Composting of Tomato Wastes and Sheep Manure: An Eco-friendly Waste Valorisation for Enhancing the Environmental Sustainability in Souss Massa Region (Morocco)

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Abstract

Each season, a huge amount of crop residues is regenerated by horticultural production. The main type of wastes are tomato stalks, leaves and axillary buds which are subsequently the result of crop operations like trimming and plants trellising and uprooting. The landfilling of corps residues is a serious problem that need to be solved. Therefore, the valorisation of these organic wastes by composting is a simple way for suitable management and the produced compost could be used as an organic amendment to satisfy the crop growth needs and agronomic soil requirements. The aim of the study is to investigate the impact of the mixing proportion of tomatoes residues and sheep manure using an experimental biocomposter of capacity 220 L with passive aeration system. Two different mixing ratios were set-up on volume basis: R1 (2/3 tomato plant residues "TPR" + 1/3 sheep manure "SM") and R2 (1/3 tomato plant residues "TPR" + 2/3 sheep manure "SM") and two controls CTRP (1/1 tomato plant residues "TPR") and CSM (1/1 sheep manure "SM"). Parameters such as Temperature, pH, EC, Carbon-to-nitrogen ratio, mineral and organic nitrogen, potassium and phosphorous were monitored for a period of 60 days. According to the results, tomato wastes proportion is negatively correlated to the Germination Index (GI) of the final compost, the nitrogen and the organic matter loss. After 9 weeks of composting, GI was 87%, 91%, 92%, and 95% respectively for CTRP, R1, R2 and CSM. Tomato plant residues are not adequate for composting alone, and could limit the efficiency of the process.

Introduction

Tomato waste generated by greenhouse industry has become environmental problem that is facing Morocco country and could have a greater impact on the environment. In Souss Massa region, tomato corps production is one of the most important horticultural scope were tomato representing 96% of national production (APEFEL 2017). In 2011, more the 1.000.000 tons of organic waste are generated which 29% are tomato plant residue(leaves, axillary buds, and the entire end cycle plant) with important proportion of organic manner and macro-nutrient (0.7% N, 0.31% P_2O_5, 1.8% K_2O) (Azim *et al,* 2017). Therefore, Tomato wastes represent a valuable source of macro-nutrient that can be profitable. On global perspective, composting can put back this nutrient into the agricultural system as compost which can be considered as a valuable source of humic substances, nitrogen, phosphorous, essential trace elements to support plant growth and might be possible to decrease their dependence on chemical fertilizers and enhance the sustainability of the nutrients cycle. (Karak *et al.,* 2013). Composting efficiency of all crop residues depends mainly on their physicochemical characteristic and environmental conditions together. According to (Onwosi *et al.* 2017) Certain chemical characteristics of the tomato plant residues are not adequate for composting alone and could limit the efficiency of the process: high N concentration for the organic-C gives low C/N ratio which can result in nitrogen loss as NH_3 and even N_2O, excess of moisture content and low porosity, which together make aeration challenging. To overcome the challenges that these peculiarities impose mixing with other compost feedstock materials can be employed. In this scenario, (Gavilanes- Terán *et al.,* 2016) sawdust and laying hen manure were added to tomato waste in order to calibrate C/N which results in a ratio range of 29-30. The C/N ratio of compost feedstock is the leading parameter when setting up a new composting process. However, the C/N should not be used as absolute parameter as it is important to identify the nature of C in the composted materials. (Maheshwari *et al.,* 2014). A similar suggestion assuming a C/N effect has been done by (Kumar *et al.* 2010), they revealed that that C/N alone is not a limiting factor for composting efficiency and low C/N is possible and depend the moisture content. In this study, the objectives were to determine whether addition of sheep manure to the stage composting of tomato plant residues, to monitor the physico-chemical changes and offering an optimal ratio that allows adequate composting and compost quality.

Materials and methods

Feedstock preparation

Composting assay was performed and monitoring at the National Centre of Agronomical Researches Melk Zhar. Tomatoe plant residues (TPR) and Sheep Manure (SM) were used to formulate starting mixture, tomatoes waste was collected during greening maintenance of greenhouse industry consisted of fallen leaves and branch cuttings. Physicochemical properties of starting material are showed in Table 1. The two wastes were crushed to obtain uniform particle size and mixed with four proportions in order to calibrate nutriment balance in the bench-scale reactors.

