Cost Benefit Analyses of Organic Waste Composting Systems through the Lens of Time Driven Activity-Based Costing

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Abstract

Time Driven ABC (TDABC) which tries to address some of ABC's shortcomings still remains unexplored in academic research. This paper focuses on the adoption of TDABC to assess the economic viability of two commonly used composting systems for organic wastes in New Zealand. The results support previous studies in terms of what TDABC model can do in practice. As with ABC, TDABC can provide two types of information for decision making: (1) it can determine the costs of objects (but with less accuracy) and (2) and can provide a link between resource pools and cost pools/cost hierarchies.

The results further show that differences in mass density and production duration/time are among the main factors influencing the economic superiority of the two composting systems investigated in this study. The results suggest that composting of organic waste is a commercially viable approach for cleaner production of farming and agricultural products. It is also a valuable alternative to landfilling, thus reducing dependence on landfill for the disposal of organic waste.

Keywords

Time Driven Activity-Based Costing (TDABC)
Organic Waste
Organic Composting
Turned Pile and Forced Vacuum Aerated Systems

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Introduction

The emergence of sustainability and environmental concepts in recent years has highlighted the value and role of cost accounting in assessing the economic viabilities of products and processes (such as waste management) affecting the environment (Mei 2011). Organic composting is a topic which has a strong link with sustainability and environment. It is a process of producing compost from organic wastes (.e.g. all plants, branches and flowers, all garden/yards waste, all green waste and all food and paper waste) as an input for agricultural and gardening products. Organic composting can lead to a cleaner production process for agricultural and gardening products by reducing the amount of wastes going to landfills, enriching the soils, improving the sustainability in production of supply chains, and reducing the use of chemical/artificial fertilizers. Despite the apparent advantages of using compost, many growers still use conventional fertilisers, perhaps because they feel the costs of using compost outweigh the benefits that can be derived from it or maybe they are unaware of the economic benefits that can be derived through composting (Cameron, How, Saggar, and Ross 2004, P:8). So, there is a need for further cost and benefit analysis of composting in general (Meyer-Kohlstock, Hädrich, Bidlingmaier, and Kraft 2012).

Contributing to the above gap in the literature, this paper assesses the economic viability of two commonly used composting systems for organic wastes (turned pile and forced aerated systems) in New Zealand through the lens of time driven activity-based costing (TDABC). Besides data availability, the 'green image' of New Zealand (which is one of marketing and government policies) is part of the motivation for choosing New Zealand as the prime target for current study (Fairweather, MasIin, and David 2005, Forbes, Cohen, Cullen, Wratten, and Fountain 2009).

We performed an empirical study working with the composting organisation's management team to develop a cost system that could enable them to determine the costs of their products while they could see a link between resource pools, cost pools/cost hierarchies and their cost objects.

Due to their importance (e.g. for sustainability and environment), the concepts of composting and waste management have received considerable attention in the literature over the past decade (Bustamante et al. 2013, Mei 2011, Romero, Ramos, Costa, and Márquez 2013, Tortosa, Alburquerque, Ait-Baddi, and Cegarra 2012, Yoshizaki et al. 2013). However, (from accounting perspective) no study has been reported to assess the economic viability of composting systems for organic wastes through the lens of TDABC.

Furthermore, this study is an important contribution to the literature as the concept of TDABC still remains unexplored in academic research (Michael and Maleen 2009, G. Michel, Yves, and Charles 2010, Ratnatunga, Tse, and Balachandran 2012). The remaining of the paper provides a background on composting and on organic waste in New Zealand and introduces the most popular suggested disposal options in the literature. It reports on some of past studies and discusses the application of TDABC for composting organic wastes in the selected composting centre in New Zealand. At the end, the paper discusses our empirical results and the conclusions.

Background

In this section we try to explain why composting is an important topic for New Zealand and why it deserves to be assessed through the lens of TDABC.
New Zealand (NZ) is internationally known for its green image and clean environment (Fairweather et al. 2005, Forbes et al. 2009). This green image is a major component of firms' marketing communications in New Zealand. In recent years, Government and commercial activities have been criticised by several parties for placing this image under threat (Cumming 2010, Greenpeace 2008, Pearce 2009).

At the same time, there are rising concerns over the effects of financial costs imposed by the Emissions Trading Scheme introduced in NZ, especially in relation to landfill gas emissions (Local Government New Zealand 2011). Consequently, there is strong interest in alternative clean approaches to waste management that can be economically viable for local government and commercial organisations (Fairweather et al. 2005, Forbes et al. 2009). Notwithstanding, this is a world-wide problem faced by most developed countries who are also searching for cost effective solutions to the landfill problem (Grice 2010).

However, despite its sustainability and its positive environmental aspects, composting hasn't been able to replace landfilling maybe due to the uncertainties in relation to its costs and benefits (Cameron et al. 2004, P:8). So, there is a need for more accurate cost benefit analyses of composting approaches to encourage its further adoption in practice (Meyer-Kohlstock et al. 2012).

This study is a contribution to the literature in terms of assessing economic viability of two commonly used composting systems for organic wastes (turned pile and forced aerated systems) in New Zealand through the lens of TDABC.

Composting organic waste can be considered as a downstream activity when it attempts to reduce or divert the amount of wastes going to landfills (Boldrin, Andersen, and Christensen 2011, Schaub and Leonard 1996). Within its own supply chain, it can also be considered as an upstream activity when it produces organic compost as an input to be used in further processes (e.g. agricultural and gardening processes), leading to the reduction of chemical/artificial fertilizers which can have substantial consequences for sustainability in production and supply chains (MacLeod and Moller 2006). Nevertheless, organic waste has been the largest proportion of waste disposed to landfills in 2007–2008, representing 28% of the overall waste stream in New Zealand (Ministry for the Environment 2009), despite a growing belief that composting is a viable alternative for dealing with organic waste (MacLeod and Moller 2006).

Among some popular disposal options available for organic waste, composting is the most sustainable, practical and useful approach for enriching soils and contributing to supply chain production in New Zealand (Low 2009, MacLeod and Moller 2006). Organic waste has significant value for supply chains (e.g. in the growth of crops and other plants) if processed in appropriate ways, for example by turning it into compost (Cameron et al. 2004). According to Ostojski and Gajewska, (2007).

Landfilling is not the best disposal option and should be selected only if waste cannot be disposed in other ways (e.g. due to technological, ecological or economic reasons). Composting organic waste has also been recognized as a preferred alternative to other options (such as incineration) both in terms of its costs and its contribution to the soils and supply chains production (Cameron et al. 2004, Scott 2000, Veeken and Hamelers 1999).

