__Original Research Article__

Use of various organics substrates and evolution of chemical parameters during composting of *Panicum maximum jacq* and *Oriza stiva L.* straw

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ABSTRACT

Aims: The present study was initiated with the objective of evaluating the quality of composts obtained from different organic substrates.
Place and Duration of Study: The test was conducted at the research station of the INERA (Institute of Environment and Agricultural Research) of Farako-Bâ in western Burkina Faso.
Methodology: Two types of biomass comprising rice and *Panicum maximum* straw and two types of substrates including cattle manure and poultry manure were subjected to windrow composting. Two treatments were defined with the combination of rice straw + cattle manure (T1) and the combination of *Panicum maximum* straw + poultry manure (T2).
Results: The study showed that the composts from both treatments gave basic pH_water and low C:N ratios (> 20) and were rich in mineral elements. The best quality compost is obtained in T2 with values of total P (0.52%), Ca (2.05%) and Mg (0.62%) higher than those of T1 by 44%, 39% and 39% respectively.
Conclusion: This study highlights the possibility of composting these substrates, which may contribute to improving the organic matter requirements of the soil.

Keywords: Rice straw, Panicum maximum straw, compost, manure, poultry manure, nutrient

1. INTRODUCTION

Agricultural development in sub-Saharan African countries is impeded by several unfavorable factors, including low soil nutrient and organic matter levels [1]. In Burkina Faso, studies indicate that organic matter content in most soils have declined to a critical level, less than 1% organic matter [2,3]. Burkina Faso's agriculture thus faces a major challenge which is to produce more on poorly fertile soils for a rapidly growing population. To cope with soil degradation, the option of crop fertilization is mainly based on the use of mineral fertilizers to the detriment of organic fertilizers, which are however essential for improving and maintaining soil fertility [4,5]. As a matter of fact, many studies have shown the effects of organic matter inputs on the physico-chemical and biological properties of soils [6,7,8]. Organic matter has an important role in maintaining soil fertility and is a significant source of nutrients such as nitrogen, phosphorus, potassium and sulphur [9]. Nowadays, due to demographic pressure, soils are intensively used over a long period of time without restitution; this leads to a decrease in soil fertility with a modification of physical, biological and chemical characteristics [2]. The use of organic matter as amendment after composting will permit to fill the organic matter gap in agricultural soils, reduce their degradation and even improve their agronomic properties. In order to improve crop productivity, the production and use of good quality, inexpensive compost is an important challenge. In Burkina Faso, compost is mainly produced from crop residues, which are insufficient. Agriculture (consuming organic matter that can be used in the field) and livestock (consuming crop residues) are in a competition for the use of crop residues [10]. Utilization of other less frequently used residues such as rice straw and *Panicum maximum* could be a solution to increase the availability of residues for composting. Furthermore, the quality and stability of compost depends on the composition of the materials used for its production [11] and on the way it is produced [12]. A variety of organic substrates such as cow dung and poultry droppings are produced and used by farmers [13]. Some studies [5,13,14] have shown that poultry droppings and manure are rich organic substrates that could be used in composting. The windrow composting technique, a cost effective organic manure production practice can produce well-decomposed organic manure in good quantity and quality if the decomposition process is well done. The combination of less often used crop residues with substrates such as cow dung and poultry droppings could improve the quality of the compost and increase the availability of organic amendment for crops. This study of the effects of different organic substrates on the evolution of chemical parameters of rice straw and *Panicum maximum* straw compost aims at evaluating the quality of composts obtained from various organic substrates.

2. MATERIAL AND METHODS

The experiment was conducted at the research station of the Environment and Agricultural Research Institute (INERA) in Farako-Bâ in western Burkina Faso. One of the geographical coordinates is 04° 20 West longitude and 11° 06 North latitude. The minimum temperature is 10 °C and the maximum 37 °C, the evapotranspiration is quite high, varying on average between 1700 mm and 1800 mm per year [4].

2.1. Experimental equipment

2.1.1. Composted material

Two (2) types of straw were used. These were rice straw and *Panicum maximum* straw, the chemical characteristics of which are provided in Table 1. The straws were obtained from the experimental plots of the INERA Farako-Bâ research station.

Table 1. Chemical characteristics of the straws used

Straw	C %	N %	C :N	P %	K %	Ca %	Mg %
Panicum maximum	52,18	0,97	53	0,07	3,29	0,85	0,22
Oriza sativa	43 ,14	1,01	42,71	0,09	2,33	1,02	0,16

2.1.2 Organics substrats used for composting

Two types of manure were also used as a source of the micro-organisms required for the decomposition of organic matter. These are cattle manure and poultry manure, the chemical characteristics of which are presented in Table 2. Cattle manure and poultry manure were collected in the cowshed of the INERA Farako-Bâ research station.

