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Fermenting for the Zombie Apocalypse

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Abstract

How does fermentation fit into your zombie apocalypse preparation plan? Fermenting can provide a number of benefits – from enhancing the nutritional value of your food, to preserving it for the long haul, to cultivating antimicrobial compounds that might help protect you from the agents of the zombie apocalypse. Fermented foods are also an example of multi-species cooperation that might serve as a good example for us all for how we might cooperate to survive the zombie apocalypse. Athena Aktipis is an assistant professor of psychology at Arizona State University, chair of the Zombie Apocalypse Medicine Alliance, and co-director of the Human Generosity Project. She is the author of the new book *The Cheating Cell* from Princeton University Press and the host of the science podcast Zombified.

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Introduction

Here I'm going to focus on fermenting for the zombie apocalypse, which includes two of my favorite topics: fermenting and zombie apocalypse. I'm going to use this as a way of also exploring a little bit about how microbes cooperate with each other to create public goods and also protect, in this case, fermented foods from pathogens that can potentially invade.

Academia + the Apocalypse

I'm a professor at ASU and the Department of Psychology, I'm also the director of the Interdisciplinary Cooperation Initiative at ASU. Perhaps the thing I'm most proud of is that I'm the chair of the Zombie Apocalypse Medicine Alliance, which is an interdisciplinary group of people that use science, humanities, and interdisciplinary research to look at the challenges we're facing now, as well as what we're going to be

facing in the future - through the lens of the zombie apocalypse. It's super fun and exciting, and I find it a great, creative way to talk about science and the arts to really think about our futures.

In addition to my role at ASU, I also write books and I'm a podcaster. I have a podcast called Zombified, which is about all these things that manipulate us without us realizing it. We also use the idea of “zombification” and the zombie apocalypse as a way of looking at things from an interdisciplinary perspective. If you like podcasts, definitely check out Zombified.

In my lab, we look at cooperation across lots of different systems. We have field sites around the world where we look at human cooperation and we look at cooperation in the lab. I'm also a computational modeler, so I make computer models of cooperation to see what makes cooperation viable or not. I also look at cancer and the human body as a cooperative system, where you can have cheating.

And then of course, most central to the topic of fermentation and also human interactions with fermented foods, I have a whole wing of my research looking at microbe cooperation (in particular in kombucha) and also looking at host microbe cooperation. Host microbe cooperation considers how our microbiome interact with us as hosts, and when it is characterized by cooperation — where microbes are helping us do things that we need to do to survive and thrive, and when is it actually characterized by conflict, where microbes might have fitness interests that are not the same as ours.

I love fermenting. Not just because it's tasty, but I also find it really relaxing. I actually started doing research on kombucha because I really liked the taste of kombucha — I brought kombucha into my home and then I got fascinated by it.

The Zombie Apocalypse

Now let's return for a moment to this bigger question of the zombie apocalypse. I want you to imagine that the zombie apocalypse has happened, and you have to figure out what you're going to take with you.

Maybe you've got a z-team, you've got your people, but you've got to figure out what you are going to take along with you.

Now I would take my family, of course. Let me introduce you to my microbial family here: I've got my kombucha, my sourdough starter, yogurt, sour cream, and some

fermented vegetables.

Why would I take all of these fermented foods with me in the zombie apocalypse?

Well, one of the challenges in a zombie apocalypse is that you potentially have some sort of agent of zombification, which could be an infectious disease. It might be a microbe of some sort that is a pathogen. And if it's an apocalypse, there might also be damage to the infrastructure. So there is a challenge of even just getting safe water to drink and finding safe food sources. Therefore, having a robust microbial culture can potentially help with those particular challenges of the zombie apocalypse.

