170	52 %
Chickens carcasses	75	23 %	90	27 %	90	27 %	75	23 %
Straw	8	2 %	10	3 %	25	8 %	30	9 %
Ash			8	3 %	13	4 %	15	4 %
Egg shells					5	2 %	3	1 %
Cattle dung							35	11 %
Total	328	100 %	328	100 %	328	100 %	328	100 %

TW = Total Weight.

also similar dimensions in all the composters at the beginning of the experiment, the constituent wastes were also used in different percentages.

The operating conditions that were used as the basis for controlling this composting experiment are those indicated in the work of Misra et al. (2005), Humeau & Lecloirec (2010), and Chennaoui et al. (2016). These operating conditions involve monitoring the evolution of pH, temperature and humidity, and then the nitrogen and carbon contents in the composters. The pH, temperature and humidity (water content) were measured every two days at 5 different locations in each experimental composter: four ends and the middle of the compost pile. Carbon and total nitrogen were assessed only at the end of the experiment (after 3 months) by the Walkley-Black method and the Kjeldahl method, respectively.

2.3. Statistical Analysis

The databases were designed and processed using Microsoft Excel 2010. Graph Pad Prism version 5.0 was used to perform the statistical analyses. The temperature, pH and humidity data, measured every second day, were expressed as weekly mean ± standard deviation on the mean. The values of these parameters collected in the first and last week were also compared using Student's t-test.

3. Results

3.1. Quantity per Type of Waste Generated at SPC Foumbot

The present study took place in the egg production and cattle rearing unit of the SPC in Foumbot. The waste produced in this unit is heterogeneous and consists of laying hen corpses, hen droppings, cattle dung, straw, incineration ash and eggs hells. **Table 2** shows that the unit producing eggs for consumption and cattle breeding produces on average 188 kg of waste per day. Chicken droppings mixed with wood shavings are the most predominant with 145 kg, representing a relative contribution of 77% of the total waste generation studied in this unit.

Table 2. Quantity of waste generated by the egg production and cattle rearing activities in SPC Foumbot.

Types of waste	Average quantity produced per day (kg)	Relative percentage (%)
Chicken carcasses	18	10
Egg shells	4	2
Chicken droppings + wood shavings	145	77
Ash	6	3
Cattle dung	10	5
Straw	5	3
Total	188 kg	100%

3.2. Current Waste Treatment at SPC and Assessment of Associated Impacts

The current waste treatment techniques at SPC are landfill and incineration. Incineration at SPC consists of the burning of laying hen corpses and wood chips at high temperatures. This is done daily in a traditional incinerator at 850˚C using dry wood and diesel fuel (Photo 1).

As for the landfill technique, it consists of burying straw, incineration ashes, egg shells, chicken droppings and wet cattle dung in a pit every day (Photo 2).

3.3. Impacts Associated with Current SPC Waste Treatment Methods

Table 3 shows the impacts of waste incineration and landfill at the Foumbot SPC farm. On the one hand, it appears that these two waste treatment processes have major negative impacts on air, conflicts, greenhouse gas emissions, soil and groundwater. On the other hand, impacts of medium significance were also observed on other components of the environment; in this case on surface water, the health of workers and neighbouring populations.

Photo 1. SPC incinerator.

Photo 2. SPC landfill.

Table 3. Impact significance matrix for landfill and incineration at SPC.

Treatment method	Environmental component affected	Impact description	Assessment of impact significance				
			Nature	Intensity	Extend	Duration	Absolute importance
Incineration	Air	Air pollution	-	M	R	Lg	Ma
	Climate	Greenhouse gas emissions	-	M	L	Lg	M
	Soil	Soil pollution	-	M	L	M	M
	Surface water	Water surface pollution	-	M	L	Lg	M
	Groundwater	/	/	/	/	/	/
	Human health	Deterioration of the health of workers and the surrounding population	-	M	R	M	M
	Conflicts	Source of conflict	-	S	R	Lg	Ma
Landfill	Air	Air pollution	-	S	R	Lg	Ma
	Climate	Greenhouse gas emissions	-	M	R	Lg	Ma
	Soil	Soil pollution	-	S	L	Lg	Ma
	Surface water	Water surface pollution	/	/	/	/	/
	Groundwater	/	-	S	L	Lg	Ma
	Human health	Deterioration of the health of workers and the surrounding population	-	M	L	Lg	M
	Conflicts	Source of conflict	-	F	L	M	M

- = negative; L = local; Lg = long, M = medium; / = no impact; R = regional; Ma = major; S = strong; W = weak.

