Compostable biopolymer use in the real world: Stakeholder interviews to better understand the motivations and realities of use and disposal in the US

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Abstract

The use of compostable biopolymers in the United States has grown over the past decade and is predicted to continue to grow over the coming years. Though many studies have been done to assess biopolymer environmental impacts, few have explored how they are actually being used and disposed of by consumers. Only with a thorough understanding of real world use will environmental assessments be able to provide meaningful results that can inform best practices for municipal waste management. This paper identifies and explores where consumers are most likely to come into contact with compostable biopolymers, actual disposal methods, and the motivation behind compostable biopolymer use and disposal. To assess where compostable biopolymers are being used, audits of local grocery stores were conducted, as well as semi-structured interviews with compostable biopolymer users in four different food service categories (cafeterias, catering companies, limited food service establishments, and recreational concessions) were completed. Findings suggest that consumers are most likely coming into contact with compostable biopolymers in a commercial food service setting. The decision to purchase compostable biopolymers was based on a variety of factors, such as their perceived sustainability, but was not directly tied to the ability to compost them. One of the clearest distinctions between those who were able to compost biopolymers and those who sent these products to landfill was the type of sustainability goals each organization set. Measurable waste

to landfill goals resulted in biopolymers being sent to compost facilities, in contrast to an amorphous goal to be sustainable, which was connected to biopolymers being sent to landfill. Yet for all food service categories, disposal decisions relied heavily on the regional waste infrastructure that was available.

1. Introduction

Over the past five decades the use of plastic has become ubiquitous. Plastics are regularly used in the manufacturing of many products, from grocery bags to synthetic lumber, and from toothbrushes to sutures. Over 15,000 plastics manufacturers operate in the U.S. with facilities located in every state. The value of shipped plastic goods in the U.S. was over $373 billion, and the plastics industry is ranked as the third largest sector of U.S. manufacturing (Carteaux 2013). In addition, plastics make up approximately 13% of the country's municipal solid waste stream, which is roughly equivalent to 32 million tons of plastic waste generated annually (USEPA 2012).

Biopolymers are one of the fastest growing segments within the global plastics market. Biopolymers (or bioplastics) are plastics that can be produced from renewable materials, including sugar, corn, soy, hemp and captured methane from waste. Biopolymers do not have to be made entirely out of renewable materials, as many produced today are blends of conventional and renewable feedstocks (Hartmann 1998, Shen, Haufe and Patel 2009, Shen, Worrell and Patel 2010). Furthermore, some biopolymers such as Bio-PET have an identical polymeric structure as their conventional counterpart and can be recycled along with regular PET. With such a variety of feedstocks and manufacturing processes not all biopolymers are biodegradable or compostable (Lopez, Vilaseca et al. 2012, Roland-Holst, Triolo et al. 2013, Hottle, Bilec and Landis 2013).

Worldwide consumption of all biopolymers including compostable and non-compostable plastics in 2012 reached 981,056 tons (less than 1% of total polymer consumption), and the market is expected to continue to grow in the United States (USDA 2008) and globally (Shen, Haufe and Patel 2009, Rapra 2012). The growth of the biodegradable and compostable subset of biopolymers is predicted at a rate of around 13% annually (Platt 2006). Of total global biopolymer production, 43% are biodegradable plastics including compostable polymers (EuBP 2014).

Compostable plastics must be able to degrade in a commercial composting setting according to set American Society of Testing and Materials (ASTM) standards including ASTM D6400-04 Standard Specification for Compostable Plastics, ASTM D6868-03 Standard Specification for Biodegradable Plastics Used as Coatings on Paper and Other Compostable Substrates, and ASTM D5338-98(2003) Standard Test Method for Determining Aerobic Biodegradation of Plastic Materials Under Controlled Composting Conditions (ASTM 2003, ASTM 2003, ASTM 2004, Song, Murphy et al. 2009). Of compostable plastics, polylactic acid (PLA) is the most abundant, but thermoplastic starch (TPS) and polyhydroxyalkanoates (PHA) are also common (Tabone, Cregg et al. 2010, EuBP 2014). Biodegradable plastics still degrade but do not conform to the timeframe in which commercial composting occurs and have a different set of ASTM standards (Kale, Auras et al. 2007). This technology is used in products like grocery bags, trash bags, packaging, diapers, and agricultural mulch films (Ammala, Bateman et al. 2011). It is important to note that while ASTM standards are an important industry codification, many commercial compost facilities are struggling to process them; this issue is discussed in more detail below.

The drivers behind the growth of compostable biopolymers vary across regions, often relating to bans on conventional plastics, bio-preferred purchasing, and zero waste initiatives. According to the literature these drivers are associated with concern over increased fossil fuel use, greenhouse gas emissions, plastics pollution, decrease in landfill space, and human health (Ren 2003, Kijchavengkul and Auras 2008, Gironi and Piemonte 2011, Álvarez-Chávez, Edwards et al. 2012, Gómez and Michel Jr 2013). For example, there are many conventional plastic bans being implemented and compostable product mandates being established. Recently the State of California has banned single use plastic bags (Steinmetz 2014), and it is estimated that over 100 U.S. cities have banned poly(styrene) (PS) food and beverage containers (Goldstein 2013). The U.S. federal government's BioPreferred Program mandates federal bio-based product purchasing, and it is likely that it has inspired cities across the U.S. to implement similar programs. After speaking with a city representative, it is clear that the City of Phoenix is one example of this (Carsberg 2014). Organizations in every state are either voluntarily adopting or being mandated to create waste to landfill reduction plans. Additionally, growth in the composting industry and new organics waste diversion policies, such as the newly passed legislation in both California and Massachusetts, which requires all commercial organic wastes be diverted from landfill, will continue to encourage waste to landfill reduction goals (Yepsen 2009, BioCycle 2014, EEA 2014).

