VERMICOMPOSTING EFFECTS ON FOOD WASTE AND SOIL QUALITY

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Contents

Introduction:

Farmers are increasingly recognizing the need for sustainable agricultural practices. The long-term use of synthetic nitrogen has yielded adverse effects on soil quality, as depleted nutrients (Khan et al. 2007), and soil quantity, as reduced organic matter (Mulvaney et al. 2008). Specifically, global soil carbon has been reduced ~75 Pg because of land conversion to agricultural (IPCC, 2001). Loss of soil nutrients has contributed to increased fertilizer requirements for non-leguminous crops. For example, the North American demand of nitrogen fertilizer is projected to increase by over one thousand tons from 2016 to 2018 (FAO, 2015), although acreage planted in high feeding crops is projected to decline (ERS, 2017).

Vermicomposting is a sustainable agricultural practice that may alleviate both nutrient depletion and improve organic matter content of soil. Vermicomposting uses earthworms to facilitate organic waste decomposition and produces high quality fertilizer with water-soluble nutrients. Specifically, worm casts contain higher nitrogen (N), phosphorus (P), and potassium (K), than the surrounding soil (Tiwari et al., 1989), supplementing available nutrients. Earthworms also influence the physical, chemical, and biological properties of the soil (Lee, 1985; Edwards et al., 1996) and their burrowing reduces soil compaction (Capowiez et al., 2012). Further, burrows can act as a preferential water pathway for nutrients to enter the soil instead of being lost as overland flow (Don et al., 2008). Thus, earthworm activity is positively correlated with soil nutrient content and productivity.

Much vermicomposting research has been done on the earthworm species *Eisenia fetida (see Sharma et al, 2005)*; however, *E. fetida* does not survive cold winters, and is therefore not considered relevant in Midwest agricultural ecosystems. Rather, Midwestern climates support thriving earthworm populations of *Lumbricus terrestris*. Unlike *E. fetida*, which dwells in surface litter and has optimal growth near 23°C, *L. terrestris* can burrow 2 meters deep within the soil, below the frost line, and can survive cold winters. If *L. terrestris* enhances composting, this species may be appropriate for incorporation into vermicomposting in the Midwest to facilitate more sustainable agricultural practices.

In this study, our objectives were to 1) quantify the effect of *L. terrestris* on food waste decomposition; and, 2) evaluate survival of *L. terrestris* in a vermicomposting environment. These objectives were met by addressing specific questions with related hypotheses:

1) How does the presence of *L. terrestris* affect decomposition of food waste?

   H1: *L. terrestris* will increase decomposition of food waste due to burrowing activity and nutrient input in earthworm casts.

2) What is the mortality rate of *L. terrestris* in vermicomposting conditions?

   H1: Vermicomposting will decrease survival *L. terrestris* due to limited habitat.

Methods:

Mesocosms

The vermicomposting experiments were conducted in plastic mesocosms (10 cm diameter) with 2 mm perforations on the bottom and sides for water drainage. Mesocosms were housed in a laboratory at ambient temperatures (20 - 25°C) under diurnal light cycles (14:10). Soil media consisted of field soil collected from an East Central Indiana corn field. Soil was dried, ground, and sieved through a 2 mm sieve for homogenization. Once homogenized, soil (250 ± 0.3 g) was added to each mesocosm, followed by 250 ml distilled water. Mesocosms were drained for one hour to eliminate excess water before addition of earthworms. Farm raised *Lumbricus terrestris* earthworms (Carolina Biological 141624) were weighed to the nearest tenth of a gram (AND HF-2000 scale), and five individuals were added to each earthworm treatment mesocosm (N = 9) with an average combined weight of 18.4 g (± 3.3 g). No earthworms were added to control mesocosms (N = 9). Apples from a ‘Granny Smith’ strain were peeled and peelings were added to mesocosms in 10 g, 20 g, or 30 g amounts. This food source was chosen on the assumption that it is one common food scrap that would potentially be used in vermicomposting. All mesocosms were covered with a fitted filter (pore size 20 microns) to maximize earthworm retention while allowing for gas exchange. Additional soil and apple peel were placed in a sealed container and immediately taken to the laboratory for initial organic matter and moisture content analyses.

