

## **Vermiculture Composting**

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### **Introduction:**

The Algal Turf Scrubber (ATS) has become an increasingly important technological advancement that restores the water quality of flows that have experienced increasing levels of eutrophication and sediment loading. Algal Turf Scrubbers have been employed in an array of fluvial, industrial, and agricultural settings, and the algal communities' nitrogen and phosphorus contents have been analyzed and reported (Craggs et al 1996; Kebede-Westhead et al 2001; Mulbry et al 2008; Kangas and Mulbry 2014; Ray et al 2015). The Algal Turf Scrubber (ATS) is an engineered system for flowing pulsed wastewaters over sloping surfaces with attached, naturally seeded filamentous algae.

The economic potential of ATS systems have been explored, and productive end uses of algal biomass have been proposed, but require further research (Higgins & Kendall 2012; Pizarro et al 2006). Economic end uses for algal biomass would offset costs associated with ATS construction and maintenance, thus making the technology more appealing from an economic perspective. Biofuels processed from algal oils have been explored but remain uneconomic (Adey et al 2011). Biofertilizers have been explored but utility and applications have not been conclusive (Tripathi et al 2008; Renuka et al 2016). ATS systems have been constructed and documented that produced between 50-88g/m<sup>2</sup>/day of algal biomass (Ray et al 2015). This high productivity invites potential for an economic use of the biomass. The nitrogen and phosphorus fractions of these harvested algae have been documented, and present a potential nutrient source for decomposers (Kebede-Westhead et al 2006; Mulbry et al 2008; Kangas et al 2009; Ray et al 2015).

Vermiculture is the process of using worms to decompose organic materials, producing a rich soil conditioner known as vermicompost which has been shown to increase plant growth and inhibit soil plant pests such as nematodes (Bachman & Metzger 2008; Warman & Anglopez 2011). Vermicomposting typically utilizes red wiggler worms *Eisenia fetida* (Oligochaeta), which are widely available (Reinecke & Ventner 1987). Food scraps are a viable feed source for red wigglers, which are widely considered to be the most important and useful composting worm (Reinecke & Ventner 1987; Williams & Diehl 1992). Based on these established criteria, a study was designed with the goal of testing the feasibility of substituting algae for food waste as a feed source for red wiggler worms in a vermicomposting setting.

### **Hypothesis:**

Earthworms are utilized for purposes such as bait worms for fishing, boosting ecosystem health through their waste products as soil amendments, and breaking down considerable amounts of organic material and assimilating them into soil profiles. Worms are able to enrich nutrients to make them easier for plants to uptake through their roots or increase soil aeration and water percolation through burrowing. These ecosystem services are well documented, and as such

employed regularly in home gardens to produce healthier flowering plants, fruits, and vegetables, as well as in school systems to educate small children about the mechanisms of composting and the crucial role that earthworms play in the process.

The purpose of this project was to determine the feasibility of using algal biomass as a feedstock for earthworms to perform composting. There is very little data available on algae-based composting using worms. If viable, this proposal could provide a possible end-use for algae that grows naturally in bodies of water, or in artificial systems such as an Algal Turf Scrubber (ATS). As previously mentioned, the algal biomass grown from the Baltimore Inner Harbor ATS system is currently being stored, since it was discerned that conversion to biofuels was an unprofitable option. To ascertain if algae was a suitable feedstock for worms, and how efficient the resulting compost process was, three treatments were established: one compost system with only food scraps, one system with half food scraps and half algae, and one system with only algae.

As a basis for comparison among the various feedstock combinations, growth and survivorship of worms were quantified, and evidence of reproduction (indicating that favorable habitat and life requirements had been met) was noted.

## **Methods:**

The process of vermiculture composting consists of using worms, preferably red wigglers, to recycle food scraps as well as algae into a valuable product. These products include a rich soil amendment which can be used to plant crops and worms to be sold as fishing bait. The items required for vermiculture composting included specific sized bins, composting worms, algae (freshwater or brackish), bedding and food scraps.

Three experiments were performed. Each experiment varied based on the algal community being studied as a food source for Red Wiggler worms. The first experiment used brackish algae from an Algal Turf Scrubber in Baltimore Inner Harbor. The second experiment used algae from an Algal Turf Scrubber processing manure effluent. The third experiment used freshwater algae from an Algal Turf Scrubber processing wastewater from the Peach Bottom nuclear facility in Pennsylvania.