Table 2. Chemical characteristics of the organic substrates used

Substrate	pH_water	C %	N %	C :N	P %	K%	Ca %	Mg %
Cattle manure	8,39	38,45	1,84	21	0,13	3,98	0,51	0,16
Poultry manure	6,90	42,96	3,39	13	0,23	2,19	2,24	0,68

2.2. Composting method

The composting of the two (02) types of organic substrates was performed using the windrow method in a simple non-randomised block design with three (03) replications. Two (02) treatments were set up per organic substrate:

- T1 : Rice straw + Cattle manure
- T2 : *Panicum maximum* straw+ Poultry manure

The different compost piles were watered every three days. The piles were turned every three weeks and a sample was taken for the determination of the following chemical parameters: pH, total organic matter, total carbon, total nitrogen, total phosphorus, total potassium, calcium and magnesium. The analytical methodologies were the following: pH [15], total nitrogen [16], total carbon [17], total phosphorus [18], total potassium [19], calcium and magnesium [20].

2.3. Data collected and analyzed

Three turnings were performed in total for each treatment, which we refer to as R1, R2 and R3 corresponding to the first, second and third replication. During the composting process, samples were taken immediately after each turning in order to evaluate the pH-water evolution and the degradation process of the organic matter. At the end of the composting process, samples were taken, dried and packaged for chemical analysis at the INERA Farako-Bâ laboratory in Burkina Faso. The parameters analyzed were pH-water, total organic matter, total carbon, total nitrogen, total phosphorus, total potassium, C:N ratio.
The data were entered using Microsoft EXCEL 2010. All measured parameters were subjected to analysis of variance (ANOVA) in order to compare their averages at the threshold of 5% by Fisher's test using XLSTAT 7.5.2 software.

Comment [FR2]: Are you referring to the 1st, 2nd and 3rd week that the batteries were turned, or to the repetitions of each treatment?

Comment [FR3]: Were the samples dried and packaged at the end of the experiment or at each sampling stage?

3. RESULTS

3.1. Evolution of pH-water, Ca and Mg levels during composting

Table 3 shows the variation in pH-water and exchangeable cation content of the different treatments at each pile turning. The statistical analysis reveals very highly significant differences between the treatments at the threshold of 5% for the parameters determined.
Treatment T1 gives the highest pH-water values at the first two turnings; but at the third turning, the highest pH can be observed in Treatment T2. A decrease in pH was observed in treatment T1, from 8.25 at R1 to 8.14 at R3. As for treatment T2, there was an increase in pH-water from 7.22 at R1 to 8.22 at R3 during the composting process. As for Ca and Mg content, treatment T2 gives levels two times higher than those of treatment T1. In general, we can observe an increase in Ca and Mg content during composting with both treatments.

Comment [FR4]: Why didn't they measure these parameters for each of the mixtures at the beginning of composting, in order to calculate the efficiency of each of the treatments?

Comment [FR5]: The difference of one pH unit in treatment T2 is significant, but not for treatment 1, which only changed from 8.25 to 8.14 and could be due to an experimental error.

Table 3. Variation of pH, Ca and Mg during composting

Treatment	R1			R2			R3		
	pH	Ca %	Mg %	pH	Ca %	Mg %	pH	Ca %	Mg %

T1	8,25^{a}	0,58^{b}	0,18^{b}	8,15^{a}	0,66^{b}	0,20^{b}	8,14^{b}	0,81^{b}	0,25
T2	7,22^{b}	1,29^{a}	0,39^{a}	7,61^{b}	2,11^{a}	0,64^{a}	8,22^{a}	2 ,05^{a}	0,62
Probability	P<0,001	P<0,001	P<0,001	P<0,001	P<0,001	P<0,001	P<0,05	P<0,001	P<0,001
Sig	VHS	VHS	VHS	VHS	VHS	VHS	S	VHS	VHS

Comment [FR6]: Why is there no difference here and in R3 with 0.01 difference if there is??

