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Food Waste Recovery with Takakura Portable Compost Boxes in Offices and Working Places

Joaquín Jiménez-Antillón *, Carlos Calleja-Amador and Luis G. Romero-Esquivel

Environmental Protection Research Center (CIPA), School of Chemistry, Instituto Tecnológico de Costa Rica, Apartado 159-7050, Cartago, Costa Rica; ccalleja@itcr.ac.cr (C.C.-A.); lromero@itcr.ac.cr (L.G.R.-E.)

* Correspondence: joajimenez@itcr.ac.cr

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Abstract: The Takakura technique converts food waste into compost. This project explored the potential use of composting in offices and workplaces. The method involves using small boxes containing a fermentation substrate where food waste is added. Two Takakura composting boxes (TCBs) were placed in the kitchens of the Chemistry Department and the Environmental Engineering buildings at the Instituto Tecnológico de Costa Rica, Costa Rica. Food waste from both buildings, comprising the food waste of 45 staff members, were composted from June to December 2015. All types of food, except grease, oil, raw meat, and bones, were processed. The mass and volume of food added to the boxes were quantified daily. A chemical analysis of the compost was also performed. A speech was given to educate the staff members about the system. A survey, before and after the speech, was developed to evaluate the knowledge and tolerance towards composting in closed spaces. A total mass of 88.29 kg, equivalent to 232 L of residues, was processed, from which 17.37 kg (37 L) of compost was obtained. This represented a mass and volume reduction of 80% and 84%, respectively. Compost analysis gave a C/N ratio of 14.7/1, indicative of maturity. Most of the staff members (92%) agreed to the separation of waste at the source. However, 37% suggested allocating the box outside the building. The survey, after the speech, showed that educating staff is necessary before installing boxes at a workplace.

Keywords: Takakura method; home composting; food waste; offices; workplaces

1. Introduction

Each year, 1.32 billion metric ton equivalent to about one-third of the food produced for human consumption, is lost or wasted [1]. Food waste has a deep moral implication and generates social, economic, and environmental costs [2]. According to the aforementioned research works, the food currently produced globally is enough to feed all the world´s population. However, 13% of the world population is undernourished [1]. In economic terms, food waste management generates high costs for governments, organizations, and consumers. Moreover, the costs of landfill planning and management are onerous, especially in developing countries, which have limited budgets [2]. From an environmental perspective, food waste includes greenhouse emissions and an inefficient use of land, water, and energy [3]. In order to tackle this problem, some institutions, such as the European Union (EU) Waste Framework Directive [4], are committed to encouraging the separate collection of bio-waste—considering composting and the digestion of bio-waste to be high priority [5]. As an example, in Sweden, organic household waste (OHW) separated at the source is composted and digested in centralized large-scale plants as the most common treatment method [6]. In Costa Rica, as well as in the rest of Latin America, economic development and the growth of urban populations has generated an increasing amount of OHW. In the near future, this increase will exceed the existing capacity of landfills [7]. The situation is complicated for small countries like Costa Rica. Furthermore, as in the rest of Latin America, the technologies that have been preferred in many developed countries for managing post-recycling wastes, such as waste-to-energy (WTE), are not competitive with landfills or show prejudices of an environmental nature [7]. In Costa Rica, since 2010, the Solid Waste Management Law (GIRS in Spanish) requests mandatory separation at the source, valorization of the materials, and alternative treatment strategies such as composting [8]. However, to date the trend continues to be the use of landfills and dumps for the disposal of OHW, usually violating environmental regulations. Until 2013, only 23% of municipalities in Costa Rica had an approved solid waste management plan [9].

Organic waste is typically the densest component of any waste stream. Consequently, its disposal is more expensive and has the highest greenhouse gases emissions once in the landfill [10]. In contrast, by transforming food waste into compost, organic matter accumulates in the soil and is not emitted into the atmosphere as methane [1]. However, this alternative has not been yet applied in government institution facilities.

Another alternative consists in producing energy via anaerobic digestion. An interesting approach was proposed by Franchetti [11], in which food waste from households and restaurants is deposit in a Greenbox prototype located in a collecting point. Once in the Greenbox, the food wastes should be transported to a large-scale anaerobic digestion plant. This method involves incentives for user participation at a community level, provided that the designed prototype operates at a low cost. In addition, it prevents landfill disposal, reduces greenhouse gases emissions, and contributes to clean energy production. The system, design by the students of the University of Toledo (OH), has a cost of US$3858 and works as an automated food waste collector. However, it requires users' collection of their food waste in plastic bags as well as the retrieval of the station once it is at two-thirds of its capacity by a transportation service. The system also indicated that users could report its potential misuse to earn incentives.

