EVOLUTION OF THE PHYSICO-CHEMICAL PROPERTIES OF TUNISIAN AGRICULTURAL WASTES DURING COMPOSTING PROCESS.

Kammoun Rigane M.[1,3], Michel J-C.[2], Medhioub K.[3]
[1]Faculté des Sciences de Sfax, BP 1171, Sfax 3000, Tunisie. Département de Géologie.
manelriganekamoun@yahoo.fr
[2]Agrocampus Ouest, UPSP EPHOR 2 rue Le Nôtre, 49045, Angers, France
[3]IPEIS, BP 1172, Sfax 3000, Tunisie. UR: Etudes et Gestions des Environnements Côtiers et Urbains

1 INTRODUCTION

Tunisia is one of the most important productive olive oil and almond in Mediterranean countries. It is well known that large quantities of wastes are generated every year as a consequence of olive mill factories and almond shelling industries. These solid and liquid residues are characterized by high organic matter contents and a substantial quantity of plant nutrients (N, P, K, Ca, Mg and Fe) (Kammoun-Rigane et al., 2008; Garcia-Gomez et al., 2003). Co-composting of these wastes to provide adequate chemical composition, particularly C/N has shown to be a suitable method needing low technical and economical requirements (Sellami et al., 2008; Garcia-Gomez et al., 2003). It is a new management priority in Tunisia. During composting, it is necessary to know the physico-chemical, physical and biological parameters evolution to improve the process. Tejada and Gonzales, (2003) showed that olive mill factories wastes composts valorization as soil amendments could increase both soil fertility and crops production. Kammoun-Rigane et al., (2009) achieved the important role of almond shell and olive wastes composts for tomato production in reconstituted anthropic soil. Several studies have demonstrated that composts derived from olive wastes have been used as component in horticultural substrate (Papafotiou et al., 2004; Herrera et al., 2008; Kammoun-Rigane et al., 2010); Urrestarazu et al., (2005) used composted almond shell as local rockwool substitute in soilless crop culture and Sellami et al., (2008) showed that co-composting of exhausted olive cake with poultry manure, sesame shells and humidification with confectionery wastewater produces a compost with sufficient amounts of available P and K to sustain the growth of horticultural crops and products tested in vivo increased the potato yield significantly. The aims of the present work, therefore, was to investigate the principal modifications in physico-chemical properties i.e pH, electrical conductivity (EC), total nitrogen (TN), C, organic matter contents (OM) and C/N rations during the co-composting processes of agricultural wastes mixtures prepared by the pile system and humidified by olive mill wastewater and confectionery wastewater. The final products may be used as soil amendments or as components in soilless substrates for horticultural production.

2 MATERIALS AND METHODS

Agricultural wastes used in this work are mainly Mediterranean wastes generated by:

- confectionery industries, i.e., almond shells (AS), sesame bark (SB) and confectionery wastewater;
- olive oil production industries, i.e., olive mill wastewater (OMW), olive mill wastewater sludge, (OMWS) collected from the natural evaporation of OMW in artificial basin from the region of Sfax (south east of Tunisia) and olive husks (OC);
- poultry-related industries, i.e., poultry manure (PM).

TABLE 1 **Main physicochemical properties of raw materials**

	pH	OM%	TC%	TN%	C/N
AS	5.2±0.1	97.9±0.1	43.8±0.1	0.3±0.05	175.2
OC	5.8±0.3	85.1±3.6	39.5±0.6	1.2±0.12	33
OMWS	3.4±0.5	62.9±0.1	42.0±0.8	1.0±0.1	42
SB	5,6±0.1	90,6±3.8	45±3.1	1.7±0.06	26.5
PM	8.2±0.3	26.0±2.9	10.6±2.7	1.2±0.11	9.3

Values are given as a mean of three replicates ± standard deviation

The most important physico-chemical properties of raw materials were presented in Table 1. The OM content in OMWS waste was relatively low compared to the other wastes used in this study but more important comparing to PM. SB is the most rich in nitrogen content and C/N ratio in AS is the highest. The pH value was alkaline for PM and acidic for the other wastes. Five windrows were prepared by mixing agricultural wastes CI, CII, CIII, CIV and CV. The mixtures were prepared in the following proportions, on a fresh weight basis and were watered by OMW and confectionery wastewater mixture. Mixtures of about 10000 kg each were composted in a trapezoidal windrow.

