

The Effects of Varying Coffee Ground Amounts on earthworm *Eisenia fetida* Biomass in Vermicomposting

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Abstract

The process of vermicomposting with *Eisenia fetida* has been regarded as a viable solution to the frequent disposal and waste of used coffee grounds. The effects of coffee grounds on earthworms have yet to be fully understood. In a manipulative experiment with varying ratios of coffee grounds and earthworms, we investigate how the amount of coffee grounds affect total earthworm biomass and also how *E. fetida* affects the initial nitrogen content of each ratio treatment. It was found that there are no significant relationships between *E. fetida* biomass and soil/coffee ground mixture pH levels and between *E. fetida* biomass and the percentage of soil/coffee ground mixture nitrogen. Vermicomposting with coffee grounds continues to stand as a valuable waste reducing process that requires furthering studying to provide conclusive results regarding the optimal quantities of coffee grounds for greater earthworm biomass and the relationships among soil pH, nitrogen content and earthworm biomass.

Introduction

The quantity of food wasted in the United States has become a huge issue in recent decades. The amount of food scraps thrown away by Americans has risen by about 50% over the last 35 years (Hall et al. 2009), while a 2006 study by a researcher at the University of Arizona determined that American households now throw away about 14% of all food they purchase (Jones 2006). This food waste makes up another 14%, or 33 million tons, of all municipal solid waste in the United States – all of which will eventually reach landfills or incinerators (EPA 2012). There are huge and immediate detrimental environmental impacts as a consequence of this food waste. When food is disposed of in a landfill, it decomposes quickly and produces significant amounts of methane gas and CO₂, both of which contribute majorly to global warming (EPA 2012). Food waste also leads to the excess consumption of fossil fuels and freshwater, which also are factors in accelerating climate change (Hall et al. 2009). Food waste continues to maintain an ecological and environmental presence that will impact future generations.

Among the types of food waste produced in the average household, coffee grounds are generated on a daily basis and commonly disposed of. Rather, they can be easily composted

through vermicomposting. In 2010, a report by the National Coffee Association found that over half of all Americans drink coffee on a daily basis (National Coffee Association 2010).

Vermicomposting has gained attention due to the great potential in both the availability of used coffee grounds and its beneficial properties in compost. In North America, almost two million metric tons of spent coffee grounds are generated annually and are either put into landfills or processed at waste facilities with other organic wastes (Liu and Price 7966-74). If coffee drinkers began to compost their used grounds instead of throwing them away, they could create a significant reduction in their environmental impact. Because of the widespread availability of coffee grounds, along with its known ability to improve soil composition, coffee grounds were chosen as the experimental compost to be further investigated.

While there have been few studies conducted on used coffee grounds, multiple studies have discovered the benefits of coffee waste, or pulp. The pulp, the fruit part of the coffee berry, is attributed to greater soil and compost quality. When the pulp is placed in the soil, its rich nutrient levels, along with the relatively high alkalinity of soil humus, contributes to reductions in soil acidity, increased retention of water, and increased levels and retention of nutrients. The organic matter of coffee waste also provides more nitrogen and potassium than common fertilizers, making it a valuable organic fertilizer (Kasongo et al. 2011). Nutrient value enhancement with the presence of coffee pulp provides soil fertility richness along with nutrients for both plants and the soil microorganisms (Raphael and Velmourougane 2010). Based off of these known positive effects of coffee pulp on soil nutrients and organisms, we look to extrapolate from these known benefits to investigate the effect of coffee grounds on total earthworm biomass.

One mechanism by which coffee ground waste output from households can be reduced is through the vermicomposting of food waste. Vermicomposting, which is composting with the aid of earthworms, is a viable, convenient way to turn a portion of these food wastes into useful resources for plants and soil while reducing its environmental impact (Orozco et al. 1996). In vermicomposting, earthworms such as *Eisenia fetida* are crucial drivers of the decomposition process, while also having beneficial impacts on soil composition (Raphael 2010). *E. fetida*, more commonly known as “red wigglers,” “tiger worms,” or “common dung worms,” are a species of epigeic (living in the surface layer of soil) earthworm that is specifically adapted to thrive in decaying organic matter (NCBI 2012). *E. fetida* can efficiently maximize the nutrient

