CEST 2023

18th International Conference on Environmental Science and Technology

Athens, Greece, 30 August to 2 September 2023

Composting Animal Mortalities: An effective method for Agro-Silvo-Pastoral Systems utilizing natural zeolite

KAVASILIS S.[1,*], DOULA M.K.[2], ZORPAS A.A.[1], CAMBANIS L.[3]

[1]Laboratory of Chemical Engineering and Engineering Sustainability, Faculty and Pure of Applied Science, Open University of Cyprus, Giannou Kranidioti 39, 2236, Latsia, Nicosia, Cyprus

[2]Laboratory of Non Parasitic Diseases Soil Resources and Geoinformatics, Benaki Phytopathological Institute, Stefanou Delta 8, Kifissia, Athens, 14561, Greece

[3]L. Cambanis S.A., Ifigenias 81, Nea Ionia, Attica, 14231, Greece

*corresponding author: Stamatis Kavasilis
e-mail: stamarg@otenet.gr

Abstract. Animal mortalities management is a challenging and ecologically concerning issue in Agro-Silvo-Pastoral systems. Conventional methods used are not environmentally friendly, are likely to disperse disease to human and animals and do not promote the circularity of livestock units. The absence of national and European legal frameworks further compounds the problem, largely due to pathogen concerns. Composting animal mortalities as an innovative solution in Europe can address these challenges by safeguarding natural resources, reducing pollution, and enhancing soil organic carbon and nutrient recycling. This study proposes a composting methodology for managing animal mortalities and green wastes (prunings), offering significant benefits to Agro-Silvo-Pastoral systems. Two composts were prepared using sheep mortalities and green wastes (GWs). Clinoptilolite (natural zeolite) was added to one of the two composts to improve the properties of the final product. Comparing compost properties with EU standards for safe compost use as soil amendments indicates that the zeolite-compost can be freely utilized for plant growth, land rehabilitation, and carbon sequestration without any limitation. The research findings demonstrate advantages for Agro-Silvo-Pastoral systems, including improved mortalities management, enhanced soil properties, and increased soil organic matter content.

Keywords: Composting, animal mortalities, green wastes, clinoptilolite, circular economy.

1. Introduction

Management of animal mortalities is a crucial aspect for the sustainability level of a livestock farm. A natural mortality rate of these animals is about 4% (SAFFR, 2005). In addition, many animals die or are killed en masse during disease outbreaks or natural disasters, resulting in the generation of huge amounts of carcasses, which are mainly managed through unacceptable practices.

Burial, rendering and incineration are the typical carcass management methods, although they are not practical for the farmers (Morse et al., 2001).

Burial is the most common method to manage animal mortalities, which, however, causes detrimental effects in the surrounding environment (Dick et al., 2018). Naturally decayed bodies cause rapid changes in soil composition as well as on the quality of water and air. (Kim et al., 2017). The potential leaching of harmful nitrogen and sulfur compounds from carcasses to ground water is an issue of concern (Kalbasi et al. 2005). The resultant leachate is characterized by high BOD5, ammonium, phosphorus, chloride and total dissolved solids (TDS), which have been identified as potential sources of ground- and surface-water contamination (MacArthur et al., 2003; Pratt, 2009). In addition, carcass burial may generate various environmental and health hazards such as odor nuisance and also insects and scavengers attraction. Pathogens, which may still be present in the decomposed material, can spread diseases in soil, plants, animals and humans (Bonhotal et al., 2014; Costa et al., 2019; Kalbasi et al., 2005). According to Bonhotal et al. (2014), the euthanized animals with sodium pentobarbital, is possible to attract scavengers and become intoxicated or die if allowed to feed on them.

Rendering is a heat-driven process through which the entire carcasses are converted into valuable materials (Gooding et al., 2016). In Greece, the small number of rendering plants and the high cost of the process are significant obstacles.

