Comparative study on the use of two substrates with microbial inoculants for organic solid waste domestic composting:

Economic Analysis

Estudio comparativo del uso de dos sustratos con inóculos microbiales para el tratamiento de residuos orgánicos sólidos en compostaje doméstico.

Análisis Económico

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Palabras clave

Compost; compostaje doméstico; residuos sólidos orgánicos; sustratos microbiales; microorganismos de montaña; método Takakura.

Resumen

Se realizó un estudio para evaluar técnica y económicamente los efectos de dos sustratos microbiales en la degradación de residuos orgánicos domiciliarios (ROD) en un sistema de compostaje doméstico. Para tal fin se comparó el método del preparado microbial de microorganismos de montaña (MM), usado en el Centro Nacional Especializado en Agricultura Orgánica (CNEAO-INA) de Costa Rica y el método Takakura (TAKA), inoculación con microorganismos fermentativos, de la técnica Japonesa, desarrollada por el Instituto para las Estrategias Globales Ambientales (IGES) de Japón.

Se estableció un experimento completamente aleatorio con 20 unidades experimentales, distribuidas en dos tratamientos (MM y TAKA), sus respectivos testigos (MMT y TAKAT), un testigo absoluto (ABST) y 4 repeticiones para cada una. Se utilizaron los ROD de 20 hogares, distribuidos en 7 aportes durante 18 días.

Los resultados destacan la calidad del proceso de compostaje y la calidad del compost obtenido por medio del sustrato TAKA en comparación con el compost del sustrato MM.

Con respecto al análisis de costos, el sustrato MM es 7% menos costoso que el TAKA, estos costos no sobrepasan los USD17. Ambos tratamientos son bajo costo, comparados con el del actual manejo de residuos en rellenos sanitarios.

Keywords

Compost; home composting; organic solid waste; microbial substrates; mountain microorganisms; Takakura method.

Abstract

A study was conducted to technically and economically evaluate the effects of two substrates in the microbial decomposition of organic household waste (OHW) in a home composting system. With this aim, two different composting inoculates were compared amongst themselves: a microbial preparation of Mountain microorganism (MM), used in the National Centre Specialized on Organic Agriculture in Costa Rica and the Takakura method (TAKA), an inoculate with fermenting microorganisms which is a Japanese technique, developed by the Institute for Global Environmental Strategies (IGES) in Japan. A completely randomized experiment with 20 experimental units was established, divided into five treatments (MM, TAKA), witnesses (TAKAT and MMT) and an absolute control (ABST); each treatment had 4 replications. Organic Household waste (OHW) from 20 households were used, distributed in 7 inputs during 18 days. Results highlight the quality of compost obtained through TAKA substrate in comparison to compost obtained with MM substrate. Regarding the cost analysis, the MM substrate is 7% less expensive than TAKA, these costs do not exceed USD17. Both treatments are inexpensive compared to the current waste management landfills.

Introduction

Decentralized composting has become a strategy to optimize the management of household waste worldwide. In this context, the developed composting process has shown efficacy and a positive impact on the management of this waste organic fraction (Arrigoni 2011). Home composting is the application of the composting techniques for domestic organic waste, mainly from food preparation and maintenance of an orchard and / or garden. This composting uses simple techniques, mainly based on compost bins and using the action of living organisms on different residues (COGERSA 2009).

Any type of organic waste generated in the home kitchen can be composted even meat and bone waste (IGES 2010), however some authors suggest caution or avoid cooked waste such as fat, meat, bones, dairy and citrus (Good 2010 COGERSA 2009). The experiences found on organic waste management at the household level (Ali 2004, Arrigoni 2011, Huerta and Lopez 2010, IGES 2010, Lundie and Peters 2005, Pacheco 2009, Papadopoulos et al. 2009, Silbert et al. 2012, Zurbrügg et al 2004) indicate increased concern and involvement of citizens in environmental issues such as awareness of waste generated and its management, having the responsibility to compost it.