- Windrow CI: was composed of AS and SB at the ratio of 75/25;
- Windrow CII: was prepared by mixing OH and SB at the ratio of 75/25;
- Windrow CIII: represented a mixture of OMWS and PM at the ratio of 70/30;
- Windrow CIV: is composed of OMWS, OH and PM at the ratios of 50/20/30;
- Windrow CV: compost was prepared by mixing OMWS, PM and AS (coarse) as a bulking agent at the ratios of 55/35/10.

During the mesophilic and thermophilic phases, the turnover of composts ensured the aeration and homogenous humidification of waste mixtures. Moisture was maintained at 55% using OMW and confectionery wastewater. The bulk temperature of piles was measured daily using a thermometer (Bioblock, France) and composts were sampled by mixing subsamples taken from the top, the medium and the bottom portions of each windrow. Compost sampling was assessed once a month during the mesophilic and thermophilic phases, and twice during the maturation phase (at 12 and 18 months). Physico-chemical analyses of agricultural residue and compost samples were established using the standard, EN Pr 13040:1999. Water content was determined by weight loss of samples, which were dried at 105°C for 48 h. The pH and electric conductivity (EC) were determined in a solution ratio 1/5 (v:v) according to standards EN Pr 13037:1999 and EN Pr 13038:1999, respectively. The organic matter contents (OM) were assessed by determining the loss-on-ignition at 450°C over six hours. Total nitrogen (TN) and carbon contents (TC) were measured by elementary analyses based on the standard, NF ISO 10694 (ISO, 1995), using a Thermoquest® analyser.

3 RESULTS AND DISCUSSION

3.1 Temperature evolution

Temperatures of the mixtures increased at the beginning of the process to thermophilic values (Fig.1). Temperature profiles for mixtures reaching the optimal temperature of 65–70°C and held during relatively a long period (Paredes et al., 2004). Zhang and He, (2006) considered that level contributed to the elimination of pathogens and harmful seeds. Indeed, the duration of process phases were related to the proportion of readily degradable carbon in substrates. The decrease in temperature was recorded approximately after three months of composting. The bio-oxidative phase of composting was considered finished when the temperature of these windrows was stable and close to that of the surrounding atmosphere (Hachicha et al., 2006; Garcia-Gomez 2003). At this stage we substituted the addition of wastewater by water.

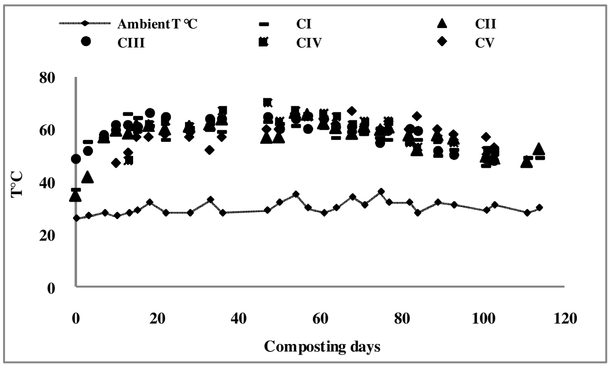

FIGURE 1 **Temperature profiles during the composting process**

3.2 Composts properties evolutions

As shown in Table 2, composts pH were alkaline with values ranging from 8 to 9.7 during the process. It may be explained by the alkaline hydrolysis of K and Na salts from wastes (Abid and Sayadi, 2006). This finding correlates with previous studies (Paredes et al., 2001). The EC values increased slightly during the first four month for the windrows CI and CII (Table 2). This increase may be related to the loss of weight and accumulation of salts such as phosphate and ammonium ions through the decomposition of organic substances (Abid and Saydi, 2006) and also salt providing from OMW used for windrows humidification. Inversely, decreases were observed for composts CIII, CIV and CV mainly composed by OMWS and PM whilst OMW use. This fact is related to a leaching effect which occurred while using water for irrigating during the maturation phase. Although, EC values were around 1.6 mS/cm in AS, OH and SB at the end of the process and were ranged from 2.5 to 3.1 mS/cm for OMWS and PM-basing composts.