Incineration is the most common method for managing animals suspected of being infected by Transmissible Spongiform Encephalopathy (TSE) or when TSE has been officially confirmed. The high moisture content of the carcasses results to high energy costs that make incineration infeasible for routine, large-scale management. Moreover, transporting animal mortalities to incineration facilities introduces biosecurity risks. Pathogens, which may still be present in the carcasses, can spread diseases in animals and humans, due to the longtime exposure and the use of equipment, machinery and farm vehicles (Bonhotal et al., 2014;, Costa et al., 2019).

Composting is an odor-free procedure as well as an environmentally sound method, especially in areas with shallow aquifers. The final product is a high-value soil amendment which improves the on-farm nutrients recycling. Composting is not an intensive method; is cost-effective, requiring low to moderate startup costs and minimal operating costs; it utilizes readily available organic materials and requires only good management and minimal training (AARD, 2011; Bonhotal et al., 2014; Kalbasi et al., 2005).

Natural zeolites, such us clinoptilolite, have been used as additives to composts, while soil application indicated that zeolite-amended composts are more effective than un-amended ones (Van Herwijnen et al., 2007). Clinoptilolite is characterized by high Cation Exchange Capacity (CEC), very good sieving properties, high water holding and odor minimization capacity, while it acts as slow-release fertilizer, gases and heavy metals absorber (Doula et al., 2018; Zorpas et al., 2008, Zorpas, 2009).

The aim of this study is to develop a composting methodology as an optimum option to manage animal mortalities and GWs with high lignin content and, also to assess the level of safety and effectiveness of the proposed composting methodology in terms of pathogens and nutrients content of the final products. The addition of clinoptilolite to the feedstock was also studied to assess potential improvement of compost's final properties.

2. Materials and methods

2.1. Feedstock

The mortalities used were 4 adult females sheeps, of about 7-8 years old and 50-55 kg each, which were purchased after slaughter and before skinning from a legal slaughterhouse. The mortalities were used without being chopped or making additional incisions to their bodies, while none of vital organs or wool were removed. GWs originated from Xerophytic Mediterranean Vegetation (e.g., Pistacia lentiscus, Cupressus sempervirens, Olea europea etc.), while small amounts of soft plant tissues (e.g., leaves of Platanus orientalis, Pinus halepensis, Ligustrum vulgare) were also used. The GWs were used after crumbling by a shredder. Clinoptilolite comes from Bulgaria and purchased from Imerys Minerals Bulgaria AD. Clinoptilolite's texture was <0.8 mm.

Composting took place in Attica Region, Greece. Before the experimentation period, a cement floor was constructed. Due to dry-warm environmental conditions, the moisture of GWs was approximately 4,5% and therefore, additional water was added by using a hose. Then, 2 compost piles (No1 and No2) were prepared by adding materials in layers; the first layer was prepared using wheat straw (ca. 2 m x 2 m x 0.3 m), while the second one using ca 1.5 m^3 of GWs. These two layers, apart from belonging to the feedstock materials, had also the role of adsorbing leakages generated during composting. Thereafter, two sheep mortalities were placed on each pile, parallel to each other and approximately 50 cm above the cement floor. Finally, the mortalities were covered with approximately 3 m^3 of GWs. The final dimensions of the compost piles were 2 m x 2 m x 1.3 m (ca. 5 m^3). Wheat straw bales were placed around the piles for preventing odors and deterring predators and scavengers. To study the impact of clinoptilolite and the potential benefits to the final products, one treatment was implemented by adding clinoptilolite at a percentage of 5% in layers.

2.2. Composting

Composting process lasted 220 days and the temperature increased up to 61-66^oC. Volume reduction of compost materials was approximately 60%. Due to the specific nature of the feedstock material, piles were not turned for the first 116 days, (1st heat cycle), while the second turning took place on day 174 (end of the 2nd heat cycle) and the third on day 228, just to confirm the end of the composting process (Figure 1). At the end of the procedure only some resistant bones were still visible e.g., heavily ossified bones, skull parts, teeth. Watering of the piles took place on days 0, 20, 22 and 32 by using a hose. However, it was observed that this was not an effective method due to the low rate of water adsorption by the raw materials. Therefore, a drip irrigation system was installed. For this, a drip line 16 mm in diameter with self-compensating embodied drippers (3 drippers m^{-1}, discharge rate 2 L/h) were placed above the piles. Four drip lines were crossing each compost pile. Thereafter, watering took place on day 42 by adding 240 L of water to each compost pile over a time span of 5 hours. On days 43, 44, 51, and 60, each pile received 480 L water over a time span of 10 hours (Figure 1).

