Potential of Earthworm (Perionyx Excavatus) in food treatment in Ho Chi Minh City

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Abstract. In Ho Chi Minh City, Vietnam, there are about 9 thousand tons of domestic waste every day and 73% of them are treated by using landfill sites [1]. With the population growth rate in recent years, the generated waste volume will then increase in the future and is estimated to reach a total of around 13 thousand tons that could cost Ho Chi Minh City about 260 thousand dollars in treating this waste in 2025 [2]. Although this treatment method is not without advantages, the downsides will be far more significant. Moreover, in recent years, the cultivation of Perionyx Excavatus, a species that had been reported to have the ability to treat organic waste in some foreign articles, has become increasingly popular in Vietnam. So, this research was aimed to evaluate the potentiality of Earthworm (Perionyx Excavatus) for food waste management of households in Lab-scale in Ho Chi Minh City, Vietnam. According to this study, the average outdoor humidity and temperature of Ho Chi Minh City are suitable the optimal conditions to raise Earthworm. In addition, our team recommends that to achieve the highest biomass ratio of Earthworm (Perionyx Excavatus), the proportion of food waste and cow dung should be 4:6.

Keywords: Earthworm (Perionyx Excavatus), food waste management, Ho Chi Minh City.

1. Introduction
Vietnam is one of the fastest-growing economies in the world. According to Vietnam's economic statistics in the last ten years (2009 - 2019), gross domestic product (GDP) reached about 266 billion USD, and per capita reached 2,800 USD from a growth rate of 5.40% in 2009 to 7.02% in 2019, the highest in the past ten years [3]. In parallel, Vietnam's population growth rate is also increasing rapidly, especially in Ho Chi Minh City which is estimated to reach a population of 12 million by 2025, including peri-urban areas [4]. As a result of the rapid population growth, there is also a steadily increasing volume of domestic solid waste, especially food waste. According to the National State of Environment Report, in 2011, the total volume of domestic waste generated nationwide was about 44,400 tons/day, which increased to 64,658 tons/day in 2019 (approximately higher 46% compared to 2010). In addition, the volume of domestic waste increased significantly in localities with high urbanization, industrialization, and tourism such as Ho Chi Minh City (9,400 tons/day) and 50-65% of domestic waste are biodegradable organic components (food waste, plant and animal carcasses) [3].
In recent years, the habitation of human beings generates a huge amount of domestic waste, especially food waste, which affects the quality of nature and our living environment. Uncared dumping of leaf litter in public places and the premises of educational institutions might lead to the decomposition of solid wastes particularly during the rainy season resulting in air, water, and soil pollution. It also causes social, ecological, aesthetic, economic problems, human health, and quality of life [5]. Hence, these wastes must be treated carefully. In the face of waste treatment, Ho Chi Minh City has to spend 1,100 - 1,200 billion VND for landfilling (69% by volume), the rest being composted (20%) and burned without energy recovery (11%) [4]. However, waste disposal still faces challenges and a lack of operational experience.

All these problems require a more efficient alternative to reduce both processing costs and the area of the landfill in Vietnam. Especially in terms of food waste, old traditional techniques of composting and organic farming are encouraged because of its environmentally friendly. During composting, the waste organic materials are broken down into different organic products which can be added to the soil with a much beneficial impact on crop growth. The benefits of compost in improving plant growth and yield due to its effects on nutrient availability and improving physic-chemical and physical characteristics of the soil are well known. However, compost is also known to play a role in suppressing various fungal and bacterial plant diseases via the activities of constituent biological, physical, or chemical agents [6].

It is recognized that Earthworms (Perionyx Excavatus) are a potential species based on their high protein and high levels of enzymes [7]. Therefore, many studies have been conducted on the speed of the process of composting (Vermicomposting) and enhance the nutritional quality of compost of Earthworm (Perionyx Excavatus), for example, research about the utilization of Earthworm (Perionyx Excavatus) in organic waste management in India [8] or Evaluation of Earthworm (Perionyx Excavatus) Growth Raised in Different Cultures [9]. In Vietnam, Earthworms (Perionyx Excavatus) are popular species for farming. Although temperature and humidity conditions, especially in Ho Chi Minh City are very suitable for the development of Earthworms, there are very few studies on using Earthworms for waste treatment.