The separation and recovery of organic solid waste (OSW) has proven to be difficult for higher education institutions (IHE) and municipalities [10]. Well-documented cases of organic waste management in university campuses are scarce. Smith et al. [10] described the University of Northern British Columbia, Prince George Campus, where a volunteer-based compost program diverts 13 metric tons of organic material each year. However, the compost program has been unable to reach its full potential given the limited financial resources and volunteer capacity [10]. On the other hand, at the Autonomous University of Baja California, Mexico, organic waste generated from food is mixed with all different types of waste inside the same bin [12]. Therefore, not only the food waste is lost but also paper and paperboard are no longer recyclable. Besides, there is no company within the locality which takes this type of waste; consequently, its final destination is the landfill [12]. As mentioned by Wilkie [13], waste audits in three primary schools in Florida showed that food waste comprised the majority of the cafeteria's school waste stream. Hence, its diversion from disposal at landfills present a clear opportunity for increasing the ´greening´ of school cafeterias. Also, because this food waste is generated at a single point, diversion is a practical option in addressing the problem of food waste.

Takakura composting is an alternative food waste management for offices and workplaces in universities and other settings in general. This household composting method was developed at the Institute for Global Environmental Strategies (IGES) of Japan [14]. The method consists in adding the food waste into "Takakura bins" with dimensions of 40 cm × 25 cm × 70 cm. There, the organic waste is transformed into compost by means of fermentative microorganisms [14]. The system is designed to operate in small spaces such as kitchens or backyards and is ideal for households of 5–10 people [15]. In this study, the term Takakura substrate is used as a synonym for Takakura effective microbes (Takakura EMs).

Takakura home composting (THC) was implemented in about 40,000 households in the city of Surabaya, Indonesia [15]. The study demonstrated a substantial improvement in the municipal solid waste management by reducing the volume of organic waste generation at disposal sites by 30%. Another study at the University of Kebangsaan, Malaysia (UKM), showed that Takakura effective microbes (EMs) in a rotatory composter were superior to other EMs tested in enhancing and accelerating the composting process [16]. Saad et al. [17] found similar results when comparing Takakura EMs with fruit EMs, obtaining good quality compost from UKM [17]. Campos-Rodríguez [18] evaluated a degrading substrate with mountain microorganisms (based on forest mulch) and another degrading substrate, and compared these with Takakura microorganisms in composting food waste methods adopted by restaurants at the Costa Rica Institute of Technology (ITCR in Spanish). The Takakura substrate was more efficient in reducing the volume of the residues [18].

The application of THC inside offices and workplaces at IHEs has not yet been reported. Consequently, it is important to evaluate the use of THC as an alternative to treat the food waste from coffee shops, offices, and workplaces, such as those at IHEs. The use of Takakura composting bins proposed in this work represents an interesting low-cost option. This document presents the results of a THC pilot study performed in two cafeterias at the ITCR, which is a public university. It explores food waste collection and on-site composting at the same time. This avoids the need for a transportation service. In terms of costs, Takakura composting boxes (TCBs) require an investment of ca. US$75/bin, and avoid completely the use of plastic bags to divert food waste. In contrast to the design proposed by Franchetti [11], TCBs are not automated. The aim of this study was to evaluate the performance of the THC technique in workplaces as well as to assess people's perceptions of use of THC bins for collection and composting at the source.

2. Materials and Methods

2.1. Study Site

The ITCR main campus hosts approximately 12,000 people, including faculty, staff, and students. The Institutional Waste Management System (MADI in Spanish) has been successful in managing glass, plastic, and paper [19]. However, food waste has two different management options. In the case of the main restaurants, raw and cooked food waste is used for animal breeding. Food waste from the rest of the buildings, which accounts for approximately 13 metric tons per year (data not yet published), is sent to the landfill. Considering that, the Chemistry Department and Environmental Engineering cafeterias were chosen to evaluate the potential use of THC bins on campus. Both facilities include 45 faculty and staff members, 31 and 14 in the Chemistry Department and Environmental Engineering buildings, respectively.

