Design Brief

SIMBIO
SOCIAL INNOVATION MANAGEMENT FOR BIOPLASTICS

FOOD SYSTEMS LAB

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CONTENTS

Background

The Emergence of Bioplastic Packaging

From the farm packing line to household fridges, plastic packaging is ubiquitous across the food supply chain. Plastics protect food against damage during storage and transport, maintain the characteristics of the product, prolong food shelf life, and are lightweight, durable, and inexpensive (Morgado, 2008). While plastic packaging offers benefits in food preservation and transportation, it also comes with numerous consequences from the resources used to produce plastics to its persistence in the environment at the end of its life.

> *"The rise of the waste crisis in urban governance in the mid-1960s has been directly connected to the proliferation of food packaging."*
>
> (Hawkins, 2012)

More than 90% of plastics are produced from virgin fossil fuel sources, representing 6% of global oil consumption (World Economic Forum et al., 2016). At current growth rates, the plastics sector will require 20% of global oil consumption by 2050 (World Economic Forum et al., 2016). Underscoring these challenges, just 9% of fossil fuel based plastics are recycled globally (Geyer et al., 2017).

Bioplastics are emerging as a replacement for fossil fuel based plastics to reduce reliance on fossil fuels for plastic production and mitigate plastic pollution in the environment. The definition of bioplastics is broad. It includes plastics that are bio-based, biodegradable, or both bio-based and biodegradable (Figure 1).

The focus of the lab is on bio-based and biodegradable plastics; for the purposes of this report we will refer to this grouping as bioplastics.

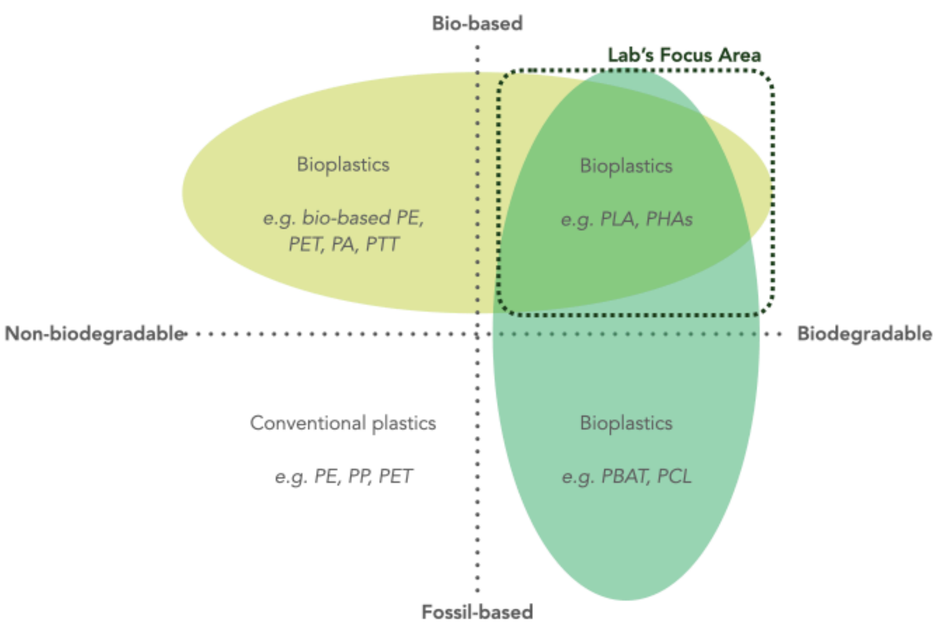


Figure 1: Classification of Plastics Based on Material Type and Biodegradability (adapted from European Bioplastics, 2018)

Bio-based bioplastics are derived or partly derived from biomass (plants) such as corn, sugarcane, or cellulose (European Bioplastics, 2018).

Biodegradable bioplastics can be broken down by microorganisms in the environment and convert it into natural substances such as water, carbon dioxide, and compost without the addition of artificial additives (European Bioplastics, 2018). These plastics can be derived both from bio-based or fossil resources. Note the biodegradable includes a broad range of degradability; biodegradable does not necessarily mean compostable.

Types of Bioplastics

Polylactic acid (PLA) and polyhydroxyalkanoates (PHAs) are the two most common bio-based and biodegradable bioplastics used for food packaging. Both are created through the use of bacterial conversion processes.