Though compostable biopolymer use is growing in response to the aforementioned trends, there have also been well documented challenges and concerns related to their use. The U.S. Composting Council has identified five key challenges which include: labeling & identification, enforcement & legislation, ASTM standards, consumer education, and impacts to the National Organics Program (California Organics Recycling Council 2011). Clear labeling or

demarcation of compostable bioplastics is crucial for helping consumers (here consumers are defined as individuals who are using compostable biopolymer products, in either a residential or commercial setting) accurately identify and separate their waste in the right disposal bins. Enforcement and legislative challenges refer to the lack of federal regulations for labeling products compostable, biodegradable, or biobased. Without enforcement concerning the use of these labels, some companies may mistakenly market products as compostable when they are not. In addition, some products that have been designed to meet ASTM compostability standards still are not degrading adequately compared to other organic wastes (Ghorpade, Gennadios and Hanna 2001, Mohee and Unmar 2007, Gómez and Michel Jr 2013). The reasons for this are varied, but one may be that some ASTM standards include decomposition times that are longer than actual commercial composting timeframes. For example, a variety of ASTM certified compostable biopolymers take over three months to decompose in a commercial compost facility and one of the largest composters in the Pacific Northwest States they have a ninety day turn around time for creating finished compost (Worldcentric 2014, CedarGrove 2015). The challenges associated with consumer education are many as there is profound misunderstanding between the terms biodegradable, compostable, bio-based, as so forth. Moreover, many consumers and compostable biopolymer users do not have a general knowledge of the differences in composting and landfilling compostable plastics. Lastly, compost that has been made with compostable bio-plastic feedstock has caused problems for organic growers as there has been debate over whether compost made with these products violates USDA Organics label rules and regulations (California Organics Recycling Council 2011).

In addition to these challenges, there has been concern over which disposal method is ideal for compostables (Weiss, Haufe et al. 2012, Yates and Barlow 2013, Rossi, Cleeve-

Edwards et al. 2014), the use of GMO feedstocks for bioplastics (Gerngross and Slater 2000, van Beilen and Poirier 2007, Snell, Singh and Brumbley 2015), and possible impacts to human health (Roes and Patel 2007, Thompson, Moore et al. 2009, Álvarez-Chávez, Edwards et al. 2012). Research around compostable bioplastics is ongoing, and many stakeholders who currently handle these products are also trying to determine best practices. For example, cities now working to divert more waste from landfill are grappling with many of the aforementioned challenges. Trying to weigh the potential costs and benefits to determine the overall sustainability of these products has become an important task for many managers, purchasers, and policy makers.

To help inform decision makers various tools have been developed to accurately assess what the impacts of different plastics products may be. Over the past decade there has been a proliferation of life cycle assessments for biopolymers but the assumptions that underpin assessment can drastically affect overall findings (Hottle, Bilec and Landis 2013). To date many environmental assessments of biopolymers have been done, including inventory improvements for life cycle assessments (Vink, Davies and Kolstad 2010, Hermann, Debeer et al. 2011) but few life cycle assessments adequately address end of life and findings vary widely (Shen and Patel 2008, Weiss, Haufe et al. 2012, Hottle, Bilec and Landis 2013, Koller, Sandholzer et al. 2013, Yates and Barlow 2013). Moreover, gaps exist in the available literature which document how compostable biopolymers are being used and their exact method of disposal. This US-based study provides information on where compostable biopolymers are most commonly found, who is using them, and how organizations using these products are actually disposing of them. In addition, the study evaluates the motivations behind purchase and disposal decisions. Our overall

intent is to provide understanding for how these products are being used so that assessments are not limited by wide ranging assumptions and can produce more meaningful results.

Through stakeholder and user interviews, this paper identifies where compostable plastics are being used and disposed, and the motivation behind purchase and disposal decisions. Stakeholders include producers and distributors in the compostable biopolymer industry, compostable biopolymer experts, and decision makers who currently manage these products like municipal solid waste professionals or commercial composters. Users include organizations that use compostable biopolymers, such as cafes, cafeterias, and recreational concessions. The findings from these interviews provide insight into how these products are now being managed and in doing so we hope to contribute key information for important environmental assessment tools, decision makers, and compostable biopolymer users, both food service businesses and customers.

2. Methods

To determine where compostable biopolymers are being used and by whom, we began with audits of bioplastics in eight local grocery stores and three preliminary interviews with stakeholders, including producers and distributors in the industry, in order to identify where consumers were using compostable biopolymers. Following the preliminary interviews, we conducted twelve interviews with a variety of regional compostable biopolymer users, such as public and private cafeterias, restaurants, and sporting venues, to understand the motivations behind their purchasing and disposal practices. A limited number of participants were interviewed through non-representative qualitative expert elicitation, an established social science interviewing methodology (Trost 1986, Sandelowski 1995).

160

161 *2.1 Grocery Store Audits*

162 In order to help define the scope of the research and gauge the availability of
163 compostable biopolymers for use and disposal in a residential setting, an audit of eight local
164 grocery stores was conducted. The audits were conducted over three days in the Phoenix
165 metropolitan area. Costco, Wal-Mart, and Fry's are food stores who also sell many other types of
166 retail items such as clothes, toys, and electronics. Safeway, Albertsons, Trader Joes, Whole
167 Foods, and Sprouts are food stores who carry mainly food items but could also have a small
168 selection of other assorted retail items. The stores were selected as they cater to a wide range of
169 consumers, affluence levels, and consumer preferences. Three stores were visited on June 16th,
170 2014: Fry's, Trader Joes and Whole Foods. Two more were audited on June 17th: Costco and
171 Wal-Mart, and the remaining three were visited on June 18th, 2014: Albertsons, Safeway, and
172 Sprouts. For all grocers, the store manager was contacted and approval for the audit was
173 received.

