THE EFFECTS OF MEAT ON EARTHWORM SURVIVAL AND COMPOST QUALITY IN A VERMICOMPOSTING SYSTEM

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ABSTRACT: The amount of meat, as a component of food waste, which can be fed into a vermicompost system while maintaining a healthy system and compost is debatable. Many reference sources state that no meat ought to be added into a vermicompost system while others consistently allow some quantities of meat in the food waste to be fed to their vermicomposting system. In this experiment compost quality will be tested given a zero, low, medium and high level (standardized by composition and by wet weight) meat treatments and each meat treatment will have three replicates. Compost quality is measured as total organic carbon, total nitrogen and carbon to nitrogen ratio. The hypothesis is that Eisenia fetida (red wiggler worms) productivity and compost quality of the treatments which contain no meat will be higher than those treatments with higher meat content.

INTRODUCTION
The topic of waste management is becoming increasingly important as our landfills continue to become overfilled. There are different methods for dealing with post-consumer biodegradable waste. Currently, developed countries use landfills while developing countries use open dumps, both of which require large areas of land (Rajeev, 2011). Vermicomposting, composting with Lumbricidae (segmented worms), is one of the methods favored for its reduced land requirements (Rajeev, 2011) and high processing speed (Lleó, 2014). Because vermicomposting is a relatively new post-consumer waste management process there are questions of how to maximize the benefits of the system while maintaining healthy compost within the vermicomposting system.
The amount of meat, as a component of food waste, that can be fed into a vermicompost system while maintaining a healthy system and compost is unclear. While compost created using traditional vermicomposting methods, which does not include meat, is plentiful in carbon, nitrogen, phosphorus and potassium (CNPK) (Sujatha, 2012), it is unclear what effects meat additives will have on total organic carbon, total nitrogen and the C:N ratio, which are used to analyze compost quality (Tognetti, 2005).

Knowing how meat influences the vermicompost will guide decisions on how thoroughly the meat must be sorted out of the food waste before adding it to a vermicompost system. The purpose of this study is to describe the changes in the compost quality associated with different meat additions in a vermicompost system.

METHODS

Food Audit

To understand how prevalent post-consumer meat is found in food waste and to evaluate possible meat treatment levels, a food audit was conducted on the California State University, Sacramento’s (CSUS) Dining Commons food waste. From March 1st, 2014 to March 14th, 2014 the CSUS’s Dining Commons separated food waste from overall garbage to be evaluated for the food audit. Wet weight of total food waste was recorded as well as composition of the food waste. Composition categories included fruit, vegetables, carbohydrates, paper, meat, plastic, dairy, and miscellaneous which accounted for items such as aluminum cans and metal utensils. Wet weight was recorded by placing one bag of food waste into a 4 ft by 2 ft plastic box which was placed on a scale. The weight of the plastic box was then subtracted from the total weight. Composition was recorded by estimating percent composition of each category in one bag of food waste. To do this, surveyors wore gloves and sifted through each bag of food waste. To
normalize the estimates of percent composition, surveyors used their fist as a representation of 5% of the total waste in one bag. Two surveyors evaluated food composition for each bag during daily recording to confirm their evaluation of food waste composition.

**Meat Treatments**

The vermicomposting experiments were conducted in five gallon buckets with a lid, 138 holes of a 0.3cm width were drilled on all sides of the bucket for aeration. All bins contained the holes in the same positions to keep the airflow consistent. Each bin contained 263g of *Eisenia fetida* (red wiggler worms), 381g of shredded paper bedding material, and 2.79kg of compost. Compost is referenced here as the pre-composted mixture without *E. fetida*. Compost contained fruit, vegetables, and coffee grounds. The exact composition of food mixture was recorded (Table 1). The fruit and vegetable waste was chopped using a food processor to create uniform food particle sizes for each bin. Food particles were chopped to approximately one square inch in size. Newspaper was shredded using a Fellowes M-7C paper shredder to create 31cm L x 0.4cm H x 2.9cm W uniform particles. Four treatments of meat composition were used: zero (control), low, medium and high level. No meat was added for the control treatment. 0.08 kg of meat was added to 2.79 kg of compost for the low level treatment and represented approximately 3% of total compost in wet weight. 0.17kg of meat was added to 2.79kg of compost for the medium level treatment and represented approximately 6% of total compost in wet weight. 0.28kg of meat was added to 2.79 kg of compost for the high level treatment and represented approximately 10% of total compost in wet weight (Table 1). Cooked ground beef was the meat additive used for this experiment and was used as a model for all types of cooked meat waste. Three replicates of each treatment were conducted for a total of twelve experimental vermicomposting bins.
Table 1. Composition of Compost Additions to Each Experimental Vermicompost Bin.