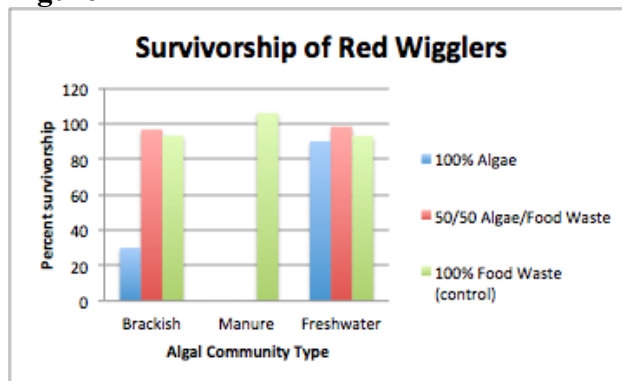
Three treatments were tested for each experiment. The first treatment bins received 100% algae as a food source for *Eisenia fetida*. The second treatment consisted of 50% food waste and 50% algae. The third treatment was used as a control and was made up of 100% food waste. Each of these treatments had three individual bins monitored throughout each experiment. The first two experiments, the Inner Harbor brackish algae and manure effluent algae, received 30 worms in each trial bin at the start of each experiment. The third experiment using freshwater algae received 20 worms in each trial bin. Prior to adding the worms to each treatment, the worms were weighed in groups of 20 or 30 depending on the experiment and weights were recorded. The 100% algae bins in each experiment received 500 mL of specified algae. The 50% food waste and 50% algae bins received 250 mL of food waste and 250 mL of specified algae. The 100% food waste bins received 500 mL of food waste. The first two experiments were given 60

grams of newspaper as bedding and an additional 15 grams of newspaper was added to the top of each bin. The third experiment was given 30 grams of newspaper as bedding and an additional 15 grams at the top of each bin.

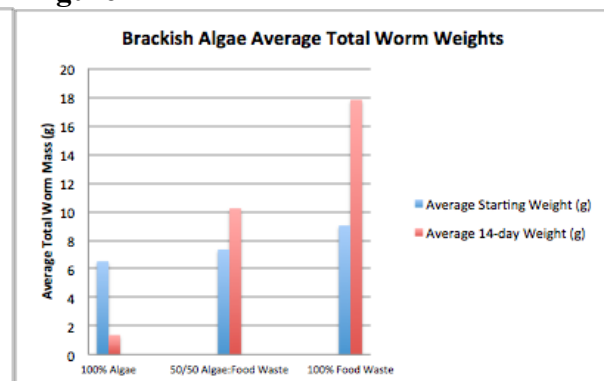
The bins in each experiment were monitored weekly and food waste was replaced when necessary. After two weeks the worms in each bin were counted and weighed in total to determine survivorship, total worm weight per bin and average worm weight. ANOVA statistical tests were performed to determine significant differences in worm weights between treatments.

## Results:

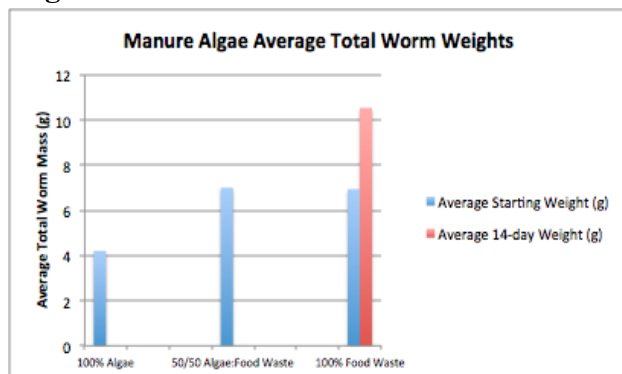
**Figure 1**



**Figure 2**



**Figure 3**



**Figure 4**

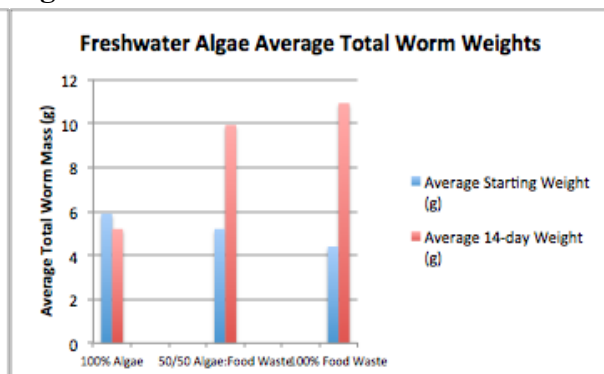


Figure 1: Depicts the survivorship of the worms in each treatment compared against each other

