

Utilizing Ants to Mitigate MSW Landfill-Generated Methane Production Through Novel Aerobic Digester System for Anthropogenic Food Waste Decomposition

ABSTRACT

According to the Journal of Animal Ecology, ants contribute to over 61% of scavenging worldwide. Because of their exceptional abilities in breaking down organic matter, specifically protein and carbohydrate-rich matter, the aim of this research was to utilize ants to decompose food waste in an aerobic digester system for implementation at municipal solid waste (MSW) landfills. This work explores how ants recycle microbial biomass carbon (MBC) and decrease methane emissions in a novel aerobic digester design. The research consists of four phases: microdosing, metabolic testing, developing the computational model for methane reduction achieved with varying ant population sizes in the aerobic digester system, and, finally, designing and testing the efficiency of the ant-based aerobic digester system. For microdosing, four species of ants (*P. barbatus*, *C. castaneus*, *L. americanus*, and *P. bicarinata*) were fed food waste in the macromolecular ratios found at MSW landfills, and *C. castaneus* ants were able to decompose the most - two milligrams decomposed per ant per day. For metabolic testing, the principles of allometric scaling, Kleiber's Law, and constant-volume respirometry were applied for determining the metabolic rates for the top three species from microdosing (*P. barbatus*, *C. castaneus*, and *P. bicarinata*). *C. castaneus* had the highest rate of 68.61 J/s, making them the species used in the computational model developed in the third phase and the testing of the aerobic digester in the fourth phase. For the computational model, the key factors taken into account were *C. castaneus* food waste decomposition rates from microdosing, their metabolic rate, and methane emissions produced for varying food waste macromolecular ratios found at MSW landfills. The computational model showed an achieved reduction in methane of 20% with 43,000 of these ants per capita at MSW landfills. For designing the digester system, the main constraints were nesting chambers and affordability (under \$50,000 per digester system). The engineering goals consisted of designing a biogas harvesting mechanism and the primary digester chamber where ants can spend the majority of the digester cycle decomposing the waste. Testing the digester system's efficiency with *C. castaneus* ants and performing the t-test, the efficiency came out to be 87.14%.

PURPOSE

The purpose of this research is to **employ ants** to sustainably **reduce the amount of rotting food waste at Municipal Solid Waste landfills** through ants performing food waste decomposition. This research aims to a) find the most effective ant species for food waste decomposition and b) create an efficient aerobic digester for ants to facilitate the food decomposition in. To tackle this, this research was divided into four phases: microdosing, metabolic testing, developing the computational model, and designing plus testing the efficiency of the ant-based aerobic digester.

CRITERION FOR SPECIES

- All species must be native (no invasive species) to the United States.
- All species must be keystone species to their respective environments.
- All species must have varying average body masses (scale of ant species' body masses used).
- All species must be able to reproduce and thrive in a tropical climate (a tropical climate is typically defined as between 20°C and 29°C).

The four species chosen for testing were *C. castaneus*, *P. barbatus*, *P. bicarinata*, and *L. americanus*.

PHASE I: MICRODOSING

Hypothesis: It was predicted that the *P. barbatus* ants will decompose the most amount of food per day, since they are known to be major desert foragers (need energy for foraging across long distances).

- The species with the highest ability to decompose the food waste were the *C. castaneus* ants—two milligrams of food decomposed per chestnut carpenter ant per day.
- *L. americanus* decomposed the least amounts: 0.4 mg per day decomposed on average by one ant.
- 30-50 ants tested per species.

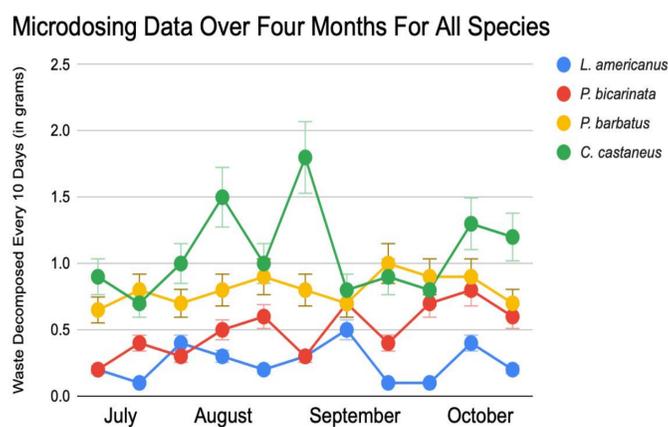


Figure 1: Microdosing data over four months for all species. Graph created by researcher using Google Sheets, 2024.

