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Hydrophysical, chemical and microbial properties of imported green waste composts

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Abstract. *El-Nagerabi SAF, Elshafie AE, Alburashdi H. 2014. Hydrophysical, chemical and microbial properties of imported green waste composts. Nusantara Bioscience 6: 13-18.* The aims of this research were to study the hydrophysical, chemical and microbial properties of the imported green waste composts (GWCs) and their suitability as an alternative to agrochemicals, four types of GWCs (Florabella, Mikskaar, Potgrond, and Shamrock) were selected. All composts showed normal physical properties, except weed seeds in Shamrock. The germination indexes comparable to the standard (90%) were 100% for Mikskaar followed by Florabella (97%), Potgrond (95%), and Shamrock (92%). Variations in physicochemical properties were shown as acidic pH 5.1-6.5 (standard 5-8), electrical conductivity (EC) 0.8-1.8 $mScm^{-1}$ (standard 0.0-4.0 $mScm^{-1}$), moisture content (MC) 54-70.5% (standard 35-60%) and water holding capacity (WHC%) 400-800%. The chemical properties were expressed as ammonia concentrations 2871-6565 mg kg^{-1} (standard <500 mg kg^{-1}), organic matter 53.3-66.2% (standard 35%). The concentrations of heavy metals (Zn, Ni, Pb, Hg, As, Cd, and Cr) were lower than the recommended levels. The bacterial colony forming unit per gram compost ranged between 330-2870 cfu/g, the most probable number (MPN) for coliform bacteria was 23-460 cfu/g, whereas the fungal cfu were 30-1800 cfu/g. *Aspergillus niger* was the predominant fungus recovered from all compost samples (100%), followed by *A. fumigatus* (75%), whereas *A. sparsus*, *A. versicolor* and yeasts (50%), and the remaining species of the genus *Acremonium* sp., *Aspergillus flavus*, *A. restrictus*, *Cladosporium* spp., and *Penicillium* spp. recovered from 25% of the samples. Generally, these composts revealed normal hydrophysical properties with obvious variation in moisture contents and elevated chemicals and microbial contamination. Therefore, there is an urgent need for quality control measurements and restrict abide to legislations and quarantine regulations.

Keywords: *Aspergillus niger*, coliform bacteria, green waste composts, heavy metals, most probable number, Oman

INTRODUCTION

Composts are produced by microbes and other organisms decaying of organic matter in warm and moist conditions (Salvator and Sabee 1995; Adeniran et al. 2003; Adegunloye et al. 2007; Briancesco et al. 2008). Green waste compost (GWC) is a biodegradable waste originates from almost pure plant materials such as garden trimming or garbage from vegetable and fruits (Wilson 1983; Anon 1997; Christensen et al. 2002). It improves the biological, and physic-chemical properties of the soil (Christensen et al. 2002; Dalal et al. 2009; Hartley et al. 2009), enhanced plant growth (Straatsma et al. 1994; Keeling et al. 2003; Ali et al. 2007), remediates contaminated soil (Van Herwijnen et al. 2007, 2008; Alvarenga et al. 2009; Hartley et al. 2009), and inhibits some soil-borne disease (Van der Gaag 2007; Lozano et al. 2009).

