Figure 8. plotted controlled path of polystyrene to be eaten day 1 © Eve Nnaji, Madhavi Ohja (2020)

STRANGE IS BETTER: AN EFFORT TO BIOLOGICALLY CONVERT POLYSTYRENE INTO ORGANIC MATTER USING MEALWORMS

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The current narrative of the World's plastic consumption, promiscuously sprawls at the shores of economically competitive coastal regions, in the streets of vulnerable developing nations, and in the digestive tracts of the native animals that depend on the dwindling resources of their environment. Since plastic waste production increasingly proliferates almost all known and unknown regions of the planet, many methods and efforts to degrade, eliminate, and convert these compounds are being investigated. This project investigates the use of biological agents, mealworms and superworms, to directly convert plastic into organic matter using their natural digestive process.

mealworms / eating / polystyrene / organic matter / converting polystyrene

Figure 1. mealworms within porous eaten polystyrene block © Eve Nnaji, Madhavi Ohja (2020)

From 1950 to 2015 the rate of plastic production increased nearly 200-fold, with PPA (polyphthalamide), PET (polyethylene terephthalate), PVC (polyvinyl chloride), and PS (polystyrene) in the lead of demand and production. Different programmes, such as Barcelona's door-to-door waste collection program, have been developed to recycle these plastics products in a manner accessible to the public (Anastasio, 2018). However, the process of recycling requires large operations consisting of various means of lengthy transportation, high energy output, machinery and hazardous chemical compositions, ultimately producing new dangerous materials, which require even more specialized disposal techniques.

Polystyrene, the fifth most hazardous waste existing, is a common household and commercial plastic that requires such arduous processes in its recycling program. PS can only be recycled if it is clean, un-dyed, and uncontaminated; contamination includes food residue which PS is often used to contain. Once PS meets the strict recycling standards, it can then be melted into a paste to be reformed. Nevertheless, the process of collecting, sorting, prepping, and processing PS is a feat too expensive and onerous for most cities to implement. Currently most PS recycling plants are operating at a loss.

Figure 2. mealsworms in porous eaten polystyrene disk © Eve Nnaji, Madhavi Ohja (2020)

Biomimicry is a process in which the design and production of materials, structures, and systems are modelled on biological entities and processes (Vincent et al., 2006). Mechanical innovations often seek shortcuts found in nature to compress tedious manmade processes efficiently. This practice has brought several breakthroughs in aerospace engineering, deep learning, and parametric architecture, but recently even larger and more sustainable innovations have been made, using biology itself rather than mimicry.

In 2015, researchers of the Civil and Environmental Engineering Department in Stanford University and Beihang University produced a study finding that mealworms (the larvae of Tenebrio molitor Linnaeus) and superworms (the larvae of Zophobas morio) are able to safely consume and biodegrade polystyrene due to the bacteria (i.e. Exiguobacterium sp. strain YT2) in their digestive tracts, which can safely breakdown PS and convert it into organic matter (Yu et al., 2015). The resulting organic matter has the potential to carry micro and nano remnants of PS, however, they are encased in fecula, the primary matter of the mass. The study found one mealworm to have an eating rate of 0.0001gram of PS per day (100 mealworms = 0.1g per day). This study became the foundation and catalyst for the agenda of this project.

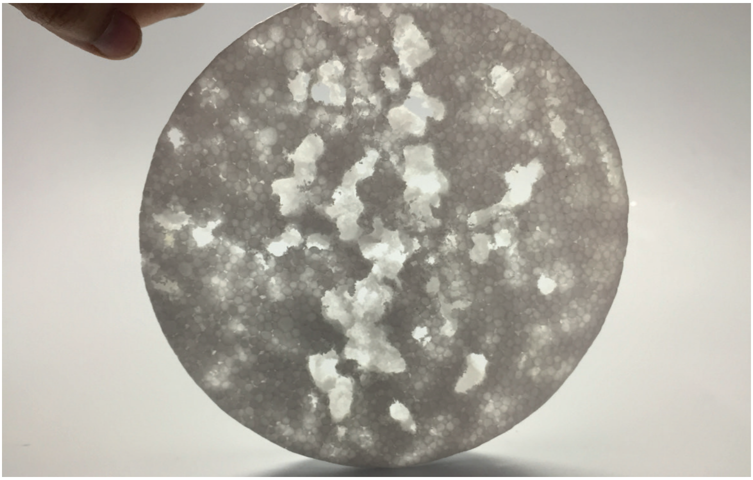

Figure 5. porous eaten polystyrene disk © Eve Nnaji, Madhavi Ohja (2020)

With this study, the project aimed to accomplish four major goals: (1) reproduce the findings; (2) perpetuate the eating rate; (3) control the eating pattern; (4) use these controls to efficiently and rapidly convert vast amounts of PS waste into organic matter at sustainable and safe rates. The first experiments were executed in order to understand the eating behavior of the mealworm and the superworm with PS in contrast with organic food, bread.