The N, C and OM contents, evolution during composting process were presented in Table 3a, b and c. Physico-chemical properties of the mixtures at the process starting were significantly affected by the nature of wastes. The OM contents in composts were higher in AS, OH and SB composts (CI and CII) than that in OMWS and PM-based composts, while significant difference was observed in the C, N and C/N ratio at the start of the process Table 3d. The composts CI containing AS as substrate present the lowest N content, whilst no significant difference was observed in the TN contents during the bio-oxidative phase for all composts. The C, OM contents and C/N ratio showed a significant decrease throughout the composting process for CII. However, the bio-degradation of AS substrates which contain more resistant compounds in CI was less intense mainly during the first three months and it presents an increasing in CIII, CIV and CV. This fact could be related to low C/N ratios in OMWS and PM characterized by low quantities of carbon-rich materials. Therefore, the using of OMW and confectionery effluent having a large quantity of organic and easily degradable substances increased C contents remarkably in these windrows and improved C/N ratio considered adequately for monitoring OM degradation. Then, decreases in C contents and C/N ratio were observed.

TABLE 2 **Evolution of pH and EC of composts during process**

	CI		CII		CIII		CIV		CV	
CM	**pH**	**CE**	**pH**	**CE**	**pH**	**CE**	**pH**	**CE**	**pH**	**CE**
0	9.7±0.2	0.67±0.13	8.6±0.1	1.03±0.12	9.0±0.2	4.4±0.4	8±0.2	3.4±0.2	9.3±0.1	3.2±0.13
1	9.4±0.1	0.67±0.08	9.4±0.2	0.97±0.24	8.4±0.4	4±0.3	9.4±0.2	2.4±0.2	9.5±0.1	2.2±0.18
2	9.5±0.1	0.64±0.09	9.7±0.0	1.18±0.19	9.4±0.1	3.7±0.2	8.6±0.0	3.4±0.2	8.4±0.1	3.4±0.22
3	9.5±0.2	0.84±0.19	9.6±0.1	1.7±0.31	9.1±0.2	4.3±0.4	9.6±0.1	2.6±0.2	8.4±0.2	1.6±0,11
4	9.5±0.2	0.75±0.2	9.6±0.1	1.2±0.17	8.7±0.1	3.9±0.2	9.6±0.1	2.3±0.2	9.3±0.3	1.6±0.2
5	9.5±0.1	1.26±0.23	9.5±0.1	2.9±0.38	9.4±0.3	4.0±0.4	9.5±0.2	1.8±0.2	9.4±0.2	1.8±0.16
6	9.5±0.2	1.18±0.08	9.6±0.2	2.05±0.41	9.7±0.1	2.6±0.2	9.7±0.2	2.6±0.2	9.7±0.1	1.6±0,21
12	9.7±0.2	1.07±0.21	9.6±0.1	1.89±0.3	9.7±0.1	2.8±0.3	9.8±0.0	1.6±0.2	9.7±0.2	1.6±0.14
18	9.4±0.1	1.61±0.11	9.2±0.3	1.66±0.16	9.5±0.2	2.6±0.2	9.4±0.2	2.9±0.2	9.1±0.0	3.3±0.23

Composting months: CM; Values are given as a mean of three replicates ± standard deviation

Through the process, the C/N ratio showed a significant decrease measured as more than 45% for AS, OH and SB and less the 35%, for OMWS and PM-based composts. Therefore, the C/N ratios at the end of the process were stabilized around 12 for olive wastes based composts and about 20 for AS based compost. Bernal et al. (1998) suggested that a C/N ratio of 20 would reflect a satisfactory degree of compost maturity, though, Mustin (1987), considers that a value below 12 indicates a high degree of compost maturity.