The modern mechanized agriculture depends on the application of large amounts of expensive and non-ecofriendly chemical fertilizers, pesticides, and herbicides which increase crop production. Nonetheless, they destroy the diversity of biota and hazardous to human health (Khan et al. 2007). These are logistic and justifiable reasons to compost needs and importation. Therefore, attention has been directed to the safe compost industry for both environment and public health. Thus, quality control of the composts is significantly important to promote the recycling of the organic wastes (Harada et al. 1993; Brinton 2000). It must comply with national and international compost standards (Anon 1997, 2002a, 2002b). These include moisture content, odor, carbon and nitrogen contents, phytotoxic substances, harmful elements, weeds, nutrient contents, plant pathogens and effectiveness to plant growth and soil amendment (Harada et al. 1993). They can be maintained by maturation of the compost which reflects the degree of transformation of the organic materials (Mondini et al. 2003). No single method can be adapted universally to all compost types due to the wide range of feedstock, the composting process (Barberis and Nappi 1996; Chen et al. 1996; Itävaara et al. 2002), and different chemicals in organic wastes (He et al. 1995; Benito et al. 2003). On the other hand, pathogens are generally present in sewage and household wastes which are commonly composted (Pahren 1987). This composting is an efficient method for pathogen destruction to a safe level for humans, animals, and plants (Christensen et al. 2002; Dumontet et al. 1999; Van der Gaag 2007).

In Oman, land is the major non-renewable resource facing the threat of soil degradation. Sustainable agriculture must be environmentally safe and produces adequate amount of quality foods with minimum fertilizers and rely mainly on the renewable resources of the farm itself (Khan et al. 2007; Chitravadivu et al. 2009). This is especially important for 90% of the farms in the third world, where agricultural inputs are often not available or affordable (Chitravadivu et al. 2009). Thus, compost is one of the inputs for meeting nutrient requirements of crops (Zameer et al. 2010). In Oman, green waste composts are imported from other countries under weak quarantine regulations with high cost and economic burden to the local farmers. There is an urgent need for development of strong legislation, analytical methods and well-equipped entry points for controlling the import and export processes of the compost. Therefore, the present study was conducted to evaluate the hydrophysical, chemical and microbial properties of imported green waste composts to determine their suitability for different uses and ability to meet the standard of agrochemical properties.

MATERIALS AND METHODS

Compost samples collection

Four imported green waste composts namely Florabella, Mikskaar, Potgrond, and Shamrock were selected and drawn according to the Gulf standard number GS0901/1997 (Anon 1997). Five samples of 1 kg each were collected from the compost bags, mixed to form composite samples and were then divided into 4 working samples and stored at 5◦C for further study.

Hydrophysical characterization

The samples were visually inspected for free-flowing, hard lumps, objectionable odor, and color. The particle size of the composts was determined according to the Gulf standard number GS01167/2002 using three replicates of 100 g oven-dried samples (Harada et al. 1993). The samples were placed on 12 mm sieve and shaken for 5 min at 100 shakes per min (Abd El-Hady and El-Dirdiry 2006). The percentage of the particles greater than 12 mm was calculated as the percent mass of the remaining materials on the top of the sieve to the mass of the original sample (Orozco et al. 1997).

For phytotoxicity and the presence of the viable seeds (El-Nagerabi et al. 2012), 6 plastic pots (10 × 15 cm) were filled with the compost samples. Three pots were seeded with 100 seeds of *Phaseolus mungo* (mung bean) and the remaining three pots were kept without seeds. As a control, another 100 seeds of mung bean were inoculated into plastic trays with moistening cotton and incubated in the greenhouse of the Biology Department, Sultan Qaboos University. The inoculated seeds were moistened and examined for the presence of the weed seeds and germination of the mung bean seeds.

The hydrogen ion concentration (pH), moisture contents (%), electrical conductivity (EC), and water holding capacity (WHC%) of the composts were detected using basic standard procedures and techniques (Wilson 1983; El-Nagerabi et al. 2012). The pH was determined in triplicate with the pH meter. The moisture content was determined by the oven method (El-Nagerabi and Elshafie 2000). Replicates of 10 g were placed in glass Petri dishes; soft lumps were crushed with spatula and dried at 105◦C in an electric oven for 16 hours. The moisture content was determined as percentage of the initial weight.

For electrical conductivity (EC), replicates of 2 g of each compost sample were added to 5 ml of distilled water and the mixture was filtered through Whatman filter paper No. 42 (Whatman International Ltd, Maidstone, UK). The EC for each filtrate was measured by electrical conductivity meter.