The composting of organic wastes is of particular interest to New Zealand as a green country (Fairweather et al. 2005, Forbes et al. 2009) where agricultural/horticultural (e.g. gardening, nursery, farming, crop growing) activities are of top priority and thus organic compost (which is an output of composting organic wastes) is a necessary requirement for such activities (Cameron et al. 2004, MacLeod and Moller 2006). According to Cameron et al (2004), the use of organic compost in agriculture leads to an improvement in yield by supplying sufficient nutrients for optimum crop growth.

Internationally, composting organic wastes is a major environmental initiative and has received considerable attention from both academics and practitioners (Andersen, Boldrin, Christensen, Favoino, and Moller 2009, Boldrin et al. 2011). For instance, approximately 2000 composting facilities for household of organic waste materials are in operation in Europe, 40% of which solely treat garden waste (Andersen et al. 2009; P.800). According to MacLeod and Moller (2006), the portion of New Zealand covered by agricultural land and exotic plantations is more than 50%. Composting organic waste is one of the most natural, sustainable, and low risk options to improve soils and agricultural supply chain activities such as producing crops, vegetables and fruits (Cameron et al. 2004). Composting organic waste is also an important waste management issue in New Zealand as currently a significant proportion of organic waste still goes to landfill. Furthermore, despite the apparent advantages of using compost, many growers in New Zealand still use conventional fertilisers perhaps because they feel the cost of using compost outweigh the benefits that can be derived from it or they are unaware of the benefits that can be derived through compost use (Cameron et al. 2004, P:8). Cameron et al. (2004) conclude that intensive cropping systems and excessive cultivation have degraded many New Zealand arable soils, and heavy applications of synthetic fertilisers have also caused pollution problems in ground water supplies. They further suggest that to protect the soil growing properties, and to ensure New Zealand food and crop production can be continued in the future, growers must adopt viable growing practices, including compost addition.

Landfilling, however, has been the most common method of disposing of Municipal Solid Waste (MSW) as well as organic waste in New Zealand. At a national level, it is estimated that 3.2 million tonnes of waste was sent to municipal landfills in 2006 (Ministry for the Environment 2007). Although the need for greater landfill space is not as dire in New Zealand as it is in other more densely populated countries (Grice 2010), landfills in some of New Zealand's larger urban areas were reaching their maximum capacities as early as 1997. Furthermore, the availability of space for new landfills in New Zealand is limited due to a number of factors such as: local opposition (the 'Not In My Back Yard' syndrome), higher environmental standards (such as the need to avoid sites that could contaminate groundwater or streams), and stricter consent requirements which parallel these. This combined with increasing levels of MSW production leads to a scenario where alternatives to landfilling must be found.

There have been many efforts in New Zealand to reduce the amount of MSW and organic waste going to landfill by using different techniques such as recovery, re-use, recycling and composting. These efforts have resulted in a considerable reduction in the total amount of MSW going to landfill from 3,156,000 tonnes in 2006 to 2,531,000 tonnes in 2010 (Ministry for the Environment, 2011). According to the Ministry for the Environment (2011), in 1997 organic waste was estimated to constitute 39% of MSW in existing landfills in New Zealand. And a further 19% was estimated to constitute paper wastes.

In short, despite all the attempts to reduce landfilling in New Zealand, it is still the most common method of disposing of MSW (Ministry for the Environment 2011). This combined with increasing levels of MSW production and the need for organic and non-chemical compost was a primary motivation for this study to examine the economic feasibility of two popular composting systems as alternative options to landfilling as well as an appropriate substitute for chemical fertilizers. The objective is to motivate and encourage government agencies and private organisations to consider further composting activities both in NZ and internationally.

Organic Composting Activities and Processes

In order to examine the economic feasibility of organic composting systems, we need to identify all relevant activities and processes for both composting systems targeted in this study. Organic composting refers to the degradation of organic matter by microorganisms. This is initially a thermophilic[1] process during which large amounts of heat are generated. Throughout this thermophilic phase organic matter is broken down, releasing nutrients and bringing about changes in the chemical composition of the composting material beneficial for plant growth. At the same time unwanted microbes, weed seeds and phytotoxins are destroyed, and organic matter particle size is reduced (Michel 1999). This is followed by a mesophilic[2] phase known as curing where compost undergoes further chemical changes at lower temperature. Finished compost is a stable humic material (Chefetz, Hatcher, Hadar, and Chen 1996). It can be applied to earth to aid in the restoration or improvement of soil condition. This can result in improvement in the growth of crops and other plants (Cooperband 2002). The microbial processes which bring about the chemical changes during the thermophilic phase are aerobic and as such composting organic matter requires continual aeration to supply oxygen (Cooperband 2002).

Composting is practised around the world by house-holds, on farms, and by large-scale commercial composters. Composting in a commercial setting refers to the process of compost production from bio-waste (known as feedstock) on a large scale, with the intent of lowering the costs of bio-waste disposal and/or generating a profit. This linear process sequentially involves feedstock acquisition and storage, feedstock preparation and mixing, the thermophilic phase, curing, screening, compost storage and blending of the final compost product prior to sale (Coker 2010). While these stages are common to almost any commercial composting operation, how they are carried out varies widely. For example, in a vermicomposting operation the curing phase consists of letting the post-thermophilic stabilised compost sit for a period of months or years whilst earthworms are allowed to feed on the compost. This introduces new microorganisms (the earthworms' intestinal flora) and further reduces particle size thereby increasing the surface area exposed to other microorganisms which thrive in the mesophilic environment (Fornes, Mendoza-Hernandez, Garcia-de-la-Fuente, Abad, and Belda 2012). Feedstock can also vary considerably across commercial composting operations; however all are forms of waste organic matter. The most commonly composted feedstock's in commercial composting operations are the food-waste and green-waste components of MSW.

Composting systems generally fall into one of two categories: passively aerated systems which rely on unassisted convective movement of air through the composting material as heat is released (Mason and Milke 2005), and actively aerated systems. Most modern systems are actively aerated as there are benefits associated with these systems such as greater control over aeration levels, better quality compost as a result, and greater rates of compost production.

Actively aerated systems themselves generally fall into one of two categories: turned, or forced/Vacuum aerated systems. Forced/Vacuum aerated systems employ fans and a network of tubes within the compost to provide aeration whereas turned systems rely on the turning of the composting material by machinery for aeration. Forced aerated systems may be positive pressure, where air is pushed through the composting material, or negative pressure (a Vacuum system) where air is sucked through the composting material (Haug 1993).

The choice of system depends upon many considerations. These include (among others) the nature of feedstock, the requirements of

[1] Requiring high temperatures for normal development, as in certain bacteria.