174 The data (i.e. number and type of polymer) was visually collected and documented while
175 walking through each aisle or section of the grocery store. In order to maintain a consistent
176 review of product categories, any areas that fell outside of the baby, beverage, bread and bakery,
177 breakfast and cereal, canned goods, condiments, cookies and snacks, dairy and eggs, the deli,
178 frozen foods, fruits and vegetables, grains and pasta, international foods, meats and seafood, and
179 cleaning and home products were not audited as some larger grocers sell many non-food items,
180 including personal care or clothing. All rigid plastic packaging in each aisle was inspected. In
181 addition to packaging, we also looked for plastic products that were made out of biopolymers (of
182 any type, compostable, biodegradable, or non-biodegradable), such as PLA flatware. The item's

name, brand, size, and type of plastic were documented for all plastic packaging or products that were labeled with number seven recycling symbol, PLA, plant-based, or Plantbottle ™. Plastics are often labeled with the number 1 through 7. Plastics labeled with a number 2-6, or that had no recycling symbol or any information about the plastic material were not documented. Number one plastics, which are PET, were inspected further to determine if they were bio-PET products. After compiling the data from the grocery stores, all products with a number seven were logged and a search was conducted through company websites to determine plastic type.

It is possible that some biopolymers were not accounted for. We sought to capture all of the Bio-PET, but it is visually indistinguishable from PET, shares the same resin recycling code (number one), and is not always labeled as plant based or have a Plantbottle™ trademark so it is possible not all Bio-PET products were identified. Film, or flexible plastic packaging, was not inspected because it is difficult to determine what thin films are made from as they are not often labeled. In addition, global production of rigid bioplastics packaging greatly exceeds that of flexible packaging (EuBP 2014).

2.2 Interviews

To scope and refine the interviews, which aimed to understand where compostable biopolymers are being used, we first conducted preliminary, unstructured interviews. We reached out to six producers and/or distributors in the supply chain who either make or sell compostable biopolymer products: Sodexo, Arizona Restaurant Supply, Western Paper, a Sprout's Farmers Market, NatureWorks LLC, and EcoProducts. Out of the six contacted three were available for interviews: a Sprouts manager, a representative from Natureworks, and a representative from EcoProducts. Both NatureWorks and EcoProducts produce and distribute compostable

biopolymers, with NatureWorks being one of the largest producers of compostable PLA resin in the United States (Nampoothiri, Nair and John 2010).The preliminary interviews were semi-structured and broad themes were set out beforehand with follow up questions that varied based on interviewees' responses. Themes included: where individual consumers are most likely coming into contact with compostable bioplastics, the distribution of compostable biopolymers, and where the majority of product sales occur. Preliminary interviews lasted between 15-45 minutes and were all conducted over the phone. During the preliminary interviews, responses were documented on a laptop by the interviewer. After each preliminary interview, the interviewer immediately reviewed the questions to ensure each one was answered adequately, check for errors, and follow up with clarifying questions.

In addition to this, a variety of other stakeholders connected to compostable biopolymer use were also interviewed. These stakeholder interviews included three governmental employees who help manage municipal solid waste, two from the City of Portland and one from the City of Phoenix, three commercial-scale composters (Recycled City LLC, Roots Composting LLC, and the University of New Hampshire), and a biopolymers industry expert to further develop our knowledge of current practices, challenges, and implications of compostable biopolymer use. These stakeholder interviews followed the same protocol as before with the exception that contact with the City of Phoenix was in the form of an email exchange.

The grocery store audit and the first three preliminary interviews with producers and distributors suggested that residential consumers were not coming in contact with biopolymers (of any type, compostable, biodegradable, or non-biodegradable), as the overall number of biopolymer products in the store was low and products that were there were not selling quickly. As such, the interview process was modified to gain an understanding of where compostable

biopolymers were being used and disposed so that we could identify organizations (compostable biopolymer users) that would be appropriate for this research (Sandelowski 1995). Since compostable biopolymers are largely found in the food service industry, we utilized the food service market segmentation strategy developed by the USDA to create categories where compostable biopolymers are being used (USDA 2010). This statistically non-representative stratified sampling allowed for a wider elicitation in overall participant experiences (Trost 1986). We delineated five main categories which included: limited service eating places (organizations where customers pay prior to receiving food or drink, such as a café), cafeterias (both public and private), recreational food concessions (such as at sporting events), caterers, and hospitals. A list of establishments, within the Phoenix Metropolitan area, which had the possibility of carrying compostable biopolymers was made for each category, upon which each establishment was contacted to confim the use of compostable plastic. A total of twelve establishments confirmed using compostable biopolymers; and were interviewed about their use and disposal practices. The second set of twelve interviewees are summarized in Table 1. Stanford was the one exception, being located outside of the Phoenix area, and was chosen as an organization to interview because no other large cafeterias were available and they are well known for their waste reduction goals and as users of compostable biopolymers.