2.2. THC Bins

Compost substrate and TCBs were acquired from the local supplier Ecolur Domestic Composting (https://www.ecolurcompostaje.com/blank-c1wfv). The substrate is a mixture of two aqueous solutions, one containing sugar, yogurt, sour cream, cheese, beer, and yeast; and the second containing salt, fruit, and vegetable peels. Along with this, semolina or bran, rice pellets, forest mulch, and charcoal are added and mixed according to Borrero [20] and IGES [14] recommendations. The total amount of substrate was 4 kg in each TCB. Well-chopped food waste (Figure 1) was diverted and disposed inside two boxes, one for each facility. All types of food, except grease, oil, raw meat, and bones, were processed. Each TCB was designed with a full size of 33 cm × 50 cm × 30 cm, a total surface area of 0.16 m^2 (Figure 1), and an estimated loading capacity of 1.2 kg of waste per day. The TCB unit consisted of a wooden box with holes to allow aeration and ensure aerobic conditions. The substrate and food waste were contained in a cotton fabric bag with a hood of the same material to avoid vectors.

Figure 1. Feeding the Takakura compost box.

2.3. TCB Operation: Feeding and Quantification

A small plastic container with an airtight lid was placed in each cafeteria to collect food waste. This small container was located next to the container for ordinary non-compostable waste. At the end of each day, in the cafeteria sink, an operator selected the waste collected in each small container by hand, chopped it, incorporated it into the TCB, and mixed all its content (Figure 1). The two boxes were fed only by one person in each facility from June to December 2015. Mature compost was obtained as follows: every three weeks, the waste that exhibited homogeneous appearance (compost) and a dark color was removed to plastic bags. The compost in opened plastic bags was left to mineralize for another three weeks, after which it was ready for chemical analysis. Special attention was given to detect the advantages and disadvantages of collecting and processing the food waste as mentioned before.

The total mass of food waste was quantified each time the waste was added to the TCBs. Average values of the volume and density of food residues were quantified by measuring, on seven occasions, the mass and volume of the waste (without being chopped or compacted). With the density (0.38 ± 0.07 kg L^{-1}) and the total waste mass, the total waste volume added to the boxes was quantified. The total compost volume produced was obtained by measuring the total compost mass produced and its density. Volume reduction through composting was quantified by total crude waste volume means and total compost volume. The leachate production was also checked during the experiment.

2.4. Temperature Monitoring

The temperature of the composting system is an indicator of microbial activity. Therefore, in a second experiment, the TCB located at the Chemistry Department building was operated again over 24 days in February 2017. The temperature was measured hourly with a Lascar Thermocouple Temperature USB Data Logger model EL-USB-TC-LCD. Every time the waste was added to the TCB, all residues were evenly distributed through the Takakura substrate. The thermocouple was installed in the middle of the substrate-residue system.

2.5. Chemical Composition of the Compost

The compost obtained by the Takakura method was analyzed at the National Institute of Innovation and Technology Transfer Soil Laboratory (INTA in Spanish). All parameters were measured in triplicates. Humidity was determined at 105 °C by the difference between the compost wet weight and dry weight. The pH was determined by adding distilled water to a compost mass up to 1 mm above the upper level of the solid, which was then manually shaken and the pH was measured. The macronutrients, total nitrogen and organic carbon, were quantified by the Dumas dry combustion method according to Kalra [21]. Total P, K, Ca, and Mg were quantified by extraction with modified Olsen solution in a microwave oven, followed by atomic absorption spectrometry [21]. The micronutrients, Mn and Fe, were quantified as well using the recommendations reported by Kalra [21]. Copper was also determined by Kalra [21] and zinc was determined following the AOAC Official Method 985.01 [22].

2.6. Perception of Users

To evaluate the tolerance, knowledge, and degree of acceptance of faculty and staff members regarding the use of TCBs for food waste recovery from both cafeterias, two surveys were developed. The first one (n = 39 individuals) was developed before an inductive speech concerning Takakura composting; the other one was conducted after the speech (n = 24). Both surveys were anonymous with closed answers. The aim of the first survey was to assess how much general information the staff members knew about composting, particularly about composting in confined spaces. The questions from the second survey were designed to evaluate how much the staff members' opinions improved concerning the Takakura method suitability. Specifically, the surveys investigated whether staff would agree to install a TCB bin in their workplace cafeteria.

A special criterion to consider was the opinion of the person that manually chopped the food waste and mixed it with the substrate. An informal interview was conducted, leading to a positive perception with no observations towards the overall preparation of the waste prior to composting.