TABLE 3 **Evolution of N, C, OM contents and C/N ratios during the composting process**

a- Evolution of N s for CI, CII, CIII, CIV and CV

	N CI	**N CII**	**N CIII**	**N CIV**	**N CV**
0	0.7±0.05	1.1±0.08	1.1±0.1	0.8±0.12	1.0±0.03
1	0.6±0.01	0.9±0.12	1.1±0.0	0.9±0.09	1.1±0.04
2	0.62±0.03	1.1±0.02	1.2±0.1	1.0±0.05	0.9±0.01
3	0.62±0.04	0.9±0.08	1.2±0.1	0.9±0.03	1.1±0.07
4	0.63±0.02	1.0±0.05	1.2±0,0	0.9±0.05	1.1±0.01
5	0.70±0.01	1.0±0.09	1.0±0.0	1.0±0.11	1.2±0.03
6	0.71±0.03	1.0±0.06	1.2±0.0	1.0±0.08	1.1±0.06
12	0.70±0.01	1±0.08	1.0±0.1	1.0±0.02	1.0±0.09
18	0.64±0.02	1.0±0.1	0.9±0.1	0.9±0.06	1.0±0.06

b- Evolution of C contents for CI, CII, CIII, CIV and CV

	C CI	**C CII**	**C CIII**	**C CIV**	**C CV**
0	21±1	30.8±0.2	14±0.1	15.3±0.8	14.7±1.2
1	22±0.9	21.5±0.6	20±0.4	14.0±0.4	17.3±0.9
2	21±1.2	18.9±0.4	17±0.6	15.5±0.4	17.5±0.7
3	21±0.8	18.9±0.3	16±0.5	14.8±1.0	22.5±1.2
4	15±1.1	21.1±0.9	18±0.5	14.9±0.09	19.5±0.1
5	15±0.7	17.4±0.2	12±0.1	15.0±1.2	16.1±1.1
6	17±1.2	14.7±0.2	16±0.7	14.0±0.7	15.6±1.3
12	12±0.6	13.9±0.6	11±0.9	11.1±0.6	11.2±2.1
18	14±1.3	13.1±0.3	10±0.5	9.7±0.2	11.9±1.0

c- Evolution of OM contents for CI, CII, CIII, CIV and CV

	OM CI	**OM CII**	**OM CIII**	**OM CIV**	**OM CV**
0	43.3±1.2	55.1±2.2	34.2±1.2	35.0±1.2	38.7±2.2
1	42.3±1.8	52.0±3.5	31.8±2.3	37.2±1.8	36.2±3.3
2	39.5±1.5	50.8±3.0	29.3±1,0	34.6±2.4	39.5±1.9
3	37.8±1.6	47.6±1.6	30.5±1.4	31.9±0.2	37.3±2.7
4	40.2±2.2	37.8±1.4	31.0±2.2	27.5±1.6	33.0±1.2
5	34.0±0.9	38.1±1.0	29.2±0.8	23.3±1.3	31.3±3.2
6	31.4±1.2	33.4±0.9	29.3±0.7	22.0±0.9	28.9±1.5
12	32.9±0.2	33.5±1.3	24.7±0.5	20.6±0.4	20.6±1.2
18	32.0±0.2	30.3±1.1	24.7±1,1	20.2±0.7	20.4±1.3

d- Evolution of C/N ratios CI, CII, CIII, CIV and CV

	C/N CI	**C/N CII**	**C/N CIII**	**C/N CIV**	**C/N CV**
0	31	28.2	14.6	18.8	14.7
1	37	22.6	19.3	14.9	15.2
2	34	17.9	14.4	15.5	19.2
3	34	19.8	13.6	16.7	20.2
4	24	20.6	15.2	18.8	18.4
5	23	16.5	12.1	16.0	13.6
6	24	14.1	13.6	14.0	14.8
12	19	13.3	12.3	11.5	11.2
18	20	12.7	11.8	12.6	11.9

4 CONCLUSIONS

It can be concluded that used agricultural wastes can be successfully co-composted and humidified by OMW and confectionery wastewater. The N contents C and C/N ratios are related to the nature of the co-composted wastes and values were significantly low in olive wastes-based composts. The effluents addition was necessary for improving the process mainly for OMWS and PM mixtures by increasing C and OM contents and C/N ratios. These values rise also by adding AS as bulking agent in CIV. The OM mineralization was less important in these composts comparing to AS, OH and SB- based compost due to the low initial contents. At the end of the process C/N ratios were stable and were ringing from 20 to 11 with the highest values for AS based-compost, indicating maturity of OM in the studied composts. The pH levels were alkaline for all composts. The EC values were higher in OMWS and PM-based composts comparing to AS, OH and SB based-composts, hence indicating a possible toxicity for plants due to salts if used undiluted in growing media or if applied by high quantities to soil. Further works should be undertaken to optimize the rate of adequate rate for using composts as soil amendments and/or components in horticultural substrates.