The implementation of home composting has positive impacts for the environment, particularly with regard to waste treatment, landfill management and emission of greenhouse gases related to transport.In a comparative study by Lundie and Peters (2005), the house composting opposite to industrial composting and disposal in landfill sites were discussed, concluding that home composting has certain environmental benefits associated with the consumption of energy and water, to reduce potential toxicity, eutrophication and emission of greenhouse gases.

There are also studies that indicate the level of positive response from neighbors in the implementation of home composting as a daily routine. Likewise, there is evidence to suggest that the quality of compost obtained at home, once the public overcome operational difficulties can reach an acceptable agronomic quality (Papadopoulos et al. 2009).

Small-scale compost from the waste itself, is responsible a behavior for the treatment of waste and towards the environment. Home composting can be a good alternative, also at the municipal level and generate significant cost savings, energy and emissions of greenhouse gases (Huerta and Lopez 2010). There are experiences of home composting in countries like Spain, the Netherlands, Canada, Sweden, Austria, Belgium, Indonesia, United States and England (Silbert et al. 2012). In the EU countries implementing composting techniques with better results are Belgium, Denmark, Germany, Spain, France, Italy and the Netherlands; in which the percentage of urban waste treated by this technique ranges from 13 to 28%. While the average for Europe is 13%, for China is 20%, 5% for India and the United States reached 8.4% (Morano and Moral 2008). These figures reflect the outcome of environmental policies that prioritize the allocation of financial resources to the management of solid waste, allowing developing environmental technologies and services for the management of waste (Medina Ross et al. 2001, cited by Arrigoni 2011).

In some specific cases in localities of Argentina, land use plans have been implemented, considering the practice of home composting as an alternative for cost reduction in waste collection tasks and how to preserve the environment (Silbert et al. 2012). As a successful experience the city of Surabaya, Indonesia, has reduced more than 23% of waste by means of a Community program for decentralized composting with the Takakura consequently this experience has been adopted in many cities in Indonesia, Thailand, Philippines, Malaysia and Nepal (IGES 2010). The objective of this study is to assess the technical and economic feasibility of using microbial substrates MM and Takakura, and its effects on the degradation of organic solid waste in home composting systems, by comparing the costs of composting organic waste at the household level with such substrates.

Methodological framework

Site and Laboratories

The field phase where the experimental units were established was held in the grounds of CNEAO-INA, located in Chinchilla of Cartago, Costa Rica in collaboration with teachers and students of organic agriculture and organic fertilizers from that institution. Laboratory tests related to microbiological aspects of compost samples from these experimental units were performed in the Laboratory of Agricultural Microbiology, of the Agricultural Research Center, University of Costa Rica (LMA-CIA-UCR), with the guidance and support by Dr. Lidieth Uribe and laboratory personnel. Analyzes related to chemical aspects was conducted by the Laboratory of Soil and Foliar, Agricultural Research Center, University of Costa Rica (LSF-CIA-UCR).

Experimental design

The experimental design established for the study was completely randomized with five treatments (MM, MMT, TAKA, Takat, ABST) and four replicates for each treatment. For a total of 20 experimental units, described below. The experimental unit consisted of one plastic container with holes, which allows air to easily pass from all directions (to ensure aerobic process); with a capacity of 0,035 m3, where the composting of organic waste from household origin was performed, with corresponding treatments

Methods compared for organic waste composting are the inoculated substrate Mountain Microorganism (MM), Takakura inoculated substrate (TAKA) MM treatments substrates without inoculation of microorganisms (MMT) and Takakura substrates without inoculation microorganisms (Takat) in addition to an absolute witness, whose residues were not using any type of substrate or microbial inoculation (table 1).

Table 1. Treatments under study.

Treatment	Description
MM	Organic waste with MM substrate inoculated with mountain microorganisms
MMT (Testigo)	Uninoculated MM waste substrate microorganisms, nor fermentation
TAKA	Residues with Takakura inoculation substrate with inoculated fermentative microorganisms substances.
TAKAT (Testigo)	Takakura Waste substrate with uninoculated microorganisms, nor fermentation.
ABST (absolute control)	Waste without substrates MM or Takakura, nor inoculation of microorganisms.