Distilled water (50 ml) was added to all mesocosms as soil dried, every two to four days. Apple peels were removed and weighed weekly for measurements of mass as described above. After four weeks, apple peels were removed, placed in a sealed bag, and taken immediately to the laboratory for final organic matter and moisture content analysis.

Percent Moisture and Organic Matter Analysis

Percent moisture was calculated as the difference between wet and dry mass. Weigh boats were tared to the nearest thousandth of a gram (Mettler AE260 Delta Range analytical scale) and samples were then added. Each sample was weighed to the nearest thousandth of a gram and placed in a drying oven overnight at 60°C. Samples were removed from the drying oven the following day and cooled to room temperature before re-weighing. Calculation of percent moisture used the equation:

$$Moisture\ (\%) = \frac{Wet\ weight\ (g) - Dry\ weight(g)}{Wet\ weight\ (g)} * 100$$

The percent organic matter was analyzed as mass loss on ignition in a muffle furnace. Samples were dried as described above. After dry weight was measured, samples were placed in a Thermoline muffle oven at 500°C for 6 h then cooled to room temperature and re-weighed. Calculation of percent organic matter used the equation:

$$Organic\ Matter\ (\%) = \frac{Dry\ weight\ (g) - Ash\ weight(g)}{Dry\ weight\ (g)} * 100$$

Results:

Decomposition

After one week incubation, apple peel weight was 25.48%, 14.31%, and 6.87% higher in earthworm mesocosms (10g, 20g, and 30g, respectively) relative to control mesocosms, though differences were not significant ($p > 0.05$). The data suggest there was a greater decomposition rate with the presence of earthworms in week two ($p = 0.074$), but more research is needed. After four weeks of incubation, apple peel mean weights were 1.97 g, 3.82 g, and 5.89g in control mesocosms, and 1.78 g, 2.95 g, and 4.39 g in earthworm treatment mesocosms for the 10 g, 20 g, and 30 g additions, respectively. After four weeks, apple peel weight in earthworm treatments was not significantly lower relative to the control treatment across all mesocosms (Fig 1).

Organic and Moisture Content

At incubation start, apple peel organic matter was 97.5% across all treatments. After four weeks of incubation, apple peel organic matter content was 23.05% lower in the earthworm treatments relative to controls ($p < 0.001$). Mean percent organic matter of apple peels was 72.9% in earthworm mesocosms and 95.9% in control mesocosms (Fig 2). With the 10 g apple peel addition, organic matter was 25% lower in earthworm treatments relative to controls ($p = 0.01$). There was a 20% reduction in organic matter content with 20 g apple peel addition ($p = 0.01$) and a 24% reduction with 30 g apple peel addition ($p = 0.002$).

Initial moisture content of apple peels was 81 ± 0.07% across all mesocosms. Final apple peel moisture content was greater in earthworm treatments (mean 9.6%, 13.3%, and 18.1%) relative to controls (5.6%, 6.3%, and 9.9%) after the four week incubation ($p = 0.01$; Fig. 2). Further, there was greater percent moisture with increasing initial apple peel weight. The correlation between increasing peel weight in earthworm mesocosms was greater ($r = 0.936$, $p < 0.001$) than that of control mesocosms ($r = 0.848$, $p = 0.004$).

Earthworm Mortality

After two weeks incubation, only one individual worm was found dead. At three weeks, mortality increased to a total of 3 worms across replicates. Additional mortality was suspected after 5 weeks incubation though no dead worms were found. After 6 weeks incubation all mesocosms were hand-sorted, and no earthworms were found indicating either mortality or escape from the mesocosms.

Discussion:

These data indicate that *L. terrestris* does not significantly alter decomposition rates of apple peels, inconsistent with the hypothesis. However, data suggest potentially higher decomposition rate with the presence of earthworms at week two of incubation ($p = 0.074$). This could be due to *L. terrestris* preference for decomposing food, as prior research suggests a preference for food sources with increased microbial content (Cortez et al., 1989). Therefore, earthworm presence may affect decomposition, but only for a short period of time though more data are needed to support this finding.

