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Graphic Communications Management
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Bio Based Polymers in Food Packaging: Finding a Balance Between Safety and Sustainability

Are there viable bioplastic alternatives to single-use plastic food packaging within the current production, agriculture and waste management infrastructures in Canada?

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ABSTRACT

Reviewing available information to determine if **Polylactic Acid, Polybutylene Succinate, and Organic Polyethylene** are viable bio-based/biodegradable alternatives to traditional single-use plastic used in industrial food manufacturing and packaging facilities within Canada. This article reviews current research efforts, techniques of production, challenges and prospects of these alternative materials in replacement of plastic film, food containers used in packaging and single-use utensils.

Bioplastics can be considered viable alternatives to conventional LDPE, PP and PS plastics however for the applications of food packaging, more research and development is needed to indubitably consider bioplastics as a direct substitute for plastic packaging.

***Keywords**: bioplastic, food packaging, Polylactic Acid, Organic Polyethylene, Polybutylene Succinate*

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INTRODUCTION

Humankind is at a critical moment in history, currently at the peak of the worst climate crisis ever documented, with plastic waste being augmented in 2020 due to the COVID-19 pandemic (Charlebois et al. 2019). The production of plastic has surpassed the production of all other materials that can be used in packaging, most of which are designed to be thrown away after one use (Giacovelli 2018)**.** Most plastics today are made with petrochemicals however is becoming an increasingly unviable material (Jagadeesh et al. 2017) due to the depletion of petroleum in the environment, growing environmental awareness among civilians, accumulation of waste, waste management and landfilling resource inefficiency, waste legislation, producer and consumer accountability, market trends and the need to reduce energy consumption (Helanto 2019).

Most plastics do not degrade; they can break down into smaller pieces known as microplastics which can be reintroduced into the environment through wildlife, if ingested by fish or other marine life (Giacovelli 2018). Microplastics that are ingested by animals can threaten the natural food chain and have even been found in table salt, tap water and bottled water (Giacovelli 2018). Microplastics are commonly found in coastal regions and areas with beaches as a result of abrasion by waves and high UV irradiation (Giacovelli 2018). Plastic items that are commonly found in the environment include cigarette butts, plastic drinking containers, bottle caps, food wrappers, plastic grocery bags, plastic lids, straws and stirrers and foam takeout containers (Giacovelli 2018).

In efforts to reduce waste and carbon emissions, many governing bodies have implemented plastic bans, including Canada. In 2019, Canadian Prime Minister Justin Trudeau announced a ban on harmful single-use plastics, with the hopes of phasing out items such as plastic cutlery, cups and straws, as early as 2021 (BOOK). Other governments have also only allowed the use of "biodegradable" plastic items, as it can reduce pollution and decrease carbon emissions (Giacovelli 2018, UrthPact 2018).

Although society is aware of the growing concern of traditional plastic, in 2010 it was estimated that only 1% of the commercially available plastic market is bio-based (Jagadeesh et al. 2017). In order to search for solutions, we have to look at issues in the production of traditional synthetic plastic and what steps we can take to minimize our energy and waste footprint. This article will summarize available information on market ready bio-based or biodegradable material substitutes for traditional single-use plastics; specifically for low-density polyethylene/linear-low-density polyethylene plastic film, polypropylene food containers, and polystyrene plastic utensils as these are items that are commonly produced and discarded.

LITERATURE REVIEW

This literature review was conducted to focus on the elements of life-cycle assessment (LCA), food safety and processability of selected bioplastic materials in order to thoroughly assess each material as a viable alternative to single-use plastics with the application of food packaging at an industrial manufacturing and processing level. With the rising waste accumulation and carbon emissions generated by single-use plastic, alternative bio-based plastics are being introduced into the packaging industry in an attempt to aid in the crisis.

All scholarly and peer reviewed journal articles were accessed through the Ryerson University online library databases; information considered was available through this database as of the publication date. The literature assessed in this review is not all encompassing, however general themes are covered.

THEME I: LIFE-CYCLE ASSESSMENT

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1. ***Second-generation bio-based plastics are becoming a reality - Non-renewable energy and greenhouse gas (GHG) balance of succinic acid-based plastic end products made from lignocellulosic biomass. Biofuels, Bioproducts and Biorefining.***

   Patel, M. K., Bechu, A., Villegas, J. D., Bergez-Lacoste, M., Yeung, K., Murphy, R., Bryant, D. (2018). Second-generation bio-based plastics are becoming a reality - Non-renewable energy and greenhouse gas (GHG) balance of succinic acid-based plastic end products made from lignocellulosic biomass. Biofuels, Bioproducts and Biorefining, 12(3), 426-441. doi:10.1002/bbb.1849