The production of MM inoculum is based on the collection of substrates that are being degraded by microorganisms in wild ecosystems (forest litter or mulch) to later place them in a particular environment that provides a high and diverse nutritional quality for multiplication and subsequent use as inoculum. These substrates are prepared to accommodate microorganisms having different ecological niches where they can settle and multiply in an accelerated manner the colony forming units (CFU) of the multiple species of saprophytic collected microorganisms (Pacheco 2009). The Takakura method is a technique for converting organic household waste into organic fertilizer, developed by Mr. Koji Takakura, Researcher, IGES in Indonesia; where waste is subjected to the composting microorganisms culture media adapted to the soil, available in the natural environment. This technique involves using fermenting microorganisms that can be obtained locally, such as fruit peels, fermented food, rice bran, rice hulls, manure, among other ordinary composting organic waste (IGES 2010).

Cost Analysis of compost family units (UCF) substrate MM and TAKA

For costs comparison of treatments used, the items related to the production of MM and TAKA substrates and their application to domestic scale were defined, considering items of development and operation, such as:

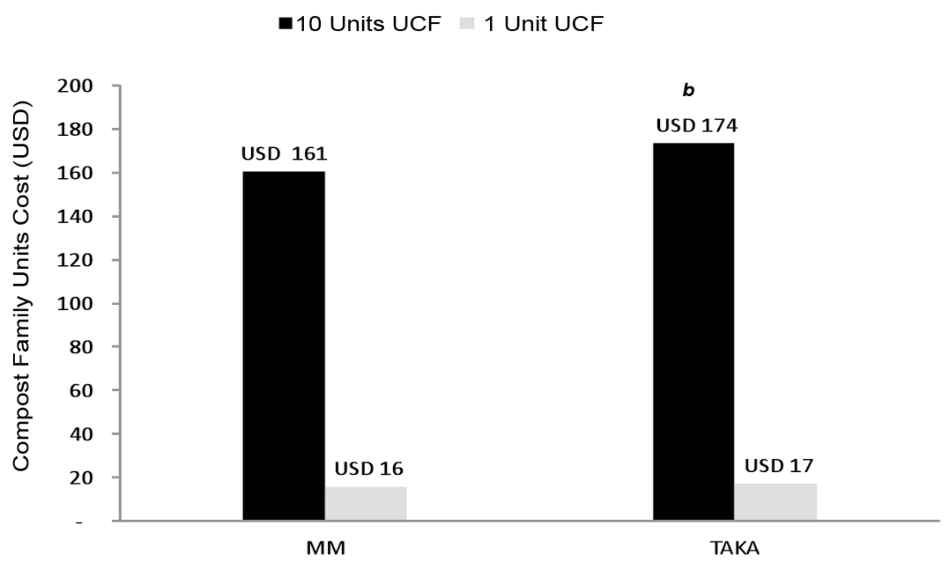
- Ingredients to produce 50 kg of each native microorganisms substrates, based on the established procedure for the production of the respective substrates. With 50 kg of either substrate a total of 10 family composting units (UCF).
- Tools used in producing containers substrates. This item qualifies as investment, since is only acquired once; however these recipients may already exist in homes.
- Labor to produce 50 kg of each substrate.
- Plastic container (compost bins) for the substrates and disposal of waste for composting. plastic boxes were budgeted for the agricultural study. However this may vary, since any container can be used that allows air flow therein.

All costs were recorded in a excel spreadsheet, where the total cost for the production of 10 UCF, in colones and US dollars was recorded (CRC exchange rate of 561.58, published by the Central Bank of Costa determined Rica 07-05-2014), as well as the percentage of the cost of each item in the total cost calculation. Likewise, the cost per capita for a UCF and the cost of the unit, with reference to three people per household were calculated. On the other hand the cost for treating a ton of organic waste with treatment MM and TAKA was calculated in order to compare these costs with the average cost of disposal of municipal solid waste in landfills which is $ 40/ton according Soto (2013).

