A Breakdown of Compostable Plastic Recovery in California

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ABSTRACT

Compostable plastics, a new form of plastic designed to breakdown in commercial composting facilities, have recently become widely available in the US. However, the extent to which these compostable plastics are accepted at California compost facilities and actually recovered to produce a final compost product has not been reported. I determined which facilities in California accept compostable plastic and how much of the compost waste stream this represents by weight. Only 14 food waste permitted compost facilities in California accept compostable plastics. Other facilities' treatment processes are unable to breakdown the plastics or have identified other reasons for non-acceptance. Further, due to consumer misconception and inaccurate labeling processes, many consumers incorrectly dispose of non-compostable plastics into the compost waste stream, requiring the need for facilities to have a pre-treatment sorting process. For some facilities, the inability to differentiate between compostable and non-compostable plastics in an economically viable manner, leads to all plastics received at the facilities being removed and redirected to landfills, preventing the recovery of compostable plastics. A lack of communication has led to a disconnect between compostable plastic producers and the waste disposal sites. This has resulted in the inability for compostable plastics to be recovered in our current waste stream, preventing California from reaching its goals of lowering landfill based methane emissions.

KEY WORDS

Waste Management, Plastic Pollution, Compost, ASTM, Petrochemical Plastic Alternatives

INTRODUCTION

Every year, 30 million tons of waste enter landfills in California. Approximately 30 percent of this waste, 9 million tons, is organic matter that could be diverted from landfills to compost facilities (CalRecycle 2018a). The pressing issue of landfill capacity limits led to the Integrated Waste Management Act of 1989 (AB 939), which set a goal for California to plan for continuous landfill capacity 15 years in advance. The waste California produces is expected to increase due to population growth, resulting in the need for the construction of more waste facilities, a process that takes 7 to 10 years for permitting and construction. Further, AB 939 states that landfill capacity demands can be reduced through 50 percent waste diversion via waste reduction, recycling, and composting (CalRecycle 2018b, 2018c). Landfills lead to non-ideal decomposition environments for organic matter. Decomposition of organic matter in landfills happens under anaerobic conditions, produced by the large quantities of decaying material depleting the environment's oxygen, resulting in methane production (Bingemer and Crutzen 1987). Methane is a more potent greenhouse gas than carbon dioxide, which results in a higher global warming potential (Lashof and Ahuja 1990). California's expansive coast also creates the concern of plastic pollution entering the Pacific Ocean.

The Great Pacific Garbage Patch, located between California and Hawaii, is the largest concentration of plastic pollution in any ocean, containing 1.8 trillion pieces of plastic (Ocean Cleanup 2019). As the issue of marine pollution worsens, waste reduction and diversion goals have become more prevalent. Different potential solutions for plastic use have been deployed, such as replacing traditional petrochemical plastics with the adoption of compostable plastics. The implementation of compostable plastics has occurred by local action or by a potential statewide initiative to phase out single-use plastics, AB 1080.

Despite waste reduction targets being set on the state level, waste management practices are decided and implemented on the city level. In 2016, California passed Senate Bill 1383, which aims to reduce methane emissions by setting specific targets for reducing organic matter sent to landfills: 50 percent and 75 percent of 2014 levels by 2020 and 2025, respectively (Lara 2016). The inaction of cities implementation of waste management practices to meet state goals leads to a disconnect between state targets and its tangible achievements (Bingemer and Crutzen 1987). Waste management services are provided through franchise contracts made between local governments and private firms, awarding firms with a monopoly on waste pick-up in that governed region (Walls et al. 2005). Each waste pick-up service has its own regulations and requirements for waste sorting. Certain compost facility regulations can impact the accepted inputs into the facility. For example, some compost facilities aim to be certified as organic, which according to the National Organics Program (NOP) means their product cannot contain certain synthetic materials, including compostable plastics (CFR 205.203). Furthermore, facilities in some regions are not food waste permitted, meaning they are unable to accept food waste despite its production in that region, resulting in large amounts of food waste not being recovered. The different requirements of each facility lead to a discrepancy in regions' compost waste production and what is actually treated at the facility. While in some regions compostable plastics enter the compost waste stream, they may be removed by facilities before treatment. Improper disposal into the compost waste stream can prove potentially detrimental for compost recovery rates. I aim to determine which facilities accept compostable plastics and to find the specific recovery rate in the state of California, a value that has not been quantified in existing literature.