2. ***Life cycle assessment of single use thermoform boxes made from polystyrene (PS), polylactic acid, (PLA), and PLA/starch: Cradle to consumer gate.***

   Suwanmanee, U., Varabuntoonvit, V., Chaiwutthinan, P., Tajan, M., Mungcharoen, T., & Leejarkpai, T. (2012). Life cycle assessment of single use thermoform boxes made from polystyrene (PS), polylactic acid, (PLA), and PLA/starch: Cradle to consumer gate. The International Journal of Life Cycle Assessment, 18(2), 401-417. doi:10.1007/s11367-012-0479-7

In general, product lifetime varies over different economies and demographics as different waste management infrastructures are operational and market trends in regards to consumption and disposal of waste are considered. It is also difficult to isolate the life-cycle of a specific plastic as there are thousands of different combinations of plastic due to additives, such as paper talc, green polymers and synthetic polymers, among many others, that will alter a product's versatility. On account of these combination plastics, it is hard to assess thoroughly the life-cycle of a given material due to the vastness of compositions. As well, there is currently little information available regarding the waste management of bioplastics in Canada, as there is not a sufficient waste management infrastructure to support introducing the separated disposal of bioplastics from landfill waste.

THEME II: FOOD SAFETY

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1. ***Safety assessment of polylactide (PLA) for use as a food-contact polymer***
   Conn, R., Kolstad, J., Borzelleca, J., Dixler, D., Filer, L., Ladu, B., & Pariza, M. (1995). Safety assessment of polylactide (PLA) for use as a food-contact polymer. Food and Chemical Toxicology, 33(4), 273-283. doi:10.1016/0278-6915(94)00145-e

Many studies regarded the material as stable and 'safe', however did not consider it's applicability to food safety. There is currently minimal research available specifically regarding the impact of food quality when using polylactic acid, organic polyethylene or polybutylene succinate as a material for food-contact packaging, except for '*Safety assessment of polylactide (PLA) for use as a food-contact polymer* ' (Conn et al., 1995) which assesses polylactic acid in the context of potential migrants of the material. Areas that must be considered when evaluating bio-based packaging are it's mechanical properties, such as durability, environmental conditions needed for degradation (if any), rate of degradation (if any), resistance to water and UV light and toxicological properties. Similar to the analysis of a material's life-cycle assessment, is it difficult to synthesize the impact of its mechanical properties on a given food product, as there several different combinations of a final plastic that is produced due to additive combinations. There are also several regulations concerning the production of food products that could affect the materials' utilization within a certain facility, such as storage requirements and material sterilization which were not accounted for in '*Safety assessment of polylactide (PLA) for use as a food-contact polymer* ' (Conn et al., 1995).

THEME III: PROCESSABILITY

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1. ***Food packaging materials and radiation processing of food: A brief review.***
   Chuaqui-Offermanns, N. (1989). Food packaging materials and radiation processing of food: A brief review. International Journal of Radiation Applications and Instrumentation. Part C. Radiation Physics and Chemistry, 34(6), 1005-1007. doi:10.1016/1359-0197(89)90343-3

2. ***Thermal analyses of poly(lactic acid) PLA and micro-ground paper blends.***
   Bubeck, R. A., Merrington, A., Dumitrascu, A., & Smith, P. B. (2017). Thermal analyses of poly(lactic acid) PLA and micro-ground paper blends. Journal of Thermal Analysis and Calorimetry, 131(1), 309-316.

doi:10.1007/s10973-017-6466-2

The application of bioplastics in food packaging are not a new technology, however it is still developing. Several studies assess the durability of the material when heat is applied, as several The manufacturing of food can also influence what materials are used in a given facility (ie. foods that are processed in an extremely hot or extremely cold environment), which must also be taken into account when analysing the processability of a material.

THEME IV: LEGISLATION

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1. ***Second-generation bio-based plastics are becoming a reality - Non-renewable energy and greenhouse gas (GHG) balance of succinic acid-based plastic end products made from lignocellulosic biomass. Biofuels, Bioproducts and Biorefining.***
   Patel, M. K., Bechu, A., Villegas, J. D., Bergez-Lacoste, M., Yeung, K., Murphy, R., Bryant, D. (2018). Second-generation bio-based plastics are becoming a reality - Non-renewable energy and greenhouse gas (GHG) balance of succinic acid-based plastic end products made from lignocellulosic biomass. Biofuels, Bioproducts and Biorefining, 12(3), 426-441. doi:10.1002/bbb.1849

Information regarding laws and guidelines standards in Canada was acquired from the Government of Canada website, rather than scholarly research. Any laws, regulations and standards referred to in this article are current as of the publication date. This article will be assessing the viability of bioplastics in Canada in regards to legislation and guidelines, for example laws surrounding manufacturing standards, waste management
There are also regulations and standards published by the Canadian Food and Inspection Agency and other governing bodies encompassing the production and packaging of safe food. According to the study conducted by M. Patel, 2018, Thailand adopts the same biodegradable standards as stated in ISO-1421 as Canada, therefore it is assumed that the certain considerations regarding bio-plastics can be translated similarly to Canadian circumstances, however not all information was applied in this article.