[2] An organism, as in certain bacteria, that grows at a moderate temperature.

governments and local authorities to protect the environment and local population, the machinery requirements, the level of management desired, and the costs of running these systems (Cooperband 2002). Overall, it would appear that the choice between a turned pile and forced aerated system rarely comes down to a comparison of the environmental impacts of each. The environmental impacts of both systems are similarly low when compared with other methods of bio-waste disposal. The decision may (to some degree) depend on factors such as levels of odour production but for the commercial composters in rural areas with few neighbours, this is rarely an issue. It appears that the decision is often made based on commercial and/or economic considerations.

Past Studies on the Economic Feasibility of Organic Composting Systems

There is some evidence which suggests that Vacuum aerated systems (once up and running) have relatively lower operating costs. A study by Brinton (1998) has shown the cost of on-farm composting of animal manure (in US$ per wet tonne of compost) to be significantly reduced by minimising the frequency of turning of composting material in order to provide aeration. However, Brinton (1998) offers no conclusive evidence as to whether a forced aerated composting system is more cost effective for the commercial composter in the long run. In contrast, Ruggieri, et al (2008) report that both the set-up and maintenance costs of a forced aerated system exceed that of a turned pile system. Furthermore, they don't provide details of their costing methods and admit their conclusion is based on a very basic economic comparison. In terms of the end product of the composting process, again few studies exist comparing the benefits of compost produced via forced aerated and turned pile systems.

Some studies have reported up to a 50% decrease in the time required to achieve a stable compost by using a forced aerated system compared with a Turned pile system (Epstein, Wilson, Byrge, Mullen, and Enkiri 1976). On the other hand, excessive aeration with forced aerated systems can cause pile or windrow cooling leading to slowing the thermophilic degradation of organic material and a reduced rate of compost production (Ruggieri et al. 2008). A comparison of the rate of production of compost by the two systems is therefore very relevant to evaluate their relative commercial merits.

Aye and Widjaya (2006) examined five different scenarios for waste disposals: open dumping (OD), composting in a large centralised plant (CPC), composting in small labour-intensive plants (CPL), biogas production in an anaerobic digester combined with compost production from the solid digester effluent (BGP), and landfilling combined with methane capture and electricity generation (LFE). Overall, Aye and Widjaya (2006) found CPL to have the lowest process cost, and CPC the second lowest cost compared with remaining alternative options.

Another study by Kim, Song, Song, Kim, and Hwang (2011) confirmed the economic preference of composting over other alternatives. Analysing waste management scenarios in Basrah City (Iraq), Elagroudy, Elkady, and Ghobrial, (2011) have also recommended the composting of bio-waste as the most preferred disposal option for the city.

Besides its economic sustainability and preference, composting can also have significant environmental benefits when it is compared with OD and the LFF alternatives (Elagroudy et al. 2011). Elagroudy et al. (2011) found that composting provides reduced environmental impacts across all environmental parameters tested in Basrah City. Several other case studies have assessed the costs and benefits of composting compared with other bio-waste disposal options (Miller and Angiel 2009, Morawski 2008). Morawski (2008) for example, concluded that the economic cost of composting various forms of bio-waste in the Niagara region of United States is much lower than landfilling. A similar study was carried out by Miller and Angiel (2009).

Their findings further confirm the environmental benefits of composting. However, the findings are not consistent. For instance, Abduli, Naghib, Yonesi, and Akbari (2011) compared two scenarios for the disposal of MSW in Tehran, Iran from both an environmental and an economic standpoint. These scenarios were landfilling of MSW with associated methane capture and electricity generation (LFE), and separation and composting of bio-waste from MSW prior to landfilling. They found that the net cost of composting one tonne of waste is higher than landfilling.

Given the above, the literature suggests that there is a need for better ways to calculate the costs and benefits of composting in general (Meyer-Kohlstock et al. 2012). Morrissey and Browne (2004) consider most of the municipal waste models identified in the literature as decision support models and divide them into three categories—those based on cost benefit analysis, those based on life cycle assessment and those based on multi-criteria decision making. Among these categories, cost benefit analysis approach has received a considerable attention in the literature (Morrissey and Browne 2004, Nahman, de Lange, Oelofse, and Godfrey 2012, Weng and Fujiwara 2011). However, no study has been reported to assess the economic viability of organic composting systems through the lens of TDABC.

Methodology

Drawing on cost benefit analysis approach, we used TDABC to examine the cost of organic (non-chemical) compost under both composting systems addressed in this study. This was an empirical study working with the composting organisation’s management team at Envirofert to develop a cost system that would enable them to calculate the production costs of their organic composts more precisely and highlight the cost benefits of organic composting for the producers of this product as well for the government and other decision makers in the community. Envirofert is a privately owned, environmentally friendly, resource recovery business based in a rural area south of Auckland, New Zealand.

The research was carried out in 2012 (from June to December) on an existing large-scale composting operation run by the resource recovery firm. In addition to operating a clean-fill for tipping of inert materials, and a terminal disposal operation for glass, Envirofert has a key line of business converting green-waste and food-waste into organic compost. This compost improves soil condition and land productivity for New Zealand horticultural and agricultural businesses offering a “long-term, viable solution for better crops and improved soil quality” (Envirofert 2012). Its products are tailored to the needs of New Zealand agricultural and horticultural producers and Envirofert is Global-gap certified. This means that its compost products can be used with confidence by growers targeting all major export markets.

Envirofert’s current operations consist of a 40 ha green-waste and food-waste composting area, which is New Zealand's largest consented composting facility, and a 16 ha clean-fill area. Envirofert was the 2010 winner of the Ministry for the Environment Green Ribbon Awards "Managing our Waste", 2010 winner of the Westpac Manukau Business Excellence Awards "Excellence in Environmental Management" and the 2006 winner of the Franklin Business of the Year, Innovation in Agriculture and Environmental Awards. Further information about Envirofert is available at the company website at: http://www.envirofert.co.nz/.

Data Collection and Analysis Method

In conducting this empirical study, multiple types of data were collected and analysed. These include interviews conducted with the company manager and operations staff as well as primary data collected by the researcher/s through observation of Envirofert’s composting systems in operation (during July to December 20102), and by the review of Envirofert documentations as shown in Table 1:

Research Results

We observed the production processes for both systems. The production processes (for both systems) start by receiving organic wastes to the plant by trucks. This is stacked into piles which are turned weekly for three months (in the case of the turn pile system) and two months (in the case of the Vacuum aeration). This step is called the thermophilic phase. For the turn pile system, piles are turned monthly for a total of nine months before they are transferred to the vermicomposting windrows where they sit for a further twelve months. In total, the turn pile system takes 24 months before the produced composts are moved to the drying area, and get screened and be placed into storage.