composition of kitchen waste (Garg et al. 2006). Although microorganisms in soil are the major contributors in the biochemical decomposition of organic matter, earthworms like *E. fetida* greatly accelerate the process by oxygenating and breaking up the soil, essentially acting as natural blenders as they reduce the soil and organic matter like food scraps into finer particles. They also increase the nitrogen in the soil, which slowly reduces the carbon to nitrogen ratio. Their contributions to the decomposition process actually encourage microbial activity and therefore further decomposition (Raphael and Velmourougane 2010). As a participant in vermicomposting, *E. fetida* generates vermicast, or worm castings, through the soil and organic matter to break down food scraps. This type of composting has been found to be an effective process that converts portions of organic waste into worm biomass and respiration products, which also aids organic matter biodegradation (Benitez et al. 1999).

There are few definitive findings about the combined optimal proportions of soil, coffee grounds, and earthworm quantity to fully optimize earthworm biomass. Online composting and gardening sites provide personal anecdotes on coffee grounds to earthworm ratios and earthworm to soil ratios, but there is a lack of concise, concrete guidelines for these ratios. In this study, we investigated how various ratios of coffee grounds to soil and the quantity of *E. fetida* influence earthworm biomass, and are also affected by original soil nitrogen content. Specifically, we ask:

1. What is the relationship, if any, between the biomass of *E. fetida* and the original nitrogen content of used coffee grounds?
2. What effect does quantity of coffee grounds have on the biomass of *E. fetida*?

Materials and Methods

Experimental Design

To determine how the amounts of compost and worms affect soil composition, we created a manipulative experiment using six ten-gallon glass aquariums as our study system. In each aquarium, three plexiglass or wood dividers were placed 12 centimeters apart to create four separate sections for treatments, labeled A, B, C, and D. Three aquariums served as replications and two aquariums as controls. Each of the four non-control aquariums contained (from the bottom-up) a layer of 1) sand, and 2) compost soil mixed with coffee grounds as well as earthworms *Eisenia fetida* interspersed into the soil. To effectively see how *E. fetida* aid

decomposition, we did not add the worms to the two control aquariums. Subsoil used was harvested from sandy forest soils (i.e. spodosols) from the University of Michigan Biological Station. Compost used was purchased by Michael Leasia from a local farmer. We collected coffee grounds from the cafeteria over three days and bought 2.5 pounds of *E. fetida* from a local bait shop in Alanson, Michigan.

Each section of the aquaria contained 1070 grams of sand, 227 grams of compost soil, and was treated with one of two coffee ground treatment levels, and one of two earthworm biomass treatment levels. Two sections contained a low coffee ground content (28 grams of coffee grounds mixed with 227 grams of compost soil) and the remaining sections included higher coffee ground content (57 grams of coffee grounds mixed with 227 grams of compost soil). Our low coffee ground content was based on a 1:8 grounds to soil ratio, while the high coffee ground content was a 1:4 ratio. These proportions were determined from a gardeners' forum which stated that for vermicomposting, coffee grounds should not exceed more than 25% of the soil mixture (Monte, 2006). Therefore, our high coffee grounds treatment was set to a 1:4 ratio.

In addition to the low and high ratios of soil to coffee grounds in sections A-D, the amount of earthworms *E. fetida* varied across the sections to evaluate how the amount of *E. fetida* changes soil nutrients through decomposition. In sections A and B, we placed half the amount of earthworms *E. fetida* than in sections C and D. We weighed 13.7 grams of *E. fetida* and placed the worms into each of the sections labelled A and B. In the C and D sections, we weighed 27.4 grams of *E. fetida* and added them into the sections. In order to prevent the worms from escaping their specific sections and the aquariums as a whole, we created cardboard covers with ventilation holes for the four treatment aquariums and placed them over the top of the dividers. We then replaced the cardboard tops with mesh screens and kept one set of fluorescent lights on to deter *E. fetida* from escaping.

After completing the construction and set-up of our experimental microcosm treatments, all six of the aquariums were placed in the Biotron. The Biotron's ground temperature provided a suitable environment for *E. fetida* to prevent desiccation. In order to maintain *E. fetida* activity and moisture, each section was sprayed with 2 ounces of water daily.

After six days of vermicomposting, we removed all *E. fetida* individuals from each treatment section. The *E. fetida* were placed in water to remove excess soil and weighed to determine the final biomass.