CONCLUSION

The industries of waste management, food packaging and food safety are ever evolving. Fundamentally, this makes the effectiveness of a particular material difficult to evaluate thoroughly. As summarized in much of the literature reviewed, there are a multitude of elements that must be considered when conducting such evaluations, such as food safety when in contact with such materials, end-of-life disposal, manufacturing energy footprints among many others. Some literature used in this article was published when bioplastics were emerging in the plastic packaging market, around the 1980s. It has been assumed that claims made were factual and any errors made in the calculations and evaluation of biomaterials in previous decades are rationalized due to market trends, access to technology and lower production rates at the publication date of the literature.

The use of language that is often used to describe bioplastics and its components can be ambiguous at times when used, for example polymer/plastic and compostable/biodegradable. It is crucially important that the distinction between certain terms are highlighted in scientific literature, such as the majority used in the creation of this article.

One of the challenges of compiling research bioplastics is that there is no consistent method of evaluation as there were different variables used to determine if they are considered 'viable'. Sufficiency of polylactic acid, organic polyethylene and polybutylene succinate varied by article, as they were assessed against inconsistent conditions. Many studies assessed the use of bioplastics at a global scale or non-canadian national scale, or under generalized (median) conditions.

A comprehensive study encompassing the entire life-cycle of a given bioplastic material is needed to entirely deem a bioplastic as a viable alternative to traditional plastic. Most existing literature reviews a specific portion of the life-cycle, for instance either the manufacturing process, mechanical properties or end-of-life process. However in order to accurately assess the material as a viable alternative, the entire life-cycle must be considered.

METHODOLOGY

The alternative bioplastics that have been considered as comparable direct substitutes for commonly-referred-to 'single-use' synthetic plastic include polylactic acid, organic polyethylene and poly butylene succinate. Generalized life-cycle assessment strategies as stated in ISO-1421 were used to evaluate these materials for candidacy when compared to single-use plastic; linear-low-density/low-density polyethylene, polypropylene and polystyrene.

A combination of qualitative and quantitative research was collected. All materials discussed in this article were synthesized as part of secondary research, including scholarly and peer reviewed journal articles that were accessed through the Ryerson University online library databases (which were available at the date of publication).

QUALITATIVE RESEARCH

Majority of the journals sourced for this article are published after the year 2010, as the information better represents the technology, market trends and waste management systems currently available at the time of publication. Few selected works published before the year 2010, as it was assumed they are notable to the bioplastics considered for this article.

TERMINOLOGY

Certain terminology used in this article are applied with the following definitions:

POLYMERS

Polymers are materials made of long, repeating chains of molecules, also known as subunits. These materials have unique properties, depending on the type of molecules being bonded and how they are bonded.

PLASTIC

Plastic is a material made through the distillation and polymerization of polymers, which have been formed into long molecular chains (UrthPact 2018). Plastics can be made either synthetically or naturally, and can be molded into shape while soft and set into a rigid or slightly elastic form. It is typically lightweight, hygienic and a barrier material, resistant to rust corrosion, moisture and oxidation while providing an economic packaging solution for many corporations. Today, most traditional plastics are synthetic, derived from petrochemical products such as fossil fuels, however, they pose an environmental issue due to their large carbon footprint and inability to decompose quickly. There are two main types of plastic:

THERMOPLASTICS

Plastics that can repeatedly be melted when heated and hardened when cooled. Due to this, they can be reshaped and remolded, making them easily recyclable. PET, PE, LDPE, PS, EPS, PVC, PP, PLA, PHA

THERMOSETS

Plastics that undergo a chemical change after it's initially heated and formed that does not allow for the material to be reheated and reformed. Due to this, the material is not considered recyclable.
PUR, Phenolic resins, epoxy resins, silicone, vinyl ester, acrylic resins, Ureaformaldehyde (UF) resins

Throughout this article, any reference to traditional plastic is considered synthetic plastic.

SINGLE-USE PLASTIC

Is often used to describe plastic packaging items intended to be used once before being thrown away or recycled (Giacovelli 2018). Polymers commonly used in single-use plastic include LDPE, HPDE, PET, PS, EPS, PP.

BIO-POLYMER

Biopolymers are natural polymers produced by the cells of living organisms.