As the trend away from traditional petrochemical plastics to compostable plastics continues, we must ensure their proper disposal in order to reach SB 1383 goals. Compostable plastics must comply with standards set by the American Society of Testing and Materials (ASTM) (Queiroz and Collares-Queiroz 2009). Compostable plastics are designed to biodegrade under certain conditions, such that they breakdown exclusively into carbon dioxide, water, inorganic compounds, and biomass at a comparable rate to other compostable items (USCC 2013). Biodegradable plastics do not comply with ASTM D6400 and cannot be processed at compost facilities, due to the longer time scale in which it takes them to breakdown (Song et al. 2009). Due to improper disposal of non-compostable plastics, compost facilities must remove the plastics that do not breakdown in its facilities.

Differentiating compostable plastics and other plastic contaminants during the sorting process may prove to be economically infeasible for compost facilities and may require removal of compostable plastics before treatment. Although these compostable plastics may be properly disposed of and counted towards California's goal of organic waste recovery, in some cases they may be removed from compost facilities and taken to landfills. This results in compostable plastics breaking down in landfills under anaerobic conditions resulting in methane production. Information about compostable plastic recovery statistics have not been studied before. An evaluation on the impacts of policies, management regiments, and product labeling on the recovery rate has not yet been performed.

Through this research I aim to evaluate the extent to which compostable plastics are actually being composted. By quantifying which facilities in California accept compostable plastics, I will also evaluate the challenges the facilities face with respect to the sorting process before treatment. By collecting data from different compost facilities in California and analyzing their current methods for addressing bioplastics, I will assess alternatives and suggest an optimum method to divert more compostable and biodegradable plastics from landfills.

BACKGROUND

Defining compostable and biodegradable plastics

Bioplastics are a category of plastics that are biodegradable or produced from renewable resources. This separates bioplastics into those that are petrochemical based and biodegrade, and those that are bio-based and either can or cannot biodegrade (Harmon et al. 2014). Biodegradable bioplastics can be made from starch, cellulose, polyhydroxyalkanoates (PHA), polyesters synthesized from a fossil source, or polylactic acid/polylactide (PLA). It is important to distinguish that the breakdown of polymer chains into smaller microscopic polymers is not defined as biodegradation by the ASTM. Without biodegradation, small microscopic polymers contribute to the largely observed issue of microplastic pollution. The presence of these microplastics have been observed in every marine ecosystem (Ivar do Sul and Costa 2014). In order for complete biodegradation to occur, the carbon chains must be digested by microbes and converted to water, biomass, carbon dioxide, or methane (BPI 2006).

Compostable plastics are a stricter sub-classification within biodegradable plastics. The ASTM specifically defines compostable plastics through their “Standard Specification for Labeling of Plastics Designed to be Aerobically Composted in Municipal or Industrial Facilities” (ASTM D6400) and “Standard Specification for Labeling of End Items that Incorporate Plastics and Polymers as Coatings or Additives with Paper and Other Substrates Designed to be Aerobically Composted in Municipal or Industrial Facilities” standards (ASTM D6868). These standards state that compostable plastic degradation must occur at a rate consistent with other compostable materials and yield an end product of carbon dioxide, water, inorganic compounds, and biomass, without leaving toxic residue (Cal Recycle 2014, Green 2007). The distinction between compostable and biodegradable plastics, with compostable plastic being a stricter categorization, is that compostable plastics have complete biodegradation after three months, and produce no toxic residue as byproduct (Philip et al. 2013).

In order for a product in the United States to be labeled as compostable it must be in compliance with the Federal Trade Commission's "Guides for the Use of Environmental Marketing Claims," which states which products are suitable for composting in commercial composting facilities. At the minimum, the label must include the word "compostable" with a 3rd party's certification label, which the ASTM can provide (USCC 2013).

