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# Minimizing Onsite Organic Household Left-Over Waste: The Emission Benefits of Keeping Pet Rabbits

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**Abstract:** As waste management is becoming all the more crucial, this study investigates the way in which house left-over organic waste can be better managed on site, in order to minimize the off-site treatment cost and maximize environmental performance. For the implementation of this research, a full year measurement was recorded, showing the organic leftover waste food intake of two rabbits in a household of four. The organic food, collected in two separate baskets suitable for composting—though one for rabbit intake—was 168.5 kg in total, plus 68.8 kg, which was delivered directly to the composting bin, along with food remains and rabbit feces. The results show that, over the examined year, a total of up to 0.417 metric tons of $CO_2$ equivalent per year emissions was avoided, suggesting that if 30 houses were to apply this methodology, one garbage truck journey per year would be saved. Overall, this study suggests that better information and environmental awareness can result in on-site, low cost, individual management of recyclable organic material, which would assist with the decrease in the cost of management, along with increased environmental performance.

**Keywords:** organic household waste; on-site management; organic waste management; rabbits

## 1. Introduction

As general consumption is growing, the levels of municipal solid waste are increasing [1], with their disposal being an important issue that needs to be handled, especially given that waste management is not sustainable [2]. The cost and environmental impact are of concern [3] along with health and energy issues [4], as the management of such waste could be difficult and could be facing many obstacles, especially in developing regions [5,6].

In light of the above, new methods need to be applied in order to minimize landfill waste disposal [6], as many municipal wastes' discarding, such as fruits and vegetables, is not trivial [7]. Organic waste management has received wide scientific attention [7–9], especially for evaluating the existing methods' environmental performance [10], in addition to better handling the cost and environmental issues, such as sanitation [11], that arise from the existing waste management methods [12].

Recycling source separation projects in households are a sustainable waste management practice, though, apart from investments, all the involved actors should be effectively targeted as well in order to produce a successful food waste recycling program [13]. For example, a supervised food waste sorting program in Shanghai resulted in 70% of residential food waste being collected from apartments [14]. In separating household waste, what have been suggested to be positive drivers are (a) the specified information of the procedure, (b) the easy and user-friendly systems, and (c) the belief that the effects will be significant [15]. This requires the in-depth analysis of each proposed technology, in order to provide the cost and environmental benefits derived.

The management of organic and food household waste is an issue much studied over the past years [7,8,16–20] in various regions. As composting is becoming a wide range choice for organic waste management [5,20], various methods have been explored, such as vermicomposting [7,17] (even for household waste [6]), as "*an alternative to centralized composting*" [8]. The composting of household organic waste is, in a sense, the on-site management so as to minimize waste: a method to make food waste valuable [8], extend landfill life, and minimize GHG emissions [21]. The benefits of on-site home composting are even better compared to those of large scale, due to the lack of waste transportation [21–23].

Food/Organic waste is a large percentage of the total household waste, as, for example, 39% in Crete, Greece [24], and up to 61.64% in Turkey with regard to the season and income level [25]. Overall, Karak et al. [26] provide a thorough review on several countries where the decreasing relation of organic waste fraction and economic development of the respective country can be observed. Other factors affecting the organic fraction in household waste are culture, climate, energy sources, as well as how often waste is collected and how it is disposed of [27]. Since worldwide the organic fraction comprises the largest part of the household waste, it is essential that management practices aiming at reducing food waste quantities will be the most sustainable ones, especially the low cost on-site options. Thus, composting can considerably relieve the waste quantities since it is easier to manage compared to other materials. For this, a successful master plan with an emphasis on public consultation is essential [28,29], along with promoting policies for affecting recycling behaviors [30], as the citizens' preferences is a factor that should be explored for optimizing such environmental conservation practices [31,32].

Rabbit is a popular pet, serving as a companion animal in many countries all over the world [33,34]. The guardians take care of the appropriate environment, diet, and exercise for their pet rabbits, also taking into account behavioral, social, and health aspects [35], while it has also been suggested that their welfare awareness and monitoring are important tasks [36]. Companion rabbit owners have an environmentally friendly perception of their pet manure, due to the consumption of fruit and vegetable leftovers and the composting of their droppings [37–39]. This is true, since less waste is disposed, while properly managed manure that will provide a product with fertilizing value could be regarded as a sustainable option in the pet food system [40]. Rabbit manure has been reported to be an effective biofertilizer [41], while Bianchi et al. [42] showed that, with the appropriate mixtures of rabbit manure, compost could meet the agronomic and legislation limits under specific conditions.