BIOPLASTIC

Bioplastics are plastic materials that are derived from renewable, organic materials. Types of Bioplastic can be starch-based, cellulose-based, protein-based. Other bioplastics are Aliphatic Polyesters, such as PHA (polyhydroxyalkanoates) and PLA (polylactic acid), as well as Organic Polyethylene, which are currently in production within the packaging industry. Bioplastic is similar to traditional plastic in mechanical properties, however, can aid in shrinking the carbon footprint by sourcing from organic materials rather than fossil fuels.

BIODEGRADABLE

Refers to the process of when a substance, object or material is decomposed fully into biomass, by microbes and bacteria when subject to a particular environment within a given time frame. In Canada, guidelines surrounding biodegradability follow those of the international standard ISO-14021 (ELEPHANT), which dictates that a material can be claimed biodegradable if it is able to decompose in the environment it is intended to be discarded in. The length of time needed for the material to breakdown is dependent on the complexity of the chemical structure of the organic materials (International Organization for Standardization 2016), however, the general length of time considered is one year.

COMPOSTABLE

Refers to the process of when a substance, object or material is decomposed into an organic soil-like matter by microbes and bacteria when subject to specifically an aerobic environment. In Canada, guidelines surrounding compostability follow those of the international standard ISO-14021 (ELEPHANT), which dictates that a material can be claimed compostable if the decomposed organic matter must not produce any harmful or substances or toxins during the fermentation process, as well as not disrupt the composting process or the compost itself (International Organization for Standardization 2016, Helanto 2019). Compostable polymers are not considered biodegradable as they degrade under specific conditions, however, typically degrade faster (Helanto 2019).

ACRONYMS AND ABBREVIATIONS

Low-Density Polyethylene = LDPE;
Linear-Low-Density Polyethylene = LLDPE;
Polypropylene = PP;
Polystyrene = PS;
Polylactic Acid = PLA;
Organic Polyethylene = Organic PE

OTHER CONSIDERATIONS

There are several types of bioplastic that currently exist, however not all were considered for this review, such as lignin-based plastics, protein- based plastics (whey, soy, gluten, collagen) and certain polysaccharides such as alginate and chitosan. These materials are no at prominent within the industry and also present certain effects on food, as they are often made from food hazardous materials such as wood and allergens.

Plastics considered are listed in Table 1.

RECYCLE CODE	MATERIAL	*Industry recognized* ACRONYM	USES
		SYNTHETIC PLASTICS	
4	Low-Density Polyethylene Linear-Low-Density Polyethylene	LDPE LLDPE	Six-pack-rings, tubing Film wrap
5	Polypropylene	PP	Industrial fibres, food containers
6	Polystyrene	PS	Plastic utensils, cafeteria trays
		BIO-BASED PLASTICS	
7	Polylactic Acid	PLA	Industrial fibres, food containers, plastic utensils, cafeteria trays
4	Organic Polyethylene	Bio-PE	Six-pack-rings, tubing, film wrap
	Polybutylene Succinate	PBS	Industrial fibres, food containers, plastic utensils, cafeteria trays

Table 1 *Plastic acronyms and commons uses.*

RESULTS

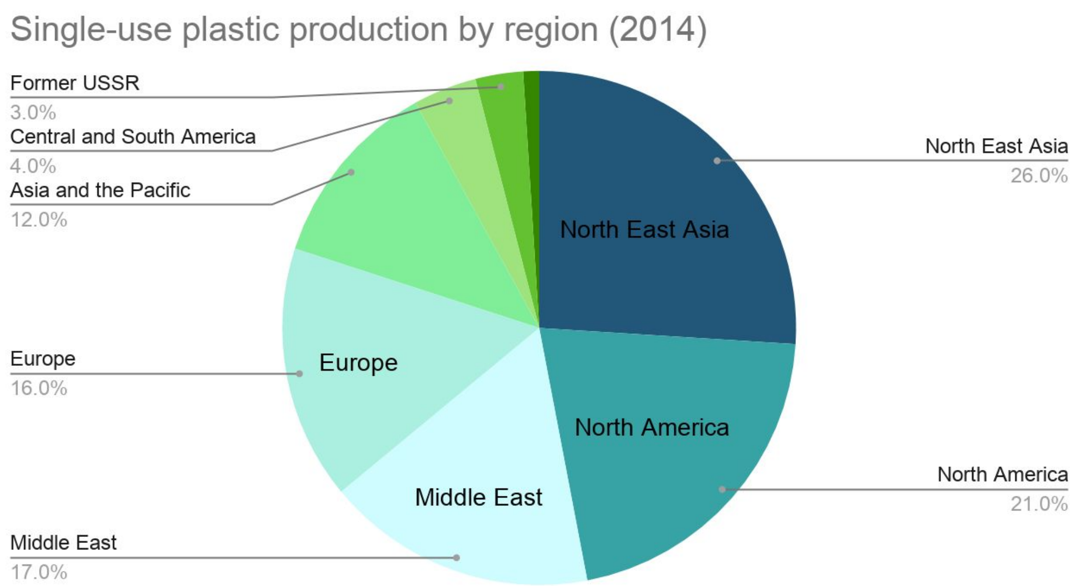

Fig. 1 *Percentage of single-use plastic production by global region in 2014. Adapted from Giacovelli 2018*.