Current plastics policies

In California, multiple policies have been enacted to address the compostable plastic disposal issue. AB 939, which passed in 1989, established an integrated waste management hierarchy that prioritized source reduction, recycling, and composting (CalRecycle 2018b). Prevailing consumer confusion has led to the connotation that littering biodegradable plastic would allow degradation. This has led to California passing legislation in 2011 that banned the sale of products labelled "compostable" or "biodegradable" without the supporting scientific evidence for the degradation certification by the ASTM (CalRecycle 2018a). With this law, California aimed to better communicate with consumers that compostable plastic degradation was not only dependent on the chemical and physical structure of the product, but also on the required high heat disposal environment. The Plastic Product Public Resource Code and SB 567 then explicitly banned the sale of plastics labeled "biodegradable," "degradable," or "decomposable" in the state of California (PRC § 42357). This ban was an attempt to prevent the issue of customer confusion between compostable and biodegradable plastics as well as increase the proper disposal of compostable plastics. Furthermore, this ban aimed to reduce biodegradable plastic contamination due to their similar appearances at compost facilities that would contribute to the need for presorting processes that result in the removal of compostable plastics. This ban, coupled with enforcement and regulation efforts, has led to the reduction of the sale of biodegradable plastic.

California Senate Bill 1383 includes a 40 percent reduction goal in methane and hydrofluorocarbons emissions from landfills, as well as a 50 percent reduction in black carbon emissions relative to 2013 levels by the year 2030 (Lara 2016). Meeting this goal is vital for California's climate action, as the diversion of compostable plastics to compost facilities is an achievable step to reduce landfill-based emissions.

In September of 2018, California passed a rigorous new standard for food packaging containers. The Sustainable Packaging for the State of California Act prohibits state-owned facilities from selling or dispensing food using food service packaging that is not reusable, recyclable, or compostable (Allen 2018). This standard will go into effect in 2021 and is a significant step towards eliminating the use of non-compostable or recyclable items in the state of California. However, it does not address the potential issues with compostable plastic use.

California's waste stream

This research aims to assess the California compost system and evaluate the acceptance of compostable plastics at each of the facilities that make up the system. There are currently 182 active compost facilities in California, as identified by CalRecycle. However, when this list is narrowed down to exclude affiliated landfills and green waste chipping and grinding facilities, there are only 92 active compost facilities, of which only 34 are permitted to accept food waste (CalRecycle n.d.). These 34 food waste accepting facilities are listed in the Appendix in Table 1 (Contreras 2019, Horowitz 2019). Because compostable plastic is primarily used for food packaging and cutlery, facilities that do not accept food waste are assumed to not receive significant levels of compostable plastics in their waste stream (Cotton 2018a, Contreras 2019, Horowitz 2019). Of the 34 facilities permitted for food waste, the number that accepts compostable plastics is unknown. Through this study I aim to evaluate each facility's sorting process and how different processes impact compostable plastic acceptance.

METHODS

Preliminary data collection

To assess compostable plastic recovery in California, the number of active compost facilities in the state that receive and accept compostable plastics needed to be determined. To quantify the number of facilities, I used the CalRecycle Solid Waste Information System (SWIS) website (CalRecycle n.d.). I used a filter on the facility search page with a regulatory status of "permitted," operating status of "active," and facility type "composting." These specifications generated a list of 182 facilities, as shown below on the CalRecycle map in Figure 1. This list contained facility activities categorized below in Table 1.

Figure 1. Map of Permitted, Active Composting Facilities in California (CalRecycle n.d.).

Table 1. Compost facility activity categories.

Facility Activities	
Compost Facility (Mixed)	Compost Facility (Green Waste)
Compost Facility (Sludge)	Compost Facility (Other)
Compost Operation (Ag)	Composting Operations (Research)
Construction and Demolition/Inert Debris	Large Volume in Vessel Digestion
Processing Facilities	Solid Waste Landfills
Land Application	Inert Debris Process Operation
Large and Small Transfer/Process Stations	Chipping and Grinding Activities/Operations

I removed all chipping and grinding facilities from the data pool because they only receive green materials, which is derived from plant materials such as leaves, grass clippings, and tree trimmings (CalRecycle. n.d.a). I also removed solid waste landfill affiliates of compost companies. Transfer/process facilities were assessed on a case-by-case basis and removed from the list if they did not have on-site compost facilities. Construction and Demolition/Inert Debris Processing Facilities and Compost Operation (Ag) were eliminated due to insignificant amounts of compostable plastics received at these types of facilities (Horowitz 2019, Contreras 2019). All research non-waste sites were also removed from this list.