3.4. Composting of SPC Waste: Evolution of Physico-Chemical Parameters in the Experimental Composters

To monitor the composting experiment, the values of the following parameters were measured over time.

3.4.1. Weight Evolution

The evolution of the weight in each composter at the beginning and at the end of the experiment is presented in Table 4. The general observation shows that there was a loss of weight in all four composters over time (Table 4).

3.4.2. Temperature Evolution

The evolution of the temperature in the different composters is presented in Figure 1. It appears from this figure that the starting temperature (the mesophilic phase) varies between 24˚C and 35˚C in the different composters on the first day of observation. Then, it increases during the first week until it reaches values above 60˚C (Figure 1); then it decreases progressively until it reaches at the end of the experiment the values of 34˚C, 28˚C, 25˚C and 24˚C respectively in the composters C1, C2, C3 and C4 (Figure 1). This decrease is significant (P <

Table 4. Weight of waste in the four composters at the beginning and end of the experiment.

Composter	Poids initial	Poids final	Perte de poids en %
C1	328 kg	240.5 kg	27%
C2	328 kg	230 kg	30%
C3	328 kg	200 kg	39%
C4	328 kg	180.6 kg	45%

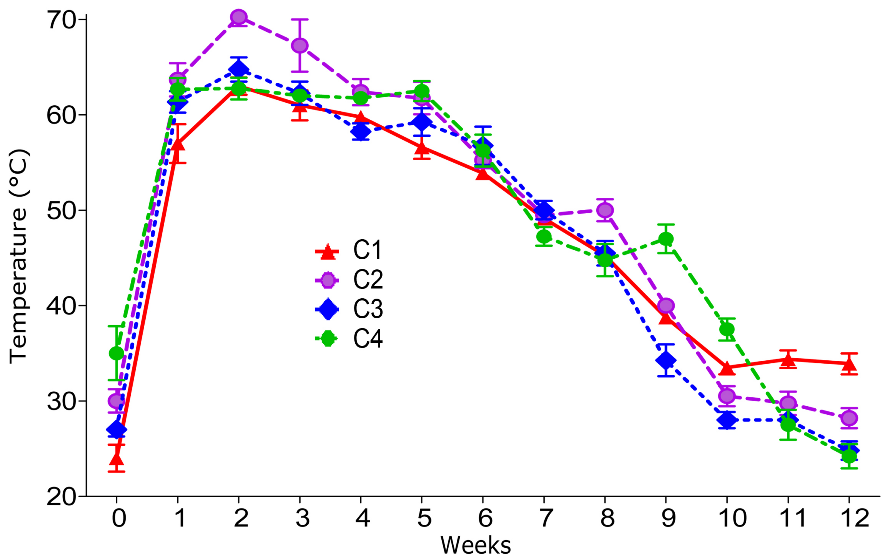

Figure 1. Evolution of the temperature in the experimental composters C1, C2, C3 and C4.

0.0001) in all composters between the first and the last week (Figure 2).

3.4.3. pH Evolution

Figure 3 shows in general that the pH increased progressively from values of 7.2 or lower to 8 in all composters at the end of the experiment. This increase in pH is also significant ($P < 0.0001$) in all composters between the first and last week of the composting process (Figure 4).

3.4.4. Evolution of Humidity

All the composters show an almost similar humidity curve (Figure 5). At the beginning of the experiment, the humidity is less than or equal to 60%, then it decreases progressively and in a general way in all the composters throughout the experimentation until rates between 37% and 41% in the four experimental composters (Figure 5). This decrease of humidity is also significant ($P < 0.0001$) between the first and the last week in all composters (Figure 6).