3. Results and discussion

Composting animal mortalities by exploiting GWs (prunings) from municipalities and natural zeolite (clinoptilolite) under the Mediterranean climate conditions could be an effective and environment friendly method to manage mortalities and GWs, as well as to promote circular economy of livestock units. Watering by a drip irrigation system is the optimum way to increase moisture content of the piles at the optimum levels. Composting procedure by using 2 sheep mortalities (about 100-110 kg) needs 180-210 days and includes 3 heat cycles to be completed (Figure 1). The GWs, the clinoptilolite and the straw bales placed around the compost piles ensured an odorless procedure, as well as deterring of scavenging animals. The composts produced are of high nutritional values and complies with most of the European and US Standards (Table 1). The addition of clinoptilolite in the feedstock improves the properties of the compost (maturity, nutrients content, germination index, pathogens etc.). The heavy metals concentration for all composts fulfills the EU Ecolabel Criteria for Soil Improvers and Growing Media, as well as the criteria for use in vegetable production and other production systems according to the US National Organic Program (Table 1). Moreover, the germination index shows that the produced zeolite-compost mixtures can be used as growing media for many plant species. Although most of pathogens were extinguished during composting, yet, the presence of Enterobacteriaceae was not eliminated (Table 1). However, the compost prepared using zeolite, have ca 680-fold lower concentration of Enterobacteriaceae than the compost prepared without the addition of zeolite, due to the well-known antibacterial activity of clinoptilolite especially against Gram-positive and Gram-negative bacteria.