These removed facilities mainly receive agricultural waste or other nonresidential or commercial waste streams that would not have significant volumes of compostable plastics. If these facilities do not receive compostable plastics in their feedstock, their inability to process compostable plastics is inappropriate to include, as it would skew the results, reducing the number of potential compostable plastic receiving facilities to 92. Facilities that were not permitted to receive food waste were also removed from the list because significant amounts of compostable plastics are not found outside of food-related waste streams (Horowitz 2019, Contreras 2019, Cotton 2018). After removing the aforementioned facilities from the list, and consulting with employees of CalRecycle, the number of food waste permitted compost facilities in California was determined to be 34. A table of these facilities can be seen in the Appendix in Table 1. After finalizing the number of active compost facilities in California, I conducted phone interviews with each food waste permitted facility in order to assess compostable plastic acceptance rates in California.

To analyze the waste stream in more detail, I compared the “maximum permitted throughput” of each facility to compare their size and their treatments percentage of the compost waste stream. The maximum permitted throughput is a legal amount of waste they are allowed to accept per day. It can be given in tons or cubic yards. To convert to a common unit, I used the average values of commercial organic waste and food waste from the US EPA’s 2016 Volume-to-Weight Conversion Factor Report (US EPA 2016, Horowitz 2019). This number was determined to be 0.136 metric tons per cubic yard.

Qualitative data analysis

To find out more on the subject of policy implementation and current issues with compostable plastic management, I conducted interviews with individuals in the waste management sector, including Neil Edgar of the California Compost Coalition, Matt Cotton of Integrated Waste Management Consulting, Danielle Lowther of Recology, and Robert Horowitz and Robert Contreras of CalRecycle.

RESULTS

Of these 34 facilities, 33 facilities were able to inform me of their compostable plastic standards, while one facility remained unresponsive, and 24 said they had a waste input that contained compostable plastics. Of these 24 compostable plastic receiving facilities, 14 accept compostable plastics, while the other 10 facilities remove the plastic pre-treatment. These 14 facilities represent 35 percent of the food waste permitted waste stream by weight and less than 1 percent of the entire California compost waste stream. Figure 2 shows the breakdown of facilities’ compostable plastic input and acceptance.