3.4.5. Values of Carbon (C) and Nitrogen (N)

Table 5 shows the chemical characteristics of the four composters obtained after the three months of experimentation. From this table it can be seen that the

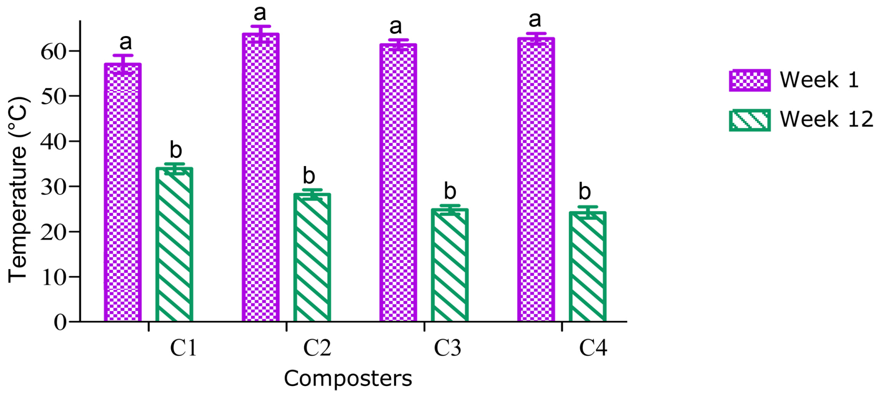

Figure 2. Comparison of temperature values between the first and last week in the experimental composters C1, C2, C3 and C4; different letters mean significant difference at $P < 0.0001$.

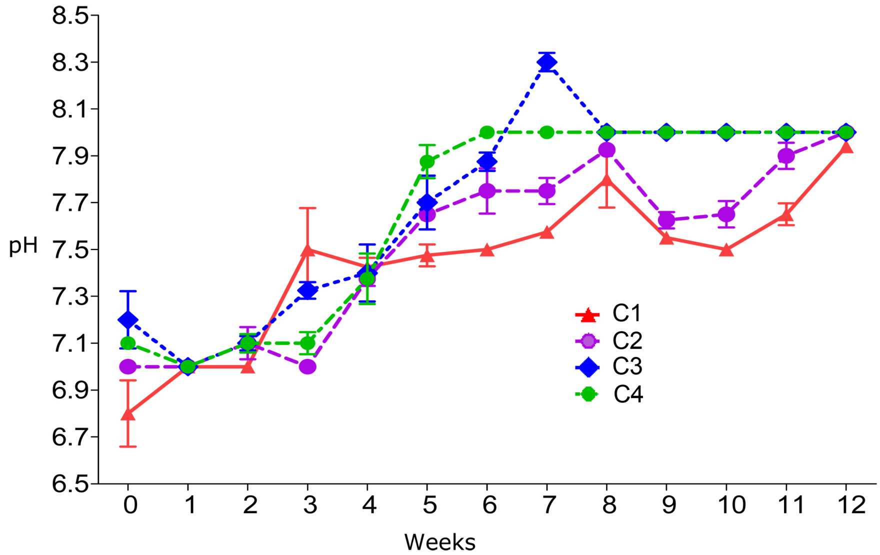

Figure 3. Evolution of the pH in the experimental composters C1, C2, C3 et C4.

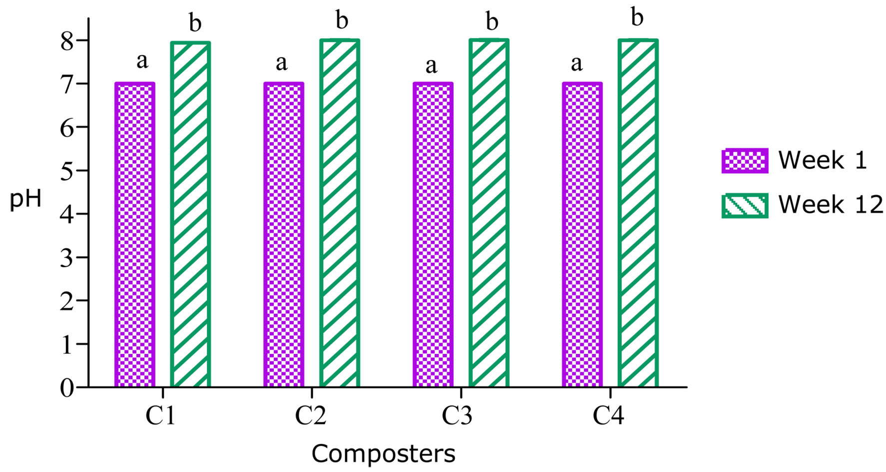

Figure 4. Comparison of pH values between the first and last week in the experimental composters C1, C2, C3 and C4; different letters mean significant difference at $P < 0.0001$.