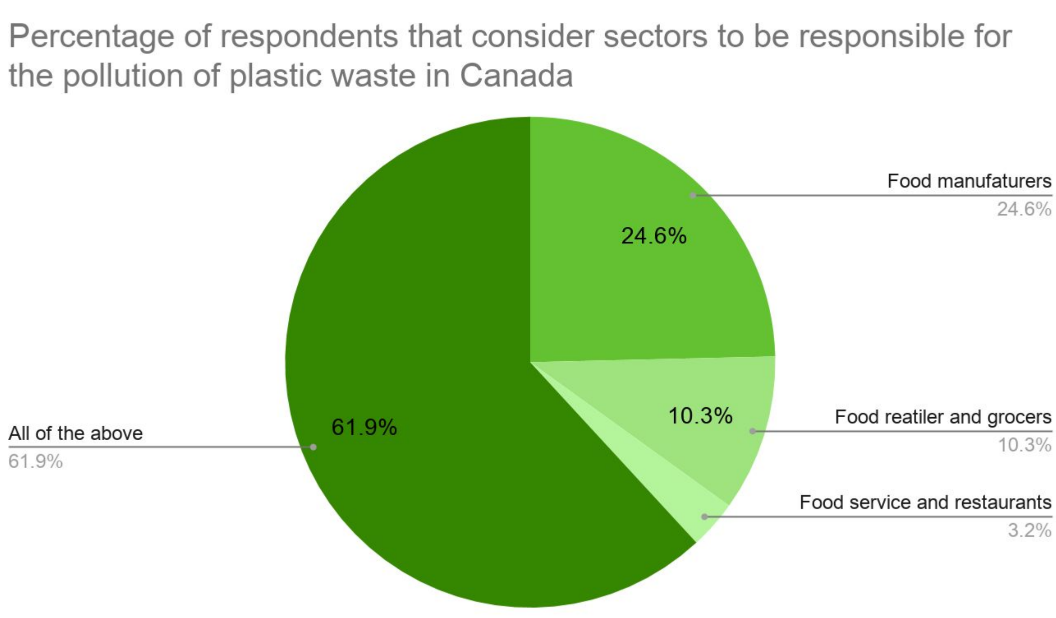

Fig. 2 *Percentage of respondents that considered which food sectors to be responsible*

for pollution of plastic waste in Canada. Adapted from Charlebois et al. 2019.

Bioplastics are considered any material that There are several different types of bioplastic, as described in Table 2. The type of bioplastic depends on the raw materials used in the manufacturing process of a given product.

Starch-Based	Simple bioplastic derived from corn starch. They are often mixed with biodegradable polyesters.
Cellulose-Based	Produced using cellulose esters and cellulose derivatives
Protein-Based	Produced using protein sources such as wheat gluten, casein, and milk.
Aliphatic Polyesters	A collection of biobased polyesters including PHB (poly-3-hydroxybutyrate), PHA (polyhydroxyalkanoates), PHV (polyhydroxyvalerate), poly hydroxyhexanoate PHH, PLA (polylactic acid), polyamide 11 (PA11). They are all more or less sensitive to hydrolytic degradation and can be mixed with other compounds
Organic-based	Traditionally synthetic plastics, such as polyethylene, propylene, polyethylene terephthalate and polyamide, have been produced from the fermentation of raw agricultural materials like sugarcane and corn, rather than fossil fuels.

Table 2 *Types of bioplastic . Adapted from UrthPact 2018 and Helanto 2019.*

The categorization of a bioplastic is determined by its raw material source and its biodegradability, as shown in **Fig 3**. A bioplastic can be considered bio-based if it is a) bio-sourced and biodegradable, b) bio-sourced and non-biodegradable, or c) petroleum sourced and biodegradable.