These experiments proved the findings of the case study, with roughly the same eating rate. The experiments also revealed the contrast of eating rate between PS and bread; the bread was swarmed and consumed immediately by the mealworms while the PS only attracted a fraction of the population. Another finding showed that the mealworms consumed the block of PS by eating the outer layer rather than penetrating the block. This noted that there was no incentive to exert energy in order to penetrate the block. In order to incentivise the worms, a syringe was used to insert juice into the polystyrene at various points. Penetration was achieved using this method and more importantly, the eating rate was also increased from 0.0001g per mealworm to 0.0005g per mealworm per day and 0.005g per superworm per day (a 5x increase). The eating pattern produced by the mealworms after penetrating the polystyrene was a porous geometry. By eating their way into the block, they were simultaneously creating cavities in which they could safely inhab-

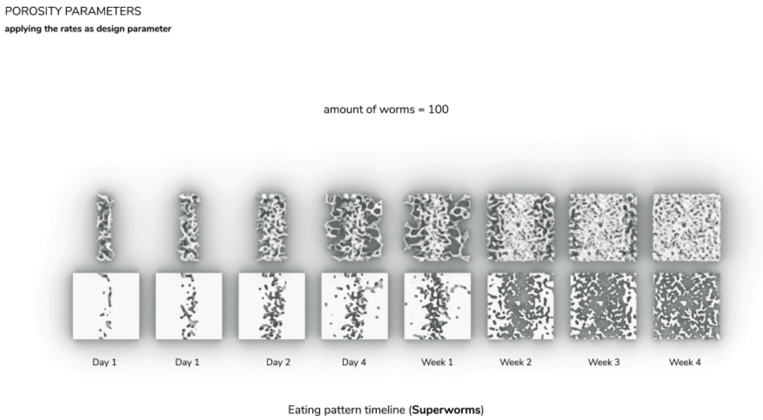

Figure 6. grasshopper porosity parameters visualization 1 © Eve Nnaji, Madhavi Ohja (2020)

it, sheltering them from direct light and exposure, a typical trait of insects (Fig.1-5). To achieve control over this eating pattern porosity, experiments were conducted focusing on the placement of juice points. In one experiment, juice points were placed within a linear boundary drawn onto the PS block. In another experiment, juice points were placed following a curved path drawn onto the PS block (Fig.8-9). The experiments yielded successful results; the mealworms and superworms only ate within the boundary, creating porosity mostly in the regions populated by juice points. A further experiment used sugar water in order to achieve control. The difference in eating rate could not accurately be measured, due to the incapacity to measure the minute difference in grams. The next set of experiments focused on the processes post consumption: samples of the organic waste matter produced were taken from mealworms 1, 2, and 5 weeks after having consumed styrofoam. The difference in these samples were visible: the samples taken within 1 week were a mixture of white and brown particles; the white being identified as styrofoam. The samples taken after 5 weeks were finer and consistent of only brown particles.

The next phase of the project focused on the reusability of the organic waste matter. The establishment of a digital system was used to parametrically design 3 dimensional porous structures baked on the studied eating patterns of the worms.

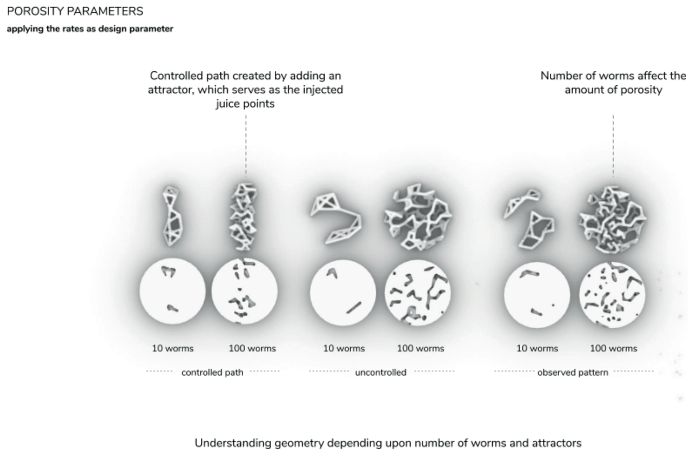

Figure 7. grasshopper porosity parameters visualization 2 © Eve Nnaji, Madhavi Ohja (2020)

By using Grasshopper in Rhino, points could be used as attractors to simulate the juice points while controlling the number of worms in the simulation, directly influencing the size and condensation of the porosity (Fig.6-7). The same process was used to design 2 dimensional patterns that could accurately simulate the eating pattern in relation to the number of worms and given area.

With the findings of the conducted experiments in hand, the next step of the project aims to tackle the last goal, eliminating vast amounts of PS. The proposed project aims to partner with waste companies in order to jointly tackle this problem. A mealworm farm will be situated on the compound of the waste company with direct access to discarded PS. The mealworm farm will host 500,000 mealworms per square meter at which a 500 square meter farm will eliminate 1 ton of PS per month, the equivalent of 18 million PS cups per month (1 cup = 0.05g). The waste produced from the worms will be used as soil in-house in order to grow crops that will be used as supplementary mealworm food, in order to supplement their diets with nutrients. Because the mealworm is the first stage of a 4-part lifecycle, the pupa will then be separated to hatch into darkling beetles, which will then mate and reproduce more mealworms. Some worms may not transform and die from natural causes, such as failure in the competition of acquiring food. These worms will be

Figure 9. plotted controlled path of polystyrene to be eaten day 6 © Eve Nnaji, Madhavi Ohja (2020)

sorted and used to create chitosan, furthering the efforts to re-loop the cycle.
The efforts of this project have, so far, educated the audience it has entertained and have led to interesting discussions and ideas bringing all parties involved closer to changing the impact of plastic in the environment. By promoting these processes of nature, these efforts aim to change the narrative of pollution that is currently stifling other natural processes in hopes of creating a new narrative, one where human needs and agendas can pave a way for these natural processes rather than stand in the way of them.

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