Fermentation and Kombucha

My first fermented project involved kombucha in my kitchen. Soon after I set it up I just started wondering: **What is happening in there?** I would come home from work, have a little kombucha, sit at the kitchen table with my kombucha, and just wonder. **What's in there? What's happening? Why are these bubbles rising?**

So I started looking at what was known about kombucha. At the time, around 2014, there was very, very little work on fermented foods in general, and kombucha in particular. I realized that there was not really very much work looking at what the composition of kombucha was or how the different microbial components are interacting to ferment it. Thus, I took some of this kombucha into my lab, and we started doing research on kombucha.

I brought in one of my SCOBYs from the top, an extra one that had accumulated, and some of the starter. Once we brought it into the lab we had to have a strict rule that nobody could drink it, because once you bring something from your home kitchen into the lab, now it falls under all these sort of requirements of doing research in the university. But we were able to start looking at some questions.

The first thing that we did was look at what are some of the best practices for how to grow kombucha in the lab. We published a paper, now in Peer J — but I'm basically looking at how you can actually grow kombucha in a reliable way in the lab by starting with just the starter and not with a SCOBY. Because it allows for having a more sort of uniform set of replicates if you're looking at specific questions.

We've also been looking at how in kombucha you have multi-species cooperation. In particular, and I think of this with special interest for the zombie apocalypse, is: **How does kombucha keep pathogens out? How does kombucha keep microbes from**

growing in there that we don't want and that also might not be good for the kombucha?

Part of our review a couple of years ago when we started looking at kombucha was really to get a sense of the metabolic stages — what's happening as kombucha is brewing. The way that you start kombucha is really with sweet tea, so you have tea and table sugar basically. And you have a little bit of starter, usually between 10% and 20% starter, which is just kombucha. Then you put those together, and in that starter you have yeast and bacteria that together break up the sucrose in the table sugar. The yeast breaks that up, and then the bacteria process the glucose and fructose to make the cellulose, to make gluconic acid and acetic acid, and together they create really what is this bubbly delicious fermented tea that we all know as kombucha.

Cooperation + Competition in Kombucha

We take this framework of cooperation and competition to examine what's happening in this process as the kombucha is brewing with the help of the yeast and bacteria.

Cooperation

We can think of invertase, which is essentially a little enzyme that cuts the sucrose up into the glucose and the fructose. That's really a public good because it makes it possible for the yeast and for the bacteria to process those sugars. This is one clear example of cooperation that's happening in kombucha.

Then there's waste removal and interaction that's happening between the bacteria and yeast to process the resources that are there. That's another example of cooperation.

We also suspect that part of what's happening with the cellulose with the SCOBY on top is resource storage, because that cellulose is actually sort of very densely packed carbon. We have seen, at least anecdotally, that oftentimes the SCOBYS will break down after a long period of time of not feeding the kombucha. Therefore, we suspect that that might actually be functioning as resource storage, which again is a potentially cooperative aspect of kombucha.

Competition

Now there's also competition. We think that competition might actually be helping to keep out those invaders that are not wanted — those pathogens that could have a negative effect on the kombucha and also potentially on human health. There's

production of acids, ethanol, and CO2, and all of those may be inhibiting microbes that are sort of not desired.

Then also the SCOBY creates a physical barrier that keeps microbes from sort of entering through the air. It also may be blocking access to oxygen for some of the microbes underneath, which could be also affecting which microbes can and can't grow in the kombucha as easily.

There are the different stages of what's happening in kombucha and what we see is that there's both competitive elements and cooperative elements that occur at each of these stages.

Kombucha + the Zombie Apocalypse: Survival and Public Scholarship

In terms of the human uses, we have here some ways that kombucha could potentially be helpful in a zombie apocalypse.

We know that acids and alcohol are antiseptic and the biofilm that's produced can potentially be helping to protect from invading pathogens. It also could be used as a biomaterial as there are actually some bandages that are made out of SCOBYs. So, in the case of the zombie apocalypse you could potentially make really good use of your kombucha culture if you have one.

We have done work in engaging with the public with kombucha and actually using that engagement with the public to address some of these questions that we have about the ability of kombucha to protect from invading pathogens.

