Creating a Structural material through Co-Operation: The Material formation through Ants and Mycelium interaction

Abstract

This research proposal attempts to create a cooperative manufacturing process with the natural world through biomimicry design. The research is an attempt to form a functional material using mycelium growth and ants to develop a structured material. The ant chosen for this research is the *Formica Subsericea*, the silky field ant. This ant primarily likes to live in soil, under rocks, and in tree barks; the ants can be in the United States and Canada; they like to live in housing constraints between 70°F - 80°F and like 20% - 26% humidity. During ant colonization and growth, *Pleurotus Djamor*, commonly known as the pink oyster mushroom, will be cultured, and grown between the constraints that allow the fungus to excel. During the mixing of agar there will be a mixture of ant nutrients incorporated to view if ant nutrition and mycelium growth could create a symbiotic relationship. After the mycelium growth between different substrates growth is determined, the data recording process will allow for the understanding if mycelium can grow with ant nutrition. Upon further research and investigation this could create a symbiotic fungus that can live and work with ant growth. If this research proves to be successful further investigation should be sought to test material structuring formed from this symbiotic relationship.

Keywords: *Ants, Co-operation, Material, Natural, Structural*

Introduction

The emissions and energy costs for the fabrication process of building materials have been rising yearly, causing the world to start to place new agreements to have zero-emission housing constraints by the end of 2030. According to statistical data, the construction process takes up around thirty-eight percent of global emissions and around forty percent of natural greenhouse gases. In 2019, building carbon dioxide reached its highest, representing twenty-eight percent of energy production worldwide. With the new policies and agreements being placed globally, there is an effect being caused on the construction and manufacturing industry. Some of the future problems that are to arise are the need to create new digital technologies, the cost of infrastructure and raw materials, and the use of sustainability. In contrast, the industry has moved closer to pre-fabrication to lower the fabrication cost and lessen the effect on nature (Rocha et al. 2022).There need to be other means to help the world globally through manufacturing and fabrication to push the boundaries and change the effect of future climate and global change related to the issues about the fabrication process. Throughout Architectural history, there have been issues with the usage of materials and the co-operation between the natural environments. Interest has risen in harnessing living systems into fabrication and structure materials through biomaterial probes. While investigations are getting out on how to co-operate between utilizing the living process, there could be methods to make the fabrication process completely co-operative with the natural environment. Studies have shown recent research integrating the natural environment and the development of material structuring. The written proposal discusses how mushrooms are being researched because of the biological system formed when growing them. It could correlate to a safer and less harmful effect for fabricating and using materials in the architectural world. While showing the different growth arrangements through different temperatures, moisture content, and angles (Ozkan et al., 2022). Mycelium growth with materials; is starting to investigate the integration process between materials and a way to create materials using living materials rather than relying dead materials to manufacture. Researching mycelium and its growth, there is a correlation between fungi ant species worldwide. Ants are known to be symbiotic with fungi and mycelium growth. Some species of ants use it as a source of nutrition, pest control, and insect repellent (Defossez et al. 2009) Ants have been known for millions of years as the world's best fungus farmers helping understand the agricultural growth that has happened through decades of crop culturing and the agriculture grown worldwide (Brian Handwerk 2017). Many species co-exist and live with mycelium and fungi growth. Within these species, few have been found to have positive and negative effects while interacting with fungi and mycelium. One of the species of ants that lives harmoniously with fungus and mycelium is the *Euprenolepis Procera*. This species of ant was and is the only one that eats only fungi as its means of nutrition. This species showed that they could eat any form of fungi or mycelium found, which causes much speculation as to how much ants have evolved to be one of the very few species that can digest fungal material (Adam Marcus 2008). Another finding in the past few years was that tropical ant species globally had a fungus that could completely take over the brain and minds of ants. This fungus, mainly found in tropical conditions, called, *Ophiocordyceps unilateralis*, is said to infect ants through pores, ultimately changing the ant's behavior and making it want to leave its nest. The fungus will make the ant go to a microclimate that supports the growth of the fungus and then make the ant sink its jaws into a leaf vein and have the ant wait for death. From this point, the fungus sends out its fruiting bodies to the ant's antennae taking control of the ant. One thing to note is that throughout this infection, very few ants in a colony are infected at any given time as well when ants are presented with three different housing types one with mycelium growth, one without any mycelium growth, and one empty. Ants choose mycelium growth housing, but this is also based on species rather than colony-specific research (Pontieri et al. 2014). Biomimicry is an effort to learn about mother nature by seeking new inquiry forms. Within biomimicry are Earth's Life's Principles; when developing the research, it was under the ideation process of cultivating co-operative relationships. From the provided research, there should be a way to create a material within the mycelium constraints as well as the constraints of the ants, with the hope that the ants will respond positively to the mycelium growth, ultimately being able to create a structured material.