Homemade organic compost from food and garden remains can assist with waste minimization, which can also be enhanced if rabbit or horse manure is independently composted onsite [43]. In addition to the financial benefits, feeding small scale chicken and rabbit populations with food waste followed by the composting of the produced manure can be regarded and classified as a sustainable model for onsite waste management [44].

Based on the above, what is of importance in the waste management field is to explore innovative ways of integrating on-site household waste management in everyday life. This study aims at investigating the method of waste management of organic material by monitoring and collecting organic left-overs suitable for rabbit food and composting. The rest of the paper is structured as follows: Section 2 consists of the method of the data collection; in Section 3, the results are presented and discussed; and Section 4 consists of the overall conclusions and further research suggestions.

## 2. Materials and Methods

The data were collected over a period of a full calendar year in a household of four, consisting of two adults and two children. For each day, the organic compostable matter of household leftovers were collected in two separate baskets, the one containing fruit and vegetable remains and peelings suitable for rabbit food, while the other contained the rest of the compostable remains, such as coffee, banana peelings, eggshells, and seeds. The first basket was used to feed two rabbits—which have a gestation period of around 31 days: one male, also known as a buck, of 2.45 kg weight, and one female, also known as a doe, of 1.25 kg weight. The contents of the second basket were discharged to the compost bin located at the house's backyard (Figure 1). Before each discharge, the baskets were weighed (gram accuracy) and, at the end of the day, the sum was recorded.

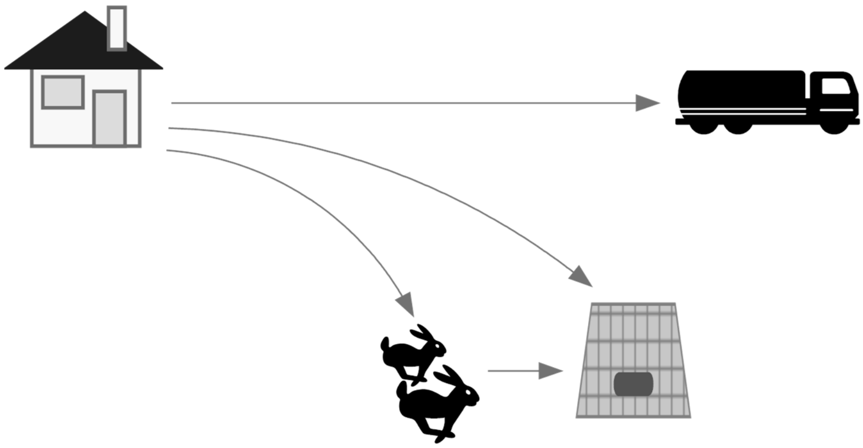

**Figure 1.** Onsite house minimization of organic waste.

This study aims at simulating what the real situation in a typical household would be in terms of quantity flows and $CO_2$ emissions saved. It is a single case design study research, as defined by Yin [45], where the household is used to test the proposed management scenario. Thus, within the everyday activities, the food remains were collected and weighted. If, for example, the family was out for summer/winter holidays or in weekend escapes, then the rabbits were fed only with commercial food. This will result in less than 365 days of data, within a calendar year.

$CO_2$ emissions were calculated using the open source EPA Waste Reduction Model (WARM): "WARM calculates and totals GHG emissions of baseline and alternative waste management practices—source reduction, recycling, anaerobic digestion, combustion, composting and landfilling" [46]. The model allows for parameters to be adjusted to approximate the conditions and distances in the study region. The general application to calculate the avoided emissions is described by Equation (1):

$$E_A = (E_L + E_R) - (E_C + E_R) \quad (1)$$

where $E_A$ denotes the emissions avoided by applying the alternative onsite management scenario, $E_L$ and $E_C$ denote the emissions due to landfilling and composting, respectively, and $E_R$ denotes the emissions due to the rabbits growing. By replacing the independent variables in Equation (1), Equation (2) is derived as follows:

$$E_A = (W_L + T_L + W_R + T_R) - (W_C + T_C + W_R + T_R) \quad (2)$$

where $W_L$, $W_C$, and $W_R$ denote the emissions due to landfilling application, due to compost application, and due to rabbits growing, respectively. $T_L$, $T_C$, and $T_R$ denote the emissions due to waste transportation to the landfill site, due to the compost site, and due to the rabbits growing, respectively. The $W_R$ and $T_R$ variables in Equation (2), i.e., the ones related to the rabbit breeding, are considered as zero, since they are house pet inhabitants (for this study).