3. Results and Discussion

Decentralized treatment of organic matter at the source is broadly agreed to be the best system to prevent inadequate management of organic waste [23]. THC seems to be a simple and cheap option to manage food waste in a decentralized manner. In that sense, THC was studied as a possible solution for workplace cafeterias in two public facilities at ITCR. Following, the main results of the production, the characteristics of the compost produced, as well as the perception of the users are presented.

3.1. TCB Operation: Feeding and Quantification

During the waste collection and compost production, no plastic bags were used for the waste transfer from the coffee shops to the composting system, as the food was processed on site. TCB composting is very effective as it requires the manual sorting of the material to prevent undesirable waste from going into the compost; this ensures a high-quality product. The use of mixed waste for composting has been proven to impair the quality of the compost, failing to meet the fertilization and heavy metal requirements of the control quality standard [24]. Like Hogland et al. [25], in this study, daily source separation and shredding of the waste reduced bad odors and enhanced microbial activity.

Table 1 shows the monthly per capita food waste processed using the THC bin from each cafeteria throughout the study period. Per capita food waste generation in both dining rooms was about one third of that reported by Wilkie [13] in their study, which was in an educational setting with a population that included students, which were factors that were not considered in our study. The bins were used for full months from August to November, and for half-months in June, July, and December due to holiday periods. During the full-time period (June to December), both facilities produced around 88 kg of food waste—62 kg and 26 kg, respectively, which is agreement with the number of persons at each facility (Table 1). Consequently, the waste generated in the Chemistry Department building almost doubled the amount in the Environmental Engineering building. Additionally, the per capita generation (0.37 and 0.39 kg month^{-1} cap^{-1}) was very similar, as expected considering that both populations were made up of instructors and administrative assistants with similar dietary habits. The amount of waste generated allowed a daily TCB waste loading of 0.59 kg day^{-1} TCB^{-1} and

0.24 kg day^{-1} TCB^{-1} (considering 20 working days per month) for the Chemistry Department and Environmental Engineering cafeterias, respectively. These amounts were well below the maximum processing capacity that each TCB was designed for (1.2 kg day^{-1}). Campos-Rodríguez et al. [18] and Borrero [20] reported food waste loadings of 1.5 kg day^{-1} TCB^{-1} and 1.35 kg day^{-1} TCB^{-1} using the same type of TCB and substrate. However, these TCBs were fed by household food waste and processed in a backyard. Considering the latter results in comparison to those reported here for the Chemistry Department, for example, a TCB for 31 persons processed 0.59 kg day^{-1}, it could be expected that a TCB located in a workplace could perform well for around 80 people if one TCB could receive 1.5 kg day^{-1}, as reported by Campos-Rodríguez et al. [18].

The impact of the use of TCB can be quantified considering the mass and volume of the waste. A reduction of the material weight assumes a reduction of the fee charged by the local landfill. Less volume of waste can also enhance the life of the landfill. When composting, no material would end in a landfill. Regarding the mass of the waste, the waste reduction to form compost was around 80%, from 88 kg of waste to 17 kg of compost (Table 1). The reduction in the volume gave a comparable reduction percentage (84%), from 232 L of food waste to 37 L of compost (Table 1). Another advantage of the implementation of TCBs is that no composting center would be needed.

A comparison of the mass and/or volume reduction from this study with that of other studies is shown in Table 2. Results of this study were superior than the 36% reported by Borrero [20] when using a similar method of composting. However, in that study the reduction in volume was measured from the height of the material inside the TCB, while in this study, it was measured by comparing the volume of crude waste with the volume of compost obtained. Another study [16] using the Takakura method in a rotatory composter obtained a 65% mass reduction (Table 2). Other authors reported a comparable volume reduction (80%) with vermicompost [26] and smaller values (54.4%) when using the Bokashi technique [27].

Table 1. Food waste processed, compost production, and waste reduction from two Costa Rica Institute of Technology (ITCR) cafeterias.

Food Waste Source (Population)	Total Food Waste kg ^{a} (L)	Monthly Food Waste per Capita (kg month^{-1} cap^{-1}) ^{b}	Daily Food Waste Processed per TCB (kg day^{-1} TCB^{-1})	Total Compost Produced kg ^{a} (L)	Waste Reduction Mass (Volume) (%) ^{a}
Chemistry Department (31)	62.56 (165)	0.39	0.59	13.04 (28)	79 (83)
Environmental Engineering (14)	25.73 (68)	0.37	0.24	4.33 (9)	83 (86)
Total (45)	88.29 (232)	0.38 ^{c} ± 0.03 ^{d}	0.42 ^{c}	17.37 (37)	81 ^{c} (84)

^{a} Period: June–December; ^{b} period: August–November; ^{c} average; ^{d} standard deviation. TCB: Takakura composting box

Table 2. Comparison of decentralized compost systems.