Method

Specific species were chosen based off their compatibility to grow and reproduce at very fast rates. The *Formica Subsericea* is known to be able to live in soil rich environments encompassing the United States and Canada. This species of ant also likes moisture rich climates that provide heat. Time restrictions also allowed for this ant species to grow at faster rates to see rapid rates of expansion and colonization while the *Pleurotus Djamor* could grow as well. The pink oyster does not need as many restrictions as it has the capability to grow from many different substrates, it does actively grow within moisture enriched soils. The pink oyster and silky field ant have also been found to have compatible growth temperatures, and humidity percentages. While pushing to grow a co-operative naturally produced material between ants and mycelium there was an opportunity to investigate if there is a way to create a mycelium that can grow with the ants as well as provide the ants nutrients and nourishment. Investigating a form of mycelium that co-operates with the ant species chosen could provide the necessary link between creating a symbiotic bond between ants and mycelium growth.

1.1. Species

After determining the best species provided for the scientific experiment the understanding of how to take care of and treat both species needed to be investigated. Silky field ants, being active having an outworld and nesting area is important to the nesting colony as it provides the workers with a place to explore as well as work to bring their queen food. Ants being democratic it is important to allow the colony to have work to sufficiently participate in the development as well as help around the colony. While having an outworld providing the proper substrate to allow ants to burrow and colonize is important which comes in the territory of starting to understand the species.

Table 1: Formica Subsericea

Formica Subsericea (Silky Field Ant)	Description	Variables
Temperature		
	Outworld	64 °F – 86 °F
	Nesting Area	68 °F – 75 °F
Humidity		
	Outworld	30% - 50%
	Nesting Area	50% - 60%
Nest Type		
	Soil, Sand-clay, gypsum	Ants need moisture.

Size		
	Worker	4mm-8mm
	Queen	12mm
	Male	8mm
Developing Time		
	77°	4-6 weeks
Diet/Nutrition	Sugary Liquids	Ant Nectar, Honey, Sugar water
	Proteins	Insects: flies, mealworms, crickets
	Fruits	Almost any type of fruit found

*Luke Doyle 2020; Ezez. 2019; Zachary Liu 2021

Understanding how to provide the proper housing and constraints is important ethically when taking care of any species of pets or insects. Understanding the proper nutrients to provide to ants provides help to the growth and development time of the colony. Protein allows queens to start to reproduce larvae at high rates another important dietary element for ants is sugars silky field ants do not need to rely as heavily on sugars as most other species as they prefer to hunt insects for the colony providing work for the workers. Silky field ants optimally grow when surrounded by moist environments leaving moisture within the ants' habitats allows for humidity changes and more humidity provided for the ant.

Table 2: Pleaurotus Djamor

Pleurotus Djamor (Pink Oyster Mushroom)	Description	Variables
Fruiting Conditions		
	Temperature	68 °F – 86 °F
	Humidity	70 °F – 85 °F
	Light	Zero light should penetrate
Cap Sizes		
	Ranked Small, to medium	.79 inch – 1.97 inch
Growth Substrates		
	Paper, cardboard, coffee grounds, mulch, soil, straw, and hardwood	Substrate helps support the growth of mycelium.
Developing Time		
	Culture Timeline	10-14 days

Fruiting Timeline	12 days

*(Sabaratnam & Raaman 2018; Adam Syaner 2009)

Pink oysters require less maintenance but require the same commitment towards their growth. Mycelium growth has different constraints as to ants but commonalities. The introduction of growing mycelium substrate introduction is important as this could cause different growth issues when the substrate does not allow for the fungi to grow. Another connection between ants and mycelium growth is how ants and mycelium colonize the best without lights. Ants do go into the sunlight, but queens prefer to colonize and stay within the protection of their habitat.