Results and discussion

Breakdown of costs per treatment

The breakdown of costs presented in table 2 and table 3 lists the items to produce 50 kg of substrate MM and TAKA respectively, which are necessary to establish 10 units of family composting (UCF). The main items are divided into substrates' ingredients, transport, tools, labor and containers for composting organic household waste. These major categories apply to both treatments, however detail varies according to the ingredients and the reproduction process according to the respective native microorganisms treatment, as explained below. The production of 10 UCF with MM substrate, has a total cost of CRC 90,210 (USD 161), whereby a UCF MM would cost a family the amount of CRC 9,021 (USD 16), on average CRC 3,007 (USD 5 35) per capita. On the other hand, the production of 10 UCF with TAKA substrate, has a total cost of CRC 97,470 (USD 174), whereby a UCF TAKA would cost a family the amount of CRC 9,747 (USD 17), on average CRC 3,294 (USD 5.79) per capita (Figure 1). Therefore, comparing the costs of both treatments, the UCF with MM has a cost of 7% lower than the UCF with TAKA.



* Values with common letters are not significantly different at a confidence level of 0.05.

Figure 1. Summary of costs for production and one 10 UCF UCF with each treatment.

As shown in tables 2 and 3, some similarities are present in the use of ingredients for the production of the MM and TAKA substrates, such as rice husks and semolina. However the amount of semolina used in the treatment TAKA is 4 times more than that used in treating MM, and corresponds to 9% of the cost of treatment TAKA while that ingredient in treating MM represents less than 2%.

As regards the tools used for producing substrates, such as shovel, water pot, shower and bucket, are used in both treatments; the differences in the large category regard the MM treatment in which for its production a sealed barrel is required increasing the tool cost; and in the case of TAKA is the use of plastic containers (for the preparation of the fermentative solutions) which decreases such cost. Another difference is in the workforce, since to produce 50 kg of MM substrate 4 hours less are required to produce the same amount of TAKA.

The cost of plastic boxes used as compost bins and transportation of materials is the same in both cases. All items required for the substrate production in both treatments, are the tools and plastic boxes; which represent a one-time investment, therefore, for future production of the substrate MM or TAKA, the cost is reduced to ingredients, transportation and labor force which is a 39% and 58% respectively of the initial costs. The production of both treatments collectively, can be an option that can reduce some costs, in a community, neighborhood or group of neighbors, where the cost of tools and labor, by the contribution of the participants themselves, or share those of those costs can be avoided, being a unique investment, as the more families the less costs.

As for the relative costs for production of UCF with MM treatment, 36% corresponds to tools especially due to the use of the airtight barrel of 200 l (CRC 20,000) representing 22% of the total cost. Use of this barrel is recommended for production of 50 kg of substrate, as this is its maximum capacity; if production is less than 50 kg is recommended to seek cheaper options, considering that the aspect to be taken into this container is to have a tight lid to ensure anaerobic conditions required for the production of MM.

Table 2. Breakdown of costs for the production of 10 units of family composting (UCF) with MM substrate.

Item	Amount	Unit	Unit cost (CRC)	Total cost (CRC)	Total cost (USD)5
Ingredients of MM substrate					
Rice semolina	10	kg	220	2.200	3,92
Ground coal	10	kg	300	3.000	5,34
Rice husks	10	kg	100	1.000	1,78
Sawdust	10	kg	100	1.000	1,78
Molasses	2	kg	500	1.000	1,78
Forest mulch	10	kg	200	2.000	3,56
Water	22	l	5	110	0,20
Tools					
Plastic barrel 200 l	1	unit	20.000	20.000	35,61
Plastic bucket	1	unit	2.000	2.000	3,56
Sprinkler	1	unit	5.000	5.000	8,90
Shovel	1	unit	5.500	5.500	8,90
Agricultural plastic box	10	unit	2.240	22.400	39,89
Transport of materials	1	unit	10.000	10.000	17,81
Labor	6	ud	2.500	15.000	26,71
			Total cost	90.210	178,44
			Cost/UCF	9.021	16
			Per capita cost	3.007	5,35