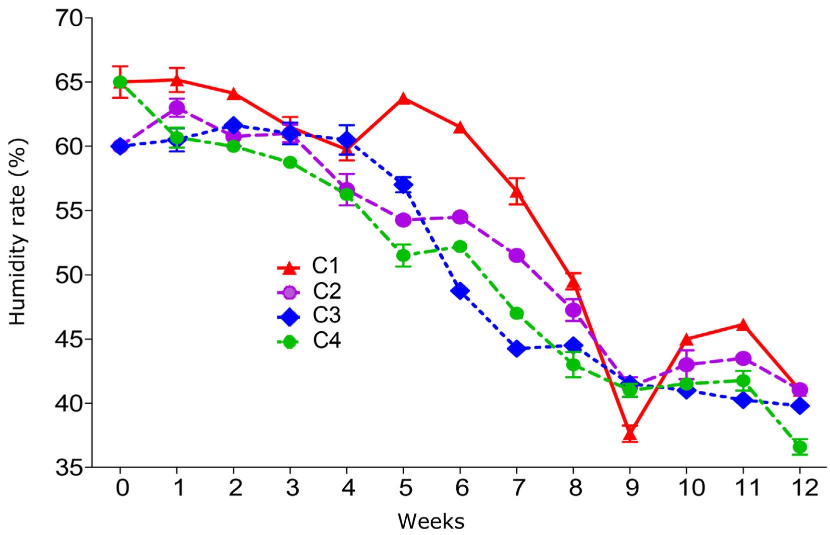

Figure 5. Evolution of the humidity rate in experimental composters C1, C2, C3 and C4.

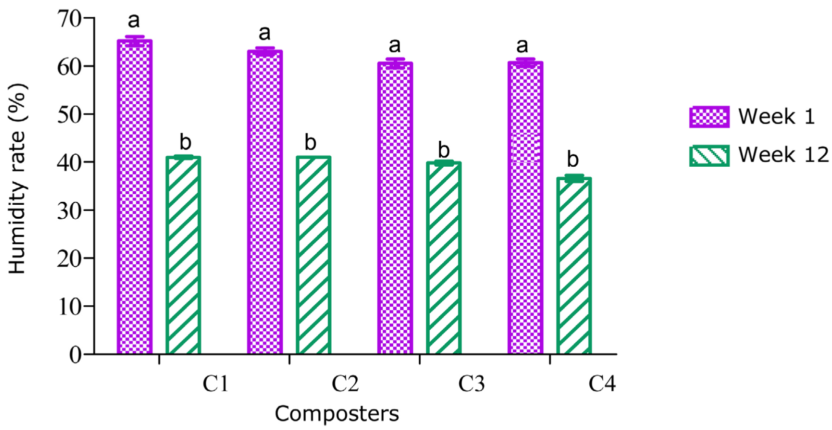

Figure 6. Comparison of the humidity rate between the first and last week in the experimental composters C1, C2, C3 and C4; different letters mean significant difference at $P < 0.0001$.

Table 5. Chemical characteristics of the experimental composters C1, C2, C3 and C4 at the end of the experiment in week 12.

Chemical characteristics	C1	C2	C3	C4
C	5.1	6.6	7.5	9
N	0.38	0.42	0.46	0.5
C/N	13.42	15.71	16.30	18

N values at week 12 ranged from 5.1 to 9 and the C values from 0.38 to 0.5. This gave C/N values between 13.42 and 18.

4. Discussion

4.1. Environmental Impacts of Current Treatment Methods of SPC

Several major negative impacts on the environment and human health have been associated with the waste treatment methods (incineration and landfill) currently applied at SPC Foumbot. These include the degradation of the health of workers and surrounding populations, the emergence of conflicts, and the pollution of the air, soil and groundwater of the site on which the farm is located. Indeed, Miquel & Poignant (1999) attest that the incineration of waste is at the origin of the formation of ash and toxic gases that cause pathologies and pollute the environment. Furthermore, Quintus (2007), shows that leachates and gases (carbon dioxide and methane), which are powerful greenhouse gases produced by landfills, contribute to global warming, water and environmental pollution, and the health degradation of living beings.