For of the water holding capacity (WHC%), 500 g from each sample was added to pre-weighed dry sieve and pressed evenly, saturated with water, kept covered for overnight, and then the dripped water was wiped off the sieve with fine tissues. The sieve with the moistened sample was weighed, placed in desiccators, allowed to dry, and re-weighed to calculate the amount of water held by the samples. The WHC was calculated as the percentage mass of the absorbed water to the mass of the dried sample according to the Gulf standard No. GS01/2002 (Anon 2002a,b).

Chemical analysis

The compost samples were stored in polyethylene bags and the chemical analyses started within 48 hours after the sample collection. The organic matter (OM) was determined by measuring the loss of mass through ignition at 550◦C according to the modified combustion method (Inbar et al. 1990; Christensen et al. 2002; Petrus et al. 2009), which adopted by the Gulf standard NO. GSO1167/2002 (Anon 2002a,b). From each sample, 10 g were used instead of 5 g in order to increase the degree of the method accuracy. The samples were dried to constant mass in an oven at 105°C and cooled in desiccators to avoid moisture absorption from the atmosphere. Ten grams of each sample was kept into an oven-dried porcelain dish, placed in the furnace, then the temperature was increased to 550◦C, and samples were converted into ash. The percentage of the organic matter was calculated in triplicates as a percentage loss of mass to the mass of the original test sample.

The ammonia-nitrogen contents were determined in triplicate using the Kjeldahl method (Kjeltec Foss, Tecator AB, Hogana, Sweden, N-Analyzer). For this, 0.5 g from each sample and one keltab catalyst (SeK_2SO_4) were added to digestion tube, mixed with 10 ml of sulfuric acid, digested for 3 hours, allowed to cool and the concentration of the ammonia was measured.

For the heavy metals concentrations, 5 g from each sample were mixed with 25 ml of distilled water, filtered with Millipore filter papers, and 10 ml of the filtrate were analyzed with Inductive Couple Plasma (ICP-MS, OPTIMA, 3100RL Spectrometer, Perkin Elmer, and Norwalk, USA) (Khan et al. 2007).

Enumeration of fungi and bacteria by agar plate technique

Both fungi and bacteria were isolated from the compost using the agar plate method. One gram from each sample was added to 9 ml sterile distilled water, vortexed, and serial dilutions were prepared. One ml was aseptically inoculated on Potato Dextrose Agar (PDA) for fungal growth at 28◦C, for 7 days, and similarly Nutrient Agar (NA) was inoculated for bacterial growth at 37◦C, for 48 hours. After incubation, the number of colony forming units (cfu) per gram was calculated. The isolated fungi were identified using different taxonomic books and monographs (e.g., Raper and Fennell 1965; Pitt 1979; Ellis 1971, 1976; Sutton 1980; Samson et al. 1995; Barnett and Hunter 1998, 2003). The presence of coliform bacteria in the compost samples was screened using the standard table of the most probable number (MPN).

Statistical analysis

Duncan's multiple ranges and one way ANOVA were used to compare between the four composts with $p<0.05$. The analysis was carried out using statistical package software SPSS (version 11.0).

RESULTS AND DISCUSSION

Physical properties of the composts

Table 1 shows the physical characteristics of the four composts. Visually all the samples were physically uniform, free-flowing, no hard lumps, dark brown to black in color, free from objectionable odor, and with particle size less than 12mm, except one viable weed seed in shamrock. It indicates the good quality of the composts, the completion of the degradation process and compost maturity as suggested by many authors (Iglesias-Jiménez and Pérez-Garcia 1992; Benito et al. 2003; Lozano et al. 2009). Nonetheless, the presence of viable weed seeds may be associated with compost immaturity and there is a high possibility for disseminating weeds (Iglesias-Jiménez and Pérez-Garcia 1992).