L. terrestris preferentially select food sources (Shipitalo et al., 1988). Thus, these results may be unique to apple peels. While apple peel decomposition after four weeks did not change in the presence of *L. terrestris*, the organic matter content of remaining apple peel was reduced. This suggests the earthworms were contributing to some reduction of organic mass. Notably, the color of apple peel in the earthworm mesocosms was black, compared to a brown color in the control mesocosms, indicating a chemical change to the peels within the earthworm mesocosm.

Available food source may have also contributed to earthworm mortality. *Lumbricus terrestris* is commonly found in fields, where apple peels are not a primary source of nutrition. With decreased food availability4/6/2017, earthworm mortality increases after approximately four weeks (Shipitalo et al., 1988), consistent with this study.

Additionally, as some earthworm bodies were found on the surface of the mesocosm, and this species prefers to live below the soil surface, space restrains could have been a contributing factor. As a general observation, *L. terrestris* often incorporates uningested food into the external opening of the burrow, combining the food with casts to create a "midden". No trace of middens were observed in any mesocosm, indicating a departure from the normal burrowing activity of *L. terrestris*. Instead of creating their own burrows, the earthworms seemed to use the cracks in the soil on the side of the mesocosm as burrows.

Another factor contributing to *L. terrestris* mortality could be the soil type. Soil was collected from a field known to harbor *L. terrestris;* however, the *L. terrestris* used in the experiment were purchased from a supplier, and had been presumably raised in different soil conditions. The sudden difference in macronutrients and microbiota may have contributed to their mortality.

Lumbricus terrestris seems to play a significant role in the moisture properties of surface organic matter. Increased drying of manure has been previously reported in the presence of earthworms (Atiyeh et al., 2008); however, our findings show a moisture increase in the presences of earthworms. This could be because traditional vermicomposting research uses epigeic earthworms, which dwell in surface litter. Our species, dwelling in the subsoil layers, could potentially move water from the damp subsoils they inhabit, to the drier surface where food is located.

This study demonstrated that although *Lumbricus terrestris* does not increase organic matter decomposition rates in field soils, they can potentially alter the moisture properties of surface organic wastes. However, *L. terrestris* may be used in conjunction with a more robust species, such as *Eisenia fetida* to enhance vermicomposting efforts. More research is needed on the combined effect of these two earthworms, as they fill different roles in the environment.

Figures:

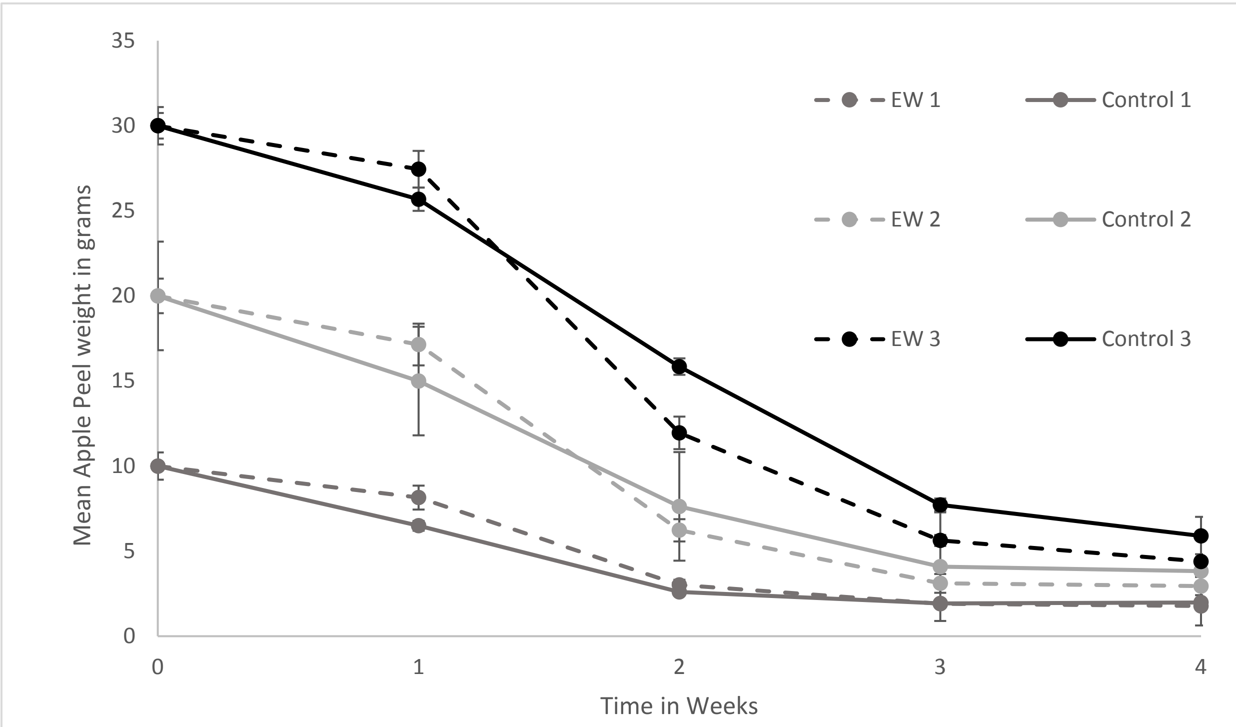

Figure 1. Apple peel mass over time. After four weeks incubation, mesocosms with earthworms (EW) had lower mass relative to controls across apple peel weights tested. Values are means ± Standard Deviation of weights taken from three mesocosms for each treatment group.