This study was focused on evaluating the potentiality of Earthworm (Perionyx Excavatus) for food waste management of households in Lab-scale in Ho Chi Minh City, Vietnam. Through this results, it was proposed an alternative method in the treatment of organic waste toward smart city in Ho Chi Minh city in 2050.

2. Research methods

2.1. Method of observation via experiments

The research has implemented 2 experimental models which were implemented from 20th December 2019 to 15th March 2020.

2.1.1. Model 1: Earthworm (Perionyx Excavatus) raising model (100% feed of cow dung, from Earthworm breeding farms) serves for maintaining the breeding stock provided for Model 2.

Designed with dimensions L x H x D: 100cmx100cmx50cm, respectively. Model 1 was designed outdoors (Figure 2). To increase efficiency, the model of storing Earthworm (Perionyx Excavatus) was designed to have a 1m² area and a height of 50 centimeters including 4 layers: clean sand, plastic mesh, biomass, and food. Each layer has its function in raising the Earthworm (Perionyx Excavatus), as below (Figure 1, 2).

- Layer 1: 3 centimeter-thickness clean sand. This layer is the buffer between the ground and the plastic mesh layer which allows maintaining the humidity at an acceptable level. When it rains, water will pass through this layer, seep into the ground helping the model not to be flooded and Earthworms not to suffocate. Moreover, the clean sand layer could prevent other insects in the soil from entering the model.
- Layer 2: 3 millimeter-thickness plastic mesh layer includes 2 plastic meshes sized 32 holes/cm². The hole meshes are small enough to help the Earthworm (Perionyx Excavatus) to stay away from the risk of being floated through the mesh and going out of the environment.
• Layer 3: 6 centimeter-thickness biomass layer. This layer is the ‘house’ of the Earthworm (Perionyx Excavatus) that should keep at an optimal temperature for the Earthworm life (at 20°C-28°C). Besides, the soil must be porous, clean, and nutritious so that the Earthworm (Perionyx Excavatus) can develop well.
• Layer 4: Food layer. This layer is the mixture of cow dung and food after incubating for 2-3 days.

2.1.2. Model 2: Earthworm (Perionyx Excavatus) raising model by organic waste.

Model 2 for evaluating the efficiency of Earthworm (Perionyx Excavatus) by feeding organic waste with a variety of mixing organic feed rates. This model was designed with dimensions L x H x D: 40cm x 20cm x 20cm by 5 mica pieces (0.5cm in thickness). The mica material was used because of the waterproof, the transfer limitation, and the transparency, which allows observation of biomass easily (as Figure 3, 4). There were 4 layers like the storing Perionyx Excavatus model:
• Layer 1: 3 centimeter-thickness clean sand.
• Layer 2: 3 millimeter-thickness plastic mesh layer.
• Layer 3: 7 centimeter-thickness biomass layer.
• Layer 4: Food layer.

2.2. Method records

The evaluation parameters include temperature (surroundings and in the experimental model), humidity, and biomass were analyzed in the laboratory to assess the factors affecting the culture process and the biomass speed of Earthworms. The experiment was recorded every two weeks because the feed of the Earthworm (Perionyx Excavatus) also changed after two weeks. Moreover, using rule, scale, and handheld digital humidity & temperature meter to determine. Moreover, using Microsoft Excel to take notes during the experimental period.