PLA: The first version of the process to create PLA was discovered in the 1800s, but was not developed into a commercially viable product until the 1990s by Cargill and Dow Chemical (Sin et al., 2012). In modern PLA production, lactic acid is created from the bacterial fermentation of dextrose, a starch found in plants like corn, sugarcane, and potatoes and then polymerized through converting it into lactide and then PLA (Sin et al., 2012). Globally, approximately 240,000 tonnes of PLA are produced per year between the NatureWorks facility in the United States and Luminy facility in Thailand (Barrett, 2018).

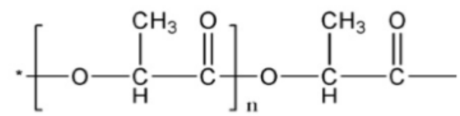


Figure 2: Chemical structure of PLA (Jiang and Zhang, 2012)

PHAs: PHAs are produced by bacterial metabolism (Sin et al., 2012). The bacteria generate polymers as carbon and energy storage when subjected to conditions where they have limited nutrients and an excess carbon source (Sin et al., 2012). These polymers are stored in the cells of the bacteria and then extracted. PHAs were first produced in the 1980s, but due to high production costs and unstable thermo-mechanical properties, they have had limited success in commercialization (Chen and Jiang, 2017). However, research and development is still ongoing on PHAs, with some products now at a stage where commercialization is becoming more viable.

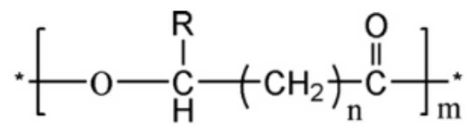


Figure 3: General chemical structure of PHAs (Jiang and Zhang, 2012)

Evolution of Bioplastics in the Food Industry

Bioplastics are similar in texture and functionality to fossil fuel based plastics (van den Oever et al., 2017) and therefore could be used in place of the majority of conventional plastic products. When PLA was first introduced on the market, it was used for agricultural applications such as twine and film (Researcher, personal communication, April 9, 2020). Early products were relatively simple, mostly films that were made into bags for food scraps collection as organic waste collection programs were being launched (Association/NGO, personal communication, March 17, 2020). When PLA was found to be safe when placed in contact with fatty, acidic, or aqueous foods, products such as cups, takeout containers, straws, cutlery, and other food-contact items were developed (Siracusa et al., 2008).

More recently, the types of products became more complex, such as coatings on paper products or packaging with multiple types of materials like coffee pods. Besides the expansion of product types made with bioplastics, improvements have been made in their performance, such as antimicrobial and antioxidant functions, absorption of undesirable substances that limit the shelf-life of food, and better control of permeability (Jariyasakoolroj et al., 2018).

Recycling and Composting

It is technologically possible to recycle or compost bioplastics such as PLA (Thakur et al., 2018). Recycling bioplastics in a dedicated material stream would be similar to fossil fuel based plastics and is an option to prolong their life cycle as they can be turned into other plastic products. Recycling is taking place in the manufacturing process, such as re-integrating overcuts of PLA into feedstock, but is not currently implemented for post-consumer products. Chemical recycling, which is emerging for conventional plastics, is also possible for bioplastics, whereby the materials are broken down to their base components to be used again as raw materials (Researcher).

Biodegradability is heavily dependent on the chemical nature of the polymer and numerous environmental factors, including moisture, acidity, temperature, presence of oxygen, and enzymes (Kale et al., 2007; Bátori et al., 2018). Compostable bioplastics are designed to be processed at industrial facilities. One of the most common tests for compostability in Canada is the American Society for Testing and Materials (ASTM) D6400, which requires “degradation by biological processes during composting to yield [carbon dioxide], water, inorganic compounds, and biomass at a rate consistent with other known compostable materials and leave no visible, distinguishable or toxic residue” (ASTM International, 2019). For a product to be certified compostable, it needs to undergo a series of assessments and tests with a third-party certification agency. Only products that meet the requirements of the agencies may bear a certification logo. However, not all products on the market that claim to be compostable are certified compostable. Furthermore, even if products are certified, they may not necessarily break down in a composting facility if the conditions are not ideal, or may be screened out as contamination if the product resembles a conventional plastic product. Lastly, bioplastics can contaminate the waste stream and negatively impact recycling efforts (Gooch et al., 2020).