For the Vacuum aeration system, piles are transferred (after two months as explained above) to the Vacuum aerated windrows. There is a further intermediate step if food waste is to be added (where the broken down organic waste is mixed with food waste and then transferred to the Vacuum aerated windrows). Air is sucked through the windrows for 15 minutes per hour for three months and then the piles are transferred to the vermicomposting windrows. The piles are stored there for 12 months and then dried, screened and transferred to storage. In total, the Vacuum aerated system takes 17 months being the two months in the turn pile system, three months in the Vacuum aerated system and 12 months in the vermicomposting phase.

Table 1: Sources of Data

Sources of Technical Data	
Primary Data	Direct field observation of Envirofert's composting systems in operation
	Envirofert documentation including: • *Protocol for the Management of the Thermophilic Composting Operation* • *Vermicomposting Site Management Plan*
	The opinions and estimates of Envirofert personnel including Envirofert's Scientific Officer, Managing Director, Site Manager, and Labourers
Secondary Data	Standards and averages derived from academic and industry literature
Sources of Financial Data	
Primary Data	Envirofert documentation including: • *Financial statements and relevant accounts for financial years ended 31/03/2011 and 31/03/2012* • *Trading Account for financial year ended 31/03/2011* • *Itemised Sales Summary for financial year ended 31/03/2011* • *Management Account for financial year ended 31/03/2012* • *Fixed Assets Register at 31/03/2012* • *Current Employees Pay Register at 15/07/2012*
	The opinions and estimates of Envirofert personnel including Envirofert's Managing Director, Administrator, and Accountant
Secondary Data	Standards and averages derived from academic and industry literature
All information related to the costs of composting systems were reviewed and examined	

The Adoption of TDABC

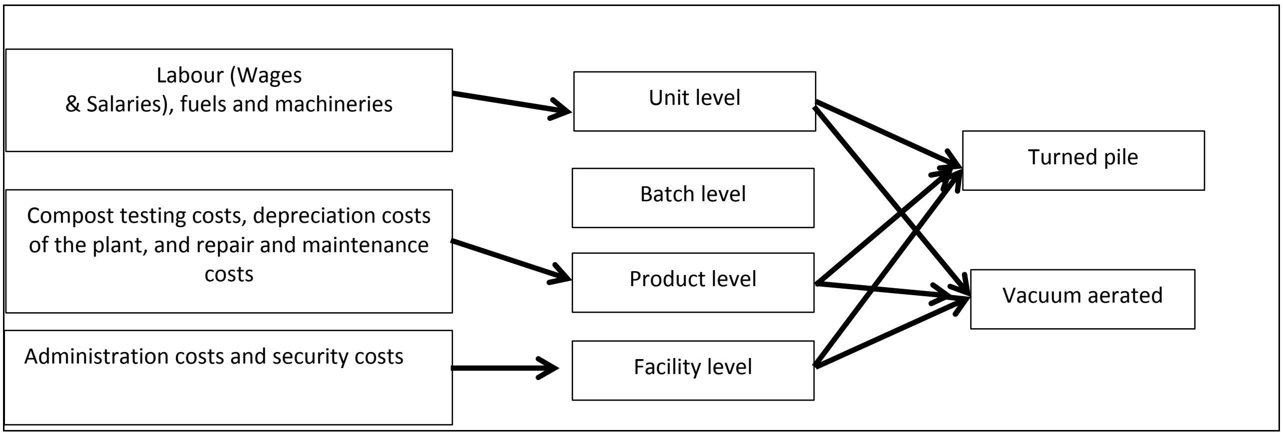
Despite its theoretical superiority, the adoption of Activity-Based Costing (ABC) still lags behind traditional volume-based costing models in most organisations (Askarany and Yazdifar 2012, Askarany, Yazdifar, and Askary 2010, Michael and Maleen 2009, Ratnatunga et al. 2012, Yazdifar and Askarany 2009). According to Askarany and Yazdifar (2012), the adoption rate of ABC in most organisations in developed countries such as Australia, New Zealand and the UK is less than 30%. The complexity of ABC in terms of its need for too much data and using too many cost drives are among the cited reasons for its relatively low apportion rate by many organisations (Michael and Maleen 2009, Ratnatunga et al. 2012). To address some of these issues surrounding the adoption of ABC,

TDABC is introduced (Ratnatunga et al. 2012).

TDABC is a simplified model of ABC that addresses most of the complexities and application issues associated with ABC (Kaplan and Anderson 2007, Michael and Maleen 2009, G. Michel et al. 2010, Ratnatunga et al. 2012). ABC is relatively a complex costing systems as it uses too many cost drivers to calculate the costs of products or services (Ratnatunga et al. 2012, Schniederjans and Garvin 1997). TDABC in contrast doesn't need multiple costs and cost drivers. It only needs the cost of supplying the capacity and the duration of time using the capacity (Kaplan and Anderson 2007, Ratnatunga et al. 2012). Despite ABC method which asks employees to specify the time needed for different activities, TDABC method estimates the total time to perform necessary activities via multiplying the number of tasks by the hourly time needed to perform each task (Michael and Maleen 2009, G. Michel et al. 2010, Ratnatunga et al. 2012). We implemented TDABC in order to assess the costs and benefits of two adopted composting systems (turned pile and forced aerated systems) in Envirofert.

The activity driver rates in TDABC are based on the costs of supplying activities divided by practical capacity in terms of available time for the period (Kaplan and Anderson 2007, Michael and Maleen 2009, G. Michel et al. 2010). TDABC is therefore, simpler than other forms of ABC which calculate multiple cost-drivers. It is also possible via this method to calculate the efficiency of a system at a given output by comparing the time taken to produce a given level of output with the total practical capacity supplied. However, according to Ratnatunga (2012), in spite of its merit, the notion of TDABC concept is largely ignored both in practice and in the academic literature. The TDABC which we used in this empirical study differs in two aspects: its "hybrid nature" with respect to ABC and the traditional cost-centre based costing and the "hierarchy" of activities deployed (Ratnatunga et al. 2012). According to Ratnatunga (2012), the relationships between resource cost pools, activities and cost objects used in the ABC-based costing model can be kept in the TDABC-based model via 'resource groups' by using either single or multiple time-based drivers to allocate costs to cost objects. However, to keep the accuracy of the ABC system, we have used the ABC cost hierarchies rather than 'resource groups' and used single time-based driver for each cost hierarchy (which means multiple time-based drivers for all hierarchy levels) to allocate costs to cost objects as it is shown in Figure 1.