2.3. Method calculation and conversion temperature and humidity

Temperature and humidity are two crucial factors in raising Earthworms [9, 10]. According to the previous researches, the optimum temperature for Earthworm (Perionyx Excavatus) is between 25°C and 28°C [10], and the temperature difference between outdoors and in the experiment is 10°C – 20°C [9]. In the experiment, it was not possible to directly measure the temperature at the raising model, so it was calculated by the outdoor temperature + 1°C.
2.4. Method of calculation Perionyx Excavatus’ biomass

The mass ratio of Earthworm (Perionyx Excavatus) over time was determined by the following formula (according to Mazanraeva):

\[
\text{Growth rate (kg/worm/day)} = \frac{W_2 - W_1}{t_2 - t_1}
\]

\( W_1 \): The initial weight of worms (kilograms)
\( W_2 \): The final weight of worms (kilograms)
\( t_1 \): Age of the worms at the start of the experiment (in days)
\( t_2 \): Age of the worms at the end of the experiment (in days)

2.5. Statistical methods and data analysis via Microsoft Excel

The experimental data were analyzed and evaluated by Microsoft Excel Office 2019 to construct the humidity and temperature graph, the growth rate of Perionyx Excavatus, and the percentage of biomass increased. In addition, this software was used to calculate the mass of Earthworms in Model 1 and Model 2.

3. Results and discussion

3.1. Domestic Solid Waste Management in Ho Chi Minh City

The socio-economic development and the rapid population growth cause pressure on the environment when the amount of solid waste and especially domestic solid waste is arising more and more. Ho Chi Minh City is the core of Vietnam’s largest urban area, which is expected to reach 12 million people by 2025, including peri-urban regions. Ho Chi Minh City is facing a steady increase in domestic waste volume, with a generation rate of 10% – 15% which is higher than the rest of Vietnam (8% – 10%) [12]. It is estimated that Ho Chi Minh City has a high rate of domestic waste generation (over 1.0kg/person/day) and the total volume of domestic waste is at about 7,200 –7,800 tons/day (excluding waste sludge) [4].

Figure 5. Ho Chi Minh City Map.

Source: [13]
Sources of domestic waste arise from households, commercial and service areas, offices, public areas, and the daily activities of production facilities. In addition, the main components of domestic waste are organic (food waste, paper, cloth, etc.), inorganic (plastic, rubber, metal, etc.), and other wastes such as e-waste, batteries, waste oil (shown in Table 1).

### Table 1. Composition of Domestic Solid Waste from households, schools, markets, sanitary landfills, and compost processing plants in Ho Chi Minh City (% by wet weight)

| Waste component | Households | Schools | Markets | Sanitary landfills | Compost plants |
|-----------------|------------|---------|---------|--------------------|----------------|
|                 | 2009 | 2015 | 2017 | 2009 | 2015 | 2009 | 2015 | 2012 | 2014 | 2015 |
| Food waste      | 74.3 | 64.8 | 59.2 | 28.7 | 25.5 | 86.8 | 87.8 | 68.9 | 67.9 | 53.2 |
| Wood, straw     | 2.8  | 0.9  | 2.4  | 6.9  | -    | 3.6  | 1.4  | 0.7  | 0.3  | 1.0  |
| Paper           | 6.2  | 5.1  | 6.4  | 17.6 | 35.0 | 2.5  | 1.9  | 3.0  | 2.5  | 5.7  |
| Plastics        | 5.5  | 11.5 | 13.9 | 35.7 | 36.4 | 4.7  | 7.7  | 16.0 | 16.4 | 13.7 |
| Diapers         | 1.8  | 8.1  | 0.6  | -    | -    | -    | -    | 2.3  | 0.6  | 10.7 |
| Textiles        | 1.0  | 3.2  | 4.0  | 1.1  | 1.0  | 0.4  | -    | 5.0  | 7.2  | 10.7 |
| Leather         | 0.2  | -    | 0.6  | 0.1  | -    | -    | -    | -    | -    | -    |
| Rubber          | 0.9  | 0.9  | 2.0  | 1.4  | -    | 0.4  | -    | 0.7  | 0.7  | 0.7  |
| Glass           | 1.3  | 1.4  | 2.6  | 0.5  | 1.2  | 0.2  | -    | 1.2  | 0.2  | 1.7  |
| Metal           | 1.0  | 0.8  | 5.5  | 2.8  | -    | 0.3  | 0.1  | 1.6  | 3.6  | 0.3  |
| Crockery        | 0.8  | 0.5  | 2.8  | 0.6  | -    | 0.1  | -    | -    | -    | 2.4  |
| Ash and dirt    | 3.2  | 2.8  | -    | 4.0  | -    | 1.0  | 1.2  | -    | -    | -    |
| Cinders         | 0.4  | -    | -    | -    | -    | -    | -    | -    | -    | -    |
| Seashell        | 0.8  | -    | -    | -    | -    | 0.2  | -    | 0.8  | 0.6  | -    |
| Hazardous waste | 0.002| -    | 0.1  | -    | 0.1  | -    | -    | -    | -    | 0.1  |