Figure 2: Depicts the starting and ending average worm weight in the brackish algae

Figure 3: Depicts the starting and ending average worm weight in the manure algae

Figure 4: Depicts the starting and ending average worm weight in the freshwater algae

After the experiments concluded, a statistical analysis was performed with the final data to see if there was a significant difference between the final average worm weights of each treatment. This was chosen to see if the treatment clearly had an effect on the health of the worms because all other variables remained constant throughout the duration of the experiment. As seen in figures 2, 3 and 4, there is a clear visual difference between the ending average weights for each

treatment but statistical testing is required to determine the statistical significance of the numbers.

**Null Hypothesis:** Average worm mass 100% algae = 100% food waste = 50/50 algae/food waste

**Alternative Hypothesis:** Average worm mass 100% algae  $\neq$  100% food waste  $\neq$  50/50 algae/food waste

**Brackish Algae P-value:** 1.54e-08

**Manure Algae P-value:** 4.26e-05

**Freshwater Algae P-value:** .00022

Due to a p-value below the significance level of .05, the null hypothesis is rejected. There is a statistically significant difference between the average weights of the worms in each treatment for all three types of algae.

### **Discussion/Conclusion:**

After allowing the experimental treatments to remain untouched for a two week period, with the exception of adding moisture to the treatments, the treatments were examined. Treatments were examined to determine if the worms made any progress in breaking down and using the three different 100% algae substrates, 50% algae/ 50% food waste mixture, and 100% food waste as viable sources of energy. Surprisingly, the worms grew in both mass and volume faster than expected. Not only did the red wigglers show an increase in both mass and volume, but the worms also displayed signs of reproduction. The signs of reproduction were noted when cocoon eggs were observed in each of the treatments. The mass and volume of the red wigglers were significantly different when in the presence of 50% algae/50% food waste mixture and 100% food waste versus the three 100% algae substrates (brackish, manure, and freshwater) that were tested. The average mass of each bin's worms was around six grams at the start of the experiment. At the end of the experiment each bin's total worm mass ranged from 10 to approximately 18 grams. Similar results were not shown for the worm's mass when in the presence of the three different algae substrates. The results showed that the 100% algae treatments negatively impacted the worm's mass, volume, and increased mortality.

Figure 1-3 highlights the increase in both mass and volume of the red wigglers in each treatment as well as the decrease of mass and volume in each treatment. The 50% algae/50% food waste mixture and 100% food waste produced worms that were healthy and thriving in their specific environments. The worms not only decreased in mass and volume, but completely decomposed in the presence of 100% brackish and manure algae. Consequently when the three treatments were compared, the freshwater algae produced worms with significantly higher mass and volume than the brackish and manure algae.

The data shown in Figure 1-3 captures how red wigglers were able to breakdown and digest the 50% algae/50% food waste mixture and 100% food waste efficiently. The successful breakdown of the substrates provided the necessary nutrients for the worms to flourish. The three algae substrates used for the 100% treatments were not as successful in providing the red wigglers with the necessary nutrients to flourish. It was determined that moisture content and salinity were the main factors in why the red wigglers did not breakdown and digest the 100% algae as efficiently as expected. Additionally, diatoms in the algae could be another contributing factor in why the worms responded negatively to the algae due to lesions from the different algae tested.

Another result found to be significant was the survivorship of the red wigglers in each of the treatments. Red wigglers responded very well to the 100% food waste which had close to a 100% survivorship rate and even produced offspring. The 50% algae/50% food waste treatment had close to a 100% survivorship rate, but failed completely when mixed with manure algae. Lastly, the 100% brackish and manure algae had relatively low to no survivorship rates, but the 100% freshwater algae had a 90% survivorship rate. Based off the survival rate of the red wigglers, it was concluded that moisture content was the limiting factor in worm fitness.

Of the three experiments designed to determine if algae provided suitable feed for red wigglers, the red wigglers responded negatively to brackish and manure algae while remaining in stasis with the treatment of freshwater algae. Worms experienced decreased volume, mass and even death in the presence of brackish and manure algae. Furthermore, in the presence of 100% food waste, red wigglers grew significantly in mass and volume and also produced offspring. Similar results were found in presence of 50/50 food/algae mixture for all the algae treatments. To ensure no bias, further experiments are necessary.

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