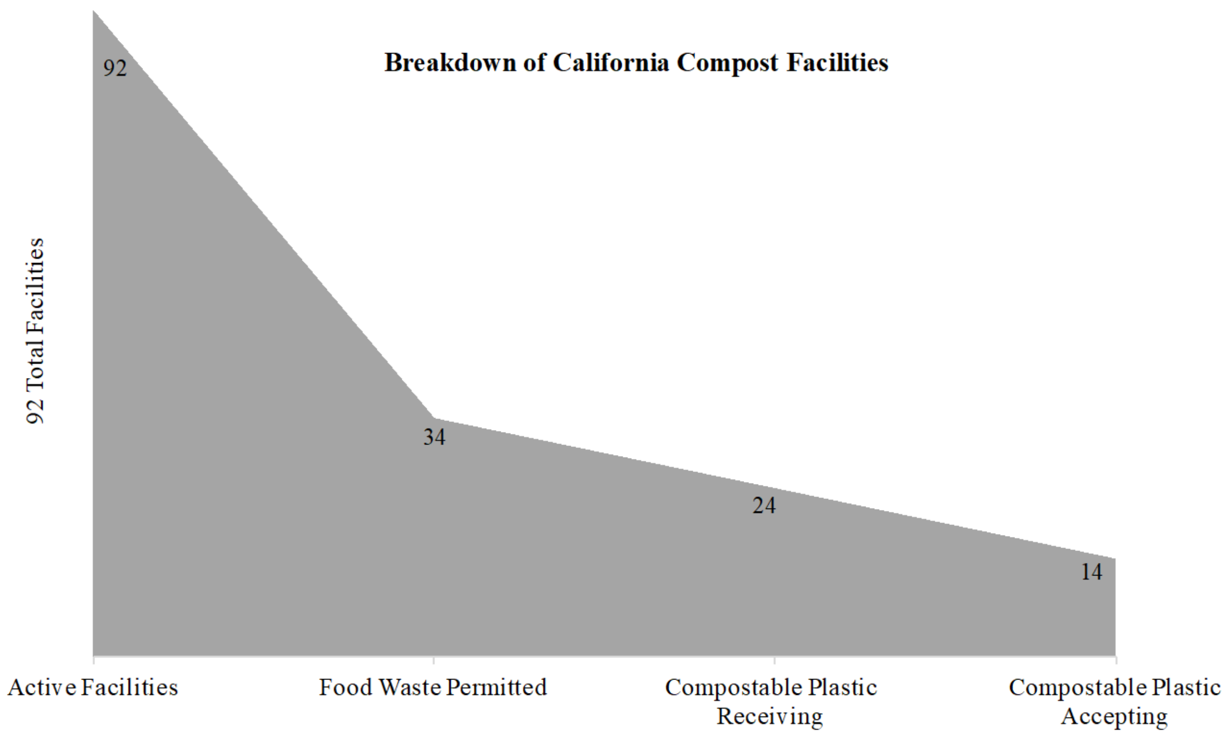

Figure 2. California compost facilities input and acceptance of compostable plastics.

Qualitative data collection

A binary answer to compost facilities' acceptance of compostable plastic was able to be determined for some facilities, but other variables impact some facilities' acceptance of compostable plastics creating conditional answers. One such example is Engel and Gray Inc., a facility that limits its acceptance of compostable plastics. They are responsible for the hauling of waste for their own waste stream, and when they contract with special events and venues, they make sure each event hand sorts the material that goes into the compost bins. For the events they haul for, they preapprove of the compostable plastic that will be used to ensure their facility has tested that specific plastic's ability to breakdown during their treatment. MidValley Disposal Compost Facility accepts compostable and biodegradable forms of plastics as well, and has employees trained to sort and differentiate plastic types before treatment. They also have a program available to work with different restaurants to ensure the cutlery and dishware they use is compliant to their facility's specifications, along with an educational program for their customers. Pebble Beach Avalon Facility has specifications in which they only accept corn-or rice-based plastics.

Harvest Lathrop's facility does not accept compostable plastics; however, they have no pretreatment sorting process and sometimes find chunks of unprocessed compostable plastic in their final product. Some facilities, such as B Goodrow Inc., do not accept compostable plastic because they wish to remain organic certified. The Jepson Prairie Organic Facility is a specific example of the detrimental effects compostable plastics can have on compost facilities and food waste diversion. Due to excessive amounts of plastic contamination entering their facility, Jepson Prairie has stopped accepting food waste all together. Despite being a food waste permitted facility, the cost of sorting through food waste for plastic contaminants made accepting food waste not economically viable (Lowther 2019). A majority of facilities that technically accept compostable plastics have sorting standards that result in plastic contamination being removed during or before treatment, including compostable plastics.

Through my interviews with Robert Horowitz and Robert Contreras from CalRecycle, I learned more about the implications of compostable plastics from the regulatory perspective. Although they work for CalRecycle their observations and thoughts are their own and not the official point-of-view of CalRecycle. Through their time working with compost facilities, they have assessed that compostable plastics are generally viewed as an economic and physical burden for facilities. Compostable plastics are mainly regarded as another form of plastic contamination that is not differentiable and thus removed just as other plastics would be. This results in the removal of both compostable and non-compostable plastics from compost facilities to landfills, where they will slowly breakdown in anaerobic conditions, resulting in methane release.

The main observed benefit that compostable plastics potentially offer is through the use of compostable plastic bags, which increase the ease of food recovery for many commercial and residential streams. Compostable bags have increased the participation in food waste collection programs, maximizing organic recovery from consumers and further prevented loss via residue that would otherwise be left behind during transport to the facilities (BPI 2012, Garaffa et al. 2012). Overall, the use of compostable plastics is mainly viewed as a campaign that falsely provides consumers with the idea that their actions are environmentally superior, when in fact other optimal options actually exist. With the exception of compostable bags, most compostable plastics have been observed to do more harm than benefit for the waste industry. Horowitz and Contreras further observed that from a consumer-stand-point the use of compostable plastics is seen as an environmental solution despite many venues, establishments, and workplaces not containing compost receptacles for their disposal. This commonly leads to the improper disposal of compostable plastics into recycling or landfill receptacles, preventing their recovery. With lack of compost collection available and low acceptance rates at compost facilities when composted, the use of compostable plastics becomes ineffective.