Reference	Technique	Setting	Dimensions Requirements	C/N	Final pH	Maximum Temperature Reached (°C)	Composting Period (days)	Percentage Reduction (%)	Food Waste Processed (kg day^{-1} TCB^{-1})
This study	Takakura composting box (TCB)	Office cafeterias	33 cm × 50 cm × 30 cm	15	6.0	54.0	42	84 (volume)	0.42
[18]	TCB	Composting facility	30 cm × 50 cm × 25 cm	N.R.	7.5	55	N.R.	N.R.	1.5
[20]	TCB	Composting facility	33 cm × 50 cm × 30 cm	15	7.6	60	17 and 35	36 (volume)	1.35
[16]	Composter barrel with Takakura effective microbes (EMs)	Backyard	N.R.	17	7–8	60	42	N.R.	N.R.
[16]	Rotary composter with Takakura EMs	Backyard	90 cm × 70 cm × 95 cm	13	7–8	73	28	65 (mass)	N.R.
[17]	Composter barrel with Takakura EMs	Cafeterias	N.R.	17	7–8	60	42	N.R.	N.R.
[16]	Composter barrel with fruit waste EMs	Backyard	N.R.	13	7–8	50	42	N.R.	N.R.
[17]	Composter barrel with fruit EMs	Cafeterias	N.R.	13	7–8	50	42	N.R.	N.R.
[26]	Vermicompost (*Eisenia foetida)*	Composting facility	N.R.	5.6	8.2	N.R.	90	80 (volume)	N.R.
[27]	Bokashi techinique	Market	N.R.	26–32	7–8.5	65	13	54.4 (mass)	N.R.
[28]	Aerated pile	Composting facility	1.5 m × 1.4 m × 1.0 m	16–21	7.0	46–64	26	N.R.	N.R.

N.R.: not reported.

3.2. Temperature Monitoring

The high temperatures (up to 54.0 °C) obtained in this study permitted the action of mesophilic and thermophilic microbes that grow between 10 and 45 °C and between 45 and 50 °C, respectively. This microbe action allowed the volume and weight of the residues to be reduced, causing their humification (C/N = 15/1) (Table 2) and darkening. Figure 2 shows the temperature of the composting process throughout the feeding period of fresh food waste.