1.2. Materials

Resources that had to be outsourced, had to be shipped from across state lines. Understanding that when using ants there are specific permits that must be had when buying and using ants. With these permits not being readily available for all as well as for some sub-species of ant's government approval to house and hold them is required. Outsourcing resources provided more findings in nutrients supplied for ant species. Ant nectar is a nutrient that supplies ants with honey water and sugar water but formulated differently.

Ant Nectar contains:

Sugars

Electrolytes

Mineral Salts

Table 3: Outsourced Materials

Material	Amount	Description
Formica Subsericea	×4	Queen, 4-5 workers
Outworld	×4	Small blank outworlds
Nesting Area	×4	Test Tube Array Formicarium
Mealworms	×2	Zoo med Can O' worms
Fruit	×2	Bananas
Ant Nectar	×1	60ml Sunburst Ant Nectar
Sugar Water	60ml	3 tbsps. of sugar, 1 ¾ cup of water
Soil	1g	Per outworld

Indoor Grow Tent	4ft×4ft	Heating and humidifier controlled by fan.
Heat Mat	×2	Zoo Med Under tank Heater

*Ezez. 2019; Luke Doyle 2020
The outsourced ant must have a permit ethically there are rules to contain and allow the continual shipment of ants. Ordering ants if they arrive deceased; washing them down the sink is morally ethical as if you are to allow other species to contain the environment around, it could become harmful to other species that habitat the area already. Working with ant species causes ethical morals to work into play as it discusses the cause and effects of spreading species across international and state borders. Ethically speaking this could cause detrimental issues to the environment.

Table 4: University of Colorado Denver, LODO Lab resources

Material	Amount	Description
Blender		Blend mealworms
Pressure cooker		Sterilize
Petri Dishes	×15	60mm ×15mm
Pleurotus Djamor	.9ml	.05ml per petri dish

*Assia Crawford 2023; Marc Swackhamer 2023

The University of Colorado Denver, LODO lab provided the opportunity to research bio-design information. The laboratory requirements were suitable and gave full capability to test and perform scientific study. Assia Crawford and Cynthia Fishman guided us through optimal growth outputs for specific algae and fungi growth to allow for successful output of mycelium growth.

1.3. Agar and Ant Set Up

To provide the best growth to pink oysters it is required to start from liquid culture, production of mushroom growth then relies on a growth substrate to support the expansion of its growing molecules. In the design build process the production of agar is used as the substrate to grow the pink oyster.

Agar Formula Followed: *per 500ml Distilled water.*
- *5g Agar*
- *5g Malt Extract*
- *1g Yeast*

Table 5: Scale Mixture

Agar	Mealworm + 66 ml Agar	Banana + 66 ml Agar	Sugar + 66 ml Agar	Mixture + 66 ml Agar
66 ml	.50g	.50g	.50g	.50g
66 ml	.75g	.75g	.75g	.75g
66 ml	1.00g	1.00g	1.00g	1.00g

The agar was poured into Petri dishes, sealed, and placed to become gelatinous, forming a substrate for the mycelium to grow on. Investigating how the growth affects ants, the agar substrate was mixed with the three separate types of ant nutrition to form a symbiotic process allowing ants to eat and live with the mycelium growth. After the agar solidified .05ml of *Pleurotus Djamor* is syringed and introduced to the agar through a ventilation hub. Following incubating the agar it was placed in a grow tent within the following conditions.

Grow Tent Conditions: (a humidifier was placed inside to keep the humidity levels up)

Temperature: 70°F - 80°F

Humidity: 65% - 70%

Light: No light allowed

The agar was incubated in these conditions for twenty-eight days watching the growth from each of the different substrates.

During the growth process of the mycelium the ants had arrived. During their arrival the setup of their outworld and nesting area needed to be set up. The ant nesting hubs provided an opportunity to pour water into an enclosed area providing four separate nesting chambers with four different humidity options based on the amount of water provided.