Figure 1: The TDABC-Based Costing Model: The Hierarchy Groups (Multiple-Drivers)



According to Ratnatunga (2012; P:293), attempting to simplify ABC "(by using a single-volume related cost driver) ultimately makes TDABC no different than traditional costing systems". So, in order to keep ABC accuracy, we used ABC cost hierarchy system (unit level, batch level, product level and facility level) and categorised all activities under these cost hierarchies. We identified and categorised all relevant activities for both organic composting systems and gathered all their relevant costs separately. We used the information from interviews, the general ledger, and our own observation to map resource costs to activity cost hierarchies. We used top-down costing approach to determine the costs of all activities under each cost-hierarchy level (we obtained all relevant costs for composting activities-for both systems-from Envirofert's accounts). Then we divided the costs of each cost hierarchy by their practical capacities (in terms of their available time for the period) to determine hourly rate for each cost hierarchy. Of course it is possible to have no cost hierarchy with TDABC or place all resource groups under one umbrella and use a single-driver rate (Figure 2). However, using a single-driver rate

TDABC is a backward step, and trades perceived 'simplicity' in place of 'accuracy' (Ratnatunga et al. 2012; p: 291).

Given the duration of rainy and wet periods in Auckland through the year as well as the nature of the composting processes (as an outdoor process), we used 80% of normal working hours through the year as normal capacity in this study. So, the normal capacity used in this study is calculated as follows: 40 hours per week * 50 weeks * 80% = 1600 hours per year.

By performing a Time and Motion study, we identified the total (actual) time needed (from each hierarchy level) to produce one tonne of compost under both composting systems separately. Time studies are widely used in manufacturing industries for many reasons, including cost identification (Aft 2010). They are used extensively in the commercial composting industry often coupled with motion studies in the form of Time and Motion Studies (Coker 2010). Then we multiplied the required time for each cost hierarchy level by its hourly rate to determine the production cost of one tonne of compost from each cost hierarchy level. Finally we added up all cost hierarchy levels (for one tonne of compost) to determine the total production costs of one tonne of compost (separately for both of composting system). So, the time was the main cost driver for each cost hierarchy level. Usually, it is difficult to use the time as driver for unit level cost hierarchy but not in our case. Because, there was no material cost (e.g. there was no need for the purchase of green waste). So, we were able to relate all costs' hierarchies to the time and the production process was similar to a service operation.

Based on collected information, direct observation and reviewing the behaviours of the costs, activities and costs were classified in terms of an ABC hierarchy for both composting systems as follows:

- Unit-level activities: all direct costs such as machineries, fuels and labour costs
- Batch-level activities: none of the costs were considered to be at this level
- Product-sustaining activities: testing, resource consents,
- Facility-sustaining activities: General plant costs and administration

One interesting feature of composting organic waste in this study is that it has two revenue streams: Revenue received from the sale of compost and the revenue (fees) received by accepting the organic wastes. We have treated the cash inflow from sale as revenue and the fees received by accepting the organic wastes as cost offset in determining the production costs of organic composts in this study.

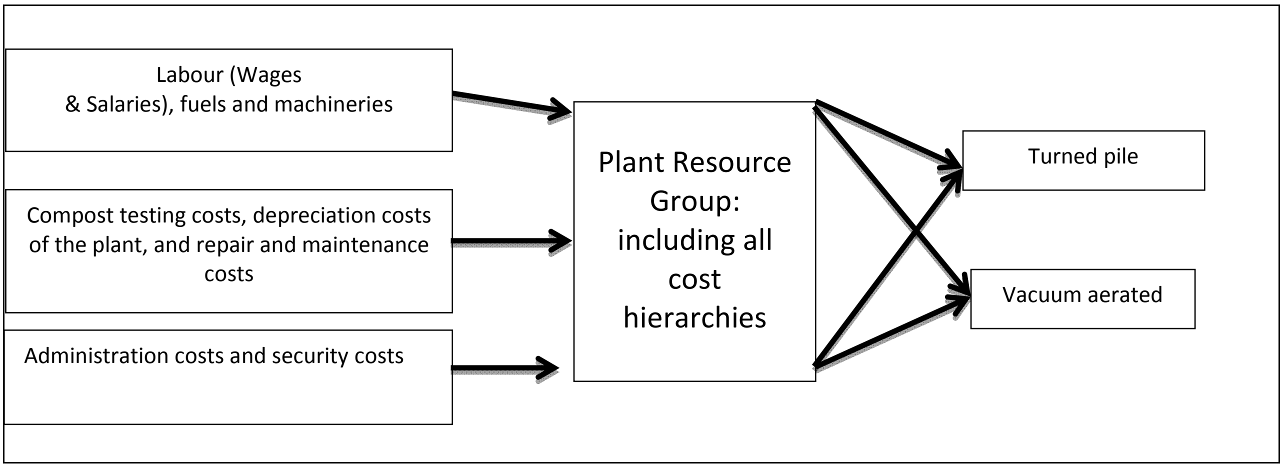
The investment cost between the two production systems is relatively similar i.e. both use common plant and similar area of land with the exception being that some fans and pipes are needed for the aerated system. Furthermore, the sale value of the compost produced by both systems is the same. However, the main difference between the two composting systems is in their operating cost (which is the main focus of this study) and is due to two factors: the differences in mass densities and production lengths.

We used one tonne of finished organic compost as cost object for both systems in this study. This made it possible to compare the production costs of organic composts between the two different systems. Using one tonne of finished organic compost as cost object was a challenge due different and highly dynamic mass flow of both composting systems. There was a mass loss between the upstream (green waste inputs) and downstream (organic composts produced) through evaporation of water, chemical decomposition of the organic content of composting material, and screening.

There was also a mass gain form of moisture whenever it was a rain. Given the above, it was necessary to model the mass flow through each composting system and calculate both the mass breakdown and the average density of composting material through each system. Based on our time and motion study, we found that the plant needs 3.01 tonnes of green wastes feedstock to produce one tonne of compost under Turned pile system while it needs 2.58 tonnes of green wastes feedstock if it uses Vacuum aerated system to produce one tonne of compost. This difference in density was due to the production processes systems.