A	B	C	D
Low <i>E. fetida</i>	13.7 g <i>E. fetida</i>	27.4 g <i>E. fetida</i>	27.4 g <i>E. fetida</i>
High coffee grounds	57 g coffee grounds 227 g compost soil	28 g coffee grounds 227 g compost soil	57 g coffee grounds 227 g compost soil
subsoil	subsoil	subsoil	subsoil

Figure 1. Aquaria 1-4 treatment set-up with varying measurements.

A	B	C	D
High coffee grounds	57 g coffee grounds 227 g compost soil	28 g coffee grounds 227 g compost soil	57 g coffee grounds 227 g compost soil
subsoil	subsoil	subsoil	subsoil

Figure 2. Aquaria 5-6 as experimental controls containing no *E. fetida*.

Statistical Analysis

To evaluate the significance of change in total biomass of earthworm *E. fetida* between each of the treatment sections, an ANOVA test in SPSS was conducted. The ANOVA provides average variances of *E. fetida* biomass between each treatment. To evaluate how the final biomass of *E. fetida* differs between the high and low coffee ground treatments, an independent t-test was used by grouping treatments A and C together and treatments B and D together. Another independent t-test was generated to determine if the final *E. fetida* biomass changes in

relation to starting *E. fetida* biomass. This independent t-test compared low beginning *E. fetida* and high beginning *E. fetida* by comparing treatment groups A and B to treatment groups C and D.

In addition, two regression lines in Microsoft Excel were generated to test for a possible relationship 1) between the final *E. fetida* biomass and original percent nitrogen content, and 2) between the final *E. fetida* biomass and original pH.

For all of the statistical tests, we did not include the two controls (Aquaria 5 and 6) since they did not contain any *E. fetida*.

Results

There was not a significant relationship between final *E. fetida* biomass and original pH of each section ($R^2 = 0.0913$).

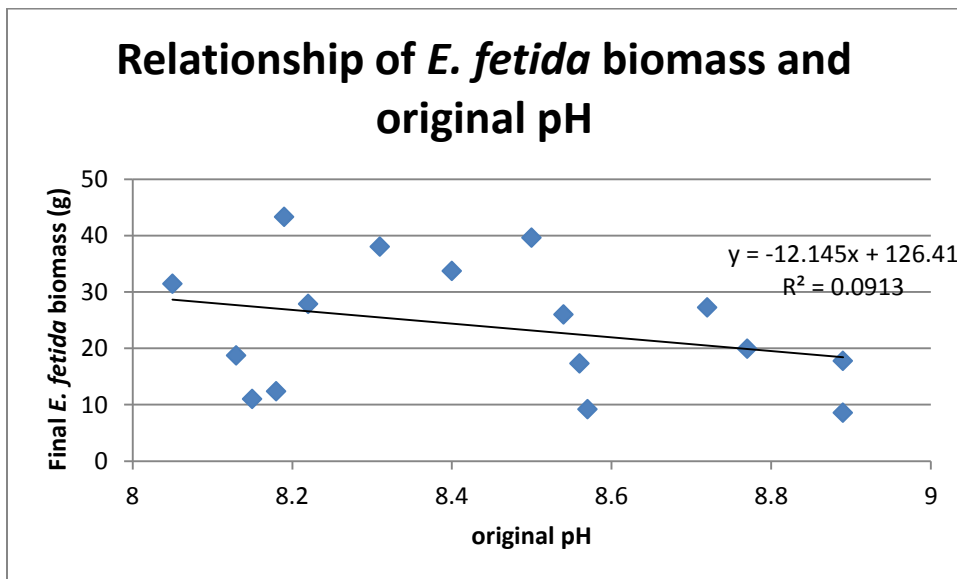


Figure 3: Final *E. fetida* biomass of each section and the original pH.

There was not a significant relationship between final *E. fetida* biomass and original percentage of nitrogen of each section ($R^2 = 0.0228$).