Why a Social Innovation Lab?

An Emerging Wicked Problem

While bioplastics are a success story in terms of technological innovation, a dearth of problems have emerged since its commercialization and rise in popularity. These problems span the entire lifecycle of bioplastics, from ethics in its production based on agricultural inputs and footprint, to its use across the food supply chain, and impact on the waste management system. Information related to bioplastics is often conflicting. For example, one study demonstrated that bio-based polymers have a lower carbon footprint than fossil fuel based plastics (de Vargas Mores et al., 2018) while another found that the upstream carbon footprint is comparable and the end-of-life impact is actually higher for bio-based polymers (Hottle et al., 2013). Despite numerous bioplastic products on the market, they still have limited application for food product manufacturers due to gaps in product functionality (Liliani et al., 2020). Additionally, while bioplastics have consumer appeal as more environmentally friendly choices, consumers also face confusion as to what biodegradable means, its impact on the environment, and where these products should be disposed (Dilkes-Hoffman et al., 2018; Taufik et al., 2020). Lastly, since recycling and composting programs for bioplastics are generally not available, they mostly end up in landfill (Kale et al., 2007).

> *"Biodegradable or not, plastics are clogging our land and oceans, threatening the health of humans and animals. The [European] Parliament today has acknowledged that biodegradable plastics are not a silver bullet to our plastic pollution crisis, but merely a distraction from real solutions. Policies that dramatically cut our plastic footprint need to be urgently implemented."*
>
> -Iona Popescu, ECOS programme manager (European Environmental Bureau, 2018)

Governments, industry groups, and international organizations have acknowledged the complexity of the plastics proliferation problem and are working towards solutions. However, these responses have been inconsistent. For example, the City of Berkeley passed a law which requires vendors to switch to compostable plastics while the City of Santa Monica and City of Vancouver passed laws that ban or limit the use of single-use items, including those made of bioplastics.

Social Innovation Lab Methodology

Social innovation labs generate holistic and practical solutions that take into account critical features of the broader system elements that may go unnoticed when products are developed in techno-centric silos (Westley and Laban, 2015). The environmental and social challenges associated with bioplastic packaging is a prime candidate for the social innovation lab approach due its "wickedness", whereby the problem is complex and the solution is not clearly defined.

We will engage stakeholders throughout the supply chain who are impacted by the production, use, and end-of-life management of bioplastic packaging. It is critical for us to assess the systems influencing and affected by packaging to ensure that solutions do not disproportionately negatively affect marginalized communities. We will strategically bring together a variety of stakeholders to develop a common understanding of a problem, the stakeholders will then work together on innovative solutions through iterations of information collection, analysis, creative engagement, and prototype development. Normally, social innovation labs take place in the form of a series of in-person workshops. As the response to COVID-19 unfolds, we may adapt these workshops to take place online, in-person with physical distancing, or a combination of online and in-person interactions.

About the Design Brief

This design brief serves as a summary document of the inputs we gathered from more than 20 stakeholders (Figure 2) in food and waste management systems to spark conversations on the topic of environmental and social impacts associated with bioplastic food packaging. Key themes that emerged from the interviews are highlighted in the Design Brief.