Table 1. **Physico-chemical characteristics of the starter material**

	pH[a]	EC (mS/ cm)	TOC (mass%)	C/N (Ratio)	TN (mass%)	TP (mg/Kg)	TK (g/kg)	Ca (g/kg)	Mg (g/kg)	Fe (mg/kg)
TPR	8.33	5.37	27,1	9.9	2.73	0.135	0.075	0.747	0.386	92
SM	7.96	2.03	28.64	12.73	2.25	0.322	0.1	0.682	0.447	153

SM: Sheep Manure
TPR: Tomatoes plant residues
[a] Percentages are based on air-dry weight.
[b] Percentages are based on oven-dry weight.

Table 2. **Starting mixture and parameter of composting assay**

	Starting Mixture (dry weight)[a]		*Starting Parameter*			*Weight (Kg)*
	TPR	SM	C/N Ratio	NT (mass%)[a]	Moisture content (%)	
R1	2/3	1/3	11.2	2.07	60	
R2	1/3	2/3	13.98	1.89		

Composting sampling and monitoring

Samples were collected as the composting mixtures every on day 0, 12, 14, 26, 38, 50, 62, On these days, three subsamples (200 g per subsample) was collected from the top, middle, and bottom of each reactor. The three subsamples were combined to form one composite sample (600 g per simple). Each sample from each reactor was oven-dried at 65°C. When dry, the samples were crushed in a small grinder, passed through soil sieves (0.5mm), sealed in plastic containers, and stored at 4°C. Temperature was measured daily at the middle of each reactor using a self-made temperature sensor with a temperature dial and 1 metre long rod. Ambient temperature was also recorded using the same temperature sensor.

Chemical properties

The pH, electrical conductivity (EC), organic matter (OM), total organic carbon (TOC), total Kjeldahl nitrogen (N-TKN), ammoniacal nitrogen (N-NH+4), total phosphorus (P–$P_{soluble}$), total potassium (TK), humic acid (HA) and micro-nutriment Ca, Mg, and Fe were determined for oven-dried samples (Pas encore terminer cette paragraphe).

Seed germination test

The germination index (GI) was determined in accordance with (Gu *et al., 2*011). 20 radish seeds and 5 mL compost extract were placed on sterilized petri dish with a filter paper. Deionized water was used as a control. The petri dishes were kept in the dark at 30 °C for 48 h. Germination rates and root length were measured. The calculation of GI was based on the following formula:

$$GI\ (\%) = \frac{\text{Seed Germination} \times \text{Length of Treatment "mm"}}{\text{Seed Germination} \times \text{Root Length of Control "mm"}} \times 100\%$$

OM and TN loss

The equations of (Paredes *et al.* 2000) were utilised to calculate the losses of OM and NT from the initial (X1) and final (X2) ash contents:

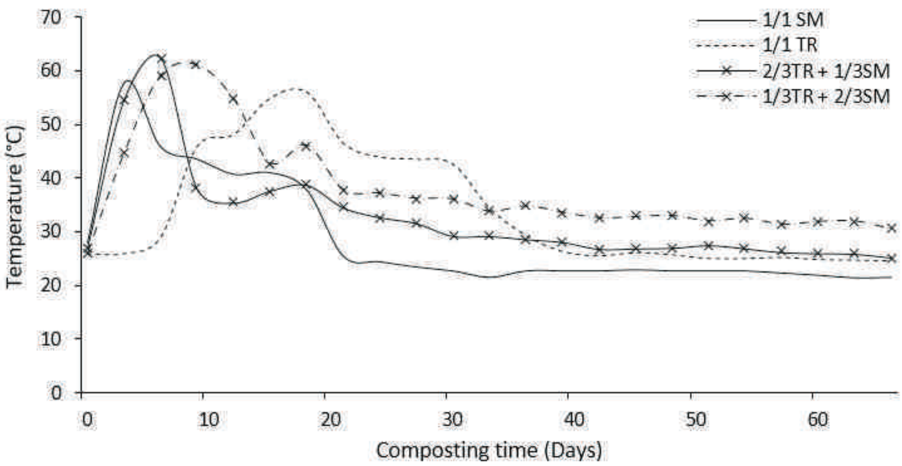
Losses of organic matter (OM) and TN were calculated according to the following equations (Paredes *et al.* 2000):

$$\text{OM loss } (\%) = 100 - 100\ [X_1(100\text{-}X_2)] \div [X_1(100\text{-}X_2)]$$
$$\text{TN loss } (\%) = 100 - 100\ [(X_1 \times N_1) \div (X_2 \times N_2)]$$

Where X_1 and X_2 are the initial and final ash contents, respectively and N_1 and N_2 the initial and final TN concentrations.