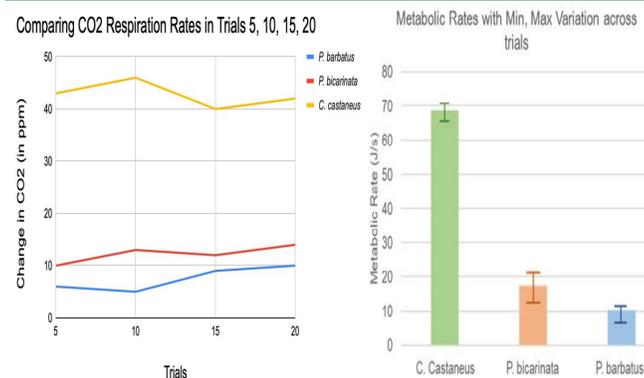
PHASE II: METABOLIC TESTING

- **Hypothesis:** It was predicted that the *C. castaneus* ants will have the highest metabolic rates as they have larger bodies (Kleiber's Law).
- **Purpose:** While microdosing gave preliminary evidence towards determining the most suitable species, metabolic testing was performed to verify the findings of Phase I. Metabolic testing relied on two concepts: constant-volume respirometry and allometric scaling.

C. castaneus ants had the highest metabolic rate and were therefore implemented in both Phase III and Phase IV of the testing.

Ant Species	Metabolic rate (J/s)
<i>C. castaneus</i>	68.61
<i>P. bicarinata</i>	17.44
<i>P. barbatus</i>	10.36

Figure 2: Metabolic testing results. Table created by researcher using Microsoft PPT, 2024.
Figure 3: Comparing CO₂ respiratory rates. Graph created by researcher using Google Sheets, 2024.
Figure 4: Error analysis for metabolic testing. Table created by researcher using Excel, 2024.



PHASE III: MODELING METHANE REDUCTION

Goal: Develop a computational system for quantifying methane reduction achieved with different *C. castaneus* population sizes.

$$N = P * F / (C * 100):$$

T=total food waste generated per day by a human population (in grams)

- F=food waste processed by one ant (per day) of those species (in grams)
- Np=size of the human population
- C=methane reduction (in percentage)
- Na=size of ant population needed (per capita)

NOTE: As shown by previous research, ants themselves emit negligible methane in comparison to the reduction that they achieve, and hence this aspect is ignored in this formulation.

C. Castaneus Ant Population per-capita US population for desired methane reduction percentage

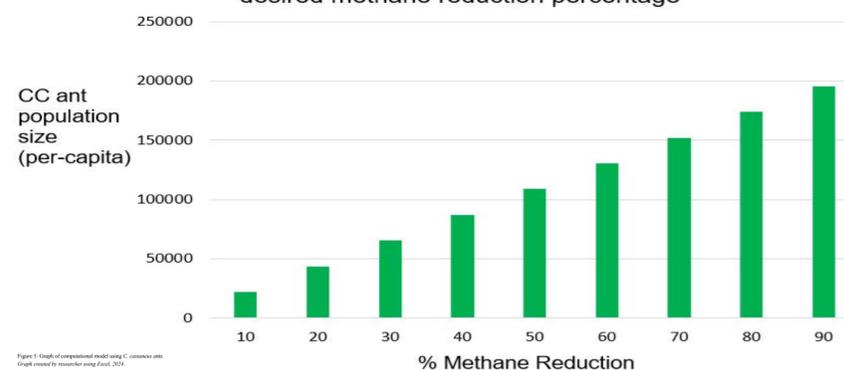


Figure 5: Graph of computational model using C. castaneus ants. Graph created by researcher using Excel, 2024.

PHASE IV: ANT-BASED DIGESTER

Goal	Constraints
Affordability	<\$50,000 USD
Biogas Harvesting Mechanism	Material must be used to prevent escape of biogas produced
Digester Chamber	Has to have some areas with fine mesh for oxygen to enter
Compost Removal from Chamber	A storage area must be designed for compost storage
Nest Simulations	Have area with ant nesting sites built

Figure 6: Phase IV engineering constraints defined. Table created by researcher using Microsoft PPT, 2024.

Time Taken for Ants to Decompose the Waste (First 30 Trials)

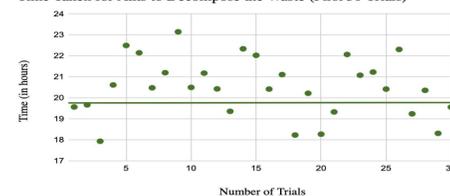


Figure 7: Phase IV Waste method. Graph created by researcher using Google Sheets, 2024.

Experimental Results: Since the difference of the means is NOT statistically significant from the t-test, the 80 trials' efficiencies were averaged to get an efficiency of **87.14%** for the aerobic digester design with *C. castaneus* ants.

Compared to **anaerobic digesters:**

- $\eta_{AD} / \eta_{AN} = 3.656x$ higher performance by the ant-based digester
- Percent change: **265.7%** greater efficiency for the ant-based digester

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