

Plastic Waste to Soil Wealth: A Microbial Makeover with Sam Baker

[00:00:00] Nataliya Shcherbatyuk:

Hello and welcome to the *Mulch Matters Podcast* where we will explore the intriguing world of mulch and its impact on agriculture and the environment, as well as update you on the latest research about soil-biodegradable mulch and recycling options for plastic mulch. I am your host, Dr. Nataliya Shcherbatyuk, and I am a communications specialist for the project, "*Improving end-of-life management of plastic mulch in strawberry system*". In each episode, we'll dive into the latest research, trends, news, and insights on why mulch matters and how we can improve plastic mulch end-of-life options. We'll also branch out and discuss other plastics as well as talk to researchers, experts, and practitioners in the field who will share their insights and experiences on how to use mulch effectively in different settings.

[00:01:10] Nataliya Shcherbatyuk:

Hello, hello, and welcome back to another episode of Mulch Matters podcast and let's welcome our special guest, Sam Baker, he will be talking to us about his project, earthworms and plastic. Hi Sam. It's so great to have you on our podcast with us today. How are you?

[00:01:29] Sam Baker:

Hi. I am. I'm doing really well. I'm really excited to be here and to talk about earthworms and earthworm research.

[00:01:36] Nataliya Shcherbatyuk:

Oh, that's exciting. So, Sam, let's start by telling us a little bit about yourself and the project you are working on.

[00:01:45] Sam Baker:

Certainly. So, my name is Sam Baker, and this is always weird to say. I am the CEO of an earthworm company called Wriggle Brew, and I was previously a chemistry researcher at the University of Central Florida. My background is chemistry and economics, and I started a team of researchers with a couple guys from the University of Central Florida, which of course became a company. And we primarily are pursuing ways to. Produce alternative organic fertilizers by using earthworms to break down food and

farm waste. And we're also working on using earthworms and earthworms related microbes to break down and destroy certain kinds of plastic waste.

[00:02:29] Nataliya Shcherbatyuk:

That sounds cool. Before I get to the project, I just had to ask you, according to your last name, do you like to bake?

[00:02:39] Sam Baker:

No, I mean, I do a little bit, but not really. It's, I do like to cook though, and I used to do quite a bit of brewing actually, which is very related to what I'm doing now for my business, which is brewing earthworm tea.

[00:02:55] Nataliya Shcherbatyuk:

Okay, let's keep going. So, what inspired you to start this project?

[00:03:01] Sam Baker:

So, a couple things, but what the project originally was an attempt to create a fertilizer that could be used by industrial scale farmers. And still be entirely organic and not contribute to soil or fertilizer runoff and not contribute to soil degradation. So, to give a little more context on that, a lot of farms right now, and a lot of agriculture right now relies on the use of nitrogen and phosphorus fertilizers. And these fertilizers primarily come in the form of either nitrogen or phosphorus salts or in soluble liquids, which contain those salts, and so those compounds are very good for boosting plant growth, but they are very reactive and they can destroy a lot of the microbiology that lives in good soil and they can also run off through that soil and cause large fish kills and enormous amounts of death in waterways. And for me, I was totally unaware of earthworms. I was actually originally as a chemistry researcher, most interested in pyrotechnics. And I was going fishing with my grandfather in Florida and one of our favorite spots he pointed out to me was destroyed, all the fish were dead. He showed me 'cause of fertilizer runoff that had happened in the local area. And it got me thinking about what, how fertilizer is being used and how much destruction it's causing, and it made me concerned that soon if something wasn't done to change the way fertilization was done of crops, there'd be nowhere left to go fishing. And so, I decided to ask some of my friends in the research space what might be done about this and my best friend Gabe, who is a biochemistry researcher, mentioned that earthworms were a really good alternative method of manufacturing fertilizers. They produce fulvic substances that are the basis of good topsoil, and they produce these substances in plenty of food waste and farm waste and material like that. So, it raised a

question, which is if earthworms can make fertilizer basically from garbage, why is that not how we're making our fertilizer? Why is it all coming from the oil industry?

[00:05:21] Nataliya Shcherbatyuk:

That's a good question.

[00:05:23] Sam Baker:

It was, and of course as you know, the basis of all science is asking questions. So, we asked that question and it turns out well, there are relatively solid reasons, the big one was shelf stability. So, it turns out that earthworm manure, worm castings are very rich and aerobic bacteria and also some anaerobic bacteria. And so, if you submerge those castings in a liquid and water and you try and store it so that you can ship it or, you know, logistically handle it so that it can get to a farmer. Many of these bacteria and fungi will go anaerobic. That is to say they will switch to an anaerobic method of metabolization, which will lead to essentially spoilage of the fertilizer. It's a very similar biological problem to what we used to have with milk actually back in the day. And as a result, these fertilizers, if you seal them up in a bottle or a tote or a truck, will go bad within 24 to 48 hours, which makes them functionally useless, as a product that can be distributed.