Table 1. Properties of mature composts and green wastes (dry weight basis)*

Parameter	GWs	C1	C2	EU Threshold	US Threshold	FAO Threshold
Moisture (%)	4.5 ±0.0	34.8 ±1.7	27.3 ±0.9		30-60[vii]	30-40[i]
pH	6.64 ±0.04	8.00 ±0.05	7.53 ±0.03	4.0-9.0[ii]	5.0-8.0[vii]	6.5-8.0[i]
EC (mS cm^{-1})	2.04 ±0.05	1.23 ±0.02	0.94 ±0.01	≤1.9[ii]	≤6.0[vii]	
Total salts (g/L)	1.2 ±0.1	0.6 ±0.1	0.5 ±0.1	<2.0[iii]		
Organic matter (%)	93 ±3	51 ±2	49 ±2	≥15[ii]	40-60[vii]	>20[i]
Total C (%)	52	29	28	≥15[iv]		
Total N (%)	0.40 ±0.01	1.3 ±0.1	1.9 ±0.1	≥1[iv]	0.5-6.0[vii]	0.3-1.5[i]
C:N	121	22	15		10-25[vii]	10-15[i]
Total P (%)	0.10 ±0.02	0.50 ±0.05	0.40 ±0.03	≥1[iv]	0.2-3.0[vii]	0.1-1.0[i]
Total K (%)	1.0 ±0.1	1.2 ±0.1	1.6 ±0.1	≥1[iv]	0.1-3.5[vii]	0.3-1.0[i]
Total NPK (%)	1.5	3.0	3.9	≥4[iv]		
Total Ca (%)		7.0 ±0.3	5.5 ±0.2		1.5-3.5[v]	
Total Mg (%)		0.37 ±0.03	0.53 ±0.06		0.25-0.70[v]	
Total Na (%)		0.03 ±0.01	0.13 ±0.01		<0.6[v]	
Total S (%)		<0.01	<0.01		0.25-0.80[v]	
Total NO3- (mg kg^{-1})		56 ±6	40 ±3			
Total NH4+ (mg kg^{-1})		37±1	15 ±1		<75: very mature / 75-500: mature / >500: immature[v]	
Nitrification index		0.7	0.4		<0.5: very mature / 0.5-3.0: mature / >3.0: immature[vi]	
Total B (mg kg^{-1})		83 ±3	62 ±2	<100[iii]		
Total Fe (%)		0.80 ±0.11	0.73 ±0.05			
Total Cu (mg kg^{-1})		21 ±1	16 ±1	<100[vi]	<450[vii]	
Total Zn (mg kg^{-1})		63 ±3	51 ±4	<300[vi]	<900[vii]	
Total Mn (mg kg^{-1})		214 ±17	302 ±20			
Total Cd (mg kg^{-1})		<0.5	<0.5	<1.0[vi]	<15[vii]	
Total Pb (mg kg-1)		5.2 ±0.1	5.2 ±0.2	<100[vi]	<300[vii]	
Total Ni (mg kg-^{1})		34 ±1	25 ±0.2	<50[vi]	<50[vii]	
Total Cr (mg kg^{-1})		32 ±1.1	22 ±1	<100[vi]		
Total As (mg kg^{-1})		4.7 ±0.3	3.6 ±0.1	<10[vi]	<41[vii]	
Total Hg (mg kg^{-1})		0.10 ±0.05	0.20 ±0.01	<1[vi]	<17[vii]	
CEC (cmol kg^{-1})		55 ±3	76 ±6			
Polyphenols (g kg^{-1})	4,9 ±0.1	0.03 ±0.01	0.02 ±0.01			
Germination index (%)	0.4 ±0.2	74.9 ±2.4	104 ±4	≥80[ii]		
Stability "Rottegrad"		V	V	V[vi]		
Enterobacteriaceae (CFU/g)		1000000 ±30000	1400 ±100	1000 CFU/g fwiv		
Salmonela spp (+/-25 g fw)		Absent	Absent	Absent in 25 g fw[iv,vi]	<3MPN/4g	
Escherichia coli (CFU/g fw)		<10	<10	1000 CFU/g fw[iv,vi]		
Total Aerobic Microbial Counts (CFU/g)		28.2E+06 ±1.2E+06	27.5E+06 ±0.9E+06			

*± indicates the standard deviation of the data, n=4

i FAO, 2015; ii ECN, 2018; iii AMAF, 1993; iv EU Regulation, 2019; v OSU, 2018; vi EU JRC, 2015; vii USNOP, 2017

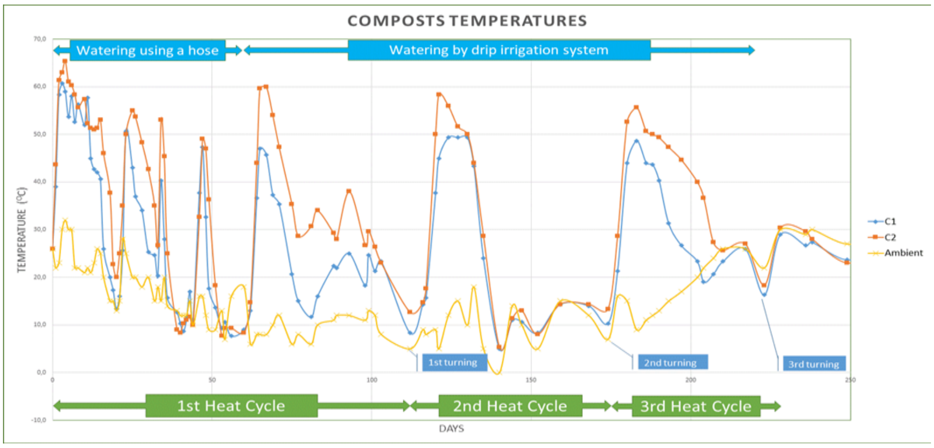

Figure 1. Average temperatures and heat cycles of the 2 experimental treatments, turnings and watering schedule.