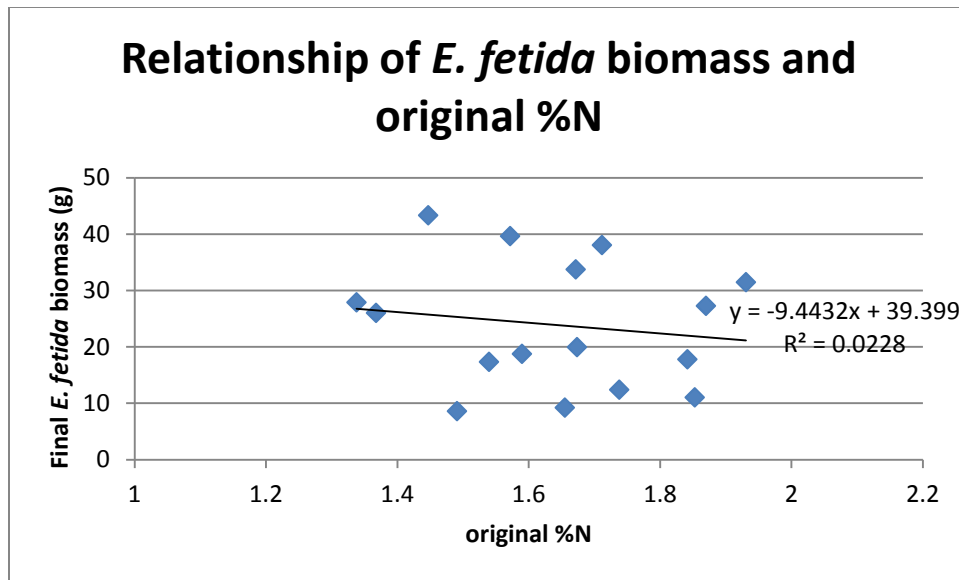


Figure 4: Final *E. fetida* biomass of each section and the original %N.

Before we ran independent t-tests and an ANOVA test, we generated the descriptive statistics for our data set and concluded that distribution was normal and equal variances could be assumed. The proportion of initial *E. fetida* was used to calculate for final *E. fetida* biomass in a uniform matter across our data. This was calculated by dividing the final *E. fetida* biomass by the beginning biomass for each section. This was necessary since treatments originally contained differing amounts of *E. fetida*.

There was not a significant difference between the final *E. fetida* biomass and the coffee content (high vs. low) of the treatment sections ($t=1.474$, $d.f.=14$, $p\text{-value}= .163$). The mean proportion of initial *E. fetida* for the low worm treatments was 1.64, while the mean proportion of initial *E. fetida* for the high worm treatments was lower, calculated as 1.01. However, the difference is not significant to conclude that final *E. fetida* biomass depended on coffee content of the section.

An ANOVA test was used to compare the amount of variance of *E. fetida* biomass between the treatment groups A, B, C, and D. Equal variance and normal distribution was assumed, while each treatment group was concluded to be an independent case. There was a significant difference between each group's average proportion of initial *E. fetida* ($F=35.955$, $d.f.=3$, $p\text{-value}= 0.00$). Treatment A (low coffee, low worms) resulted in the highest amount of final *E. fetida*, while treatment C (low coffee, high worms) gave rise to the lowest amount of *E. fetida*, as seen in Figure 5.



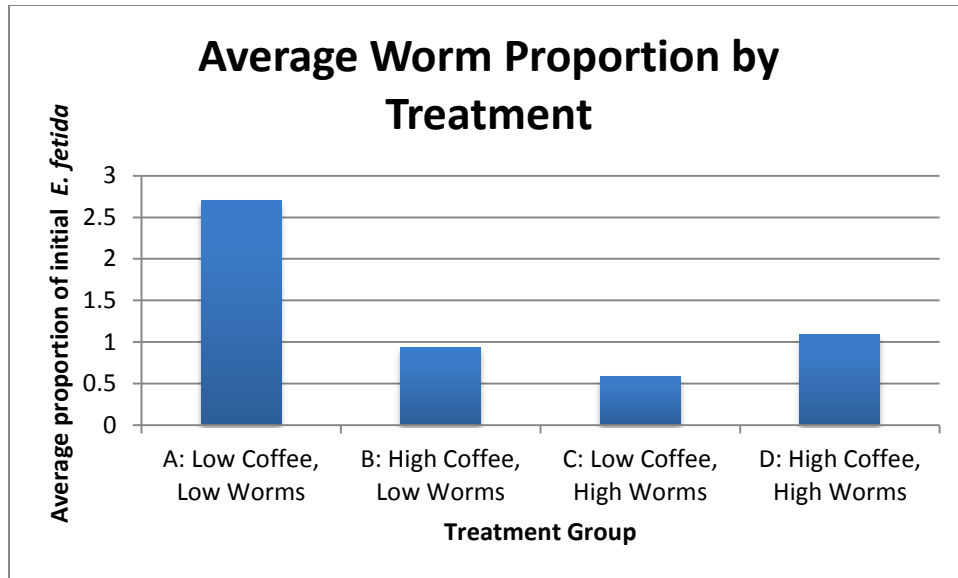


Figure 5: Average proportion of initial *E. fetida* separated by treatment groups containing differing original amounts of *E. fetida* and coffee grounds.