[00:06:30] Nataliya Shcherbatyuk:

Interesting. So, you know, when I was reading through the. Project that you've been, you're working on, I've seen some fancy words that I definitely want you to explain to get to our audience. So, can you, can you explain what pyrolyzed poly is? And let me know if I actually even said it right.

[00:06:52] Sam Baker:

So pyrolyzed polystyrene. So that has to do with the plastic digestion side of our research. So that when we started this, we were concerned with making fertilizer from worm castings, and so we spent a lot of time studying worms and studying earthworms. How they digest things and we ended up stumbling across this phenomenon in other papers, which were published on the ability of some worms, especially larval worms, to eat and digest polystyrene. So polystyrene is a kind of plastic, and in fact, there are these worms that are now able to eat. Plastic, poly plastic as a food source, and so it raised a lot of interesting questions. Among them being if some worms can eat plastic, can we use them to deal with the massive amounts of plastic waste we have?

[00:07:49] Nataliya Shcherbatyuk:

Yep. Definitely. We have a lot of food for them.

[00:07:52] Sam Baker:

And, and two, can that manure that they produce from eating all that plastic be used as a fertilizer? Is it functional as a kind of vermicompost? And so those are the two research questions we pursued in that direction, and we ended up discovering that yes, you can use these worms to deal with large volumes of plastic waste, although not necessarily in the way you might think. And two, the manure that these worms produce is not suitable as a fertilizer precursor, but with some extra work, you can get it there. So, what that looked like is we built a bunch of very large worm habitats, so larva, worm habitats and fed them all kinds of different foam and foam plastic and watched them eat through it and measured how much they were eating and varied the different conditions. And we discovered that they can eat about in proper conditions, about a hundred worms can eat roughly 10 grams of polystyrene plastic in six weeks or so. So that's not very much, but if you isolate the bacteria from their gut and you put that into a bioreactor so, basically a big vessel that simulates the conditions of the worm's gut. You can have it eat about a hundred grams of plastic in five days. So, it is much more efficient compared to using just the larval worm. And then it gets even better if you pyx the polystyrene. So, if you heat it up really, really hot in the absence of oxygen, you can turn it into a series of liquid components. So, things like styrene, which wind fed to the bioreactor can be digested even more quickly in even greater quantities. So about 450 grams in five days. So, then you're looking at about a pound or so of plastic being eaten in a single bioreactor. And that's very impressive and it's very, and it's happening very fast time. And the other thing that's really cool about that is when that's done, what comes out of that process? What's di what? What's left over from the digestion is completely free of micro nano plastics and it's an organic material, kind of what you'd find halfway through the digestive process of the worm's gut. It is a digestive material that can be solidified and can then be fed to earthworms to complete the digestion process, and they produce worm castings from that, which is what we can use to make fertilizer.

[00:10:28] Nataliya Shcherbatyuk:

That's pretty cool, on the worm topic, can you recall again, so what kind of microbes and worms' organisms are you actually using? And most specifically, why, why those?

[00:10:42] Sam Baker:

So, for digestion of plastic, we primarily use *Zophobas morio*, it's the darkling larva. Or rather the beetle, the larvae of a darkling beetle. And they are very voracious eating, beetle. And what makes them. So useful is that they can live for up to a year in their larval state, which makes them very easy to study. And they're also very capable of hosting. A couple species of bacteria that assist them in degrading things like polystyrene and getting food and nutrition from it. Now, I cannot talk too much about the actual bacteria that they are using in their guts. But there are a number of species involved in that, which are

actually responsible for producing the enzymes necessary to break down polystyrene polymers and ligaments. So, we selected actually a couple different larvae to compare the *Zophobos morio* to we studied black soldier fly larvae. We also studied mealworms, the common mealworm and so those other larvae have some of the same bacteria in their gut and they are also relatively long-lived, and they also are quite good at chewing, which makes them voracious eaters, but neither of them was quite as effective as *Zophobas morio*. When it came to eating the actual polystyrene it requires a lot of moisture and doesn't seem to be able to subsist off of polystyrene solely and mealworms are much smaller on average the individual organism is and so even when you scale up the quantity to match the biomass of *Zophobas morio*, they do not seem to be able to eat just quite as fast and as efficiently.