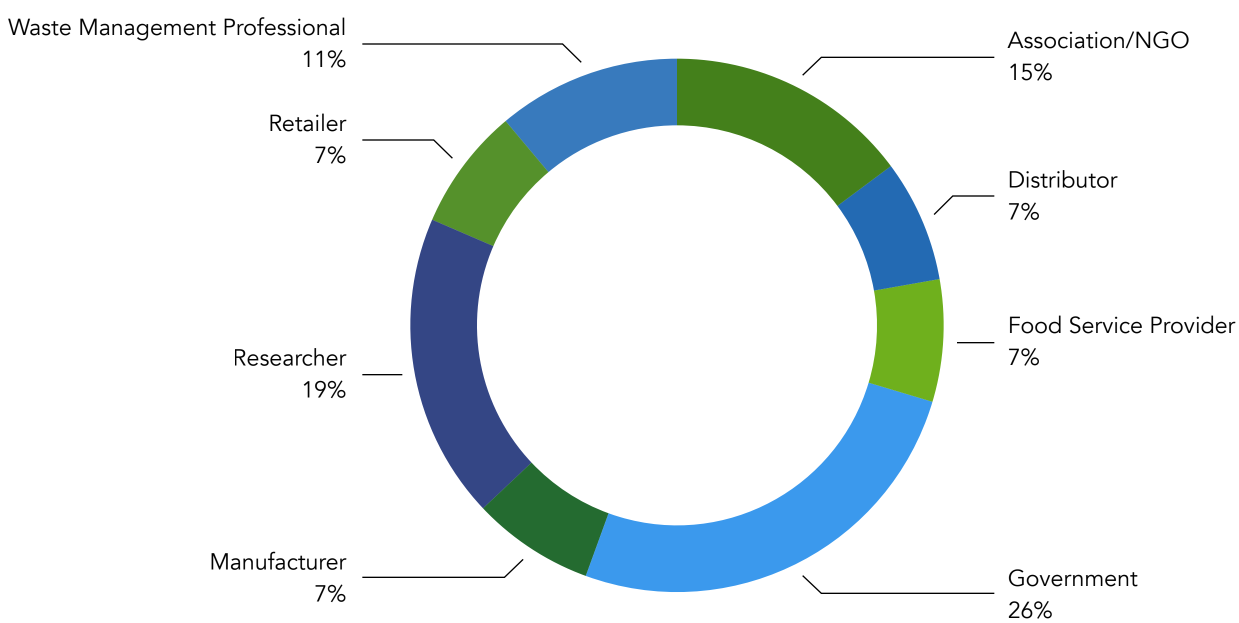


Figure 2: Interview Participants

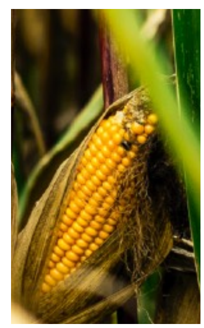
The Role of Bioplastics in a Circular Economy

There was a large range of opinions on how bioplastics should be used for food packaging. Some respondents suggested that bioplastics should replace all conventional plastics for food-contact packaging, while others preferred that bioplastics not be used at all. Generally, interviewees acknowledged that replacing fossil fuel based plastic with bioplastic could be environmentally beneficial to reduce the environmental impacts associated with fossil fuel extraction. However, there were also concerns about greenwashing, displacing food production, and proliferating single-use plastics.

Many interviewees said they would support use of bioplastics if certain conditions were met, such as ethical sourcing of raw materials, the existence of closed-loop recycling systems, full biodegradation in the environment, having comparable costs with conventional plastics, and limiting their use to applications where reusable packaging is less feasible (e.g. stickers, tags, ties, food-contact packaging for preservation). While fibre and other non-plastic bio-based materials were identified as possible alternatives to bioplastics, there is still concern on their environmental sustainability due to the resources needed for such products (e.g. deforestation, industrial agriculture). There was general consensus that unpackaged or reusable packaging is still the best option where possible.

Materials

Bioplastics are not created equally; the material source matters



“In the early days it was exclusively corn and really high sugary foods, but there’s been a lot more research and effective production of bioplastics now from food waste and methane from wastewater treatment. So the long term goal for bioplastics is to increasingly source from waste materials.” -Distributor

“They call any material that has over 25% renewable… so if you have a material which is 25% and higher, basically bio-based, they call it a bioplastic, right? So, a bioplastic has a very wide definition. So, it could be a fuel-based plastic with a lot of other additives and now you add 25% of some sort of fibre that is natural and then you have bioplastics.” -Manufacturer

“Every time we grow edible crops or arable land that we use to grow packaging, that’s less food that we’re actually producing because we’re growing packaging instead of food that people can eat.” -Retailer

“The starches need to come from somewhere. So, you have now growers that they grow for starches that is not going into food production, that’s going now into production of plastics. And those plastics don’t have any…food value or so basically so it’s kind of diverging land from producing food into producing other stuff.” -Government

“It would have to meet the true definition of circularity and not be contributing to any environmental negative consequences. I think, essentially, it would have to come, like the bioplastic itself, would have to come from 100% post-consumer source.” -Association/NGO