References

AARD (2011), Large animal mortality composting, Alberta Agricultural and Rural Development, Alberta Government, Agdex 400/29-4, Canada.

AMAF (1993), Kompostqualität: Anwendungsformern-Güteklassen (Compost Quality - Application Classes) in Handbuch der Kompostierung, Austrian Ministry for Agriculture and Forestry, Vienna, Austria.

Bonhotal J., Schwarz M. and Rynk R. (2014), Composting animal mortalities, Cornell Waste Management Institute, Department of Crop and Soil Science, Ithaca NY, USA.

Costa T. and Akdeniz N. (2019), A review of the animal disease outbreaks and biosecure animal mortality composting systems, Waste Management, **90**, 121–131.

Dick H.C. and Pringle J.K. (2018), Inorganic elemental analysis of decomposition fluids of an in situ animal burial, Forensic Sci. Int., **289**, 130-139.

Doula M.K., Elaiopoulos K., Kouloumbis P. and Zorpas A.A. (2018), In situ application of clinoptilolite to improve compost quality produced from pistachio bio-wastes, Fresenius Environmental Bulletin **27** (3), 1312-1318.

ECN (2018), Guidelines – Specification for the Use of Quality Compost in Growing Media, European Quality Assurance Scheme, ECN-QAS, Part D.

EU JRC (2015), Revision of the Ecolabel Criteria for soil Improvers and growing media, JRC science for policy report, European Commission.

EU Regulation (2019), Laying down rules on the making available on the market of EU fertilising products and amending, Regulations (EU) 2019/1009.

FAO (2015), Farmers Compost Handbook, Food and Agriculture Organization of the United Nations.

Gooding C.H. and Meeker D.L. (2016), Review: Comparison of 3 alternatives for large-scale processing of animal carcasses and meat by-products, The Professional Animal Scientist **32**, 259-270.

Kalbasi A., Mukhtar S., Hawkins S.E. and Auvermann B.W. (2005), Carcass Composting for Management of Farm Mortalities: A Review, Compost Science & Utilization, **13 (**3), 180-193.

Kim H.H., Seo J., Kim T.H., Shim B., Cha S.M. and Yu S. (2017), Pyrosequencing-based assessment of microbial community shifts in leachate from animal carcass burial lysimeter, Science of the Total Environment, **587-588**, 232-239.

MacArthur A.J., Milne J.C. and Young P.J. (2003), Leachate characteristics arising from the foot and mouth mass burial site in Scotland, 9th International Waste Management and Landfill Symposium, Sardinia, Italy.

Morse D.E., Friendshuh K., Hanks M., Iwan R. and Schmidt D. (2001), Composting Animal Mortalities, Minnesota Department of Agriculture, Agricultural Development Division, Minnesota, USA.

OSU (2018), Interpreting Compost Analyses, Oregon State University, USA.

Pratt D.L. (2009), Environmental impact of livestock mortalities burial (Master Dissertation), University of Saskatchewan, Saskatoon, Canada, 117.

SAFRR (2005), Composting animal mortalities: A producers's guide, Saskatchewan Agriculture, Food and Rural Revitalization, Regina, Canada.

USNOP (2017), Guidelines for assessing compost quality for safe and effective utilization in vegetable production, US National Organic Program.

Van Herwijnen R., Hutchings T.R., Al-Tabbaa A., Moffat A.J., Johns M.L. and Oukia S.K. (2007), Remediation of metal contaminated soil with mineral-amended composts, Environmental Pollution, **150** (3), 347-354.

Zorpas A.A. and Loizidou M. (2008), Sawdust and natural zeolite as a bulking agent for improving quality of a composting product from anaerobically stabilized sewage sludge, Bioresource Technology **99** (16), 7545-7552.

Zorpas A.A. (2009). Heavy metals leachability before, during and after composting of sewage sludge with natural clinoptilolite, Desalination and Water Treatment **8** (1-3), 256-262.