Completed Interviews		
Compostable Biopolymer Users ~	**Location**	**Date**
Cafeterias		
Arizona State University	Tempe, AZ	8/13/2014
Intel	Chandler, AZ	8/1/2014
Stanford University	Stanford, CA	7/31/2014
Catering Companies		
Atlasta Catering and Event Concepts	Phoenix, AZ	7/25/2014
Bruce Brown Catering Company	Phoenix, AZ	7/21/2014
Santa Barbara Catering Company	Tempe, AZ	7/9/2014
Limited Food Service Establishments		
Anonymous Café	Tempe, AZ	7/8/2014
Pomegranate Café	Phoenix, AZ	7/30/2014
The Cutting Board Bakery and Café	Mesa, AZ	8/11/2014
Recreational Concessions		
Arizona Diamondbacks	Phoenix, AZ	8/27/2014
Desert Botanical Gardens and Arizona Science Center	Tempe & Phoenix, AZ	8/29/2014
Phoenix Convention Center	Phoenix, AZ	7/28/2014
Other Compostable Biopolymer Stakeholders *		
Composters		
Recycled City LLC	Phoenix, AZ	7/23/2014
Roots Composting LLC	Flagstaff, AZ	7/31/2014
Universtiy of New Hampshire	Durham, NH	7/10/2014
Industry Expert		
Brenda Platt, Institute For Local Self Reliance	Washington, D.C.	8/29/2014
Government		
City of Phoenix	Phoenix, AZ	7/30/2014
City of Portland, Solid Waste and Recycling: Residential Composting	Portland, OR	6/23/2014
City of Portland, Solid Waste and Recycling: Commercial Composting	Portland, OR	6/24/2014
Producers and Distributors		
EcoProducts	Boulder, CO	7/25/2014
NatureWorks LLC	Minnetonka, MN	6/20/2014
Sprouts Farmers Market	Tempe, AZ	6/29/2014

Table 1: Interviews conducted with various stakeholders across the compostable biopolymer supply chain. ~ indicates the second set of interviews, * indicates preliminary interviews.

For the second set of twelve interviews, initial contact was made through email or phone, where upon the interviewer explained the research and scheduled an interview in order to speak with a representative about the organization's use and disposal of compostable biopolymers. All interviews were over the phone or in person except one exchange with a catering company (Bruce Brown Catering) that was conducted over email. The interviews were semi-structured and each category of food service had a list of questions and general themes to address. In all cases, respondents answered questions about the types of compostable biopolymers they used, why they chose to purchase them, and the method of disposal. The interviewers also asked follow up questions to gain further insight and elucidate their compostable biopolymer use and disposal stories. Again, while interviewing, answers to questions and notes were typed in real time. After each interview the interviewer immediately reviewed the questions to ensure each one was answered adequately, check for errors, and follow up with clarifying questions. The original interview questions can be found in Appendix I.

The interviews were analyzed using qualitative content analysis (Hsieh and Shannon 2005). The results and interview analysis only represent organizations from the second set of interviews with compostable biopolymer users (Table 1). Responses were classified according to three critical questions identified based on gaps in the literature including: motivations behind compostable biopolymer purchase, disposal practice, and motivation behind disposal choice. Next we searched for the challenges each organization associated with using and disposing of biopolymers. In addition, special attention was paid to how much influence individual consumers had on the purchase decision and disposal of these products.

3. Results and Discussion

3.1 Grocery Store Audit

Eight out of nine grocers carried items that were made from or packaged with biopolymers. Figure 1 presents the findings of the audit for all grocers audited. There were a variety of different types of products found with some of the most common being bio-PET bottles, PLA utensils, and compostable trash bags. Figure 2 shows the types of products found at all of the grocers. This represents the total number of biopolymer products available in each store and does not account for the total number of plastic products in each store. The percentage of biopolymer products, compared to all conventional plastic, was very small, and the biopolymer products are not always clearly identifiable. For example, the Stonyfield yogurt cup label does not mention anywhere on it that the packaging is plant based, instead the bottom of the yogurt cup states "this cup is made from plants." There were an abundance of number seven products, over forty items across the eight stores, including items such as 4 oz. Motts Applesauce packs, Nescafe Tasters Choice packaged coffee, and some of the one gallon bottles of Arizona Tea. According to the ASTM a number seven resin code on plastics incorporates all other possible types of polymers and materials which are made out of multiple resins or are multi-layered (Wilhelm 2008).

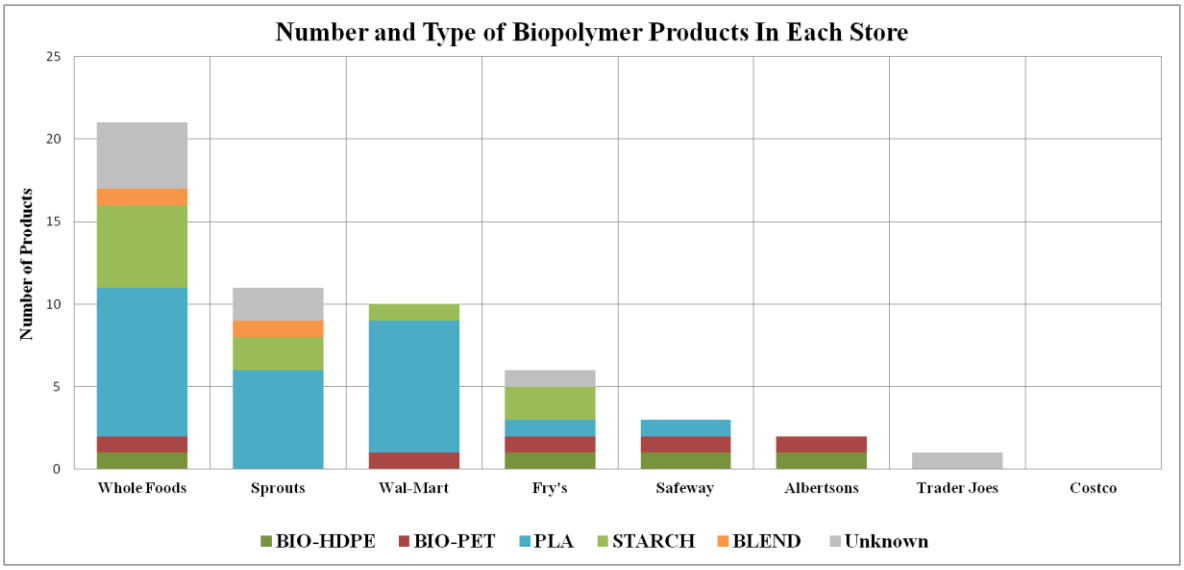

Figure 1: The number of biopolymer products found at each grocery store categorized by the type of biopolymer material. Products where no information on the type of biopolymer material used are labeled as unknown.