ACKNOWLEDGEMENTS

The authors would like to thank Odile Douillet from UMR SAGAH for technical assistances.

REFERENCES

Abid N, Sayadi S 2006. Detrimental effects of olive mill wastewater on the composting process of agricultural wastes. Waste Manage. 26, 1099–1107.

Bernal M P, Paredes C, Sanchez-Monedero M A, Cegarra J 1998. Maturity and stability parameters of compost prepared with a wide range of organic wastes. Bioresour. Technol. 63, 91–99.

Garcıa-Gomez A, Roig A, Bernal M P 2003. Composting of the solid fraction of olive mill-wastewater with olive leaves: organic matter degradation and biological activity. Bioresour. Technol. 86, 59–64.

Hachicha S, Chtourou M, Medhioub K, Ammar E 2006. Compost of poultry manure and olive mill wastes as an alternative fertilizer. Agron. Sustain. Dev. 26, 135–142.

Herrera F, Castillo J E, Chica A F, López Bellido L 2008. Use of municipal solid waste compost (MSWC) as a growing medium in the nursery production of tomato plants. Bioresource Technology 99, 287–296.

Kammoun-Rigane M, Mnif T, Medhioub K 2008. Composts de déchet organiques agricoles : évaluation des propriètés physicochimiques et potentiel agronomique. Congrès International Gestion des Déchets Solides & développement Durable du 27 au 30 Mars 2008 Hammamet-Tunisie, GDSDD'08: 121-126.

Kammoun-Rigane M, Medhioub K, Mnif T 2009. Exogenous organic matter: Short-term effects on amended soil irrigated by the drips system in pilot scale. Proceedings of the 10th International Meeting on Soils with Mediterranean Type of Climate, June 22-26, Beyrout-Liban. pp. 112-115.

Kammoun-Rigane M, Michel J-C, Morel P, Medhioub K 2010. Properties of Tunisian wastes composts assessment for use as components in soilless substrate. Proceedings of the Soil Fertility and Crop Nutrition Management in Mediterranean Organic Agriculture, March 23-25, Sousse-Tunisia, pp XX

Mustin M 1987. Le Compost : Gestion de la Matière Organique. Dubusc, F. (Ed.), Paris, pp. 117–263.

Papafotiou M, Phsyhalou M, Kargas G, Chatzipavlidis I, Chronopoulos J 2004. Olive-mill wastes compost as growing medium component for the production of poinsettia. Scientia Horticulturae 102 167–175.

Paredes C, Bernal MP, Roig A, Cegarra J 2001. Effects of olive mill wastewater addition in composting of agroindustrial and urban wastes. Biodegradation 12, 225–234.

Paredes C, Cegarra J, Bernal MP, Roig A 2004. Influence of olive mill wastewater in composting and impact of the compost on a Swiss chard crop and soil properties. Environ. Int. 31, 305–312.

Sellami F, Jarboui R, Hachicha S, Medhioub K, Ammar E 2008. Co-composting of oil exhausted olive-cake, poultry manure and industrial residues of agro-food activity for soil amendment. Bioresource Technol. 99, 1177–1188.

Tejada M, Gonzalez JL 2003a. Effects of foliar application of a byproduct of the two-step olive oil mill process on maize yield. Agronomie 23, 617–623.

Urrestarazu M, Martínez GA, Salas MC 2005. Almond shell waste: possible local rockwool substitute in soilless crop culture. Sci. Hortic. 103, 453–460.

Zhang Y, He Y 2006 Co-composting solid swine manure with pine sawdust as organic substrate Bioresource Technol. 97 (2006) 2024–2031