Thus, Equation (2) is simplified, described by Equation (3) as follows:

$$E_A = (W_L + T_L) - (W_C + T_C) \quad (3)$$

On the generalized application of this equation where pets do not preexist, the livestock emissions from pet (or household) animal breeding do not require major energy intensity due to its decentralized nature. The WARM tool compares the baseline and the alternative scenarios, helping with calculating emissions avoidance from management practices. However, not all alternatives, such as rabbit breeding, are included in the options of this online tool. In addition, there is also a positive benefit not estimated by this tool, i.e., the emissions avoided from the conventional food production. Further explanation of the methodology is provided by EPA WARM Documentation [47].

## 3. Results and Discussion

Over the examined year of data monitoring, a total of 168.491 kg of organic wastes suitable for rabbit food were collected, while 68.802 kg of other compostable organic waste were composted, bringing the total of on-site managed material to 237 kg. During this year, a total of 15 kg of rabbit food was purchased, in addition to the 168 kg of kitchen leftovers selected as suitable for feeding them, while the doe delivered 11 kits.

As shown in Figure 2, there is a variation of the family kitchen leftovers. From the 365 days of the study year, the food remains were collected and measured for 279. The remaining days there was no presence or kitchen activity to justify food remains in the house. Note that the data collection was carried out by the end of each day.

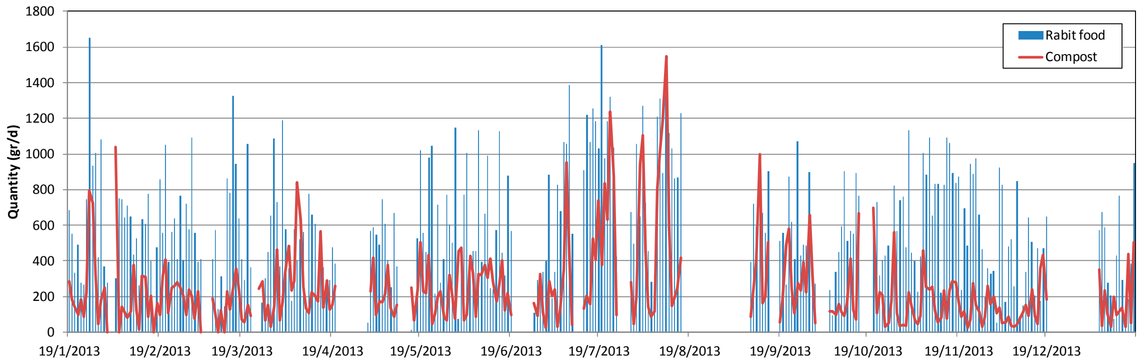


**Figure 2.** Daily variations of organic remains meant for rabbit food or composting.

As suggested in previous work on the subject, composting of household waste on-site can have a positive effect on the environment, as emissions from waste resulting in landfills can be decreased [8], where the average composition being organics 46%, paper 19%, plastic 9%, metals 5%, glass 16%, and others 16% [48]. The results of the present study indicate that the projection to a higher degree of the population would result in considerable savings. Table 1 consists of the descriptive statistics for the organic material, showing that at some points during the examined period the food availability for the rabbits was either very low or very high. In the case of low availability, commercial supplement was provided to the rabbits, while in the case where the organic waste was not consumed, it was diverted to the composting bin along with their feces.