Seed germination indexes in compost are biological method to evaluate the degree of the compost maturity of the composted materials. It shows the degree of the decomposition of phototoxic substances such as ammonia and acids produced during the early active composting stages (He et al. 1995; Wu et al. 2000). In the present study (Table 1), the germination percentages of the mung bean seeds in the four compost types ranged between 92-100%. The germination level lower than the acceptable index (>90%) can be attributed to the phytotoxic effects of the organic acid and ammonia toxicity produced during the active composting process (Wong 1985; Wu et al. 2000). In the present study, the ammonia concentration in the four composts ranged between 2871-656.5 mg kg^{-1} (Table 3). Similarly, the electrical conductivity (EC) which indicates the salt contents of the compost, is injurious to plant roots and prevents their growth (Cai et al. 2010). Therefore, higher level of bean seed germination may be due to acceptable electrical conductivity for Mikskaar (0.4 $mScm^{-1}$), Shamrock (1.8 $mScm^{-1}$), Potgrond (0.8 $mScm^{-1}$), Florabella (1.2 $mScm^{-1}$), which ranged within the standard limit (0-4 $mScm^{-1}$) and not harmful to the plant growth. Nonetheless, the high salt contents in the compost are associated with the high electrical conductivity and will be added to the receiving soil as beneficial to the plant growth and soil remediation. In similar studies, it was found that the electrical conductivity varies considerably and ranged between 0.12-17.08 $mScm^{-1}$ (Tang 2003). This wide range of electrical conductivity expressed the diversity of the chemical and microbial properties of the various compost products. This suggests mixing compost with vermiculite or adding less compost to the soil of low salt contents to adjust the optimum growth conditions of the amended soil.

Hydrophysical properties of the compost

The hydrogen ion concentration (pH) varies at the beginning of composting and ramped from 7.3 to 7.7 as the composting proceeded up to 8.8-9.6 (Adegunloye et al. 2007). The pH of the screened compost (5.1-6.4) was found to be within the recommended limit (Anon 1997, 200a, 200b; Alvarenga et al. 2009). This acidity of the composts may be due to the production of phytotoxic organic acids during immature composting, which causes immediate growth injuries (Wong 1985). Thus, the addition of this compost to soil may modify the pH of the final mix and buffer the soil pH (Adegunloye et al. 2007).

The moisture contents of the composts ranged between 3.1-82.7% and varied considerably with the variation in the composted materials (Tang 2003). The moisture content of the compost was considerably higher in the first 3 weeks of composting and increases significantly in the later weeks (Adegunloye et al. 2007). Therefore, the addition of compost provides excellent drought resistance and great efficient water retention. In the present study (Table 2), the moisture contents of these composts (64-74%), which were higher than the acceptable limits (35-60%). The moisture content of between 50-60% was considered as the optimal level for further composting (Tiquia et al. 1996). Nonetheless, the compost with higher moisture content will inhibit aerobic degradation (shouldn't' be decomposed any more) and enhanced the unpleasant odor from the growth of anaerobic sulfate-reducing bacteria. Yet, the ideal moisture content depends on the potential uses of the compost.

Water retention capacity of the substrate is generally considered as the quality determining factor (Abd El-Hady and El-Dirdiry 2006). The highest saturation of the compost is 75% and the good compost must have high water holding capacity and low filtration rate for supporting the plant growth. In the present study (Table 2), the water holding capacity (WHC%) of the tested composts was found to be more than four to eight times their actual weight. The water holding capacity ranged from 400-800%. Therefore, these composts can be used separately or mixed with sandy soil with low water holding capacity if they satisfied the other quality control parameters and the essential plant growth requirements.

Chemical properties of the compost

The chemical properties expressed the diversity of various compost products and the raw materials used (Tang 2003). The total carbon content (TC) was in the range of between 16.9-51.0%. An approximately 11-27% of the total carbon was lost during the 7 days of active composting, and 62-66% during the whole composting time (Vuorienin and Saharinen 1997). Table 3 shows the total organic matter for tested composts (53.5-66.2%) is significantly higher than the standard set by the Gulf countries (35%, optimum 40-60%) (Anon 1997). The high organic matter contents of the compost indicate the presence of uncomposted organic materials which can be degraded slowly by microorganisms and eventually used by higher plants (Bary et al. 2002).