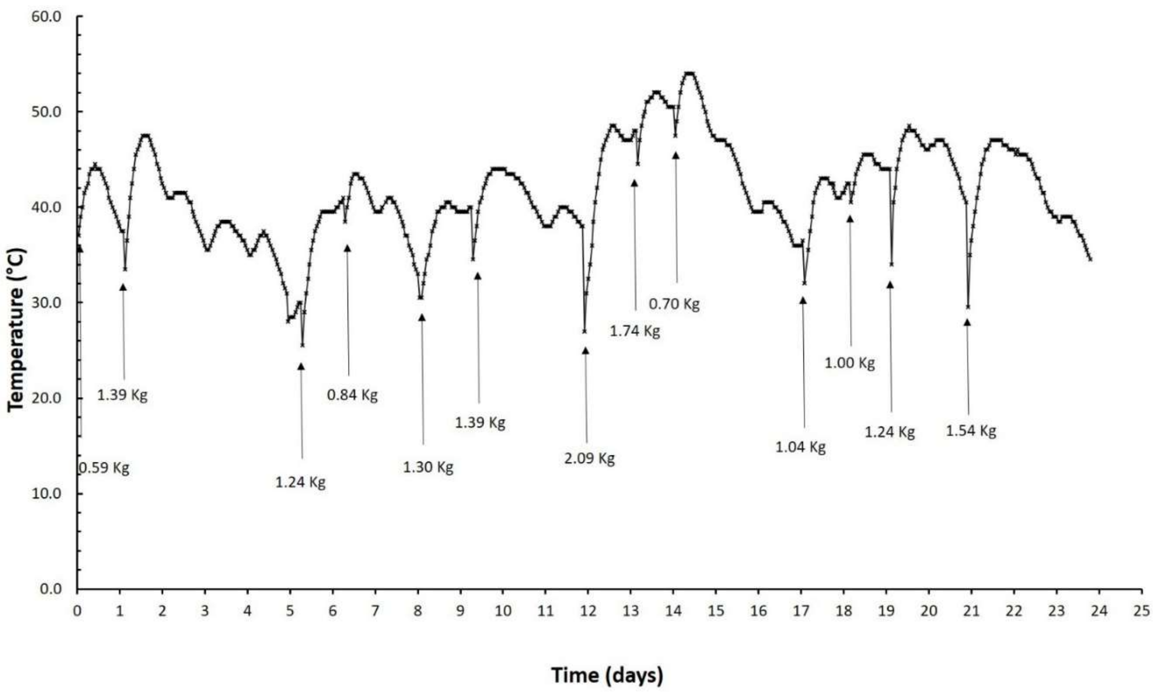

Figure 2. Composting process temperature profile while feeding the TCB.

Each time the waste was added, the composting system was homogenized (aerated) completely. Therefore, minimum temperature values were observed whenever food waste was added (see the arrows below Figure 2). Peak temperatures were observed within one day after the addition of new material. As more consecutive days passed and a greater mass of waste was added to the TCB, higher temperatures were reached. This was observed from days 12 to 15 and 17 to 20, which had the highest consecutive amounts of waste. Each time food waste was added, the temperature exceeded 45 °C within a few hours after the addition. This condition favored thermophilic microorganisms and the possible inactivation of some pathogens. However, in agreement with Gajalakshmi and Abbasi [29], all pathogens would be destroyed at approximately 60 to 70 °C. When no waste was added, after a peak in temperature, the temperature gradually dropped off as the degradation rate of organic matter decreased [29]. These authors showed that this phenomenon results in the adequate stabilization of organic matter and drying of the compost, in addition to contributing to the diminishment of the pathogens burden. Unfortunately, in the present study, no pathogens determination was conducted. Therefore, considering that the higher temperature in the TCB was 54 °C and that international regulations [30] establish a compost temperature above 55 to 60 °C to eliminate pathogens, further research on this aspect is recommended.

Other authors reported higher peak temperatures (60–73 °C) (Table 2) when using Takakura EMs as in the present study [16,17,20]. Those temperatures were higher than when fruit EMs were used. For example, Abushammala et al. [16] and Saad et al. [17] obtained peak temperatures of 50 °C (Table 2). Campos-Rodríguez et al. [18] also reported lower peak temperatures (53 °C) when using mountain soil microorganisms. The above demonstrates that the organic matter decomposition by Takakura EMs has a greater magnitude [31] than that achieved by the application of fruit or mountain

EMs. This indicates that for proper pathogens removal, the type of microorganism in the substrate is relevant. Further research on this subject is needed as well.

3.3. Chemical Composition of the Compost

3.3.1. Humidity and pH

The results of the physical and chemical analysis conducted on a sample of mature compost generated by TCBs are discussed herein. The moisture content of the compost obtained in this study was 21%, a value much lower than that recommended for compost (35–50%) [31]. This could be because the three weeks when the compost was left to mineralize in an opened plastic bag caused a loss of excess humidity. Other authors reported higher moisture content in the final compost when using the Takakura substrate. Borrero [20], with no mineralization step, obtained 45% humidity; in Abushammala et al. [16], 51–53% humidity was obtained using a rotary composter. Saad et al. [17] obtained 48–57% humidity when using a composter barrel.

Accordingly, with the humidity results presented, the absence of leachate in the composting process would be expected. This was confirmed in this study when a TCB or composter barrel was used, and confirmed by other authors [16–18,20]. This is explained owing to the high temperatures developed during the composting process (54–60 °C, Table 2) and because the composting was conducted in open systems, which reduced the excess humidity. On the contrary, Abushammala et al. [16] observed leachate from a rotatory composter using the Takakura substrate with coconut husks (to reduce humidity) when processing food and yard waste. The latter was detected even though higher temperatures (73 °C) were observed during the composting process. Possibly, the design of the composter was the cause of the presence of leachate, given that the waste was more confined than that inside a TCB.

The pH of the compost was 6.0, which is slightly lower than the level recommended by Moreno and Moral [31] (between 6.5 and 8.5) and the values reported by other studies (Table 2). However, it is expected that a pH of 6 would not affect the quality of the soil, as they are usually mixed in a 1:3 compost to soil ratio. Other authors using the Takakura method reported final pH values in compost between 7 and 8 (Table 2).