**Table 1.** Descriptive statistics of the organic material (N = 279).

| Statistics | Rabbit Food (kg) | Compost (kg) |
|---|---|---|
| Mean | 0.604 | 0.247 |
| Std. Deviation | 0.323 | 0.235 |
| Skewness | 0.525 | 2.247 |
| Kurtosis | −0.191 | 6.352 |
| Minimum | 0 | 0 |
| 25th percentile | 0.369 | 0.097 |
| Median | 0.557 | 0.184 |
| 75th percentile | 0.834 | 0.305 |
| Maximum | 1.651 | 1.546 |

Note that, on average, 0.6 kg of organic leftovers were fed to the rabbits, while the low percentile was 0.369 kg. A box plot of the day weight of the two baskets is shown in Figure 3.

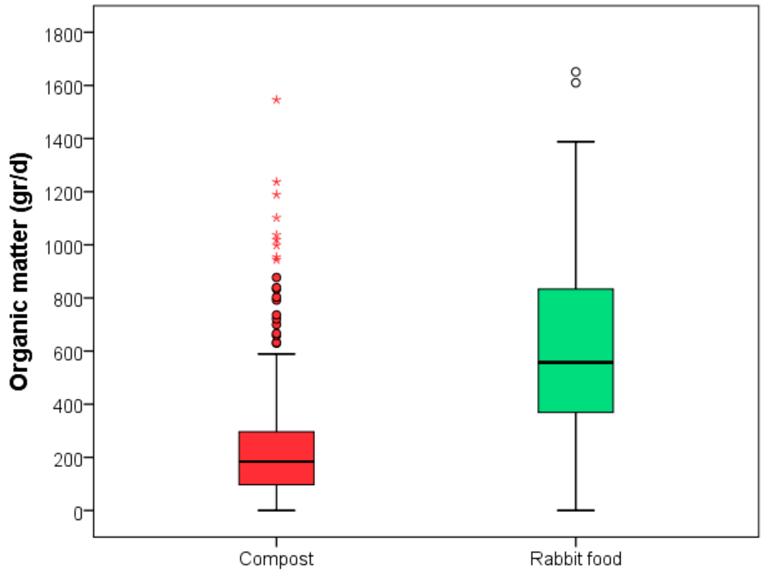


**Figure 3.** Distribution of the daily quantities of organic remains according to the destination.

In the WARM model, the baseline scenario was considered to dispose 237.3 kg of "Fruits and Vegetables" to the landfill, as would be the case in the study region. The alternative management scenario was that 68.8 kg were composted, while 168.5 kg were reduced to the source (which is the rabbit food). This scenario resulted in negative 0.417 Metric Tons of Carbon Dioxide equivalent ($MTCO_2E$) compared to the baseline scenario. If the alternative scenario is that all food waste go to composting, then 0.373 $MTCO_2E$ are saved compared to the baseline scenario. Table 2 consists of different scenarios of $CO_2$ emissions avoided. The WARM model does not include the option of waste minimization resulted by feeding animals. However, in this case, the emissions can be regarded to approximate the value of 0.417 $MTCO_2E$.

**Table 2.** $CO_2$ emissions avoided according to different scenarios.

| Scenario | Quantities (kg) | | | $MTCO_2E$/Year Saved |
|---|---|---|---|---|
| | **To Landfill** | **To Rabbit Food** | **To Composting** | |
| One household | | | | |
| Baseline | 237.293 | 0 | 0 | 0 |
| Alternative 1 | 0 | 168.491 | 68.802 | 0.417 |
| Alternative 2 | 0 | 0 | 237.293 | 0.373 |
| 30 households | | | | |
| Baseline | $7.119 \times 10^3$ | 0 | 0 | |
| Alternative 1 | 0 | $5.055 \times 10^3$ | $2.064 \times 10^3$ | 12.510 |
| Alternative 2 | 0 | 0 | $7.119 \times 10^3$ | 11.190 |

Thus, in addition to the other benefits resulting from composting, the examined household avoided emissions of 0.417 $MTCO_2E$/year. If this method were to be implemented in, for example, 30 households, one garbage truck journey per year and a total of 11.19 to 12.51 $MTCO_2E$/year would be avoided.

In order to valorize food waste, especially given that about 1/3 of total food production goes to waste [12], composting is indeed a valuable method of organic waste management [5]. Good waste management can also decrease the waste of resources [1], as food waste is regarded to be a renewable resource [8]. Thus, the method of on-site food management could assist with (a) cost reduction of waste management and (b) better environmental performance due to reduced emissions and better use of resources.

