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Assessing and monitoring the effects of filter material amendments on the biophysicochemical properties during composting of solid winery waste under open field and varying climatic conditions

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ABSTRACT

Waste management in winery and distillery industries faces numerous disposal challenges as large volumes of both liquid and solid waste by-products are generated yearly during cellar practices. Composting has been suggested as a feasible option to beneficiate solid organic waste. This incentivized the quest for efficient composting protocols to be put in place. The objective of this study was to experiment with different composting strategies for spent winery solid waste. Compost materials consisting of chopped pruning grape stalks, skins, seed and spent wine filter material consisting of a mixture of organic and inorganic expend ingredients were mixed in compost heaps. The filter material component varied (in percentage) among five treatments: T1 (40%) lined, T2 (20%) lined, T3 (0%) lined, T4 (40%) ground material, lined and T5 (40%) unlined. Composting was allowed to proceed under open field conditions over 12 months, from autumn to summer. Indicators such as temperature, moisture, enzyme activities, microbial counts, pH, and C/N ratio, were recorded. Generally, season (df = 3, 16, $P < 0.05$) had significant effects (df = 1, 3, $P < 0.05$) on heap temperature and moisture in all treatments. Similarly, microorganisms (actinobacteria and heterotrophs) varied significantly in all treatments in response to seasonal change (df = 3, 16; $P < 0.05$). Enzyme activities fluctuated in accordance with seasonal factors and compost maturity stages, with phosphatases, esterases, amino-peptidases, proteases and glycosyl-hydrolases being most prominent. Compared to treatments T2 and T3, compost treatments with higher percentage waste filter materials (T1, T4 and T5) had higher N (16,100–21,300 mg/kg), P (1500–2300 mg/kg), K (19,800–28,200 mg/kg), neutral pH, and lower C/N ratios (13:1–10:1), which were also comparable with commercially produced composts. Filter materials therefore, appears to be a vital ingredient for composting of winery solid waste.

1. Introduction

Recycling of organic waste is one of the successful waste treatment systems used worldwide. Wineries are increasingly using solid waste as part of the composting material. Composting of organic waste is based on the transformation of biodegradable organic material from various sources including winery waste into humic substances (Golueke, 1977; Bertran et al., 2004). It is mainly a microbial process because microorganisms through different kinds of substrate-based hydrolytic enzymes, promote the degradation of organic materials (De Bertoldi et al., 1983; Tiquia et al., 2002). These enzyme activities vary in time as a consequence of a complex sequence of microorganisms, where populations of bacteria, actinobacteria and fungi change in time depending on the specific conditions during composting evolution (Mckinley and Vestal, 1985; Tiquia et al., 2001, 2002).

While it is well- recognized that composting mimics the natural biodegradation process in soil (De Bertoldi et al., 1983) and could yield a stable end-product from biological oxidative transformation of organic wastes, there are challenges that are retarding the implementation of sustainable and efficient composting programs. Firstly, there are gaps in the current knowledge of the composting process, especially with respect to microbial and enzyme activities. Since enzyme activities vary in time depending on the specific conditions during composting evolution (Mckinley and Vestal, 1985), detailed characterization of microbial communities along the process of composting may provide valuable information regarding the evolution of the process, the rate of biodegradation and the

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measure of compost maturity. Secondly, the current composting procedures are not very efficient; hence it is important to optimize current composting protocols in order to improve on the agronomic and environmental qualities of the end-product. Many workers are investigating the potential benefits of incorporating used organic materials during composting of winery waste materials. Bustamante et al. (2010) assessed the effect of compost stability on C mineralization dynamics by applying organic materials (grape stalk, grape marc, exhausted grape marc and vinasse, with sewage sludge or animal manure) from different stages of the composting process, and results obtained showed that the addition of exogenous organic matter stimulated microbial growth, enhanced soil respiration and increased water-extractable C contents in both soils, particularly in the days immediately following amendment. A study by Doublet et al. (2011) suggested that the inclusion of bulking agents influenced the time to reach organic matter (OM) stability and the biochemical evolution of OM during composting. While many studies have looked at the enhancement effects of organic filter materials during composting, very few studies have investigated the beneficial effects of including inorganic filter materials during composting of solid agricultural wastes. Preliminary results obtained by our colleagues, Mulidzi and Shange (unpublished) suggested that the addition of filter material that consisted of inorganic and organic filter ingredients to solid winery wastes could improve composting of the latter, thus warranting further evaluations.