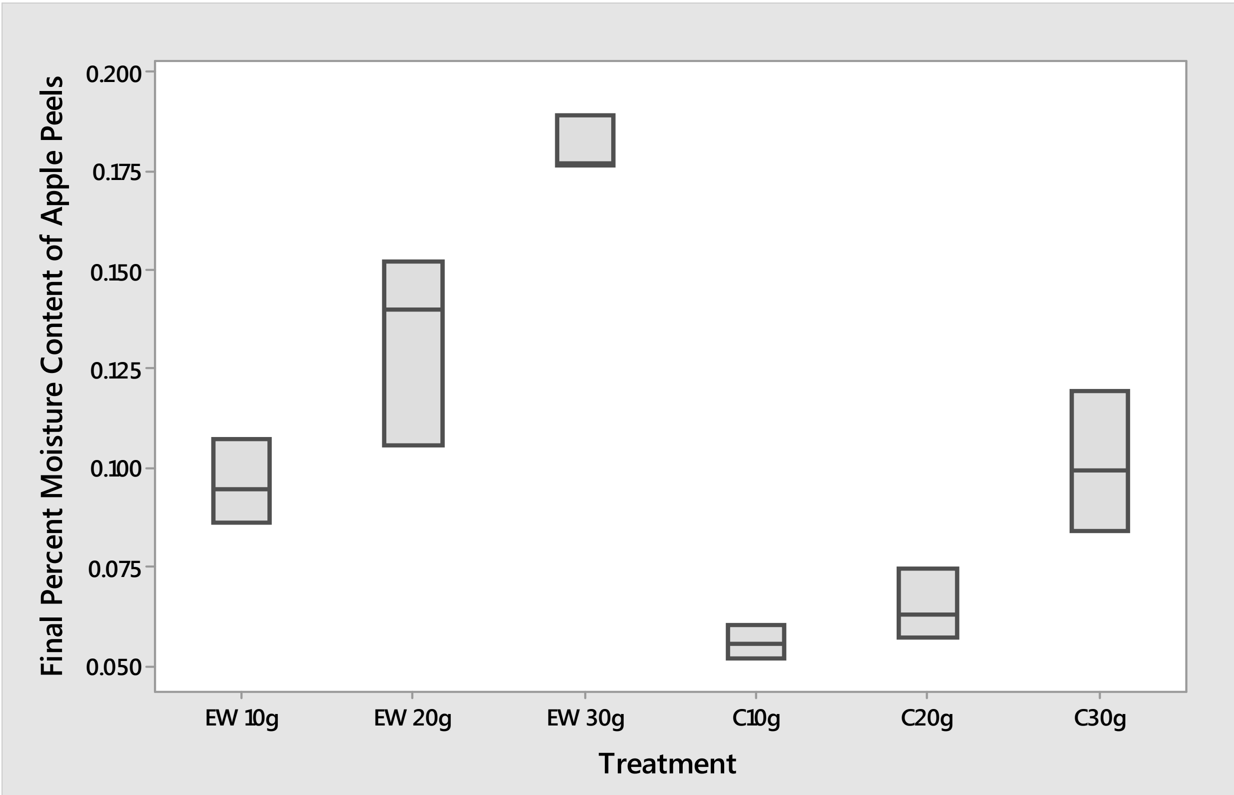

Figure 2. Final percent moisture content by treatment groups. Differences seen between EW and Control groups were all significant. Correlation between initial weight of apple peel was significant (p=0.004)

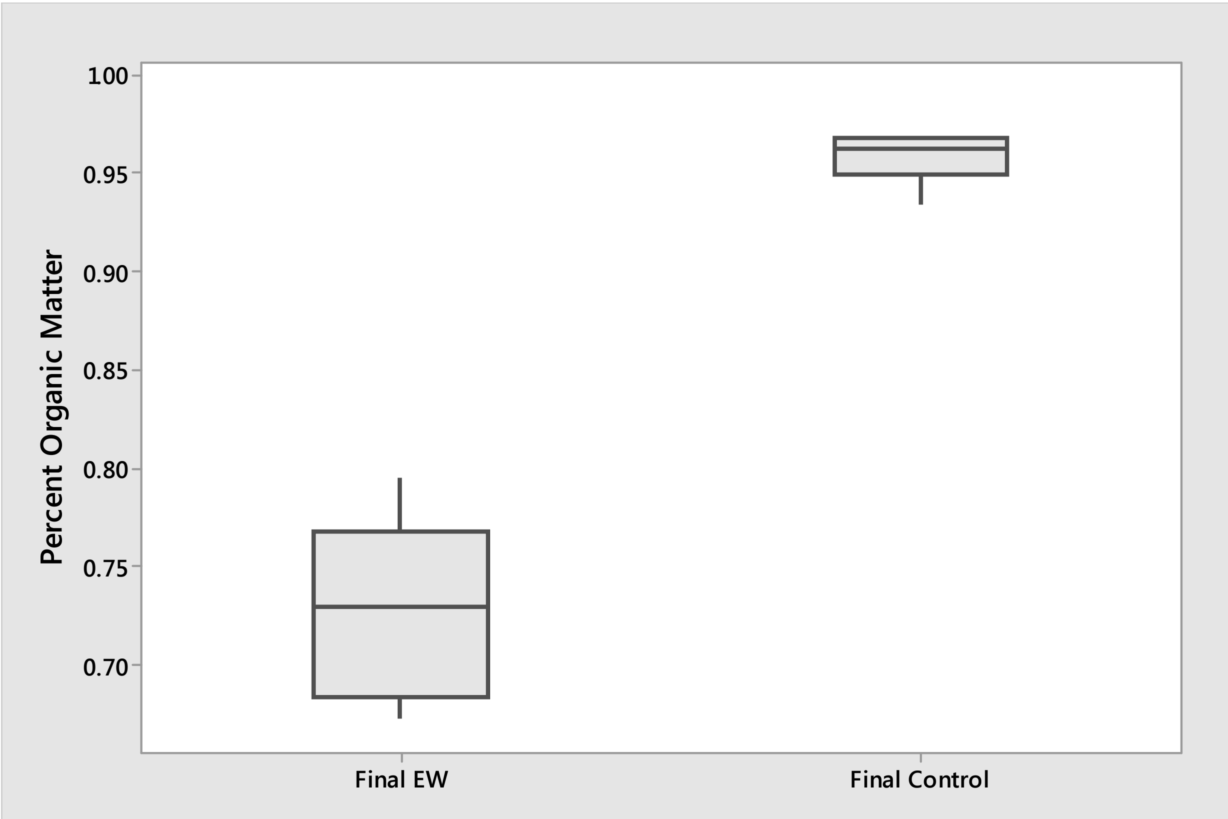

Figure 3. Percent organic matter after four weeks of incubation. Earthworm mesocosm apple peel percent organic matter was significantly lower than control apple peels.

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