Source: [4]

It is shown that food waste is the main component of domestic waste, which takes up to more than 50% of the wet weight of the domestic waste volume, followed by recycling components such as plastic, paper, and metal. According to statistics, biodegradable organic components (food waste, plant, and animal carcasses) were found in nearly 9,000 tons of domestic waste collected every day in Ho Chi Minh City which accounts for about 50 - 65% of the volume (wet) equivalent to the volume of 4,500 - 5,850 tons of organic matter generated per day [4].

To handle the amount of domestic waste collected, Ho Chi Minh City has to spend 1,100 - 1,200 billion VND for landfilling (69% by volume), the rest being composted (20%) and burned without energy recovery (11%) [4]. However, it has not yet achieved high efficiency and especially landfills are a problem causing environmental pollution in recent years. For instance, Da Phuoc Landfill is reported in air pollution and recommended that an alternative sustainable technology is needed to reduce the rate of landfilling (Figure 6) [14].
For another example, Tay Bac Solid Waste Treatment Complex (Figure 7) directly affects groundwater, air, and surface water sources, which is the cause of serious environmental pollution for many years [15].

3.2. Processing of Experiments

3.2.1. Model 1: Earthworm raising model at the laboratory

The purpose of the experiment in Model 1 is to create a source of Perionyx Excavatus for their experiments and check the ability of the worms to grow when it is completely fed with cow dung. The preparation of the mixture and the incubation process took place within 2-3 days. After incubating, the mixture was spread into lines with 2.5-3.5 kilograms of food and feeding Earthworm (Perionyx Excavatus) 2-3 times a week. The feeding process and the growth of Earthworms are shown in Figure 8.
3.2.2. Model 2: Earthworm raising model by organic waste

The mixture of cow dung and organic waste was incubated for 5 -7 days and then spread into lines in which 0.3-0.5 kilograms each line. The Earthworms were fed 2-3 times per week like model 1. Firstly, it fed Earthworm (Perionyx Excavatus) with a ratio of 9.5:0.5 (cow dung: food waste) in 2 weeks, and then up the rate to 2.b (9:1) feed in the next 2 weeks. Next, the ratio components like 2.c (6:4) were an experiment in the 5th and 6th weeks. Then, Perionyx Excavatus was fed with a ratio of 8:2 in the last 2 weeks. Finally, it is going on to feed 100% of food waste in this model.

Figure 8. The feeding process of Model 1.

Figure 9. The feeding process of Model 2.
3.3. Results

3.3.1. Preliminary Data Collection and analysis

3.3.1.1. The moisture levels
The interplay of the moisture level and temperature dramatically affects both the growth rate and biomass of Earthworm (Perionyx Excavatus). A suitable level of moisture for Perionyx Excavatus is about 60-70% [18] and the average outdoor humidity of Ho Chi Minh City in the first three months of the year ranges from 71% to 73.8% (Figure 10) [12]. Therefore, during the research, models always are ensured the appropriate moisture level.