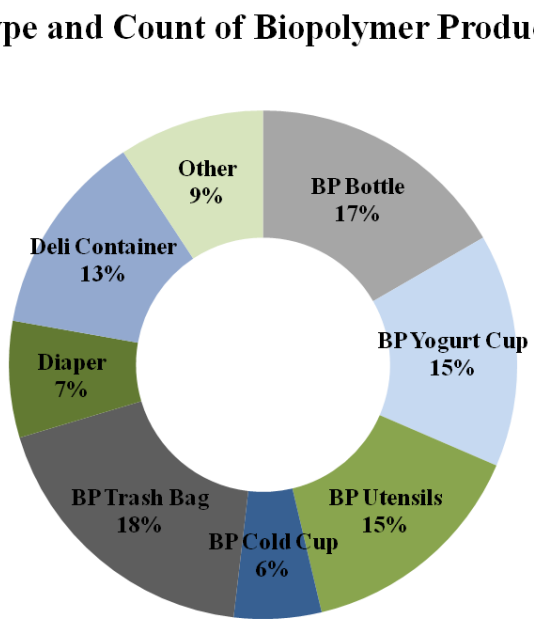

Figure 2: The total count of biopolymer products found categorized by product type. The "other" type consists of sponges, a soap bottle, straws, and a party pack with assorted biopolymer products such as compostable utensils and cups. BP = biopolymer

There are a limited number of biopolymer products (of any type, compostable, biodegradable, or non-biodegradable) available for residential consumers to buy and the Sprouts store manager described the sales volume for compostable utensils as low. Furthermore, even with the number seven plastics, the total number of products identified represents a very small portion of all the plastic products and packaging in the grocery section of the stores, which the Spouts manager estimated ranged from hundreds for smaller grocers, to thousands for larger grocery stores. The results from this audit show that individuals are not coming into contact or purchasing many biopolymer products, of any kind, via their local grocers, and as such, use and disposal of any type of biopolymers in a residential setting is still quite low.

Preliminary interviews with NatureWorks LLC and EcoProducts supported these findings, and suggested that if and when consumers do come into contact with compostable

biopolymers, it is most likely occurring in a commercial foodservice setting (e.g., restaurant) rather than at home. A representative from NatureWorks, stated that though they have some sales in grocery retail and food packaging they have more contact with the commercial food service sector. EcoProducts, a large manufacturer and distributor of compostable plastic products, reported that the vast majority of their sales are to commercial food service businesses. The main types of businesses EcoProducts sells to fall into six main categories: colleges and universities, corporate campuses, health care, large venues (e.g. professional sports arenas), restaurants, and the hospitality industry. The EcoProducts respondent also noted that as these products are not as competitive in a retail setting, such as a grocery store, compostable biopolymers do not see as much use in homes. In addition to this she stated that because of new mandates, such as the ones banning conventional plastics, larger organizations are increasingly turning towards compostable biopolymers. Though consumers are using compostable plastics in a limited way in a residential setting, the majority of contact is within institutional settings, specifically commercial food service.

3.2 Compostable Biopolymer User Interviews

More than thirty organizations with a commercial food service component and possible compostable biopolymer use were contacted. Out of those thirty, twelve interviews were conducted between June 1st, 2014 and September 1st, 2014. Each food service category had three interviews attributed to it, except hospitals as we were not able to find any in the Phoenix area that used compostable biopolymer products. The interview process proved helpful because it revealed information typically missed in quantitative data collection related to compostable biopolymer disposal, particularly related to the importance of communication in the overall

waste management system. Generally, most organizations using compostable biopolymers sent their waste to landfill. Out of the twelve organizations, three composted their compostable biopolymers – all from the cafeteria category. None of the organizations interviewed disposed of their compostable biopolymers by recycling, which is logical as these products are not accepted in municipal recycling facilities (Song, Murphy et al. 2009).The motivation behind these disposal decisions, and reasons given for purchase, will be discussed in the subsequent sections.

3.3 Understanding motivation

For each food service category there were a variety of reasons cited for the decision to purchase and use these products. Figure 3 is a graphical representation of the motivations that food service organizations shared for purchasing compostable plastics. Many of the reasons given from recreational concessions, limited food service establishments, and caterers were related or overlapped, and out of the four food service types all but cafeterias sent their compostable biopolymers to landfill. All companies who landfilled their compostable biopolymers (recreational concessions, limited food service establishments, and caterers) stated that using compostable biopolymer products aligned with the organizations' intention and desire to be a sustainable company. In addition, they wanted to use biopolymers for their perceived environmental benefits, to have the "greenest" footprint possible, and to align with their environmental branding. Another common reason given among the landfillers of biopolymers was that integrating sustainability into business practices is considered the norm and that using compostable products helped them fulfill that expectation. Many recreational concessions noted the need to stay competitive in contract renegotiations and used compostable biopolymers as a way to signal a move towards sustainable business operations and to align with their contractors'

goals. Other reasons given across the organizations who landfill compostable biopolymers included wanting to use products that broke down (they believed the PLA products would degrade in landfills), wanting to avoid the use of conventional plastics, and that they wanted to support products that used bio-based feedstocks. There was only one case where the main reason for purchase was driven by individual consumer preference. In this instance, a caterer bought biopolymers to have on hand in case a client specifically asked for them.