<table>
<thead>
<tr>
<th></th>
<th>Control</th>
<th>Low Treatment Bins</th>
<th>Medium Treatment Bins</th>
<th>High Treatment Bins</th>
</tr>
</thead>
<tbody>
<tr>
<td>% Comp</td>
<td>Wet Weight (kg)</td>
<td>% Comp</td>
<td>Wet Weight (kg)</td>
<td>% Comp</td>
</tr>
<tr>
<td>43% Fruit</td>
<td>1.20</td>
<td>43% Fruit</td>
<td>1.20</td>
<td>43% Fruit</td>
</tr>
<tr>
<td>46% Vegetable</td>
<td>1.28</td>
<td>46% Vegetable</td>
<td>1.28</td>
<td>46% Vegetable</td>
</tr>
<tr>
<td>11% Coffee Grounds</td>
<td>0.31</td>
<td>11% Coffee Grounds</td>
<td>0.31</td>
<td>11% Coffee Grounds</td>
</tr>
<tr>
<td>Total = 100%</td>
<td>Total = 2.79</td>
<td>Total = 100%</td>
<td>Total = 2.79</td>
<td>Total = 100%</td>
</tr>
<tr>
<td>Meat Added</td>
<td>0.08</td>
<td>Meat Added</td>
<td>0.17</td>
<td>Meat Added</td>
</tr>
</tbody>
</table>

The experiment was conducted in an enclosed room underground with average temperature of 20°C ± 1° and humidity levels of 50% ± 4%. The average temperature and humidity were based on the average of recorded values during two week monitoring period. Vermicomposting bins were placed side by side with the meat treatment bins interspersed with one another. Bin placement was assigned using a random number generator (Table 2). Bins were put on top of wooden pallets to provide airflow from the bottom. Prior to the *E. fetida* being added into the compost bin, compost was homogenized through mixing in a 208L barrel; the compost aged and mixed daily for three weeks to accumulate microorganisms that the *E. fetida* feed on. During this time the compost was unintentionally seeded with *Hermetia illucens* (soldier fly larva) which hatched in all 12 experimental vermicompost bins. At the end of the three week period the 12 test bins were created by covering the bottom of the bins with damp shredded newspaper, then adding *E. fetida* to bottom of the bin as well as compost mixture plus the corresponding level meat treatment.
Table 2. Location of Bin Placement with Corresponding Meat Treatment.

<table>
<thead>
<tr>
<th>Medium</th>
<th>Low</th>
<th>Control</th>
<th>Control</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>Medium</td>
<td>Low</td>
<td>High</td>
</tr>
<tr>
<td>High</td>
<td>Medium</td>
<td>High</td>
<td>Low</td>
</tr>
</tbody>
</table>

Temperature, pH, and moisture of each bin were monitored and recorded every other day between 19 October 2014 and 27 October 2014. The amount of time it would take the *E. fetida* to consume the compost which was input into the system was calculated to be 10 days based on *E. fetida* consuming their body weight in food per day. Temperature, pH, and moisture measurements were taken from the center of each bin. Each bin was evaluated for health of the worms based on a visual inspection. Notes were taken if *E. fetida* were seen exiting the bin or if any *E. fetida* were found deceased. At the end of the experiment *E. fetida* were separated from the compost and their wet weight recorded using a EatSmart Precision Pro Digital Kitchen Scale model# ESKS01;02;06;07;08.

Vermicompost samples were collected from each bin, separated from *E. fetida* and diptera (flies), then dried and ground for analyzing. Samples were dried by placing one cup of wet compost from each bin into a paper cup and microwaving the samples for six 2 minute intervals, opening the microwave door between intervals for 1 minute to allow additional ventilation. Samples were weighed after each 2 minute drying interval and were determined dry when no mass was lost between the 5th and 6th drying interval. Each sample was ground using a mortar and pestle. Ten grams of dried and ground compost was collected from each bin to be analyzed for compost quality. Compost quality was measured by analyzing the compost sampled from each bin for total organic carbon, total nitrogen and carbon to nitrogen ratio. Compost samples were analyzed...
by the Control Laboratories Inc. A LECO 628 CNH analyzer was used to measure the nitrogen and carbon. An ANOVA test was performed using Statcrunch statistical analysis program, http://www.statcrunch.com/ to compare C:N ration between the four meat treatments.