Table 1. Physical properties of the imported green waste composts

Properties	Composts types			
	Florabella	Mikskaar	Potgrond	Shamrock
Free flowing	+	+	+	+
Hard lumps	-	-	-	-
Objectionable odor	-	-	-	-
Normal color	+	+	+	+
Particle size (<12 mm)	+	+	+	+
Foreign viable weed seeds	-	-	-	+*
Germination of bean seed%	98	100	95	92

Note: * Presence of only one germinated weed seed.

Table 2. Hydrophysical properties of the imported green waste composts

Properties	Compost types				Standards
	Florabella	Mikskaar	Potgrond	Shamrock	
Hydrogen ion concentration (pH)	5.2C*	6.4A	5.6B	5.1C	5-8
Electrical conductivity ($mScm^{-1}$)	1.2B	0.4D	0.8C	1.8A	0-4
Moisture content (%)	65C	74A	70.5B	64C	35-60
Water holding capacity (%)	400D	646C	800A	757B	100

Note: *Within rows, number with different upper case letters differ significantly ($P<0.05$).

Table 3. Chemical properties and heavy metals concentration (ppm) of the imported composts

Properties	Compost types				Standards
	Florabella	Mikskaar	Potgrond	Shamrock	
Ammonia (mg/kg)	4452.3c*	6179b	2871d	6565a	<500
Organic matter (%)	53.3b	64a	66.2a	65a	35
Copper (Cu)	0.05c	0.08b	0.12a	0.06bc	150-250
Nickel (Ni)	0.02a	0.03a	0.03a	0.03a	50-70
Lead (Pb)	0.01a	0.03a	0.03a	0.02a	120-150
Cadmium (Cd)	0.08a	0.03b	0.03b	0.02b	3-5
Arsenic (As)	0.04a	0.03a	0.05a	0.04a	15-25
Chromium (Cr)	0.45c	0.50b	0.19d	0.57a	100-150
Zinc (Zn)	30.0c	79.4b	120.3a	120.7a	350-500
Mercury (Hg)	0.00591a	0.00591a	0.00591a	0.00592a	1.5-3

Note: *Within rows, number with different lower case letters differ significantly ($P<0.05$).

Table 4. Microbial properties of the imported green waste composts

Properties	Compost types			
	Florabella	Mikskaar	Potgrond	Shamrock
Bacteria (cfu/g)	2870A*	2580B	1720C	330D
Fungi (cfu/g)	200C	270B	1800A	30D
MPN (cfu/g)	460A	43C	240B	23D
Acremonium sp.	-	-	+	-
Aspergillus flavus	-	-	-	+
A. fumigatus	-	+	+	+
A. niger	+	+	+	+
A. sparsus	-	+	-	+
A. restrictus	-	+	-	-
A. versicolor	+	-	-	+
Cladosporium spp.	-	-	+	-
Penicillium spp.	+	-	-	-
Yeasts	-	-	+	+

Note: *Within rows, number with different upper case letters differ significantly ($P<0.05$).

Heavy metals, as harmful elements are one of the determining factors for compost quality (Harada et al. 1993). They may come from sewage water, organic waste, chicken manure, animal dung, and the soil added. They negatively affect the plant during the slow degradation process. On the contrary, compost reduces the mobility of some toxic metals to the plants through formation of some complexes. In this study (Table 3), although, there were significant variations in the heavy metals concentrations (Zn, Ni, Pb, Hg, As, Cd, Cr) the levels of these metals were lower than the limits suggested by the Gulf countries (Anon 1997), Germany (Benito et al. 2003), and Canada Food Inspection Agency (1997). Nonetheless, the high contents of heavy metals may be due to the addition of these metals to animal feeds (Harada et al. 1993) or contamination during plant growth or plants themselves (Van Roosmallen et al. 1987).