For example, we had people swab their hands and then put those swabs into containers of either kombucha or sweet tea with no kombucha. The initial starting condition for kombucha was 80% sweet tea, 20% kombucha. And the sweet tea was 100% sweet tea. Those hand swabs went in both and then we looked over 10 days at what happened to those beakers.

What we saw was that the sweet tea with no kombucha in it became disgusting with the hand swabs in it. Conversely, the kombucha demonstrated no evidence of contamination by mold or any other things that could compromise the kombucha.

This suggests to us that the community, the microbial community in the kombucha, is somehow able to suppress all of these other microbes that might otherwise be making use of the sugar in the sweet tea. And it's able to basically maintain this population of

microbes from the initial inoculation with the kombucha, even though lots and lots of hand swabs went into that from the general public.

What we also found is that when we looked at the microbial composition, there was a dramatic shift in the yeast and bacterial profile of the sweet tea from the beginning of the experiment until the end, but for the kombucha there was a very stable profile of yeast and bacteria. For the tea in particular, we found Enterobacteria, bacteria that are not good for humans, colonizing the tea and a pathogenic fungus, Aureobasidium, dominating the tea later on during a studying occurring over 30 days. This is evidence that the bacterial profile is changing, the fungal profile is changing in the tea, but not so much in the kombucha, that something about the kombucha is allowing for that to stay stable.

What this suggests to us is that the kombucha is able to really maintain the stable population despite all of this sort of inoculation with microbes from the outside world.

We did a very similar experiment during the 2018 Night of the Open Door event at ASU and what we saw again was that the kombucha was maintaining a very kombucha-like phenotype and the tea got really gross. Even when the kombucha had the hand swabs it still looked very similar.

We also looked at the kombucha with hand swabs and without hand swabs — and the reason we did this is because we suspected that maybe part of what was going on with the hand swabs is that it was actually generating an even more robust SCOBY than we saw without the hand swabs. This really just came from our observations from earlier studies, because we were really surprised at how healthy and robust the SCOBYs looked on the top. And so when we did this study, for the 2018 Night of the Open Door, we included a sort of additional control where we had kombucha without any hand swabs going in it. Ultimately, when we put the hand swabs in, that actually produced a much thicker biofilm then when we didn't put the hand swabs in.

The SCOBY

The way that we're starting to think about this is that this SCOBY and some of the other elements of the kombucha might actually resemble a sort of immune system, but for this multi-species community. So when these pathogens are introduced through the hand swabs, it may be that there's a more robust response to try to create a physical barrier that will protect the kombucha from invasion.

We're looking at this hypothesis with these kinds of studies. We're also varying the initial amount of kombucha that goes in. In doing so, we're seeing that when you actually put a smaller amount of kombucha in at the beginning, sometimes you get a very large biofilm — which is sort of counterintuitive if you think that it's sort of just a linear relationship between how many microbes go in and how big the biofilm is. But if it is really part of the sort of defense system, then that observation makes a little more sense.

Surviving + Thriving in the Zombie Apocalypse

Now let's back up a little bit to the big picture here, and I want to ask you again, sort of what would you take with you in the zombie apocalypse?

I would take with me my microbial cultures, these multi-species microbial ecosystems that could potentially have many uses in terms of protecting us from pathogens and maybe even helping us to deal with wounds that we might get from zombies.

That's how I would approach the zombie apocalypse.

Now, I have a whole other set of work around zombies and the zombie apocalypse, and I want to invite all of you to join us. We have meetings that serve as a sort of hybrid between a parody television channel about the zombie apocalypse and an academic meeting. If you're interested in learning more about that, you can find us at zombiemed.org. We're going to be opening up abstract submissions, and it would be wonderful to have any of you who are working on fermentation submit proposals for talks or sessions because we definitely see fermentation as an important part of surviving and thriving in the zombie apocalypse.

We'll also have a lot of content that will be available for general audiences as well, so you can find all of that at zombiemed.org. Channel Zed launched in October 2020.

And thank you for your time and attention and sharing your brains, it was my pleasure to share my brains with all of you this afternoon.