Results and discussion

Temperature is a major parameter provides composting efficiency, a good thermophilic is important for effective inactivation of pathogens and splitting lignine and cellulose in compost (Soobhany *et al.,* 2017; Tuomela *et al.,* 2000).



After the addition of each mixtures in the bioreactor, increasing in temperature was observed in all treatment, indicating a marked microbial activity. In composters containing the controls CTPR (Tomato plant residues) and CSM (Sheep manure), the thermophilic phase (up to 47°C) lasted 15 and 5 days respectively for CTPR and CSM. The maximum temperature inside of controls composters is 57°C for CSM and 55.7°C for CTRP, reached within 2 days and 4 days respectively. For composters contending the mixtures of tomato plant residues and sheep manure at different ratio R1 and R2, the thermophilic phase is lasted 12 and 5 days for R1 and R2 respectively. The maximum temperature inside composter was higher than all controls and was 62°C observed for R1 and 61 °C for R2, reached within 2 and 5 days respectively. The high temperature reached during composting process in all digesters ensured higher efficiency of hydrolysis rate and was sufficient for destruction of pathogens and weed seeds according to (Converti *et al.,* 1999; Remade Scotland, 2003; Ziemba *et al.,* 2010; Bayr *et al.,* 2012 and). All temperature variation versus time of composting is shown in Fig. 1.

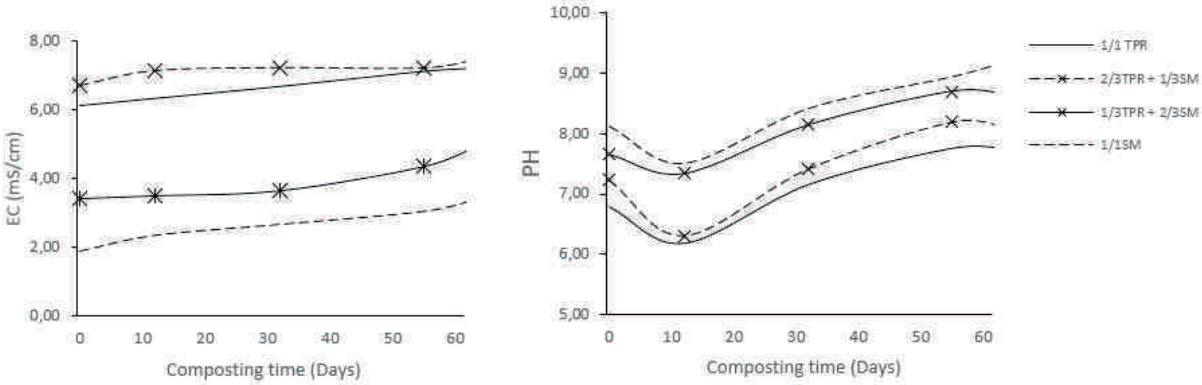


Figure 1. **Change in pH and electrical conductivity (EC) during composting of pH variations**