The Vacuum aerated system needed 17 months to produce one tonne while the Turned pile system took 24 months. The longer production period (under turned pile system) might have contributed to more chemical changes (e.g. burn out, evaporation of water, chemical decomposition of the organic content of composting material, etc.) and the need for more of green waste feedstock to produce one tonne of compost under turned pile system. Selling price as well as selling costs of composts were the same for both systems

Figure 2: The TDABC-Based Costing Model: The Resource Groups (Single-Driver)



However, the cost of land and other facility level costs were allocated to each system based on the duration of each production process. There was another difference between two composting systems in terms of input/feedstock. As previously noted, the Turned pile system processes only green-waste, whereas the Vacuum aerated system processes both green-waste and food-waste. However, a balance between green-waste and food-waste must be maintained whereby the food-waste content does not exceed 50% by mass. Both systems involve mass reduction which is heavily dependent on feedstock

Table 2: TDABC Cost Information

Cost hierarchies	**Total costs (NZ$)**	**Rate per hour**	**Turned pile(NZ$)**			**Vacuum aerated (NZ$)**		
			Hours needed for one tonne	***Unit costs***	***Total costs***	***Hours needed for one tonne***	***Unit costs***	***Total costs***
Unit-level Costs	253,290	158.31	0.1549	24.52	139,102	0.127	20.13	114,188
Batch-Level Costs	0	0	0	0	0	0	0	0
Product-level Costs	193,597	121	0.1326	16.05	91,066	0.149	18.07	102,531
Facility-level Costs	623,766	389.85	0.1650	64.35	365,148	0.1170	45.58	258,618
Total	1,070,653			104.92	595,316		83.78	475,337
Offsetting costs				75.25			64.5	
Net cost				29.67			19.28	

The mass reduction through the Turned pile system with green-waste as a feedstock is calculated to be 3.01. This means in producing compost through the turned pile system, each tonne of finished compost requires on average 3.01 tonnes of green-waste. The mass reduction through the Vacuum aerated system with green-waste as a feedstock is calculated to be 2.58. This means in producing compost through the aerated system with green-waste, each tonne of finished compost requires on average 2.58 tonnes of green-waste. These figures were observed by comparing the weights of input (organic wastes) used and outputs (composts) produced by the composting systems through the year.

The Vacuum aerated system was processing approximately 50% of the green-waste accepted by Envirofert into compost; the remaining 50% was processing through the turned pile system. At the time of investigation, Envirofert was processing very little solid food-waste (less than 5% of total feedstock composted).
Adopting TDABC (as explained before), we gathered all production costs for all production activities and then categorized all activities into cost hierarchies based on their behaviour (in terms of their reactions to the levels of production changes) as shown it Table 2.

The unit level costs include direct costs such as labour, fuel and machinery costs. The lower unit-level cost of the Vacuum aerated system is due to less use of machinery, fuel and labour given the nature of the process.
Product-level Costs include indirect costs such as compost testing costs, depreciation costs of the plant, and repair and maintenance costs. The product level cost of the Vacuum aerated system is higher due to additional costs of depreciation on aeration system, installation and fittings plus cost of power to run aeration system.

Facility level costs contain facility administration and security costs. It includes yearly rental costs of land, security costs and other administration costs. According to our time and motion study, Turned pile system share of facility level costs is about 141% of Vacuum aerated system for producing one tonne of compost. This is due to the differences in the duration of production processes as it is 24 months for Turned pile system and 17 months for Vacuum aerated system.

Offsetting costs include tipping received for green waste feedstock at the front end. This is calculated based on density rate of feedstock under each production system. For, example, the plant earns $25 for one tone of green waste. Given that the reduction density under Turned pile system is 3.01 and under Vacuum aerated is 2.58 (it means that the plant needs 3.01 tonnes of green waste to produce one tonne of compost under Turned pile system, and 2.58 tonnes of green waste to produce one tonne of compost under Vacuum aerated), the offsetting fee for one tonne of compost under Turned pile system and Vacuum aerated system is calculated as follows: $75.25 ($25*3.01) and $64 ($25*2.58) accordingly. After determining time driver rate for each cost hierarchy (through dividing hierarchies' costs by their normal capacities in terms of time, 1600 hours per year), we calculated all hierarchies' costs to produce one tonne of compost under each production systems separately (we used time and motion study to estimate the required time needed from each cost hierarchy to produce one tonnes of compost under each system). Table 2 shows the detail cost hierarchies, required time, unit cost and the total costs of composting production for both systems.

The production cost of one tonne of compost though the Turned pile system is $NZ104.92 compared with $NZ83.78 through the Vacuum aerated system. The tipping fees which are received for accepting the feedstock (organic waste) are deducted from the production cost to provide the net production cost of $NZ29.67 for the Turned pile system and $NZ19.28 for the Vacuum aerated system .
Examination of capacity utilisation showed that the company could reduce its production costs further if it increases its level of activities towards its practical capacity. The company is currently producing 11,348 tonne of compost per year (5674 tonnes through Turned pile and 5674 tonnes through Vacuum systems). According to our investigation, the company is currently working (1600 hours per year) at 66.67% level of its theoretical capacity (based on 8 hours per day for 300 days per year).

However, as discussed earlier, given the duration of rainy and wet periods in Auckland through the year as well as the nature of the composting processes (as an outdoor process), the practical capacity is not supposed to be more than 2000 hours per year (40 hours per week * 50 weeks). So, if we consider 2000 hours as practical capacity, the 1600 hours (normal utilized capacity) represent 80% (1600/2000) of practical capacity. It means they could increase the current level of production from 11,348 to 14,185 (11,348/80%) tonne compost without additional costs at facility level and with minor changes in product level costs. Given that the facility level cost is a significant portion of the total cost of production (under both systems), this increase in activity level could result in a considerable reduction in production costs.

Conclusion and Limitations

This study shows its readers some practical solutions to real-world problems. The paper discusses a very interesting topic. We need to have more of these interdisciplinary research ideas analysing the effect of using various management accounting practices to cost and trigger environment waste management decisions. The paper includes a very rich review of literature and contributes to the costing and management accounting literature as well as to the cleaner production literature by demonstrating the economic viability of composting through the lens of TDABC. The original contribution of this empirical study lies in the classification of composting activities in a simplified ABC cost hierarchy across two composting systems which allows a finer grained analysis of cost behaviour for each level where time is the key cost driver. In other words, to preserve the improved accuracy of the ABC system, we have maintained the ABC cost hierarchies but used time drivers (TDABC) rates for each hierarchy level (using multiple time drivers rather than single time driver rate).

The findings of current study are consistent with those of Ratnatunga et al's (2012) work in terms of what TDABC model can do in practice. As with ABC, TDABC can provide two types of information for decision making: (1) it can determine the costs of objects (but with less accuracy) and (2) and to provide a link between resource pools and cost pools/cost hierarchies.

The results show that the differences in mass densities and production lengths are among the main factors influencing the economic superiority of two composting systems investigated in this study. More specifically, the mass breakdown via the Turned pile system (3.01) is greater than that via the Vacuum aerated system (2.58). According to our study, another difference between production costs (under both systems) is due to the duration of the production process: 17 months for the Vacuum aerated system and 24 months for the turned pile system.