Table 6: Amount of water provided in Nesting Chamber

Nesting Chamber	Amount of Water Added
Nesting Chamber 1	.01ml
Nesting Chamber 2	.02ml
Nesting Chamber 3	.03ml
Nesting Chamber 4	.04ml

Each nesting chamber was provided with different amounts of water. Allowing this variation gave more comfort to the queens. Connecting the nesting area to the outworld with a clear plastic tube, the outworld needed to allow the workers to come and go as well as be able to collect their food source. The outworld was provided with approximately one gram of soil that was found locally sourced and placed inside then 1ml liquid feeders were placed inside of the outworld. The liquid feeder gave the ants ant nectar and sugar water providing them with some nutrients when entering their new world. Once the ants were introduced to their new homes each ant outside world was provided a piece of fruit as well as protein, which was mealworms. This was done to allow the queen to get started producing new eggs to productively induce the act of larvae birth.

Grow Tent Conditions: (a humidifier was placed inside of this tent as well)

Temperature: 70°F - 75°F

Humidity: 65% - 70%

Light: On a timer to mimic sun cycle

Discussion

During the investigation process to determine which substrate had performed the best under its growing constraints. There was statistical as well as visual data gathered to try and best track which one performed best. The ideal way to measure the growth was to use a microscope that could capture the rate at which the mycelium would grow. The formula used was to track the percentage of increase daily by measuring the growth from where the original mycelium growth had started to occur. By tracking this percentage, the ability to see which substrate had the most successful growth through a twenty-eight-day timeline. With the gathered data it was concluded that throughout all the mycelium growth the one that had succeeded most was mealworms. Because of the blended dry mealworms incorporated with the mycelium and agar growth the mealworms acted as if it was responding to growth rates presented from mycelium grown with sawdust. The research has proven that within mycelium production and ant nutrients there is a correlation as to the growth rates and proteins provided. The continuation of this project seeks to define whether the mealworm nutrient substrate could supply growth to mycelium as well as a nutrient rich fungus for ants to create a symbiotic relationship between mankind and the natural co-operation of the environment around. After pursuing another study as to whether the ants could live symbiotically with nutrient rich mycelium and ants, there should be a study as to how the influence of this mycelium growth could correlate into the future architectural developments. This correlation could be in the uses of material structuring, formulation of architectural buildings, cities, and planning, and finally to try and remove the manufacturing process completely. Previous studies have shown that ants do prefer to live within an environment sustainable to mycelium growth as it is a fungus that has caused ants to create an antibiotic mechanism while eating mycelium and fungus. Future studies should determine whether it is ethically correct to investigate and research with insect species, as introducing ants directly into contact with mycelium has proven to cause either fungal zombie diseases that take over ants or it has killed them while trying to see which housing ants preferably live in.

Conclusion

In conclusion, emissions, and energy costs for the fabrication process of building materials have been rising yearly, causing the world to start to place new agreements to have zero-emission housing constraints by the end of 2030. While investigations are getting out on how to co-operate between utilizing the living process, there could be methods to make the fabrication process completely co-operative with the natural environment. The research provided shows to grow a co-operative naturally produced material between ants and mycelium there was an opportunity to see if there is a way to create a mycelium that can grow with the ants as well as provide them nutrients and nourishment. Investigating a form of mycelium that co-operates with the ant species chosen could provide the necessary link between creating a symbiotic bond between ants and mycelium growth. The experiment has proven that within mycelium production and ant nutrients there is a correlation as to the growth rates and proteins provided. The continuation of this project seeks to define whether the mealworm nutrient substrate could supply growth to mycelium as well as a nutrient rich fungus for ants to create a symbiotic relationship between mankind and the natural co-operation of the environment around. The future of this project relies on determining the morals and ethics of investigating studies of insects and animals. This could determine whether the push to figure out not only the symbiosis between ants and mycelium growth but also how mankind and insects could work together to create new perspectives or future biophilic formations in the future. The investigation could lead to a symbiotic correlation that could create a method in manufacturing goods and structural materials that would not include the necessity of man or machines to process. Moving materials, as well as producing material goods such as OSB, MDF, and other forms of material goods are commonly made with different chemical components to allow them to last longer. The symbiosis between ants and mycelium could result in the production of materials that do not include harmful chemicals to ingest or use in production, also affecting the future health of human beings. While not only allowing for implications to improve through production but as well as lifetime health and longevity provides sufficient evidence as to how pursuit of this production and manufacturing mechanism could prevail to benefit the future. Mycelium also requires a biodegradation test to understand the full long-term effect using mycelium products.

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