[00:12:27] Nataliya Shcherbatyuk:

And so going back to your bioreactor technology and thinking about its development. What are the biggest challenges that you're facing?

[00:12:38] Sam Baker:

So, there's a lot of challenges with running a bioreactor design to digest pyro plastics or thermally degraded plastics and one of the big challenges we had with that is some of the products of pyrolysis are quite volatile. So styrene, for example, is a product of pyrolysis, of polystyrene, and styrene is both relatively toxic to humans and is evaporative. So, when you put it in a bioreactor, it will start to evaporate outta the bioreactor and it becomes very hard to measure how much is being digested from how much is just evaporating into your fume hood. So, we had to figure out a way to recapture that styrene so that it could continually be used in the bioreactor so that we could get a much more solid measurement on how much was truly being digested. And so, we ended up having to build, because we could not find any equipment for this what's called a vapor recovery unit. And a Vapor Recovery unit is a piece of machinery which uses differential pressure and cooling to collect the evaporative off gassing of in our case, styrene and liquid, and reify it, and then drip that liquid back into the bioreactor. So, we had to build one of those ourselves 'cause we could not find any that were, you know, that were usable for our kinds of bioreactors, so, we, you know, we got a mini fridge and we had to learn how to, you know, do a lot of like, brazing with pipes and we got a compressor and had to code an Arduino specifically to run the whole thing. So, it became quite involved just to build this one little piece of equipment so we could get a solid measurement on the digestion rate and there are numerous other issues, you know, we encountered along the way as well. So, it's a very unique. Another problem is how do you measure what's the standard procedure for measuring what quantity of micro, nano plastics you have left over. That's still somewhat of a developing field, so, you know, how do you measure that? And that was a challenge for us. We had to develop kind of

a, of method of microscopy to sort through the offtake of this bioreactor to see if we can identify pieces of micro and nano plastic. It's not something you can easily run through like an HPLC, for example.

[00:15:01] Nataliya Shcherbatyuk:

And how long have you been working on this project?

[00:15:03] Sam Baker:

So, the plastic project began in 2023, so we've been working on it for essentially two years and have changed now and we originally proposed it to the National Science Foundation in 2022, so, a lot of our experimental design and background research took the greater part of 2022 to actually develop. So, in total, it's been really three years, working on this, we were funded \$275,000 in a phase one SBIR grant from the National Science Foundation. And that really got us started. But we really wanted to get phase two. We actually wrote a phase two proposal. We sent it in, we got some really good feedback, trying to figure out new ways to get this research funded. And so we're working with a couple groups, nonprofits, and others to make that happen.

[00:15:51] Nataliya Shcherbatyuk:

Well, going back to your end product, can we talk a little bit more about the end product? And I'm talking about organic fertilizers. So, what does it look like? And I know you spoke a little bit about that before, but let's recall it. So, what does it look like and how that can actually benefit agriculture in its landscape?

[00:16:13] Sam Baker:

That's a very, very good question. So, the end product of our original work and still the end product we are commercializing at this moment is what's called a worm tea. It's a vermicompost liquid. So, basically what that means is its worm castings or earthworm manure soaked in water in order to extract the soluble nutrients from it. And then it is treated through a process we developed to make it shelf stable and given a proprietary microbiome of bacteria, so that this liquid can then be applied to soil, provide soluble nutrients, but also provide a culture of bacteria kind of like a yogurt or kind of like a probiotic that inoculates the soil and provides species that are capable of fixing nitrogen, solubilizing, phosphorus, and a host of other things, which improves the quality and performance of a farmer's soil and also helps to improve the yield of the crop that they grow. So, we've had a lot of farmers grow things like soy and corn, and those are row crops, so they have very demanding needs, and when this vermicompost liquid is used on it, there are comparable, if not better results compared to a lot of existing synthetic fertilizers, and that has very beneficial ecological outcomes. So. By replacing the nitrogen or phosphorus fertilizers they are

using with this vermicompost liquid with this wriggle brew, we are reducing the quantity of nitrogen that's running off and the quantity of phosphorus that's running off, and that leads to less decay of the soil, less damage to the microbiome, and a significantly lessened amount of excess nutrients ending up in the water table. Which is huge.

[00:18:07] Nataliya Shcherbatyuk:

And talking about plastic recycling and waste to fertilizer system. 'cause that's what you're focusing on. What do you think, how your approach is different from the rest they exist in now considering the plastic recycling, you know, and waste to fertilizer system.