According to our results, the production cost of one tonne of organic waste compost though a Vacuum aerated system is lower than through a turned pile system. The targeted company in this study could reduce its production costs even further if it increases its level of activities to get closer to its practical capacity.

According to our investigation, the company is currently working at 80% of its practical capacity. So, it is able to increase its current level of production from 11,348 to 14,185 (11,348/80%) tonne compost without additional costs at facility level and with minor increase in product level costs. Given that the facility level cost is a significant portion of the total cost of production (under both systems), this increase in activity level could result in a considerable reduction in production costs.

This research suggests that existing and prospective privately owned composting operations processing or wishing to process source-separated green-waste on a large scale in New Zealand are better off if they adopt a forced aerated system of composting. It also recommends that when considering the large-scale composting of green-waste as an alternative to landfilling, local authorities (councils) should regard a forced aerated system of composting as commercially superior to a turned pile system.

However, due to the nature of current empirical study, caution needs to be taken in generalising the results of this study to other existing or prospective organic waste composting operations in New Zealand and elsewhere. For example, the differences in the duration of production processes (which is 24 months for Turned pile system and 17 months for Vacuum aerated system in our targeted plant) could be different in other countries (with different weather conditions).

Furthermore, it is important to recognise that there are different types of turned pile and forced aerated composting systems. The results of this study (regarding two composting systems adopted by Envirofert) may not be the same when applied to other types of composting systems. It should also be noted that this study only focus on economic viability of targeted composting systems (from an accounting perspective and through the lens of TDABC). Other factors such as social and environmental factors should also be taken into consideration for final decision to implement a composting system. Finally, the conclusions drawn from this research are highly specific to the processing of organic waste.

We considered 80% utilisation of the plant as normal capacity and therefore didn't have an ideal capacity to calculate its cost. Furthermore, we used actual data (rather than standard costs) for all calculations. Using different level of capacity as well as using standard costs instead of actual costs may change the results. So, caution needs to be taken in generalising the results of this study to other composting operations.

This study is the first in the literature which holistically compares the commercial and economic benefits of two different composting systems for the processing of organic waste and producing organic compost in New Zealand through the lens of TDABC. Waste management is an important part of the sustainability value chain and therefore, investigating the cost attractiveness of composting systems (compared with other waste disposal methods) is a worthwhile avenue for future management accounting research. Further studies would assist in generalising these results.

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References

Abduli, M., Naghib, A., Yonesi, M. and Akbari, A. (2011). Life cycle assessment (LCA) of solid waste management strategies in Tehran: Landfill and composting plus landfill, *Environmental Monitoring and Assessment,* 178 (1-4): 487.

Aft, L. (2010). Don't Abandon your work measurement cap, *Industrial Engineer,* 42 (3): 37.

Andersen, J. K., Boldrin, A., Christensen, T. H., Favoino, E. and Moller, J. (2009). Composting and compost utilization: accounting of greenhouse gases and global warming contributions, *Waste Management and Research,* 27 (8): 800-812.

Askarany, D. and Yazdifar, H. (2012). An Investigation into the mixed reported adoption rates for ABC: Evidence from Australia, New Zealand and the UK, *International Journal of Production Economics,* 135 (1): 430-439.

Askarany, D., Yazdifar, H. and Askary, S. (2010). Supply chain management, activity-based costing and organisational factors, *International Journal of Production Economics,* 127 (2): 238-248.

Aye, L. and Widjaya, E. R. (2006). Environmental and economic analyses of waste disposal options for traditional markets in Indonesia, *Waste Management,* 26 (10): 1180-1191.

Boldrin, A., Andersen, J. K. and Christensen, T. H. (2011). Environmental assessment of garden waste management in the municipality of Aarhus, Denmark, *Waste Management,* 31 (7): 1560-1569.

Brinton, J. W. (1998). *On Farm Composting Evaluation of Manure Blends and Handling Methods for Quality Composts,* United States Department of Agriculture Tech Centre, Chester, PA.

Bustamante, M. A., Restrepo, A. P., Alburquerque, J. A., Pérez-Murcia, M. D., Paredes, C., Moral, R. and Bernal, M. P. (2013). Recycling of anaerobic digestates by composting: effect of the bulking agent used, *Journal of Cleaner Production,* 47 (May): 61-69.

Cameron, E., How, N., Saggar, S. and Ross, C. W. (2004). *The Cost-Benefits of Applying Biosolid Composts For Vegetable, Fruit, and Maize/Sweetcorn Production Systems in New Zealand, Series No*. 27 (1-33). Landcare Research, New Zealand.

Chefetz, B., Hatcher, P., Hadar, Y. and Chen, Y. (1996). Chemical and biological characterization of organic matter during composting of municipal solid waste, *Journal of Environmental Qualit,y* 25 (4): 776-785.

Coker, C. (2010). Controlling costs in compost manufacturing. *BioCycle,* 51(9): 26.

Cooperband, L. (2002). *The Art and Science of Composting: A Resource for Farmers and Compost Producers,* Leslie Cooperband, University of Wisconsin-Madison: Center for

Integrated Agricultural Systems, Madison, Wisconsin, USA.

Cumming, G. (2010). New Zealand: 100 per cent pure hype, *Wednesday Jan 6, The NZ Herald*

Elagroudy, S., Elkady, T. and Ghobrial, F. (2011). Comparative cost benefit analysis of different solid waste management scenarios in Basrah, Iraq, *Journal of Environmental Protection,* 2 (5): 555-563.

Envirofert. (2012). *Envirofert Website: About Us*, from http://www.envirofert.co.nz/about-us/

Epstein, E., Wilson, G., Byrge, W., Mullen, D. and Enkiri, N. (1976). A forced aeration system for composting wastewater sludge, *Journal of the Water Pollution Control Federation,* 48 (4): 688-694.

Fairweather, J. R., MasIin, C. and David, G. S. (2005). Environmental values and response to ecolabels among international visitors to New Zealand, *Journal of Sustainable Tourism,* 13 (1): 82-98.

Forbes, S. L., Cohen, D. A., Cullen, R., Wratten, S. D. and Fountain, J. (2009). Consumer attitudes regarding environmentally sustainable wine: an exploratory study of the New Zealand marketplace, *Journal of Cleaner Production,* 17 (13): 1195-1199.

Fornes, F., Mendoza-Hernandez, D., Garcia-de-la-Fuente, R., Abad, M. and Belda, R. (2012). composting versus vermicomposting: a comparative study of organic matter evolution through straight and combined processes, *Bioresource Technology,* 118 (2012): 296-305.