DISCUSSION

Despite compostable plastics having advantages such as maximizing organic recovery from consumers and preventing loss via residue from transport to the facility, compostable plastics have created issues for the waste management industry (Garaffa et al. 2012). The introduction of compostable plastics was initially intended to serve as a potential replacement for petrochemical plastics and to alleviate the copious amounts of this products from entering recycling facilities, landfills, and our waterways each year. Globally, packaging is the main use of plastic, with 146 million tons used in 2015 (Ritchie et al. 2018). A 2015 US EPA report stated that 29.7 percent of municipal solid waste is generated from the packaging sector, which calculates to 77.9 million tons (US EPA 2017). This is waste created for a temporary purpose of packaging that will then sit forever in landfill environment due to its inability to breakdown, or too often skips the landfills and results in marine pollution. Plastic pollution has become such an issue that by 2050 the ocean is predicted to contain more plastic than fish (As You Sow). As compostable plastics for food packaging, cutlery, and bags have entered the waste stream, issues have arisen creating complications for compost and recycling facilities.

Current Waste Recovery Infrastructure

Senate Bill 1383 aims to reduce organic matter sent to landfills, and divert it to compost facilities (Lara 2016). This will result in an increase in organic matter that the current compost infrastructure is not capable of handling. Approximately 100 new large facilities will need to be built by 2025 to meet the 75 percent diversion goal (Horowitz 2019). Permitting and construction of facilities can take 7 to 10 years, so the possibility of reaching the 2025 goal in the next 6 years is highly unlikely (CalRecycle 2018c). The construction of these facilities continues to remain stagnant due to a “chicken-and-egg” dilemma of whether to increase organic waste diversion with nowhere to send it, or to construct new facilities before a guaranteed waste stream exists. In many California regions, current compost facilities are not permitted to pick up food waste, only green waste, so it is not collected commercially or residentially. In addition, non-food waste accepting facilities are not expected to have waste streams containing significant amounts of compostable plastics (Horowitz 2019, Contreras 2019). Food waste collection is a challenge for facilities, as it requires multiple new permits to be acquired, such as water board permits and local air permits, whereas regulations for green waste facilities are less stringent (Lowther 2019, Horowitz 2019). These additional permit requirements would further elongate the construction process. Until a system to collect this increase in food waste diversion is in place, it is not plausible to build facilities with no guaranteed revenue source; however, there is also no incentive to increase organic matter collection if there is no capacity at existing compost facilities (Horowitz 2019).

At this time, there is a debate over whether all compostable plastics are categorized as synthetic, or if they can be considered organic. Due to this gray area in some compostable plastics' organic status, all compostable plastics are considered to be synthetic materials according to the National Organic Standards Board (NOSB), meaning organic certified facilities will not accept them in order to retain their organic certification (Tucker 2011). In order to increase the number of facilities that accept compostable plastics, these synthetic materials would need to be approved as organic by the NOSB so they can be accepted into organic facilities.

Policy effects

Current compost policies do not effectively address the issues associated with compostable plastics. In 2011, California effectively banned biodegradable plastics statewide, in order to reduce improper disposal of these plastics into compost facilities. This successfully stopped the contamination that biodegradable plastics created. Nonetheless, compost facilities continue to face issues during pre-treatment in differentiating compostable plastics from conventional plastics that have been improperly disposed of (Edgar 2019, Contreras 2019, Horowitz 2019). Large-scale contamination of the compost waste stream with non-compostable plastics, leads compost facilities to sort out all plastic received, including compostable plastics. Thus, the state ban of biodegradable plastics did not stop the issue of non-compostable plastic contamination at compost facilities. However, the introduction of compostable plastics has been an issue in itself because it has resulted in increased consumer confusion of proper disposal of different forms of plastics. Further research has concluded that it is very detrimental when compostable materials are disposed of via recycling, landfilling, or incineration, because it contaminates recyclable PET, produces methane when landfilled, and creates air pollutants when burned (Mistry et al. 2018).