4.2. Composting Experiment

As a result of the composting experiment, the temperature increased considerably in the first week in the four composters as shown in **Figure 1**, and then decreased gradually from the second week until the end of the experiment. High temperatures characterise aerobic composting processes and are an indicator of high microbial activity induced by the presence of organic, easily biodegradable materials (Albrecht, 2007). According to Attrassi et al. (2005), the temperature of the compost increases (thermophilic phase) progressively during the first 15 days to reach a maximum of about 70˚C. Misra et al. (2005) show that the ideal temperature for the initial phase of composting is 20˚C - 45˚C. Our results are therefore supported by those of Misra et al. (2005) and Attrassi et al. (2005). This thermophilic phase is followed by the maturation phase, during which the temperature in the composters is progressively lowered to values below 40˚C. According to Soudi (2001), a drop in temperature is due to the slowing down of the activity of microorganisms due to the exhaustion of easily degradable organic matter. And according to Humeau & Lecloirec (2010), the temperature of a mature compost varies between 20˚C - 35˚C. The temperatures obtained in our experiment were between 24˚C and 34˚C and are therefore within the range of values for ready-to-use composts.

The pH gradually increased in all experimental composters to a value of 8 at the end of the process. An increase in pH during composting is due to the degradation of fatty acids and the release of ammonia in the ammonification process as a result of the degradation of organic acids (Mustin, 1987). Beck et al. (2003) confirm that a stabilisation of the pH at the end of the composting process is attributed to the oxidation of ammonium by bacteria and the precipitation of calcium carbonate. Furthermore, Forster et al. (1993) indicate that a pH between 7 and 9 characterises a mature compost. Therefore, our experimental composts with a pH value of 8 are mature.

As for the moisture content, it decreased overall gradually until the end of the experiment (**Figure 5**). According to Mustin (1987), the moisture content tends to decrease under the combined action of the rise in temperature and the aeration due to the inversion, which leads to water losses in the form of vapour. In 2010, Humeau & Lecloirec showed that a moisture content between 40% and

60%, as found in the present study, characterises a ready-to-use compost.

The C/N ratio controls the microbiological balance of the soil (Francou, 2003). It is frequently used to assess the stability of organic materials and to evaluate the maturity of the compost. A C/N ratio between 15 and 20 corresponds to mature compost (Misra et al., 2005). Therefore, with the exception of the C1 compost whose C/N ratio of 13.42 was below 15, the other experimental composts, namely C2, C3, and C4, showed C/N ratios in the range of mature and ready-to-use composts.

Our results also showed a loss of waste weight in all experimental composters. But the highest percentages of weight loss compared to the initial weight were observed in C4 (45%) and C3 (39%) composters, when compared to the losses in C1 (27%) and C2 (30%). According to Gueye (1986), the dry matter loss of straw-rich compost is high and reaches after 5 months 70% of the initial stock. In the case of the composters in our trial, C4 was richer in straw, followed by C3, which would justify the high relative loss of their weight.

In the end, apart from the C1 compost which did not meet all the conditions of a mature compost (C/N < 15), all the others, i.e. C2, C3 and C4, presented all the characteristics of a ready-to-use compost. It should be recalled here that the composters were made up of chicken carcasses and droppings mixed with wood shavings, straw, incineration ash, egg shells and cattle dung. C1 consisted of the first three waste types, for C2, C3 and C4 a new waste was added in the order in which they are listed here. Therefore, we recommend that the SPC waste be composted according to the mixtures observed in C2, C3 and C4. This would allow the recycling of waste from the egg and cattle production unit of SPC Foumbot on the one hand, and would considerably reduce the negative environmental impacts of the waste treatment methods currently applied in this farm on the other hand. These results are very interesting in that chicken droppings are not the only poultry farm waste that can ultimately be used as agricultural amendments.

5. Conclusion

At the end of our study, incineration and landfilling, as methods of waste treatment practised at the SPC of Foumbot, have major negative impacts on several environmental components. The experimental recycling of these wastes has resulted in composts with physico-chemical characteristics of a mature compost ready for use. In view of this, we can conclude that composting is a technique that can reduce the environmental and health impacts of current SPC waste treatment methods by recycling the waste through composting. However, further experiments could be interesting in order to test the practical effectiveness of these three mature composts, obtained from this experiment of SPC waste as agricultural input.

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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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