“And one solution is not one-thing-fits-all and many times, specifically in compostable food packaging there is this combination of different raw materials, different films made of different resins by different companies and so each of these products has its own characteristics, performance, and compostability time frame.” -Manufacturer

Replacing Conventional Plastics

There may be a niche for bioplastics, but it is an uphill battle

"I see that in the very near future everything in the food service is going to be bioplastic. Because that's the only way that we can do a huge step forward. We cannot keep using mixed material and then just making the life of recycling facilities harder, the life of composting facilities harder, and then at the end of the day moving everything to landfill." -Manufacturer

"If they are truly compostable, or truly biodegradable, in a waste disposal system, then they provide a solution to damaging permanent plastics that last for millions of years in the environment." -Association/NGO

"If we can truly get it right, I see it as, you know, hopefully we can have compostable plastics that really, you know, can replace some single use items that we have right now… in situations where we can't say, reuse an item, we have that option." -Government

"I think that there's lots of opportunities for them to replace conventional, fossil fuel based plastic. Especially if it comes to the point that it's fully compostable in industrial processes." -Waste Management Professional

"I describe compostable packaging as a solution looking for a home." -Researcher

"I'm not 100% dead set against bioplastics, again I don't know enough about them to make that decision, but I think it's something that we're just not prepared right now to handle properly, is my understanding." -Retailer

"I think that the other piece is that there is a significant traditional packaging lobby that has a dramatic impact on government regulations in this regard. And I think actually, probably municipal officials don't understand the impact of that group of lobbyists on the outcomes." -Association

Cost

Bioplastics are more expensive

"The cost of a bioplastic I want to say is one of the biggest challenges that is there. And specifically, particularly for the cost sensitive application like food packaging, because in order to motivate many customers like you have to basically provide your package at a competitive price with their current fuel based packages." -Manufacturer

"I think consumers are willing to pay more if you can tell the story about why bioplastic is better for the planet and for the environment. So I think that's where probably, you know, I would spend the most amount of my time, is how do you tell the story as to why bioplastics is better for the planet and for the environment, and not actually compete on price because you probably cannot." -Food Service Provider

Perpetuating Single-Use Packaging

Are bioplastics an innovative solution or are they contributing to the problem?

"I think one of the unintended consequences of that is it continues to foster a reliance on the single use items as opposed to investing in cyclical reuse systems." -Government

"They're still disposable, they still perpetuate our throwaway culture, and they still perpetuate a linear, take-make-waste model.. it does still perpetuate this idea that we take, we use, it turns into waste, and then, you know I think the dream is that it's composted, put back into the soil, and then, you know, it's, it's an alleged circular or option, but the reality is much different." -Association/NGO

"And no wonder we have plastic in all the oceans of the world and the seas and marine animals are choking on it. Because we have this insatiable appetite for packaging and excessive packaging of consumer products." -Researcher

Alternatives to Bioplastics

Refilling and going package-free

"How about nothing? How about a fresh food system? How about taking our North American models and localizing them more... You have entire models where if they can have no packaging, they have no packaging." -Distributor

"Myself, I did grow up in a time where we went to the butcher, he cut the meat and we got it, we brought back our boxes…we went to places where they pumped the milk into our gallon and…pumped it in." -Government

"What's better than a compostable fork? A metal one!" -Government

Policy

Regulation to create a level playing field

"[Create] a proper regulatory framework which weeds out the bad actors and amplifies the good ones, because right now there is no difference [between certified and uncertified products]. Like you could have the best product in the market but someone doing a terrible thing with the same green brand with its lower price point will beat out the good players." -Researcher

"A clear regulatory standpoint on the acceptability and definition of compostable plastics is probably the key piece, right? Either they are accepted, or they aren't. And what's the definition of what is compostable versus not." -Government

Biodegradability

There was a general consensus among all interviewees that the biodegradability of bioplastics is a top concern. There is no regulation on the use of the terms compostable or biodegradable in Canada. Manufacturers may market their products as compostable or biodegradable without any tests or certifications, leading to confusion amongst users as to how to dispose of these items properly. Tests for biodegradability are intended for industrial composting facilities only, not for backyard composting, the marine environment, or terrestrial environment. Therefore, there were concerns that products that end up in the natural environment still cause plastic pollution.