We also used an independent t-test to question whether original *E. fetida* content influenced the final *E. fetida* biomass. The t-test showed that there was a significant difference between the final *E. fetida* biomass and the differing original high and low *E. fetida* amounts ($t=2.619$, $d.f.=14$, $p\text{-value}= .02$). The mean proportion of initial *E. fetida* for the low *E. fetida* treatments was 1.82, which was higher than the mean proportion of initial *E. fetida* for the high *E. fetida* treatments, calculated as 0.83.

Discussion

After data analysis, it was concluded that there was no significant difference between the final *E. fetida* biomass and the coffee content of the treatment sections (high vs. low). The average proportion of beginning earthworm biomass and end earthworm biomass was the highest for Treatment A, while Treatment C had the lowest proportion. This was possibly due to the availability of resources, namely soil nutrients due to the coffee grounds content, in the given environment. Treatment A had a smaller population of individuals, meaning that there was a greater amount of space and resources (soil nutrients, water, etc.) available for each individual, allowing a greater opportunity for growth and an increase in overall biomass. Treatment C had the lowest average proportion of initial to final *E. fetida* biomass, meaning that there was the least change in biomass. Opposite of Treatment A, Treatment C had a greater number of worms

for the limited resources available in the tank environment (not considering the amount of coffee grounds present). Thus, there were fewer resources for each individual, limiting the possible change in biomass.

Treatments B and D, however, do not apply to this finding. The two treatments with average proportion values that were in between the largest and smallest average proportions of initial and final *E. fetida* biomass were compared due to having the same coffee ground content (high). High *E. fetida* had a slightly larger average proportion of biomass increase compared to low worms. This result is contrary to the reasoning behind the results for Treatments A and C. For B and D, there was a larger average proportion of biomass change for the high *E. fetida* treatment even though coffee ground quantity was the same between the two, providing the assumption that resources were the same for each treatment. This result could be attributed to the error of *E. fetida* traveling between treatment sections before successful tops were constructed for the aquaria, or the possibility of reproduction due to a greater availability of individuals for more mating opportunities. Between all of the treatments, the greatest biomass change was due to low earthworm and low coffee ground content.

Furthermore, data analysis concluded that there is no significant linear relationship between final *E. fetida* biomass and original pH of each treatment section. It was also concluded that there is no relationship between *E. fetida* biomass and original percent Nitrogen concentration. Therefore, according to our results, changes in earthworm biomass do not depend on the amount of nitrogen present in the soil. The lack of relationship between *E. fetida* biomass and original percent Nitrogen concentration runs contrary to the finding that earthworms increase soil nitrogen content. (Raphael and Velmourougane 2010).

We conclude that *E. fetida* biomass is not dependent on soil %N, soil pH, or coffee ground content. However it was found that *E. fetida* biomass is less overall in conditions where there was a higher amount of individuals to start with in the soil. This means that in terms of home composting, *E. fetida* will compete for space and the individuals left in the compost soil will grow and have chances to reproduce. According to our results, the amount of coffee grounds that is added to a home compost pile does not influence *E. fetida* biomass, and their resulting decomposition activity.

This study was limited by a number of factors and the presence of confounding variables. First, time was a major constraint. The earthworms were only in the soil/coffee ground mixture for six days and we speculate that with a longer experiment time, greater changes in nitrogen content and earthworm biomass would be more detectable. Second, the experimental design was flawed, and thus could have been improved. During the first two days, the earthworms frequently climbed up the walls of the aquaria, and there is a high likelihood that they may have traveled between their designated sections due to aquarium dividers that were not tall enough to completely separate each *E. fetida* treatment. Ten percent of the worms, or 31 in approximately 300, also escaped from their tanks completely and were found on the ground dead. This was remedied by adding mesh screen covers on top of the dividers. Also, in order to discourage the worms from emerging out of their respective sections, we turned on one fluorescent ceiling light on each side of the experiment set-up after the second experiment day to encourage them to burrow into the soil. These measures could only be added after a number of worms had already escaped or died.

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