3.3.2. Macronutrients and C/N Ratio

Most important macronutrients in a compost are N, P, K, and the C/N ratio. The total N, P, C, and K concentrations obtained in this study were within the optimum ranges reported by Altamirano and Cabrera [32] (Table 3).

Table 3. Macronutrient concentrations of the compost from different origins.

Reference	N	C	P	K	Ca	Mg
			(%)			
This study	2.09 ± 0.17	30.6 ± 3.1	0.98 ± 0.09	1.55 ± 0.12	0.52 ± 0.04	0.44 ± 0.04
[20]	2.41	36.72	1.88	2.87	0.62	0.88
[32] *	0.4–3.5	8–50	0.3–3.5	0.5–1.8	1.5–7	0.5–1.5

* Recommended values.

Those concentrations were comparable (as expected) to those reported by Borrero [20], who used a similar food waste and composting technique. However, there were different residence times of the waste inside the TCBs and subsequent mineralization times. The authors of Borrero [20] made several waste contributions to the TCBs, but a unique crop of compost after 35 days was taken as the total period of the assay (Table 2). This implies that some of the compost was as young as 17 days old or as old as 35 days. In the present study, the finished compost had an average age of 42 days (Table 2). However, the macronutrient contents were within the ranges of the finished compost Altamirano and

Cabrera [32], with the exception of Ca and Mg, whose concentrations were below the optimal range (Table 3). The low calcium content found in Borrero [20] and this study was justified in part by the absence of calcium-rich foods such as bones.

A C/N ratio between 12/1 and 14/1 corresponds to that observed for organic improvement with high N liberation, which is considered an indicator of maturity [29]. The carbon to nitrogen ratio obtained in this study (15/1) (Table 2) was within the acceptable parameters for mature compost. Other authors reported similar C/N ratios of the final compost when using the Takakura substrate (Table 2) [16,17,20]. In another study by Mbuligwe et al. [28], in an aerated pile without effective microbes, the C/N ratio for composting organic household waste was reported to be in the range of 16/1 to 21/1. All the references in Table 2 show C/N ratios in the range of 13/1 to 21/1, except the composts obtained by vermicompost (5.6/1) [26] and by the Bokashi technique (26/1 to 32/1) [27]. In accordance with Gajalakshmi and Abbasi [29], vermicompost has a lower C/N ratio than conventional compost irrespective of the source of organic waste, which means a greater availability of nutrients to the soil.

Regarding the composting period, in this study it was 42 days—three weeks inside the TCB plus three weeks of mineralization at room temperature. After that, the chemical analysis was performed. This period was chosen arbitrarily; that is, it was not based on any indicator (e.g., pH, temperature). The experiences with Takakura systems reported in Table 2 show a composting period of 28 to 42 days and C/N ratios between 13/1 and 17/1. Both parameters, reported here, are within those values. In general, the significant differences are shown with other types of composting techniques. For example, vermicompost needed a longer composting period and produced a lower C/N ratio (Table 2).

3.3.3. Micronutrients and Heavy Metals

Concentrations of micronutrients Fe and Mn and heavy metals Cu and Zn found in the compost in this study were below the maximum allowable concentrations for compost based on the legislation of The Netherlands [30] (Table 4).

Table 4. Micronutrient and heavy metal concentration of the compost from different origin.

Reference	Fe	Mn	Cu	Zn
	(mg kg^{-1})			
This study	1181 ± 177	327 ± 49	35 ± 5	103 ± 15
Borrero [20]	3616	371	26	81
Durán and Henríquez [26]	5714	218	47	1118
MAC [a]	N.A.	N.A.	300	900

N.A.: not available. [a] Maximum allowable concentration for The Netherlands, Brinton [30].

For iron and manganese, there are no maximum concentrations reported. Concentrations of the same order of magnitude were found by Borrero [20], given that the same type of substrate and organic waste were used in both studies. However, the concentrations of Fe, Cu, and Zn found in the Takakura compost output were always lower than those in vermicompost output reported by Durán and Henríquez [26] (Table 4).