![Figure 10. Humidity in Ho Chi Minh City in 3 months (%).](image)

3.3.1.2. The temperature
One of the main factors that affect both the growth of the rate of Earthworm (Perionyx Excavatus) as well biomass and vermicomposting production is temperature, therefore, the too high or too low temperature can lead to reduced worm production. According to statistics, Ho Chi Minh City has two distinct seasons: the rainy season from May to November and the dry season from December to April next year. The average temperature is 27.55°C with high humidity and rainfall. The month with the highest average temperature is in April (28.8°C) and the month with the lowest average temperature is between December and January (25.7°C) (shown in Figure 11). In addition, the optimal temperature of the background for Earthworms is in the range of 25°C to 28°C [10]. Therefore, it can be seen that the temperature conditions of Ho Chi Minh City are suitable for the development of Earthworms.

![Figure 11. Ho Chi Minh City average temperature and rainfall in 12 months.](image)
The below chart indicates the temperature variation of the experimental model, which is conducted in the period from January to February. In the first month, the temperature is quite stable, fluctuating between 22°C and 33.5°C. Although the environment and substrate temperature in the first month are not optimal for the development of Earthworms, the growth rate of Earthworms remains stable. In the second and third months, the temperature fluctuates from 25°C to 35°C, higher than the first month. However, the application of appropriate methods helped a stable growth rate of Earthworm (Perionyx Excavatus) as Figure 13. The data is from [12].

![Figure 12. The change in ambient temperature during the experiments.](image)

### 3.3.1.3. The growth rates

To evaluate the growth of Earthworm (Perionyx Excavatus) as well biomass and vermicomposting production, the mass of model 1 and 2 with different feed rate had investigated and shown in table 2.

| Model | Input (kg) | Output (kg) |
|-------|------------|-------------|
| Model 1 | 20 | 35.5 |
| Model 2 | 2.a | 1.7 | 3.1 | 5.8 | 11.7 |
|       | 2.b | 3.1 | 5.8 | 11.7 | 11.7 |

According to Table 2, the proportion of biomass of Model 2 is higher than that of Model 1. Especially, in terms of increasing the ratio of food waste in the feed instead of cow manure like 2.c, the growth rates of Earthworm (Perionyx Excavatus) in 2.c rose nearly 1.56 times than its Model 1 and 4.42 and 2.21 than the growth rate of Model 2.b and 2.c, respectively. The growth rate of Perionyx Excavatus in Model 2.d is zero (as Figure 13).
Figure 1. The growth rate of Perionyx Excavatus (kg/worm/day).

In addition, the percentage of biomass in Model 2.c is the highest compared to the remaining experiments (about 50.43%), while that of Model 2.b and 2.a is 46.56% and 45.16%, respectively. The percentage in Model 1 is smaller, with 43.66%. The biomass of Model 2.d for 2 weeks has no change (as Figure 14).

Figure 14. The percentage of biomass increased (%).
3.3.2. Preliminary Findings

After 4 months of project implementation, the experimental results have been achieved as follows:

- Due to experiments placed outdoors, the temperature of the Earthworm (Perionyx Excavatus) raising model (estimated) fluctuated in the range 29°C to 31.5°C, higher than optimal conditions.
- The average outdoor humidity of Ho Chi Minh City ranges from 71% to 73.8%, higher than optimal conditions. The feed directly affects the development of Perionyx Excavatus. The highest growth rate and biomass increase of Perionyx Excavatus are in the feed like Model 2.c (0.42 kg/worm/day) with a ratio of 6:4 (cow dung: organic waste).
- The percentage of biomass witnessed an increasing proportion when rising food waste in the feed to 4:6 (50.43%) with food waste and cow dung, respectively, before declining dramatically in the ratio of 80% food waste and 20% cow manure.

4. Conclusions

This research shows the potential of Earthworm (Perionyx Excavatus) for food waste treatment, which was help not only to reduce the cost of municipal waste treatment but also minimize the amount of waste needed to dumping at landfills. In addition, the output of this process is biomass, which can be fertilizer to vegetable farms in this area for supplying fresh vegetables in Ho Chi Minh City and the Southern of Vietnam.

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