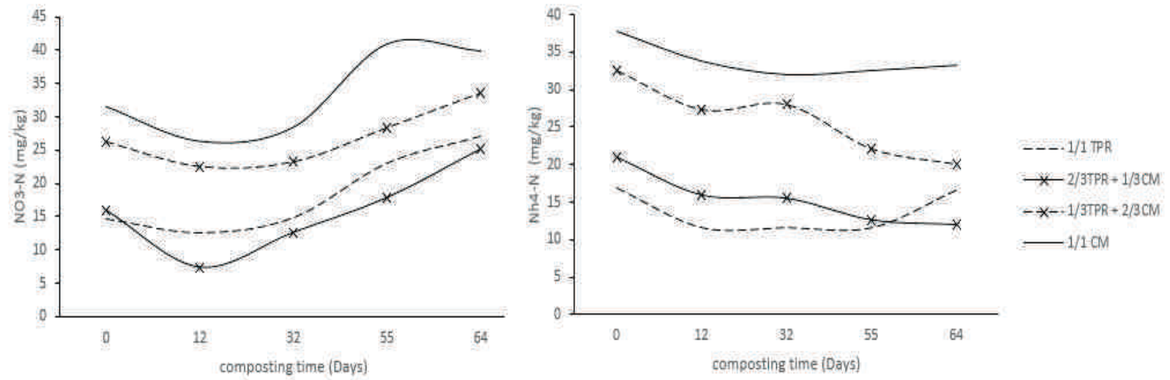
pH is one of selective factors for microbial population and influencing the microbial activities and community during composting process (Chan *et al.,* 2016). As shown in Fig. 2a and 2b, most of starting materials and mixture are a pH value ranging between 6, 75 to 8, 12, generally adequate for composting and couldn't limit the efficiency of the process. pH profile decreased during the first week and then was stable around 6.2 for CTRP, R1 and around 7.4 for R2 and CSM. This decreasing in pH values is likely due to the accumulation of organic acids and volatilization of ammonia as suggested by (Ref). As composting is progress, pH profile show a little alkalization and then was stable in neutral value and R2 and higher than 8 for R1 and CSM. After 9 weeks of composting the final pH values were 7.76, 8, 01, 7, 61 and 8.95 respectively for treatment CTPR, R1, R2, and CSM. This increase in pH is one of indices of compost maturation according to Juarez *et al.* (2015). During this study, the proportion of TPR in the mixture show a direct influence on pH evolution. Since, in two first weeks, CTRP and R2 had slightly higher pH compared to R2 and CSM, the pH becomes more acid if the proportion of TPR in mixture is higher. By against, acidification is low in the control CSM and R1 which the proportion of sheep manure is higher than TPR. After 2 weeks of composting, the pH gradually decreased and stabilized in alkali values for the two composting mixtures and their controls.

Electrical Conductivity

Electrical Conductivity is an important laboratory measurement since it reflects the total salt content coming from microbial mineralization of organic matter fractions present in the substrates of the composting (Jiang *et al.,* 2015; Shah *et al.,* 2015) and thus reflects quality of the compost as a soil amendment. The variations of electrical conductivities of the all treatments are shown in Fig. 2(2a and 2b). During the first week of monitoring, the EC of mixture R2 was constant and they show a gradual increase for R1 mixture and two controls CTRP and CSM. After that, all treatments continued with a slow increase in EC till the end of composting process. Awasthi *et al.* (2014) suggested that increases of EC could be caused to the "biotransformation of complex materials to simple compounds and mineral salts such as phosphates and ammonium ions. This hypothesis is clearly confirmed in Tab which during the composting process, concentration of NO_3^--N increase in all treatments, especially after 2 weeks.

Nitrogen dynamics

Concentrations of mineral ammonium nitrogen ($NH4^+$-N and $NO3^-$-N) in all the treatments increased only during the two first weeks. After that, $NO3^-$-N continued their increasing. The release of $NH4^-$-N through ammonification coincided with the active degradation of organic matter during thermophilic phase (voir Karak 2015).



Composting times (Days)	HA (%)	C_{ha}/C_{ha}	C_{org}/T_N	GI
Biocomposter 1 : TRP (1/1 tomato plant residue)				
0				
12				
32				
55				
64				
Biocomposter 2 : R1 (2/3 TPR + 1/3 SM)				
0				
12				
32				
55				
64				
Biocomposter 3 : R2 (1/3TPR + 2/3SM)				
0				
12				
32				
55				
64				
Biocomposter 4 : CSM (1/1 sheep manure)				
0	44±4		13,62±1	
12	47±4		13,69±1,09	
32	45±5		11,74±0,7	
55	52,6±1		10,32±1	
64	44±4		8,6±1,52	

	Starting Materials			Final Product		
	TPR	SM	TW	R1	R2	CM
Ca						
Mg						
Na						
K TOT						
P TOT						
Zn						
Fe						
Mn						
Cu						
GI						

Organic matter degradation