Currently, there is no municipal organic waste management in the study area, while this is the case for most Greek cities as well. According to Eurostat [49], the per capita waste generation in Greece was 485 kg in 2015, while on average a 2.5% (12 kg) was composted and digested, substantially less than the 78 kg of the EU28 average, putting Greece one place before last amongst EU countries. This study showed that, if the proposed management practice were employed, then the per capita collected leftovers (237.3/4=) 59.323 kg—referring to one (out of 4) family member—can be used as food for the rabbits or be composted, which could increase this percentage to 12.2% (in households with rabbit caring capacity and/or composting facilities). The rabbit food is (168.5/4=) 42.125 kg or 8.7% of the per capita municipal waste.

As indicated by the results, if such a method were to be implemented on a larger scale, the benefits would be important, especially as non-centralized organic waste management is yet at an early stage [50]. This study, however, has some limitations. At first, a parameter not addressed is the qualitative composition of the composted product, which should be monitored before its use. The literature is scarce on the subject of waste management by engaging domestic and companion animals, while very few scientific papers address qualitative issues for the management of the animals' wastes. Paredes et al. [51], for example, managed to produce a stabilized compost from an equal (dry base) mix of goat and rabbit manure after 90 days, but it bears application limitations due to high pH (9.4) and salinity (EC of 13.4 dS/m). Similar pH limitations were observed by Li-li et al. [52], who, using a mixture of rabbit manure, mushroom residue, and rice straw, observed that a more stabilized product, with a pH of 8, was produced. Furthermore, Canet et al. [53] reported that a well stabilized product can be derived from the composting of different combinations of rabbit manure with olive mill pomace, rice straw, or almond shells, but they also found agronomical limitations due to high pH and salinity. Finally, Sobrinho et al. [54] compared composting products derived from the manure of rabbits, mouse, Guinea pigs, and hamsters, which were mixed with cotton waste. As was the case with all pets' manures, rabbit waste was tested positive for Salmonella, and had the highest MPN of fecal coliforms (greater than 1100 per gr). After 100 days, the stabilized product had a negative occurrence of Salmonella, while the fecal coliforms MPN was ranging from less than 0.3 to 15 per gr per pile, i.e., had a 97–100% removal efficiency.

In addition to the qualitative limitations, calculating carbon dioxide emissions is a complex approach in assisting with taking decisions for waste management alternatives [55]. The results of such analyses are case-specific and cannot be generalized [56]. For example, in a study in a Region of Italy, it was shown that incineration was preferable to anaerobic digestion and composting [57]. Furthermore, the composting scenario could increase uncertainty in the calculations [58]. Additional or alternative management options—such as anaerobic digestion—may be superior than composting at municipal systems in terms of carbon emissions [59]. Finally, $CO_2$ emission analysis fails to include the benefits deriving from the commercial value of the produced compost [60].

Awareness and information of the wider public on the subject is crucial for the waste management field, as about 57% of total waste production is organic, with their highest percentages found amongst low income regions [25]. This kind of organic household management would be very suitable and valuable in farms, especially if initiative was taken to implement this case study on a larger scale. The two rabbits lived to their age expectancy, and all the while enjoyed the care and attention of the two children of the household.

## 4. Conclusions

This study examined the carbon benefits of feeding organic household waste to two pet rabbits over a calendar year. The results of this study showed that a total of 0.417 $MTCO_2E$/year emissions were avoided in a single household with the organic waste being fed to the rabbits, while, if 30 households were to follow this method of waste management, in addition to the other benefits resulting from composting, one garbage truck journey would be saved and a total of 11.19 to 12.51 $MTCO_2E$/year would be avoided.

Overall, what is suggested by this study is that better on-site individual management of organic household waste can result in decreasing and then possibly minimizing the disposal of waste in landfills and the off-site cost of management, along with increasing environmental performance through the decrease of emissions and the lessening of resource use. Moreover, the qualitative and quantitative monitoring of the produced compost would significantly improve the existing knowledge of designing a large-scale project in the future.

Future research on the subject could include a pilot scale implementation of this case study, including more households as well as a qualitative investigation of the produced composted product, as to further elaborate on the advantages of on-site organic household waste management on both the economic and environmental aspects of sustainability.

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