Microbial estimates of the compost

Bacteria and fungi are present in large number during composting and they are essential for slow degradation of partially decomposed organic materials (Adegunloye et al. 2007). The pathogenic fungi and bacteria were normally detected in composted household wastes, and sewage sludge (Pahren 1987). However, composting is an efficient method for destruction of pathogenic microorganisms to an acceptable level, which is safe for human, animals, and plants (Dumontet et al. 1999; Christensen et al. 2002; Van der Gaag et al. 2007). But reasonable amount of microorganisms is still present in the compost at maturity (Adegunloye et al. 2007). In the present study, the average of the bacterial colony forming unit per gram of the compost was 330-2870 cfu/g, whereas the colony forming unit of fungi in the compost was 30-1800 cfu/g (Table 4). It is evident that Florabella, and Mikskaar have the highest bacterial colonies, whereas Potgrond contains low numbers of fungal colonies. These large numbers of bacterial and fungal colonies (standard <1000 cfu/g) may be responsible for the slow degradation of the organic matter (Christensen et al. 2002; Benito et al. 2003; Souza Dias et al. 2009).

Most of the thermophilic genus and moisture tolerant *Aspergillus* species were responsible for the slow degradation of the composts. In the present study (Table 4), *A. niger* was the predominant species recovered from all compost samples (100%) at the later stage as reported by many authors (Millner et al. 1977; Adegunloye et al. 2007; Souza Dias et al. 2009). This fungus was followed by *A. fumigatus* (75%), where *A. sparsus*, *A. versicolor* and yeasts (50%), and the remaining species of the genus *Acremonium* sp., *A. flavus, A. restrictus*, *Cladosporium* spp., and *Penicillium* spp. were recovered from only 25% of the samples. In similar studies, different species of *Aspergillus* and *Penicillium* were isolated from different composts (Straatsma et al. 1994; Adegunloye et al. 2007; Souza Dias et al. 2009). Pathogenic bacteria were isolated from various composts and composted materials (Christensen et al. 2002; Adegunloye et al. 2007). Fecal coliforms found in the raw materials composed of *Escherichia coli*, wherein the finished compost the majority of the coliforms were probably of non-fecal origin (Christensen et al. 2002). In the present results, the most probable number (MPN) was used to determine the fecal contamination of the composts. Our findings (Table 4) showed that Florabella was contaminated with coliforms (480 cfu/g), followed by Potgrond (240 cfu/g), Mikskaar (7 cfu/g) and Shamrock (4 cfu/g). The presence of coliforms in Florabella and Potgrond may indicate the possible contamination of these composts with sewage water or other animal products during the composting process. Therefore, there is a high possibility of transmission of serious diseases during handling and usage of compost in addition of expected infestation of the cultivated plants with serious devastating pathogenic bacteria and fungi. Whereas compost which has undergone well controlled composting process is safe and can’t transmit serious diseases.

CONCLUSION

It is apparent that the investigated composts were visually free from physical constraints, except one viable weed seed in Shamrock which indicates compost immaturity. The composts contain high concentrations of ammonia, elevated moisture content, large amount of total organic matters, and low level of heavy metals. The composts were contaminated with variable levels of saprophytic fungi and coliform bacteria. It is evident that these composts revealed some variations in their general properties; however, it is feasible to be used for plant growth, soil biofertilizer and soil amendment as environmentally friendly products with proper adjustment of their physical-chemical and microbial properties. There is an urgent need for setting detailed legislation, regulation policies, proper testing methods, quality control measurements, and restricted quarantine regulations for export-import of the green waste composts. Attention should be given to the local production of high-quality composts which serve the environment, waste management, and recycling industry and satisfaction of the local markets.

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