Table 3. Breakdown of costs for the production of 10 units of family composting (UCF) using TAKA substrate

Item	Amount	Unit	Unit cost (CRC)	Total cost (CRC)	Total cost (USD)6
Ingredients of TAKA substrate					
Soluciones fermentativas	20	l	569	11.380	20,25
Rice semolina	40	kg	220	8.800	15,67
Rice husks	10	kg	100	1.000	1,78
Forest mulch	2	kg	200	400	0,71
Tools					
Plastic bucket	1	unit	2.000	2.000	3,56
Sprinkler	1	unit	5.000	5.000	8,90
Shovel	1	unit	5.500	5.500	9,79
Plastic boxes	2	unit	3.000	6.000	10,68
Agricultural plastic box	10	unit	2.240	22.400	39,89
Transport of materials	1	unit	10.000	10.000	17,81
Labor	10	horas	2.500	25.000	44,52
			Total cost	97.470	173,56
			Cost/UCF	9.747	17,36
			Per capita cost	3.249	5,79

5 Exchange rate by the Banco Central de Costa Rica, 07-May-2014, CRC 561,58.

6 Exchange rate by the Banco Central de Costa Rica, 07-May-2014, CRC 561,58.

Plastic boxes are the second highest cost which corresponds to 25% of total investment, however this item is not really exclusive to the production process of the substrate MM, but for UCF establishment. Labor is the following cost category corresponding to 17% of total production costs for MM substrate. The ingredients to produce and transport MM correspond to the lowest percentages of all items, 11% each item.

Potential economic impact using UCF MM and TAKA

Despite differences between MM and TAKA treatments' costs, these are low when you consider that either of these two treatments with a UCF can take care about management of an organic fraction of generated that would end up as municipal solid waste from each of the households in the country, averaging 401.5 kg correspond to organic waste per year per household, according to estimates by the PEN (2013) figures. A UCF of MM or TAKA, is capable of efficient and harmless compost 548 kg of organic waste per year, a little more than is generated in a house on average. With a single initial investment of US $ 16 (MM) to US $ 17 (TAKA) per household in the first year and $ 6 (MM) to $ 10 (TAKA) the following years, a corresponding production of 5 kg of substrate to inoculate again one UCF every 6 months.

According to Soto (2013), the cost for disposal of municipal solid waste in a landfill is an average of $ 40 / ton. If disposal costs are considered to represent 30% of the total cost of waste management (Soto 2006), the total cost for the management of municipal solid waste is US $133/ ton. Extrapolating the cost of MM and TAKA treatments for the management of one ton of organic waste, the first year to handle a ton with UCF MM would amount to US $ 29 and with UCF TAKA a cost of US $ 31; for subsequent years this cost would be US $ 11 and US $ 18 with MM and TAKA treatments respectively, as shown in Figure 2; reducing significantly costs for managing organic waste from 77 to 89% on average for both treatments, when compared to the current cost of handling a ton of municipal solid waste in landfills, without considering the environmental and social costs, which are generated with current waste management.

Another aspect to be highlighted as a potential economic impact, is the recovery of organic waste by converting them into high quality compost, in this regard the cost of producing 1 kg of organic fertilizer for the first year is 59 CRC/kg with MM and 89 CRC / kg with TAKA. For the second and subsequent years the cost of production of organic fertilizer at the household level would be reduced to 23 CRC / kg with MM and 52 CRC / kg with TAKA (Figure 49). Comparing these costs with those of organic fertilizer production from residues of a coffee mill and a sugar mill which belongs to CoopeAgri Cooperative (which is approximately CRC 22/kg of fertilizer), it can be seen that the production of organic fertilizer with MM the second year has a cost 6% more than it has CoopeAgri with TAKA treatment.