Sig : *Significant ;* ***VHS*** *: Very Highly Significant. The values followed by the same letter in each column are not statistically different at the threshold of 5% in Newman Keuls test. T1 : Rice straw + Cattle manure ; T2 : Panicum maximum straw+ Poultry manure.* ***R1 :*** *First turning ; R2 : Second turning ; R3 : Third turning.*

3.2. Evolution of carbon and major nutrient content

Table 4 shows the evolution of chemical parameters according to the different treatments during the three turnings. The statistical analysis reveals very highly significant differences for total P and total K and significant differences for C/N ratios between treatments at the threshold of 5%. During the composting process, treatment T2 gives total P levels two times higher than those of treatment T1 in all turnings (R1, R2 and R3), i.e. 0.31, 0.55 and 0.59% respectively. Treatment T2 also provides the lowest C:N ratios during the second and third turning, i.e. 18.12 and 17.99 respectively. A general decrease of the C:N ratio is also observed during the composting process. Treatment T1 gives the highest total K ratios at the first and second turning, 3.05% and 2.71% respectively.

Table 4. Evolution du taux de C, N, P et K

Treatment		T1	T2	Probability	Significance
R1	C %	40,20	40,42	*P >,06*	NS
	N %	1,50	1,44	*P >,06*	NS
	C :N	26,73	28,15	*P >,06*	NS
	P %	0,18^{b}	0,31^{a}	*P<,02*	S
	K %	3,05^{a}	1,59^{b}	*P<,004*	HS
R2	C %	38,93^{a}	29,18^{b}	*P<,0004*	THS
	N %	1,60	1,61	*P>,73*	NS
	C :N	24,37^{a}	18,12^{b}	*P<,0001*	VHS
	P %	0,20^{b}	0,55^{a}	*P<,0001*	VHS
	K %	2,71^{a}	1,35^{b}	*P<,0001*	VHS
R3	C %	33,03	33,50	*P>,05*	NS
	N %	1,73^{b}	1,86^{a}	*P<,01*	S
	C :N	19,08^{a}	17,99^{b}	*P<,02*	S
	P %	0,22^{b}	0,59^{a}	*P<,0001*	VHS
	K %	1,90	1,93	*P>,54*	NS

Comment [FR7]: Separate these values with a space because they correspond to R2 and must be together with C:N, p and K

NB : S : *Significant ;* ***NS*** *: Not Significant ;* ***HS*** *: Highly Significant ;* ***VHS*** *: Very Highly Significant. Values followed by the same letter in each column are not statistically different at the threshold of 5% in Newman Keuls test. T1 : Rice straw + Cattle manure ; T2 : Panicum maximum straw + Poultry manure.* ***R1 :*** *First turning ; R2 : Second turning ; R3 : Third turning.*

3.3. Chemical characteristics of the composts obtained

The two final composts have alkaline pH, i.e. 8.25 for treatment T1 and 8.23 for treatment T2. They have high organic matter levels, i.e. above 30%, and a C:N ratio between 15 and 20, i.e. 17.31 and 15.12 respectively for T1 and T2. The treatment T2 provides the lowest C:N ratio but it gives levels of total P, Ca and Mg twice higher than those of T1. Total P, Ca and Mg levels are respectively 0.52%, 2.05% and 2.14% for treatment T2. Treatment T1 gives the best total K level of 2.14%.

Table 5. Chemical composition of the composts obtained

Treatment	pH_water	MO %	N %	C :N	P %	K %	Ca %	Mg %
T1	8,25	52,42	1,76	17,31 a	0,20 b	2,14 a	0,90 b	0,27 b
T2	8,23	49,95	1,92	15,12 b	0,52 a	1,61 b	2,05 a	0,62 a
Probability	P<,54	P<,34	P<,14	P<,002	P<,004	P<,02	P<,04	P<,04
Significance	NS	NS	NS	HS	HS	S	S	S

***S :** Significant ; **NS** : Not Significant ; **HS** : Highly Significant. The values followed by the same letter in each column are not statistically different at the threshold of 5% in Newman Keuls test. T1: Rice straw + Cattle manure; T2: Panicum maximum straw + Poultry manure. **R1:** First turning; R2: second turning; R3: Third turning.*

4. DISCUSSION

The observed difference in pH-water values during the composting process can be explained by the pH-water of the initial organic substrates. The pH reflects the biological activity related to the different phases of the composting process [15,21]. In fact, the pH-water of the manure used was 8.39, which is basic, leading treatment T1 to give the highest pH-water. That of the poultry manure was 6.90, which is close to neutrality, hence the lower pH-water at the start of composting for treatment T2. The results also show a decrease in pH-water (8.22 to 8.14) for treatment T1 during composting. The decrease is explained by an increase in the production of organic acid during the mesophilic phase in order to create a favorable condition for the development of the mesophilic flora because the initial organic substrate had a high pH (8.25). Ammonia volatilization is frequent above pH 8, which affects the quality of the compost [22]. The production of CO_2 during aerobic degradation contributes to the acidification of the environment through its dissolution in water and the production of carbonic acid [23]. On the other hand, the results reveal an increase in pH-water during composting in treatment T2. This is explained by the degradation of polymers by microorganisms leading to an increase in pH [21]. According to authors [24], the pH of the compost water can undergo alkalinization through the production of ammonia gas. This alkalization phase is the result of ammonia production from the degradation of protein amines during the ammonification process on the one hand and the release of bases present in the organic matter on the other hand [25,26,27]. The ammonia thus generated would partly neutralize the acid substances [28,21].