Compostable plastic standards

Another concern is that not all certified compostable plastics actually breakdown in facilities due to operational variations; this can burden facility operators with higher costs caused by the un-composted pieces found post-treatment (Mistry et al. 2018). This is due to the longer time requirements for compostable plastics to breakdown for ASTM certification compared to the timescale in which facilities conduct their compost treatment. ASTM tests are performed in a lab environment and require compostable plastics to biodegrade in 120 days with over 90 percent disintegration complete in 12 weeks. However, over 50 percent of compost facilities only run their treatment period for 70 days or less (Harmon et al. 2014). A plastic can be ASTM certified as compostable, but this certification process does not accurately replicate the compost recovery process, resulting in a disconnect between the label "compostable" and the reality of their ability to breakdown in a compost facility. The lack of timeline consistency between the compostable certification requirements and the current practices conducted by facilities has produced a product that is legally compostable, but unable to be processed within compost facilities. Thus, if the issue of non-compostable plastic contamination was resolved, and a pure stream of ASTM certified compostable plastics were to be sent to compost facilities, the issue of lack of degradation of compostable plastics under the current facilities' treatment timeline would still persist.

In order for compostable plastics to breakdown in compost facilities, ASTM certification standards need to better reflect the treatment process of compost facilities. Allowing for compost facilities to participate in the certification process could create compostable plastics that would be feasible with actual treatment processes. This disconnect between a plastic being labeled "compostable," and its ability to be composted, is an issue that will continue to persist if the compostable plastic standards set by the ASTM are not made more stringently in alignment with compost facilities treatment processes.

Consumer disposal information

Not only is there a lack of communication within the industry, but there is also a lack of information given to customers regarding proper disposal protocol. As the trend of consumer environmental concerns increases, the plastic market has preemptively searched for an alternative to traditional petrochemical products (Harmon et al. 2014). With increasing varieties of plastics entering the market, consumers are not educated on their proper disposal. Placing terms such as "plant bottle," "bioplastic," and "compostable" on plastics, along with the Resin Identification Codes (RIC), are not straightforward categorizations for disposal (O'Connor 2011, Harmon et al. 2014). In addition, the RIC code, identifiable as the "chasing arrows" sign with a number in it, misleads many consumers to believe it indicates the recyclability of the item. The current labelling systems do not adequately inform consumers of where to dispose of their plastics, especially when regional recycling and compost facilities do not have uniform acceptances.

The term "bioplastics" has created an illusion that these plastics will disappear after being disposed of, when in reality not all bioplastics are compostable. This sense of "green washing" is problematic and has created large disposal confusion. There are around 13 different type of bio-based plastics in existence today, however not all of them are compostable or recyclable. If PLA is sent to a recycling center due to improper disposal, infrared sensors can be used to sort it appropriately; however, this is a highly expensive process that is not profitable. If PLA and other non-PET plastics are sent to recycling facilities at high enough concentrations, the entire bale of plastic will be sent to the landfill. Compostable plastics have detrimental consequences to not only compost facilities, but the recycling industry in the cases of improper disposal (Mistry et al. 2018, O'Connor 2011).

The inability to distinguish between compostable plastics from conventional plastic contamination in compost facilities inhibits compostable plastics' recovery. Due to their similar appearances, compostable plastics are treated as plastic contaminants at many facilities and sorted out and disposed of to landfills (Edgar 2019a). This struggle to differentiate between the two prevents compostable plastics from going through the treatment process and potentially being recovered. Instead, these plastics are taken with other contaminants to landfills, where they will slowly breakdown under anaerobic conditions, resulting in methane production.

Increasing educational programs about local waste collection procedures is a necessity for compostable plastics. Local programs explaining proper disposal of different plastics and ensuring equal access to trash, compost, and recycling bins can allow for more consumers to accurately dispose of their plastic waste, leading to a reduction of contamination.

Limitations

California's current waste recovery infrastructure is not equipped for optimizing compostable plastic recovery. As shown in the above results, a majority of the food accepting waste stream in California is unable to process compostable plastics, resulting in their removal and transfer to landfills. Responses to the interviews I conducted indicated that California will not have the time to meet 2025 diversion goals, due to the lengthy permitting and construction processes of the needed new compost facilities (Horowitz 2019, Contreras 2019).

The changing materials market conflicts with California's ambitious recovery goals (Harmon et al. 2014). In order to ensure long-term sustainability of packaging material options, packaging producers need to work closely with the recovery industry (Harmon et al. 2014). Until compostable plastic standards are made to align with actual compost facilities' treatment timelines, the term "compostable plastic" will continue to be misleading.