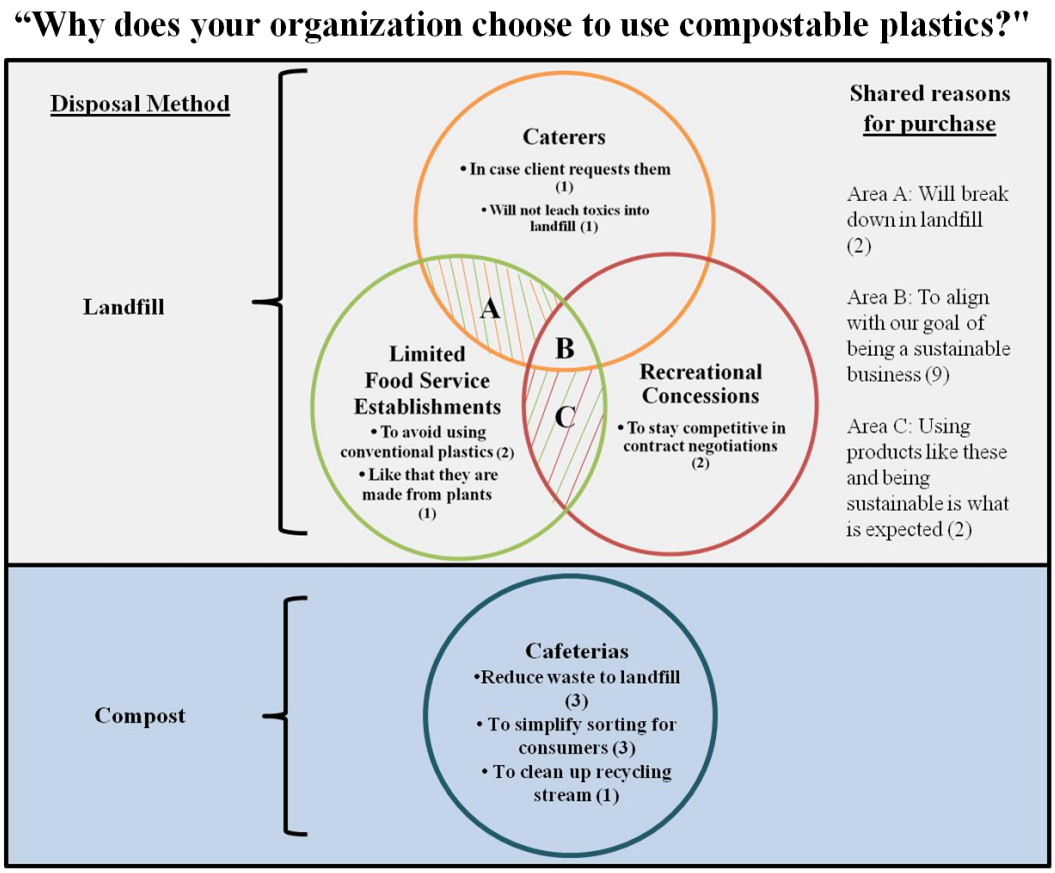

Figure 3. Responses given to the question "why does your organization choose to use compostable plastics?" For each food service category there were three organizations interviewed; the four categories are Caterers, Limited Food Service Establishments, Recreational Concessions, and Cafeterias. The numbers in parentheses next to the stated reasons indicate how many organizations gave that particular response.

Cafeterias, the only food service category where compostable biopolymers were being sent to compost facilities, had noticeably different reasons for purchasing biopolymers. It is

important to note that this is not likely the case for all cafeterias across the nation, as an elementary school or correctional facility cafeteria may operate in a much different manner. Like the other food service types, all three cafeterias valued integrating sustainability into their business practices or are motivated by broader sustainability goals to use compostable bioplastics, but unlike the rest of the organizations they all cited specific and measurable waste reduction goals that they were trying to achieve. All three organizations also said that they used biopolymers in order to simplify sorting so as to achieve greater waste diversion. Using compostable biopolymers can reduce the time individuals spend sorting trash and help simplify the process, which reduces contamination and thus helps drive diversion rates higher, as previous research has shown (Hottle, Bilec et al. 2015). Other reasons given were that that switching to completely reusable products (e.g. ceramic plates and cups) was cost prohibitive and that compostable biopolymers were able to replace a wide variety of products typically destined to landfill which would further reduce the overall waste of the organization.

Out of all the reasons given between cafeterias and the other food service categories, interviewers documented very few instances of greenwashing, which is defined as "a superficial or insincere display of concern for the environment" (Collins English Dictionary, 2014). In most cases the organizations felt strongly about working to make decisions that produced positive impacts for both the environment and the organization. For most all food service categories, these products were more expensive than conventional disposables, but purchasers were willing to pay more because they believed they were making the right choice. One limited food service establishment was so committed to buying compostable biopolymers that after a period of financial hardship where they were not able to afford compostable bioplastics they promptly resumed buying them even before they had completely recovered financially.

Though all organizations cared about the environment and the responsibility of the choices they were making, not all organizations had the resources to allocate to detailed analysis and management of these products. This can been seen in the two instances where respondents' purchase decision was motivated in part, because they believed the compostable biopolymers would degrade in landfills; compared to cafeteria managers who thoroughly understood where these products would and would not degrade. All of the cafeterias interviewed (ASU, Stanford, and Intel) were part of larger organizations that employ hundreds or thousands of people and have substantial annual operating budgets. Similarly, all cafeterias also had strategic sustainability plans and measurable sustainability goals. Even for recreational food courts, which are relatively large, their concessions were contracted (in two out of the three cases) by smaller local companies. In addition, each cafeteria had a dedicated project manager who specifically focused on issues related to sustainability and waste management.