[00:18:27] Sam Baker:

So kind, what makes it novel? And that's a really important question because there's a lot of other people in the plastic fertilizer or in the plastic recycling space. Now, we know from studies published repeatedly in the last decade or so that recycling is not very effective. We have seen again and again that plastic is recycled at very low rates 30% seems to be about the maximum that's naturally achievable. So, recycling does not account for most of the plastic. And then other processes, for example, incineration is one big process require a lot of logistics and emissions work that is not easily done in the United States. And, so a lot of these other plastics disposal methods are very insufficient. What makes ours very interesting is that rather than taking the plastic and trying to turn it into more plastic by recycling or just trying to, you know, eliminate it by landfill or by incineration, we are still trying to turn it into a valuable substance. In this case, worm castings so soil and fertilizer precursor, but we're doing it in a way that allows us to convert, you know, nearly 99.99% of the plastic we receive into this material. So, plastic when recycled. One of the reasons recycling is not successful has a very low value add. So, if I take a pound of polystyrene and I put that through the recycling process, at best I'm going to get 10 cents to the pound if I'm able to clean it and, and prepare it. Whereas if I turn that polystyrene, that, that same pound into worm castings, well worm castings are worth in bulk. 50 cents a pound, 60 cents a pound. Okay. Okay. So many multiples, more valuable, and if I turn it into a liquid fertilizer, which can be plugged into a farmer's existing system, now it's worth two to \$5 a pound. And, so that is a, a vast multiplication of the value, and it also is eliminating the plastic. So in recycling, you're taking old plastic and making new plastic with it, which is generation that happens, the majority, 60 odd percent, end up just getting thrown away rather than recycled again, but in this case, we're not making new plastic with it. We are eliminating it from the plastic value chain, and we're turning it into something completely different.

[00:20:50] Nataliya Shcherbatyuk:

I see. So, ask questions for you. Where are you taking your plastic from? Are you collecting it from specific places, so you have some sort of recycling, I don't know, pile that plastic is being delivered to you? What kind of plastic are you using right now?

[00:21:06] Sam Baker:

So, at the moment we are, we are very much on a pilot scale. This is still a lot of research. It's not commercialized to a degree where we can deal with, with large quantities of plastic. Right. But we've been getting some from our local municipal waste. So, our, the, you know, the landfill and waste disposal people near us have been giving us some, we've also gotten a little bit from a few local businesses, and so we have plenty of it. In fact, there's people always asking us to take it. And we can only handle so much. Yeah. So, there's no shortage of it. But what we'd like to be able to do in future as we scale this research up is set up a larger and larger pilot facility that will eventually be able, handle. Waste streams the entire waste stream of the of the local area, at least with regards to certain plastics. So, the county that I live in, Seminole County, has 5% of its waste stream consisting of polystyrene plastic alone. And so, if we could divert that entire waste stream from Seminole County, we could turn that into more than enough fertilizer for the local farms.

[00:22:12] Nataliya Shcherbatyuk:

So, in the future you would be able to work with agriculture plastic, like let's say mulch p mulch?

[00:22:20] Sam Baker:

Potentially that would be one very exciting direction to go in. The process seems to work on not just polystyrene, but lots of other kinds of plastics. So, there are many, many different opportunities. For example, grocery stores use enormous quantities of plastic bags. I was recently in conversation with someone involved at a large grocery store, and they were very interested in the concept of their plastic bags being. Processed through this method, into some agricultural material. That they are willing to potentially pay a significant amount of money for the disposal, uh, of the plastic bags in a, in a more ecological way. So, there is a, there is a, certainly a business model that's possible that could result from this research where plastic disposal. Could be a, a profitable front end and there'd be a profitable backend where fertilizer is produced and provided to farmers.

[00:23:18] Nataliya Shcherbatyuk:

Well, that's definitely exciting. So, are there any current or maybe future collaborations that you are very excited about?

[00:23:27] Sam Baker:

There are, unfortunately, I cannot talk about most of them.

[00:23:30] Nataliya Shcherbatyuk:

Understandable.

[00:23:32] Sam Baker:

You know, that's the nature of business these days. But I will say this, we are right now in the process of finalizing an agreement with a very large distributor and fertilizer producer up north from us. And we are aiming to produce 10 times the quantity next year. We made fertilizers this year with their help with and getting to their network of farmers. So, we are, this year we've produced 30,000 gallons of fertilizer, which is a very significant amount.

[00:24:04] Nataliya Shcherbatyuk:

That's quite a lot.