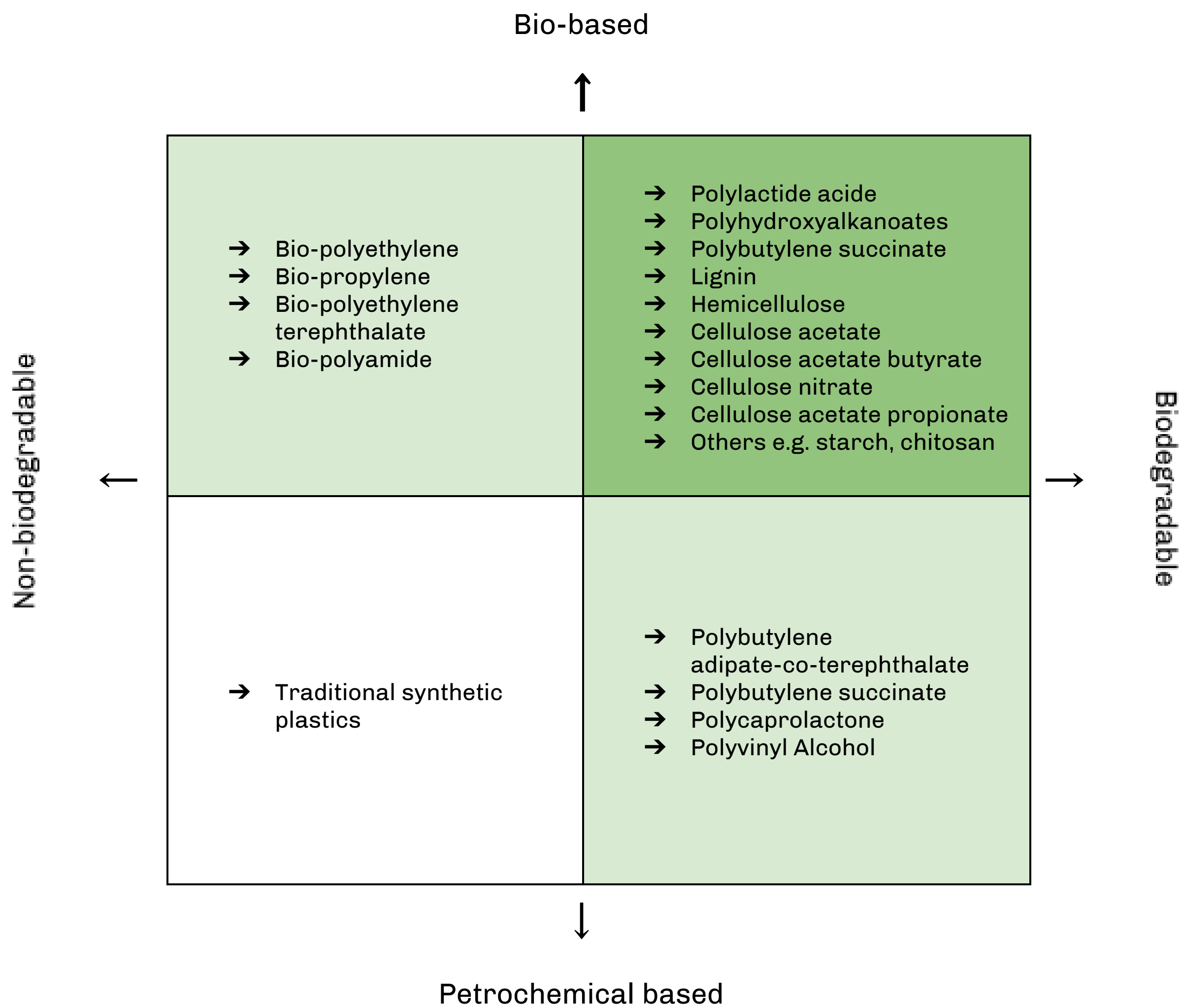

Fig. 3 *Polymers and biopolymers shown according to their biodegradability and source. Adapted from Helanto 2019.*

Retailers and consumers started seeing a decline in the use of natural polymers such as wool, silk, pitch, and natural rubber between the 1940s and 1980s as synthetic, petroleum-based polymers offered a more economical alternative to manufacturers due to the low-cost raw materials and ease of manufacturing (Jagadeesh et al. 2017). Most plastics today are made with petrochemicals however are becoming increasingly unviable material due to the depletion of petroleum in the environment (Jagadeesh et al. 2017) growing environmental awareness, accumulation of waste, waste management, waste legislation, producer and consumer accountability, the need to reduce energy consumption and market trends (Helanto 2019). Development of green composites began in the late 1980s yet in 2010 it was estimated that only 1% of the plastic market is bio-based (Jagadeesh et al. 2017). In 2014, plastic packaging accounted for half of the plastic waste that exists in the world, with only an estimated nine percent produced being recycled and 12% being incinerated (Giacovelli 2018).