For the most part, companies from the other three categories were much smaller, and the individual deciding what to purchase had many other duties and responsibilities. For example, for all limited food service establishments the owner was the purchaser, as well as the marketing director, human resources, the kitchen manager, and they also often worked in the café during the day cooking or serving. All organizations from the different food service categories were trying to make good choices but the disparity in overall organizational resources impacted decision making. In the case of organizations with limited resources, some switched over traditionally recyclable products (such as cold cups) to a compostable biopolymer product which resulted in an increase in waste being sent to landfill as they could not compost the cups, which could have previously been sent to a recycling facility.

Larger drivers, i.e. conventional plastic bans, organics recycling mandates, and a growing trend to reduce waste to landfill could also be seen in organizations' decision to purchase compostable plastics. It is most clearly reflected in the cafeteria food service segment, especially in Stanford's case where they are working to meet state and city waste diversion goals and abide by laws that ban PS and conventional plastic bags. Over the past few years both Intel and ASU decided, independent of regional laws, to establish waste to landfill reduction goals, with ASU originally having set a goal to reach zero waste by 2015. In every case organizations were using compostable biopolymer products in response to the growing social trend to integrate sustainability into business practices and, for a variety of reasons, they believed using compostable biopolymers represented a more sustainable option. Aside from cafeterias, the decision to purchase compostable plastics did not seem linked to organizations' ability to compost them. In addition, purchasing decisions had very little to do with individual consumer preference. Out of the twelve organizations only one stated that they bought compostable biopolymers because of customer demand. Many organizations stated that few customers had ever explicitly commented on the use of compostable bioplastics or seemed to have any awareness of them. Overall, our findings suggest that neither residential consumers nor food service patrons are driving the purchase and use of compostable biopolymers; the primary drivers are linked to organizational waste diversion and sustainability goals. Legislative bans were not found to be the exclusive drivers among interviews; though they did accompany organizational drivers in states with bans.

3.4 Understanding disposal

As noted before, all organizations in the catering category, the limited food service category, and the recreational concessions category sent compostable biopolymers to landfill. In contrast, all three organizations in the cafeteria category did their best to send the compostable biopolymers to composting facilities. Out of the nine facilities that sent their compostable bioplastics to landfill, all stated lack of access to commercial composting infrastructure which were also able to accept these products, as the main reason for landfilling. Two of the three limited food service establishments have a commercial composter, but explained that their composter did not accept compostable biopolymers. For recreational concessions and caterers a handful of organizations had some kind of pre-consumer organics disposal stream, so that organics could be composted or anaerobically digested. Pre-consumer organic waste are the kitchen food scraps, and other organic waste such as cardboard, that is generated behind the counter by the kitchen or the organizations staff. The Phoenix Convention Center used an ORCA on-site organic waste aerobic digester which allows food waste to be sent to wastewater treatment for disposal, Desert Botanical Gardens had staff that came and picked up food scraps to use for composting, and Atlasta Catering composted all pre-consumer organics with a local commercial facility. All nine of the organizations that did not compost their compostable biopolymers explicitly stated a desire to find a commercial facility that would accept them, even if it meant paying more for the service. One of the catering companies stated that they have been looking for two years to find a composter in the Phoenix valley that will accept their post-consumer organics waste. The Arizona Diamondbacks, which have occasionally held zero waste events, noted that they were only able to do so because the events were special occurrences and as such they had organics trucked approximately 140 miles away to a facility that accepted compostable plastics. It was decided that long-term transport to this facility was neither

economically or environmentally sustainability for the organization. For the Phoenix area, and many other parts of the country, there is no easily accessible composting infrastructure. Even if there are commercial composters, it can be a challenge to find one that will accept organics mixed with compostable biopolymers.

Despite the infrastructure challenges, cafeterias that were located in the Phoenix metropolitan area were able to find a composter for their pre and post-consumer organics waste. Even though the cafeterias have been able to compost their compostable plastics, all three also stated sufficient composting infrastructure as one of the biggest challenges to using compostable biopolymers. In each of the three organizations project managers worked hard to find, collaborate with, or create the necessary composting infrastructure. For example, ASU worked with their hauler, Waste Management Inc., to find a location to which they could send their organic waste. In contrast, Stanford has had access to more commercial composting facilities, but finding a good fit was still a challenge. Stanford's respondent explained that development of the composting market has been crucial. In Stanford's vicinity three composting facilities are now operating: one that only accepts and sells high quality organics and soil amendment, one that creates a low quality compost for fill in construction projects and accepts most anything, and a composter that sits in between – they will accept compostable biopolymers and work to create a medium quality soil amendment that can be sold to residential and commercial customers. For Stanford it was the development of the regional compost market that dictated their ability to find a facility that would accept their post-consumer organics and compostable biopolymers. In sum, it seems that three components created the necessary conditions that enabled cafeterias to send their compostable biopolymers to a compost facility: they each had measurable waste to landfill goals, waste diversion and organics programs were actively managed and monitored, and each

cafeteria had the resources to dedicate to the above tasks and to secure a commercial composter or connect to robust regional infrastructure that was already intact.