[00:24:07] Sam Baker:

It's a lot. You know, it's like a swim. It's like several swimming pools worth. And next year we are projecting with this partnership to be put out at least. A hundred thousand, but more likely 300,000 gallons.

[00:24:23] Nataliya Shcherbatyuk:

That's, that's very cool. And also, it looks like I'll be reaching out to you again, you know, to tell us more in the future.

[00:24:32] Sam Baker:

Absolutely. I'll, hopefully have some very cool pictures to show you and some really interesting data to share on the impact of all these farms on the farms.

[00:24:43] Nataliya Shcherbatyuk:

So, what has been the most surprising or maybe rewarding aspect of working on this project?

[00:24:50] Sam Baker:

Well, I think the most surprising and rewarding aspect was figuring out this plastic digestion, because that's not what we sought out to do originally. We really sought out just to find ways to improve. The so-called worm teas, the liquid vermicompost fertilizers, and we succeeded in that research, but along the way, we were shocked by this plastic digestion, and it's been extremely gratifying to see this research advance and to see it work on more and more kinds of plastics and to learn more about how. It could potentially be expanded to deal with the plastic crisis because we do have a massive plastic crisis on our hands as a species, and so something's gotta be done about it. And a lot of research, I think, has been kind of spinning its wheels in the wrong direction. And this seems to be an element of, of part of, the research movement lately that's finally starting to make some traction against plastic.

[00:25:54] Nataliya Shcherbatyuk:

If you have a chance right now to talk to those, you know, who want to be involved in sustainability and environmental health, what advice would you give to others?

[00:26:05] Sam Baker:

That's a very, very good question. So, one piece of advice I think I would definitely give is that I think of a lot of people in the sustainability world, the organic world when you're making products that are sustainable or environmentally beneficial focus too much on trying to make their product a premium. I think it's very, very important that organic, sustainable, environmentally friendly options be price competitive. And if not, price competitive, if possible, more affordable, cheaper. Then the synthetic or the toxic, or the non-sustainable alternatives. And the reason is adoption. We cannot afford to have real solutions, good solutions, good alternatives to important products being locked behind a paywall because they will not get adopted. I've seen this happen again and again. Fertilizer companies especially have been really guilty about this. We'll make an organic alternative, and they will then think, oh, because this is organic, we can command a premium for it because farmers will pay more to that's not a good idea. And it applies with everything. You should try to be cheaper than those. Other things. And it's not because farmers aren't willing to pay a premium for organic, it's not because consumers aren't willing to pay a premium for organic, it's because they shouldn't have to and it creates a big limitation on the adoption of those technologies when you commit, when you try to demand that premium. There are plenty of farmers I've met who want to grow organically. They just literally cannot afford to, or they don't feel like they can afford to and trying to convince someone to spend more money on something through the guilt that they're currently doing it in a way that's maybe bad is not a good strategy. And it's gotta change, I think this was a big problem with electric vehicles, for example, the EV world. Electric vehicles are a lot better than petroleum cars. They're a lot better, not just because of the way they are powered from day to day,

but because they have, you know, fewer belts and hoses inside of them, fewer replaceable parts. So, they last longer. They require less maintenance. They place less of a logistical burden on the environment. But EVs are, are more expensive than gas vehicles are in most cases. They're sold as luxury vehicles. That's a very poor philosophy, and it has utterly hampered the adoption of these vehicles because people are, they, maybe they like the concept, but they don't want to spend 25% more just so that they can sleep better at night. They have a family to worry about. They have a business to worry about. They have a farm to worry about, so it becomes very difficult for them.

[00:28:57] Nataliya Shcherbatyuk:

Yeah. So more affordable solution. That's the way to go.

[00:29:01] Sam Baker:

By all means. Yes.

[00:29:03] Nataliya Shcherbatyuk:

Sam, thank you so much. That was quite interesting. Good luck and I will definitely be reaching out to you soon to hear the progress. What's going on. Yeah. Thank you so much.

[00:29:16] Sam Baker:

Thank you very much for having me. It's been a pleasure.

[00:29:18] Nataliya Shcherbatyuk:

That's it for today and until the next episode. You can find more information by following us on Instagram and LinkedIn by @mulch_matters and going to our websites www.smallfruits.wsu.edu and choose mulch technologies. This work is supported by Specialty Crops Research Initiative Award 2022-51181-38325 from the USDA National Institute of Food and Agriculture. Any opinions, findings, conclusions, or recommendations expressed on this podcast are those of the author(s) and do not necessarily reflect the view of the U.S. Department of Agriculture.

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