The high Ca and Mg contents of treatment T2 may be explained by the richness of the initial organic substrate in these elements. The Ca and Mg content of poultry manure is indeed 4 times higher than that of cattle manure. The increase in Ca content is due to the release of Ca into the environment through the transformation of the initial materials.

The speed of the composting process depends on the speed of mineralization of the organic matter, and depends on the balance between the mineral elements. The ratio between

Comment [FR8]: I do not believe that the decrease of only 0.08 pH units is due to the production of acids, since these generally lower the pH to values close to 6. I believe that it could be due to a measurement error..

Comment [FR9]: They say it decreased not that there was an increase, so what does ammonia have to do with it?

Comment [FR10]: Like which polymers? They must discuss better these results nitrogen and carbon, commonly called the C:N ratio, is one of the most considered parameters to facilitate composting [29]. During the composting process, the C:N ratios of the different treatments decreased considerably. This decrease may be explained by the fact that micro-organisms consume more carbon (the main component of organic molecules) than nitrogen. The decreases in the C:N ratio are also due to the release and/or transformation of carbon. As a matter of fact, according to authors [29,30], during the composting process, different transformations of carbon take place: oxidation of easily degradable carbon compounds, methanisation in the anaerobic parts at the bottom of the pile or in aggregates, production of organic acids from carbohydrates or lipids, enzymatic attacks of carbon compounds producing carbohydrates and dissolution of CO_2 in water. Our results are similar to those [31] who observed a significant decrease in the C:N ratio of slaughterhouse wastes during composting. However, it should be noted that manure is one of the best activators of organic matter decomposition, as it contains sufficient biodegradative microorganisms. Our results are similar to those [32], who found during windrow composting of rice straw, a considerable decrease in dry matter content with the manure-based treatments. Treatment T2 gives the lowest C:N ratio of 15.12. This low C:N value could reflect the relatively rapid mineralization of nitrogen and therefore its availability in the compost [33].

Phosphorus is not volatile and is much less prone to leaching than nitrogen because of its low mobility [34]). The high P content of treatment T2 might be due to the high P content of the poultry manure (0.23%). Moreover, the study of [35] highlighted that the variation in the P content of composts is linked to the substrates used. Treatment T1 gives the highest K content and this is also explained by the high K content of the cattle manure.

The final composts have basic pH values of 8.25 in treatment T1 and 8.23 in treatment T2, which is indicative of a successful composting process according to [33]. The total P, Ca and Mg contents of treatment T2 are twice as high as those of T1. This may also be explained by the richness of the poultry manure in P (0.23%), Ca (2.24%) and Mg (0.68%). According to [35], the variation in P content of the composts is related to the substrates used. Treatment T1 gives the highest K content and this is explained by the high K content of the cattle manure [14]). Treatment T2 gives the lowest C:N ratio and the highest P, Ca and Mg contents compared to treatment T1. Our results corroborate those of [33] who showed that broiler and laying hen manure composts are richer in N, P and K elements than cattle manure composts. In general, the C:N ratios of both treatments are below 20, which is an indicator of good compost [36].

5. CONCLUSION

The present study was conducted to evaluate the effect of substrate types on chemical parameters during the composting process and on the final composts. The composts obtained have basic pH-water and low C:N ratios and are rich in major mineral elements. Therefore, the composting of organic substrates improves their chemical parameters. We can also note that the compost based on poultry manure and *Panicum maximum* straw is of higher quality than that based on cattle manure and rice straw, because it gives the lowest C:N ratio and the highest N and P, Ca and Mg contents. However, it would be important to continue this study in order to evaluate the effect of these composts on crop production and the physical and chemical parameters of the soil and assess the economic benefits of the composts produced.

Comment [FR11]: It is important to carry out toxicity bioassays to know which of the composts was better, given that sometimes the soil of the fields is irrigated with synthetic fertilizers.

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Comment [FR12]: Check the references marked with red-yellow color

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