RESULTS

Food Audit

The food audit resulted in a rough understanding of the CSUS’s Dinning Commons organic waste composition. While inorganic material, including paper, plastic, and miscellaneous, accounted for 54% of the total waste, for the purpose this study only the organic waste was focused on. The majority of organic waste was composed of fruit, vegetables, and grain products such as wheat and rice. Meat was estimated to contribute 7% of the overall wet weight of organic waste. (Figure 3).

Figure 3. Percent of biodegradable waste found per category of food composition.
Meat Treatments

Carbon: Nitrogen ratios and *E. fetida* Survival were examined to determine resulting compost quality between the meat treatment bins. Statistical analysis revealed an F value of 0.89, with p<0.05, the critical values was found to be 19.00 which concluded a p-value of 0.5006 when comparing the C:N rations between meat treatments. There was not a statistically significant difference in soil quality, in terms of C:N ration, between meat treatments in each bin.

The greatest amount of *E. fetida* and *H. illucens* (soldier fly larva) biomass was found in all three of the control treatment bins which did not contain meat. There were no remaining *E. fetida* found in the three high level meat treatment bins. There were *H. illucens* found in the three high level meat treatment bins. Through visual inspection it appeared that the *E. fetida* survival was influenced by the meat treatments and the health of the *E. fetida* declined as meat levels increased. *H. illucens* appeared to thrive in all of the bins but were most successful in the high meat level treatments.

DISCUSSION

While only *E. fetida* were added into the compost to model a vermicomposting system, *H. illucens* larvae was found throughout all of the compost test bins and was responsible for processing some of the food added into each system. *Drosophila melanogaster* (Fruit flies) and *Musca domestica* (common house fly) were also prevalent in the vermicomposting system but was likely not responsible for any significant part of the food processing. The large amount of *H. illucens* likely influenced the overall health of the *E. fetida* and thus the soil quality in a way that
was not calculated for in the design of the experiment through competition with the *E. fetida* for food.

A visual decline in *E. fetida* health was seen in bins containing medium and high level meat treatments. Visual indicators included: some *E. fetidas* exiting the vermicomposting bin as well as *E. fetida* size and *E. fetida* deaths. Declining *E. fetida* health in some bins may have been driven by competition with soldier fly larvae or changes brought about by the different meat compositions of each bin. Further studies on *E. fetida* health would need to be done to identify the exact factor responsible for declining *E. fetida* health in a vermicomposting system.

*H. illucens* appeared to thrive in all of the meat treatment bins but were most successful in the high level meat treatments, in absents of *E. fetida*. This helps confirm my idea that the overall health of both *E. fetida* and *H. illucens* are affected by the presents of one another and this is likely a competitive interaction. Another visual observation supporting this idea is that when *E. fetida* and *H. illucens* were maintaining a co-habitance the *E. fetida* was found toward the outside edges of the bin while *H. illucens* were found in the center of the bin.

While compost quality, as defined by C:N ratio was not affected by meat treatments, it is still beneficial to keep meat out of a vermicomposting system due to the correlation between higher meat additions and decreased worm health and survival. A decline in *E. fetida* survival in a vermicomposting system would dramatically decrease the processing time of turning the food waste into compost, which is a primary benefit of vermicomposting in comparison to traditional composting without *Lumbricidae*. 
The relevance of this study to the food sorting methods of CSUS’ Dining Commons organic waste, it is suggested the organic waste be sorted to remove meat waste prior to adding the organic waste into the campus’ vermicomposting system.

For future experiments focusing on the effects of meat on earthworm survival and compost quality in a vermicomposting system, I would suggest a few experimental design changes. The first is to age the compost in a way that would not allow for *H. illucens* seeding, this would help the experiment to isolate the *E. fetida* survival as a result of meat treatments and not the influence of the *H. illucens* and the meat treatments. The second is to add more holes in all sides of the experimental buckets for more control over aeration and overall moisture of each vermicomposting bin. While conditions in this experiment were maintained equally for each experimental bin, conditions varied from other recommended values. Room temperature was 5 degrees C below recommended and moisture content was 30% higher in the experimental bins then the recommended 70% (Tripathi 2003). These difference may have contributed to an overall skew in *E. fetida* survival and C:N flux potential between the bins. The third is to also conduct additional soil quality parameter testing for phosphorous and potassium in addition to C:N ration for a more complete understanding of the soil quality profile. Applying these changes would lead to a better understanding of earthworm survival and compost quality as it is effected solely by the meat treatments applied.
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WORK CITED