3.3.4. Perception of Users

From the first set of questions to assess how much the staff members knew about the impact of food waste, 79% of the population mentioned the adverse impact produced once food waste was disposed of in a landfill. In addition, and over 75% of the population surveyed had general knowledge of composting. However, only 23% had heard about the Takakura method. From the second set of questions regarding the knowledge and the degree of tolerance regarding the use of TCBs (conducted after the speech), a high degree of acceptance was found by the population considering the suitability of the Takakura method. That is, 75% of the surveyed population answered positively, saying that Takakura composting was appropriate for operation in enclosed spaces such as kitchens or offices. Also, 92% agreed with the practice of collecting food for later composting with the Takakura method. However, only 63% consented to the installation of a permanent TCB in the cafeteria of the Chemistry Department; the remaining 37% suggested locating the box outside the building. The arguments against installing and operating a TCB in the cafeteria were, for example, non-tolerance of strange odors, the unattractive aspect of the TCB, the cafeteria is too small to hold a box, it would be very unpleasant to observe the operation of the TCB and the chopping of residues, and the possibility of spore pollution during food intake.

3.3.5. Final Remarks and Future Perspectives

One relevant aspect questioned by some users in the survey was whether or not there were pathogens in the air at the moment of mixing the TCB. As reported by Kristanto et al. [33], it was found that Takakura homemade composting increased total indoor bacteria and fungi concentrations in the air, coming from the mixing and turning of the TCB. Total indoor bacteria and fungi concentrations increased (roughly 1.5-fold) after the agitation, even at least 4 m from the compost bin [33]. However, the presence of pathogens was not reported in this study. This aspect, together with the presence of pathogens in the final product, require further studies to decide where to install and manipulate the TCBs and to assess the proper management of the compost produced.

The observed weaknesses in the operation of the Takakura method found from this study were:

1. Feeding the TCB was time-consuming given that it required an operator to properly select the waste, chop it by hand, and incorporate it into the TCB. Then all the materials had to be washed in order to avoid odors and vectors. The use of a blender is not convenient since it causes an excess of humidity that would lower the temperature of the decomposition process. Hence, chopping by hand is the most appropriate way to feed the TCB. The above brings an advantage; as already mentioned, due to the manual selection of waste, the incorporation of undesirable materials into the compost is prevented. This was partly demonstrated by the low concentrations of heavy metals found in the compost (Table 2).
2. Food waste manipulation prior to the feeding of the TCB should take place in a different setting than the cafeteria or in non-working hours. This is to avoid negative comments from the staff, which occurred in this study.
3. The TCB should be cleaned on the outside frequently to avoid the proliferation of undesirable insects and odors.

However, there are also many advantages to this method—such as producing a good quality compost, processing on-site to avoid transport and landfill costs, operational simplicity, no energy supply needed, and only small space required for processing.

Furthermore, the results of a successful implementation of the Takakura method at a national level would mean a significant reduction of food waste in homes and institutions (which comprises more that 50% of OHW) in urban areas, where space for conventional ground composting is not available. Currently in Costa Rica, the company Ecolur Domestic Composting has sold around 650 TCBs and has an active website: https://www.facebook.com/search/top/?q=Ecolur-compostajedomestico.

Takakura home composting implementation in other types of facilities outside universities would lower the high organic content of municipal solid waste in urban areas, thus improving sustainable waste management, which has become highly important in the urban environment agenda of cities and nations in Latin America [7]. It may also contribute to meet GIRS requirements in terms of waste valorization, giving added value to this portion of the overall waste generation.

4. Conclusions

This study found that Takakura composting boxes can be an appropriate method for the transformation of food waste into good-quality compost in about six weeks, from the cafeterias of ITCR buildings. The produced Takakura compost had a quality comparable to other techniques in its macro and micro nutrient composition, as well as in its pH level and absence of leachate.

It is important to inform potential users of the proper use of the Takakura method prior to its implementation. Some people showed resistance to having the TCB in confined places, most probably due to the lack of knowledge about the technique.

The TBC is recommended to be implemented in offices and workplaces given its operational simplicity, no energy supply requirements, low-cost maintenance, and potential to reduce landfill and transport expenses. Although it is simple to handle, the need for one person to manipulate and look after the TCB is a potential drawback if this person is not well motivated. Even though both the Chemistry Department and Environmental Engineering buildings hosted TCBs in well-ventilated areas with natural ventilation, further studies are recommended to determine the risk of airborne pathogens, as well as to investigate smell control and proper aeration in closed areas. It is emphasized that no formal complains of bad odors were reported. Utilization of the produced compost for specific activities, such as gardening and crop growth on a small scale, are currently under investigation.

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