Greenpeace, N. Z. (2008). *New Zealand's 'Clean Green Image' under threat: Government's expansion of industrial dairy increasing climate change*. Retrieved 4/5/2013, 2013, from http://www.greenpeace.org/new-zealand/Global/new-zealand/report/2008/4/dairy-and--briefing.pdf

Grice, A. (2010). *UK warned it will run out of landfill sites in eight years. The Independent,* from http://www.independent.co.uk/news/uk/home-news/uk-warned-it-will-run-out-of-landfill-sites-in-eight-years-2021136.html

Haug, R. (1993). *The Practical Handbook of Compost Engineering*, Lewis Publishers, Florida, USA.

Kaplan, R., S. and Anderson, S., R. (2007). The innovation of time-driven activity-based costing, *Cost Management,* 21 (2): 5.

Kim, M.-H., Song, Y.-E., Song, H.-B., Kim, J.-W. and Hwang, S.-J. (2011). Evaluation of food waste disposal options by LCC analysis from the perspective of global warming: Jungnang case, South Korea, *Waste Management,* 31(9–10): 2112-2120.

Local Government New Zealand. (2011). *Submission to the Ministry for the Environment on the Emissions Trading Scheme Review*, Emissions Trading Scheme Review. New Zealand.

Low, M. (2009). *Investigation into Options for Beneficial Processing of Food Waste,* Auckland Region Organic Waste Working Group, Auckland, New Zealand.

MacLeod, C. J. and Moller, H. (2006). Intensification and diversification of New Zealand agriculture since 1960: An evaluation of current indicators of land use change, *Agriculture, Ecosystems & Environment,* 115 (1–4): 201-218.

Mason, I. and Milke, M. (2005). Physical modelling of the composting environment: A review. part 1: Reactor systems, *Waste Management,* 25 (5): 481-500.

Mei, L. (2011). Full cost accounting in solid waste management: The gap in the literature on newly industrialised countries, *Journal of Applied Management Accounting Research,* 9 (1): 21-36.

Meyer-Kohlstock, D., Hädrich, G., Bidlingmaier, W. and Kraft, E. (2012). The value of composting in Germany–Economy, ecology, and legislation, *Waste Management, 33* (3): 536–539.

Michael, S. C. T. and Maleen, Z. G. (2009). Recognition of idle resources in time-driven activity- based costing and resource consumption accounting models, *Journal of Applied Management Accounting Research,* 7 (2): 41-54.

Michel, F. (1999). Managing compost piles to maximize natural aeration, *Biocycle,* 40 (3): 56-58.

Michel, G., Yves, L. and Charles, D. (2010). Time-driven activity-based costing (TDABC): An initial appraisal through a longitudinal case study. J*ournal of Applied Management Accounting Research*, 8 (2): 1-20.

Miller, I. and Angiel, J. (2009). Municipal yard trimmings composting benefit cost analysis *BioCycle,* 50 (7): 21.

Ministry for the Environment. (2007). *Waste Can Represent An Inefficient Use Of Our Valuable Resources* , Ministry for the Environment, Wellington, New Zealand.

Ministry for the Environment. (2009). *Solid Waste Composition: Environmental Report Card,* Ministry for the Environment, Wellington, New Zealand.

Ministry for the Environment. (2011). *Solid Waste Disposal 2010: Environmental Snapshot, Ministry for the Environment,* Wellington, New Zealand.

Morawski, C. (2008). Composting - best bang for msw management buck, *BioCycle,* 49 (10): 23.

Morrissey, A. J. and Browne, J. (2004). Waste management models and their application to sustainable waste management, *Waste Management,* 24 (3): 297-308.

Nahman, A., de Lange, W., Oelofse, S. and Godfrey, L. (2012). The costs of household food waste in South Africa, *Waste Management,* 32 (11): 2147-2153.

Ostojski, A. and Gajewska, M. (2007). The legal regulations of sewage sludge management, *Ecohydrology & Hydrobiology,* 7 (3–4): 261-266.

Pearce, F. (2009). New Zealand was a friend to Middle Earth, but it's no friend of the earth, *The Guardian,* UK.

Ratnatunga, J., Tse, M. S. C. and Balachandran, K. R. (2012). Cost management in Sri Lanka: A case study on volume, activity and time as cost drivers, *The International Journal of Accounting,* 47 (3): 281-301.

Romero, C., Ramos, P., Costa, C. and Márquez, M. C. (2013). Raw and digested municipal waste compost leachate as potential fertilizer: comparison with a commercial fertilizer, *Journal of Cleaner Production,* 59 (2013): 73-78.

Ruggieri, L., Gea, T., Mompeó, M., Sayara, T. and Sánchez, A. (2008). Performance of different systems for the composting of the source-selected organic fraction of municipal solid waste, *Biosystems Engineering,* 101 (1): 78-86.

Schaub, S. M. and Leonard, J. J. (1996). Composting: An alternative waste management option for food processing industries, *Trends in Food Science & Technology, 7* (8): 263-268.

Schniederjans, M. J. and Garvin, T. (1997). Using the analytic hierarchy process and multi-objective programming for the selection of cost drivers in activity-based costing, *European Journal of Operational Research,* 100 (1): 72-80.

Scott, G. (2000). Green polymers, *Polymer Degradation and Stability,* 68 (1): 1-7.

Tortosa, G., Alburquerque, J. A., Ait-Baddi, G. and Cegarra, J. (2012). The production of commercial organic amendments and fertilisers by composting of two-phase olive mill waste (alperujo). *Journal of Cleaner Production,* 26 (2012): 48-55.

Veeken, A. H. M. and Hamelers, H. V. M. (1999). Removal of heavy metals from sewage sludge by extraction with organic acids, *Water Science and Technology,* 40 (1): 129-136.

Weng, Y.-C. and Fujiwara, T. (2011). Examining the effectiveness of municipal solid waste management systems: An integrated cost–benefit analysis perspective with a financial cost modeling in Taiwan, *Waste Management,* 31 (6): 1393-1406.

Yazdifar, H. and Askarany, D. (2009). A comparative investigation into the diffusion of management accounting innovations in the UK, Australia and New Zealand, *Chartered Institute of Management Accountant (CIMA).* 5 (12): 1-11.

Yoshizaki, T., Shirai, Y., Hassan, M. A., Baharuddin, A. S., Raja Abdullah, N. M., Sulaiman, A. and Busu, Z. (2013). Improved economic viability of integrated biogas energy and compost production for sustainable palm oil mill management, *Journal of Cleaner Production,* 44 (1): 1-7.