Furthermore, the tremendous amount of single-use plastic has led to many issues such as marine pollution. Simply replacing one form of single-use plastic with an alternative form does not create a solution. Compostable plastics lead to consumer misinterpretation as they believe these plastics can be broken down by natural systems, leading to more plastic litter (Harmon et al 2014).

Conclusion

Based on the data I collected, I determined that a majority of the California food-permitted waste stream goes to facilities that are unable to accept compostable plastics. This inhibits compostable plastics in the state from being properly recovered, eliminating the potential benefits of decomposition that these new materials have. I conclude that the main issues with the introduction of compostable plastics into the waste stream are: 1) a lack of communication between producers and the waste industry; 2) unrealistic ASTM timeline standards for compost waste recovery; and 3) economic inefficiency in differentiating compostable plastics from other improperly sorted plastic contaminants.

Due to the lack of policies regulating compostable plastic production in conjunction with the lack of communication between manufacturers and the waste industry, the introduction of compostable plastics has not resulted in the anticipated benefits. In order to reap the full potential of compostable plastics, large scale changes in waste recovery infrastructure need to be made, as well as reevaluations of ASTM standards in order to make them reflective of compost facilities actual treatment lengths. The premature entry of compostable plastics into the waste stream has created large burdens for the waste industry that need to be corrected immediately for the benefits of compostable plastics to be realized.

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APPENDIX: Food-Waste Accepting Facilities' Compostable Plastic Acceptance

Table 1. California Compost Facilities. California compost facilities that are permitted to receive food waste and their input and acceptance of Compostable Plastics.

SWIS Number	Name	Compostable Plastic Acceptance	Compostable Plastic Input
27-AA-0119	AgroThrive, Inc.	No	No
40-AA-0037	B. Goodrow, Inc. Composting	No	No
23-AA-0029	Cold Creek Compost, Inc.	No	Yes
37-AA-0907	El Corazon Compost Facility	No	No
27-AA-0085	Gabilan Ag Services	No	No
54-AA-0026	Harvest Power California, LLC	No	Yes
39-AA-0051	Harvest-Lathrop	No	Yes
19-AA-0061	Pebbly Beach (Avalon) Disposal Site	No	Yes
15-AA-0307	Recology Blossom Valley Organics- South	No	No
21-AA-0068	WM Earthcare of Marin	No	Yes
17-AA-0014	South Lake Resource Recovery and Compost	No	Yes
17-AA-0014	South Lake Resource Recovery and Compost	No	Yes
30-AB-0403	Tierra Verde Industries EcoCentre	No	No
36-AA-0403	Victor Valley Regional Composting Fac.	No	Yes
48-AA-0083	Jepson Prairie Organics Composting Fac	No	No
15-AA-0311	Mt Vernon Ave Recycling & Composting Fac	No	Yes
58-AA-0015	Feather River Organics	No	No
37-AB-0003	Miramar Greenery	No	No
39-AA-0020	Forward Resource Recovery Facility	No	Yes
50-AA-0018	City Of Modesto Co-Compost Project	Yes	Yes
28-AA-0030	City of Napa Material Diversion Facility	Yes	Yes
33-AA-0292	Coachella Valley Compost	Yes	Yes
16-AA-0022	Kochergen Farms Composting	Yes	Yes
22-AA-0013	Mariposa Co. Composting Facility	Yes	Yes
10-AA-0201	MidValley Disposal Transfer Recycling St	Yes	Yes
27-AA-0010	Monterey Peninsula Landfill	Yes	Yes
33-AA-0258	Robert A Nelson Transfer Station & MRF	Yes	Yes
07-AA-0044	WCCSLF Organic Materials Processing	Yes	Yes
36-AA-0341	West Valley Materials Recvr`y Facility	Yes	Yes
43-AA-0015	Z-Best Composting Facility	Yes	Yes
50-AA-0020	Recology Blossom Valley Organics N Verna	Yes	Yes
42-AA-0053	Engel & Gray Inc	Yes	Yes
43-AN-0017	Newby Island Compost Facility	Yes	Yes
01-AA-0325	Composting Facility (Altamont Landfill)	No Response	No Response