With the implications of the global COVID-19 pandemic, plastic pollution is on the rise again with the surge in demand in meal take-out from restaurants, prepared single-serve foods and online shopping. In a study conducted by the Agri-Food Analytics lab at Dalhousie University, 977 responses from Canadians were collected regarding how the COVID-19 pandemic has impacted Canadian consumers' perspective of the use of single-use plastics in food packaging. It found that 29% of respondents felt they were purchasing more packaged goods during the pandemic (Kitz 2019) as 55% of respondents were more concerned about food safety since the pandemic, particularly female-identifying respondents in coastal regions (Kitz 2019). In another study conducted by the university, it found that biodegradable and compostable packaging solutions are popular among respondents, especially Millennials and Generation Z's, however they favoured the use of new technology rather than implementing plastic bans (Charlebois et al. 2019). Most respondents also believe that the use of compostable packaging should be encouraged and incentivized (Charlebois et al. 2019).

Bioplastics are now increasingly being used in food contact food contact packaging, with many companies such as Coca-Cola, PepsiCo. and Heinz adopting these materials as part of their packaging (UrthPact 2018).

COMPARISON OF SYNTHETIC VS BIOPLASTIC MATERIALS

	MATERIAL	PROPERTIES	ADVANTAGES	DISADVANTAGES
SYNTHETIC	LDPE/LLDPE	Petro-based Thermoplastic	Low cost Good processability Flexible Hydrophobic Safe for food packaging	Low strength Poor HDT Poor UV resistance Highly flammable Non-biodegradable
	PP	Petro-based Thermoplastic Recyclable	Low cost High strength Hydrophobic Safe for food packaging	Sensitive to microbial affect Poor UV resistance Highly flammable Non-biodegradable
	PS	Petro-based Thermoplastic Recyclable	Low cost Inert Safe for food packaging and medical packaging	Non-biodegradable Low strength Flammable
BIO-BASED	PLA	Bio-based Biodegradable Thermoplastic Similar to PP and PS	Non-clinging properties Safe for food packaging	High cost Hydrophilic Poor HDT Slow decomposition Non-biodegradable
	Organic PE	Bio-based Non-biodegradable Sourced from green polymers Similar to synthetic PE	Low cost Good processability Flexible Hydrophobic Safe for food packaging Less carbon emissions compared to traditional LLDPE/LDPE	Low strength Poor HDT Poor UV resistance Highly flammable Non-biodegradable
	Polybutylene Succinate	Petroleum-based Biodegradable Thermoplastic		

POLYLACTIC ACID (PLA)

Polylactic acid is a polymer traditionally made from the extraction and refinement of renewable starches, such as corn starch, tapioca, and sugarcane, making PLA a comparable bio-based plastic. It can be formed into single-use cups, trays, lids and blister packaging, with 70% of all PLA produced being used for packaging applications (Suwanmanee et al. 2013)). In biopolymer production stages, the polymerization for polylactic acid (PLA) showed significant impacts throughout the life cycle production (Suwanmanee et al. 2013)).

Currently for food packaging applications, starch based and starch blended plastics are used for loose fill, single-use trays (Suwanmanee et al. 2013)), bottles, medical devices and shrink wrap (UrthPact 2018) due to their non-clinging properties; making PLA as a replacement for polystyrene (Rabnawaz 2017). However, PLA boxes give a slightly higher environmental impact than the PS box since it uses a higher energy consumption during manufacturing (Suwanmanee et al. 2013)). Potential migrants, actide (the monomer), and lactoyllactic acid (the linear dimer of lactic acid) were assessed for the possibility of contamination in food-contact packaging. It has been determined that the amount of migrants found in the food were minimal and would have no impact on human health and animal health if used (Conn et al. 1995). It is concluded that PLA is safe and 'Generally Recognized As Safe' for its intended uses as a polymer for fabricating articles that will hold and/or package food (Conn et al. 1995).

Some disadvantages of PLA include it's high cost, strong water absorption (Suwanmanee et al. 2013)) and insufficient heat deflection temperatures (thermal decomposition of starch before melting) (Suwanmanee et al. 2013), Bubeck et al. 2018). PLA HDT can be increased through additive blending with poly-D-lactic acid (PDLA); however, this stereoisomer is a more expensive option. Further, the use of PDLA dramatically increases the time required for the composite to biodegrade (Bubeck et al. 2018). PLA blends with other plastics have yielded high HDT materials, but they suffer from high cost, reduced sustainability, and reduced biodegradability (Bubeck et al. 2018). Talc (a clay mineral, composed of hydrated magnesium silicate) is also a common additive used in plastics and has historically shown to enhance PLA HDT for higher weight bearing needs. However, talc is not sustainable or biodegradable and therefore diminishes the attraction of the material to consumers (Bubeck et al. 2018).