It is important to note that even with organizations who have commercial composters, some compostable biopolymers still ended up being sent to landfill. For all cafeterias interviewed, this was the case, though the percentage lost to landfill could not be determined. For post-consumer separated waste streams this is a common occurrence, and can be seen with recycling as well as with separated organic streams. For a number of reasons, it is very difficult to get 100% of waste sorted correctly and to the desired waste treatment facility. For compostable biopolymers, organizations noted that diversion loss can occur in two ways, onsite and then at the commercial composters facility itself. Within the organization, individuals not sorting their waste into the correct bin (i.e. throwing their compostable cup into the landfill bin), custodial staff not correctly sorting bags at dumpster, and staff being directed to toss composting waste because it looks as if it has too much contamination, are all ways compostable biopolymers could end up being sent to landfill. At the compost facility, composters could reject entire organic waste loads because of too much contamination, and composters may screen biopolymers out of compost because it cannot be sorted from the other conventional plastic contaminates. Both of these decisions result in biopolymers being sent to landfill.

Contrary to what was observed for purchasing decisions, it is clear that individual consumers have more of an impact on compostable biopolymer end of life. Though individuals have more impact via their disposal decision, every type of organization was working to alter the overall system design to reduce this impact, both purposefully and otherwise. For example, caterers have many events where trained servers clear and sort trash (regardless of the type of disposables used), some of the limited food service establishments do a post sort of all their

organic waste, recreational concessions may utilize bin-guards (staff that stand by the waste bins and help consumers sort all waste correctly). Cafeterias also identified a number of additional ways they mitigate losses in order to get organics diversion rates as high as possible. Intel closely monitors all landfill and compost dumpsters and follows up immediately with staff if there are unexpected tonnage increases or decreases. Strong relationships, supported by regular meetings and trainings with property management and their contract cleaning company is used to drive better diversion rates as well. ASU and Stanford use a variety of different management strategies to correct individual sorting error including effective signage and bin placement, bin guards, and post event sorting. In addition, they also work closely with their contractors be they food service, custodial staff, or waste handlers.

For all organizations the most important factor related to compostable biopolymer disposal decisions was access to compost infrastructure and the overall compost market development. For key decision makers, such as municipal solid waste managers or directors, especially in cities where bio-preferred purchasing is encouraged, it may be beneficial to devote equal attention and resources to support the composting infrastructure for products that demonstrate improved environmental impacts for composting rather than landfilling (Yates and Barlow 2013). The choice to compost biopolymers may also result in consequential diversion of food waste for composting, improving the environmental impacts of food waste and those associated with biopolymer disposal (Levis and Barlaz 2011). This would include the opportunity for all organizations with pre and post-consumer organics access to commercial composting, and for composters to be supported by a robust market that supplies compost to a variety of different sectors.

4. Conclusion

After the grocery store audits which identified relatively few biopolymers were available in retail settings, this research focused on compostable biopolymers in commercial food service settings. The decision to purchase these products is impacted by larger social trends, such as zero waste initiatives and plastics bans, but individual user motivation was based on a variety of different factors. For all food service categories disposal decisions relied heavily on the regional waste infrastructure that was available. In Phoenix where municipal commercial composting is not readily available, for the organizations we spoke with, most compostable biopolymers were being landfilled. Consequently, in regions where there is no commercial composting infrastructure, this research suggests that most food service providers are sending biopolymers to landfill, however quantifying the mass of composting and landfill waste streams will require waste audits and material flow analyses. This research also found that motivation to purchase was not explicitly linked to the ability to compost the compostable biopolymers nor driven by individual consumer preference.

Sustainability of biopolymers with a potential use in food service industries must consider the available waste infrastructure and disposal methods of commercial food service providers. In addition, the most appropriate method of disposal for compostable biopolymers may depend on individual business factors and with which impacts the organization is most concerned. For example, with a commercial food service business which uses large quantities of disposable cold cups, and is most concerned with decreasing waste to landfill, it may be more sustainable to stay with conventional plastic products that can be readily recycled (Hottle, Bilec et al. 2015). Alternatively, a business that creates large quantities of disposable, food-soiled products, and is concerned with decreasing waste to landfill, may find that the most appropriate

option for their business is compostable biopolymers as most material recovery facilities do not accept small plastics like utensils and have trouble with organic contamination in the recycling process.

However, it is beyond the scope of this paper to decide if compostable bio-polymers can ultimately be considered a sustainable product or which end of life treatment is the most environmentally beneficial. It is important to note that the peer reviewed literature lacks evidence and consensus one way or the other related to the sustainability of compostable biopolymers. Most compostable biopolymer assessments to date focus on plastic production and ignore the complicated realities of waste handling (Gerngross and Slater 2000, Tabone, Cregg et al. 2010, Hottle, Bilec and Landis 2013, Vink and Davies 2015). Many studies on municipal solid waste treatment methods vary widely. For example, composting has been found to be one of the best ways to treat food and food soiled waste because of the reduced methane generation compared to landfill while on the other hand it has been demonstrated to be one of the worst options because there is no opportunity for energy recovery via anaerobic digestion or landfill gas capture (Finnveden, Björklund et al. 2007, Marchettini, Ridolfi and Rustici 2007, Favoino and Hogg 2008, Kim and Kim 2010, Saer, Lansing et al. 2013). For compostable bioplastics which are not food soiled some studies show it may be preferable to landfill them (Lundie and Peters 2005).

This research clearly demonstrates a demand for compostable biopolymer plastics among various food service providers but the ambiguity regarding end of life is pervasive. The uncertainty concerning end of life could undermine the investments and efforts of stakeholders throughout the supply chain who are creating and using products they hope will have improved environmental performance. Though there is clearly a need for further research around what end of life treatments are the most beneficial, the compostable biopolymers continue to expand into

the plastics market. In order to improve the overall environmental performance of compostable biopolymers it is important to understand the motivations behind purchasing, and for compostable biopolymers that perform better in composting situations, create robust waste systems that can accommodate increasing volumes of compostable waste. Increased communication along the life cycle for compostable biopolymers can help stakeholders create a dialogue, clarifying their goals and expectations as they assume greater responsibility for the impacts of the products they use.

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