Very few composting facilities accept these materials and they are generally considered a burden. Operating conditions at a facility often do not match the controlled lab tests for certification. Simpler products such as food waste bags tend to perform better, but rigid plastic products like cups, containers, and cutlery, may persist. There are almost no visible differences between compostable plastics and non-compostable plastics; facilities will often screen out anything that looks like plastic as contamination because their customers do not want to see plastic in their compost products.

Standardization and Testing

Mismatch between the lab and field testing combined with lack of enforcement

"At the moment there's no one enforcing any standards or specifications that would help in establishing a more robust, effective system and few people are actually investing in it. Investing in systems that would enable their disposal, such as this, the vast majority of plastics that are currently compostable even if, or called compostable, actually go to landfill where they will sit and just, well they'll just sit, and they will not decompose." -Researcher

"Most of these tests aren't done in actual large-scale compost facilities. They're done in lab based field tests, so lab based tests, which is understandable because science, you know you need to separate from your environment as much as possible, but you do lose a lot of actual information when you take them out of those conditions." -Researcher

"Some companies would get a bio-based [product] and hope, believe it might be compostable when it's not compostable, just a bio-based plastic or a biodegradable plastic. You know, it's not a compostable plastic so there's a lot of confusion and misunderstanding about what they are. And then the other side of that is then, are the materials accepted in an existing recycling system or not? Do they meet those processes or are they actually a totally different product that isn't recyclable amongst the regular recycling stream user, and confusion about that as well." -Government

Compost Operations

Processors are feeling the burden of bioplastics

"They [composting facilities] don't seem to want them. Some of the ones that do accept them they're usually either bleeding it into their products and it's creating a lower quality product than what they would have if they didn't have those bioplastics in their mix, or they're just not accepting them all together." -Waste Management Professional

"[You can] pull out a compostable fork that has gone through the system many, many times and you can basically dust it off and still use it… which is great for usability because it's durable… but it doesn't quite break down like maybe it was promised to." -Food Service Provider

"When we talk to the composters, they tell us that they screen out all materials including compostable plastics and send it to disposal. And most of the businesses that are accepting compostable plastics are pretty shocked to hear that." -Government

"I know that municipalities such as [redacted] had tremendous problems with it [bioplastics] dangling on equipment and not breaking down in colder spots... [they] actually banned the use of biodegradable plastics in their compost facility." -Researcher

"So as a society we want recyclable and compostable materials and then you know the processing systems are going to have to be set up in a way that it's not treating compostable materials like a contaminant coming in the door." -Association/NGO

Environmental Impact

Potential for long-term contamination

"You go from a large thing to a smaller thing, to a tinier thing, to nothing. So you know, even bio-based biodegradable plastics will form microplastics in the environment but those microplastics will only persist for a small amount of time. But, what is the impact of those microplastics as they accumulate, for example, in our soils? You know, as this plastic is degrading it's releasing acidic degradation products so it's creating an acidic environment around the microplastic, and if that acidic environment interacts with for example plant nodules or root nodules, is there an impact?" -Researcher

"If you can't create a compost… it has to be sold as what's called a non-agriculturally sourced material, NASM, and you've got to essentially pay farmers to put this contaminated soil on their land." -Waste Management Professional

Horns of the Dilemma

A key characteristic of a wicked problem is the presence of polarities, also known as “horns of the dilemma” (Westley and Laban, 2015). Polarities are outcomes that are considered desirable, but also appear to oppose each other. Polarities are the building blocks in developing convening questions. Multiple polarities surfaced from the interviews, indicating the challenge of integrating different viewpoints and goals related to bioplastics.

Based on these polarities, what should be the convening question(s) of the Social Innovation Lab?

How can we…	While…
Reduce reliance on fossil fuels to make plastics by using bio-based raw materials	Ensuring land and resources needed for food production are preserved for food security
Make bioplastics cost competitive with fossil fuel based plastics	Maintaining fair wages and working conditions, environmentally sustainable processes for raw materials and products
Divert more bioplastics to composting	Generating high-quality compost that is acceptable for use in agricultural and home gardening applications
Create a bioplastic product that has high functionality and durability	Decomposing in typical compost facility and/or backyard composting conditions
Increase the market share of bioplastics	Optimizing the downstream management and capture of the products Prioritizing its use for durable reusable goods Avoiding the proliferation of single-use plastic packaging

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