The objectives of this study were (i) to assess the effects of incorporating varying amounts of used filter materials (consisting of used perlite, diatomaceous earth, wine lees and effluent) with solid winery waste during composting on composting indicators such as heap temperature, microbial extracellular enzyme activity, heap moisture, C/N ratio and nutrient content, and (ii) to determine the progression of extracellular enzyme assemblages, heap temperature and moisture during composting of winery solid waste over time, with respect to the varied treatments.

2. Materials and methods

2.1. Experimental site

The experiment was carried out on a designated research plot at Agricultural Research Council Infruitec-Nietvoorbij for Deciduous Fruit, Vines and Wine, situated just outside Stellenbosch (GPS Coordinates: Latitude: −33.9262|Longitude: 18.897162) Western Cape, South Africa. The research site has dark alluvium and clay soils, which are well-drained and on a hilly terrain. The area has a Mediterranean climate, which is characterized by summers that are dry and warm to hot, and winters that are cool, rainy and sometimes relatively windy. Spring and autumn are colder seasons. These climatic conditions have been proven to be excellent for viticulture. The study was conducted from March 2013 to February 2014.

2.2. Compost material

Compost heaps were made from a combination of chopped pruning canes, grape stalks, skins and seeds (standard ingredients) from Nietvoorbij farm, and spent wine filter materials (product of drum filtration that contained perlite from Chemserve (Pty) Ltd and wine lees waste and diatomaceous earth from the Douglass Green (located in Wellington) [GPS Coordinates: S33°52′27.5″, E018°58′34.4] and Koelenhof winery (located in Stellenbosch) [GPS Coordinates: 33°50′04.92″S, 18°47′52.68″E]. Plant materials were collected after the harvest from the fields and used immediately. Spent wine filter materials were raw, moist, and had some waste effluent in them, and wine aroma. They were not mixed together, but were layered on compost heaps individually, after they have been weighed in bags according to its treatment requirements.

2.3. Treatments

The description of each treatment is contained in Table 1. Prunings for T1, T2, T3 and T5, were chopped using hand pruning cutters, whereas prunings for T4 were ground using a wood chipper (Bearcat 5 in. PTO chipper, L × W × H 49 × 50 × 187, weight 720) of particle size approximately 7.6 cm (3 in.). The soil surface was first cleaned and levelled before the layering of the heaps. Plastic was placed underneath heaps in the various treatments T1, T2, T3 and T4 with the exception of T5. All treatments were prepared in one week, one treatment a day (with its five replications). The experimental design was a complete randomized block design with 5 treatments replicated 5 times (Total plots: 5 × 5 = 25 plots). The total volume per heap was 1 m^3. Trenches were dug between rows for run-off; the space between heaps was 2 cm. The site where the trial was located was steep (20° angle), surrounded by vineyards and adjacent to a dam. Water was supplied to the compost heaps through an irrigation system. Irrigation pipes were linked to a tap next to a dam (water source) for irrigation. Irrigation was done twice a week for one hour; however, this depended on moisture levels. Mixing of the heaps was done twice a week using a spade to increase aeration and the oxygen supply to microorganisms until the end of the trial. All treatments were uncovered and exposed to environmental conditions. Certified commercial compost materials were used as positive control. The commercial compost products were sourced from reliable distributors; Agrimark PTY LTD (Stellenbosch, Cape Town), Stodels PTY LTD and Game PTY LTD (Somerset West Cape Town). Composting was allowed to proceed under open field conditions over twelve months, from autumn to summer. In literature, composting periods vary from three to ten months under open field conditions (Bertran et al., 2004; Gea et al., 2013). Furthermore, not much was known on the materials composted in this study. For comparison purposes, data of each of the physicochemical parameters obtained from the commercially-produced composts were pooled and the means were compared to those of the end-products of treatments.

2.4. Determination of heap temperature and moisture content

After preparation of the heaps, moisture and temperature were measured twice a week, Mondays and Fridays, and twice each day in the mornings and afternoons until the end of the composting process; the average daily data were subsequently pooled to give mean monthly data. Moisture content was measured using Mud-

Table 1
Treatments (T1-T5) applied at the Nietvoorbij experiment farm during composting of spent winery waste under open field conditions from autumn to summer.

Treatment	Description
T1	40% spent wine filter materials + 60% standard ingredients[a], lined with black plastic underneath
T2	20% spent wine filter materials + 80% standard ingredients[a], lined with black plastic underneath
T3	0% spent wine filter material + 100% standard ingredients[a], lined with black plastic underneath
T4	40% spent wine filter materials + 60% standard ingredients[a], ground, lined with black plastic underneath
T5	40% spent wine filter materials + 60% standard ingredients[a], unlined

[a] Chopped pruning canes, grape stalks, berry skins and seeds.