However, when comparing the costs of production of fertilizer treatments with the selling price of this product by the company "Abonos del Occidente" whose selling price is 160 CRC/kg of fertilizer (Figure 3), it can be said that families engaged in home composting with MM or TAKA, could earn an income from the sale of compost generated annually between CRC 17,520 to CRC 24,528 respectively, with profits in the first year of 63% with MM and 45% with TAKA and from the second year the profits from the sale of compost would be 86% with MM and 68% with TAKA. With the above economic viability if families do not use it, the sale of compost becomes an income option. However, this requires an organization at community level or family to provide quantities of compost with a feasible management as marketing and registration is required to sell such products.

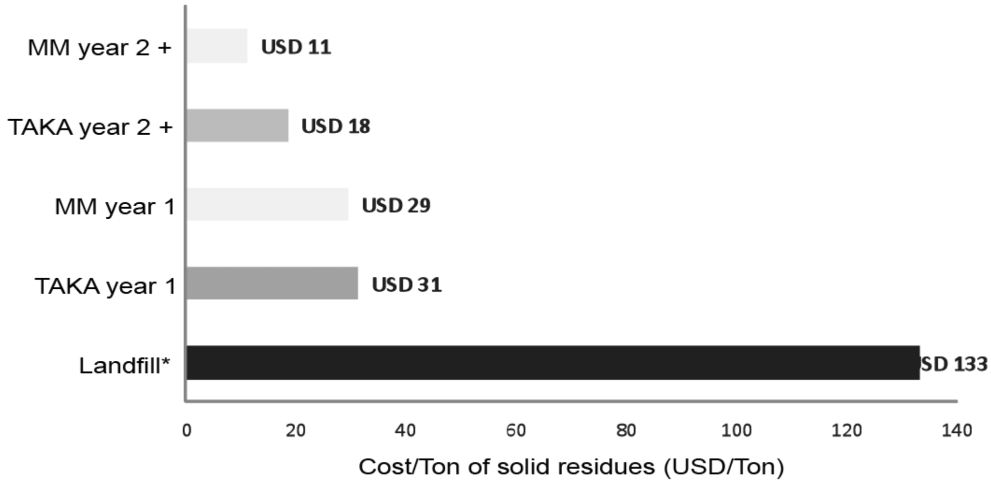


Figure 2. Cost (USD/ ton) estimated for the management of organic solid waste with every UCF MM, TAKA and landfill. (source: Soto 2013)

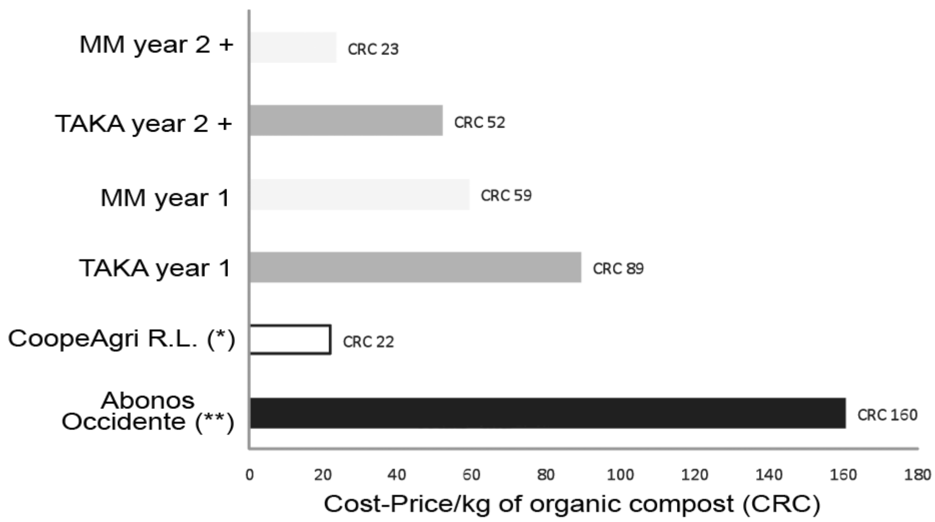


Figure 3. Cost-price comparison for organic fertilizer production between treatments and commercial fertilizers.

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