A PLA/starch blend has been tested as a suitable combination for single use or nondurable packaging and provides easier degradability in the environment (Suwanmanee et al. 2013). A PLA/starch blend is also cheaper than synthetic additives as it is an abundant and renewable raw material making it an effective option to reduce material cost and while also maintaining good performance (Suwanmanee et al. 2013)). There were no unexpected mechanical benefits gained by using micro-ground paper (or talc) in PLA recorded within the limited set of tests performed (Bubeck et al. 2018).

ORGANIC POLYETHYLENE

Organic PE, which is also known as bio-based PE, is mechanically similar plastic to synthetic PE however has been produced from the fermentation of renewable raw resources such as wheat, maize, sugarbeet, sugarcane, and Miscanthus (Bos et al. 2012). Organic PE and synthetic PE are chemically identical and therefore have the same material properties (Bos et al. 2012). In terms of end-of-life, orgic PE offers limited benefits compared to synthetic PE (MUSIC) as they are both considered non-biodegradable (Helanto 2019). A possible shortcoming of organic PE in terms of processability and food packaging is it's limited tensile strength and weaker barrier properties, however can usually be improved with the use of laminates, additives and coatings (Briassoulis & Giannoulis 2018).

Compared to PLA, organic PE uses three times less land use for agriculture raw materials as PLA requires a substantial amount of fermented sugarcane per tonne of product (Bos et al. 2012). PLA overall has a greener net energy output however is not as industrially or commercially available compared to organic PE (there is more market need for PE), therefore there is a possibility in the future for the technology of organic PE to surpass the development of PLA (Bos et al. 2012).

POLYBUTYLENE SUCCINATE

PBS is mechanically extremely similar to PLA, therefore they share a great deal of characteristics, however it is produced from petrochemical sources yet is still biodegradable (Nazrin et al. 2020). It is still a more recent material and is still developing. Of tests that have been conducted thus far, PBS is shown to demonstrate low oxygen barriers, high mechanical properties, such as softness and melting viscosity (Nazrin et al. 2020). To strengthen the material it is often mixed with natural biopolymers, such as cellulose, starch, soy protein, and various plant fibers. This can also help reduce the cost, as it is relatively expensive to process/

A major issue with PBS is it's hydrophobicity, which often makes it difficult to bond with other materials (Nazrin et al. 2020). Often, nanocellulose will also be incorporated to enhance the practical properties of PBS for food packaging as many packages are multi-layered.

DISCUSSION

THE NEED FOR BIOPLASTIC

As a culture that has adapted to plastic overuse, it is not reasonable to assume that at this point in time that plastics can be eradicated completely. Plastics are an essential resource to modern society, continually providing functionality that cannot easily be replaced by other materials, especially in packaging. Compared to other materials, such paperboard and cardboard, plastic typically provides better protection for items and their exterior environment (Helanto 2019). The plastic industry also carries a large energy and carbon emission footprint, requiring the manufacturing and refining of crude oils, fresh water, and occasionally dyes and additives. With limited degradation of synthetic plastic, the waste generated after these products are discarded can put pressure on landfills across the globe as plastic is the one of the most disposed of materials outputted to landfills (Giacovelli 2018). There is also an increased risk of toxic chemicals entering the environment from these plastics as they pollute landfills and oceans, which adds an increasing strain on wildlife and nature. A solution is needed that provides continued access to materials similar to plastic, however avoids these serious problems generated by traditional plastic.

Bioplastics are the next generation of materials to be introduced into the packaging and retail industry as they offer both a reduction in carbon emissions and strain on disposed waste in the environment. When access to petroleum diminishes, the value of bioplastics is likely to increase as there will be an urgency to replace the source of raw materials of plastic. As bioplastics become standard, manufacturing of raw materials sourced from agriculture more abundantly, making the raw materials cheaper as well. Although the option is currently available, as technology advances bioplastics can be made to avoid the monomers and additives that present harmful effects on human health or wildlife on a larger, more industry recognized scale.

APPLICATION of PLA, ORGANIC PE and POLYBUTYLENE SUCCINATE IN FOOD PACKAGING

The art and engineering of food packaging rely on creating a protective barrier with shelf-stable materials without compromising food safety. Many foods require multi-layered structures, using barriers made from plastic or metal to provide protection from the exterior environment (Helanto 2019). Depending on the item, packaging needs to prevent oxygen, carbon dioxide, moisture, aromatic compounds, water, micro-organisms, and grease (Helanto 2019). When applied correctly, packaging can enable shelf life, reduce food loss, and enhance food safety by supplying mechanical, chemical, and biological protection (Helanto 2019).

Each material is hard to assess due to the amount of additives that can be added to their compounds. There are often hundreds of combinations that can be created with different compounds, making testing the materials for migrants, oxo-barrier deficiencies, and durability difficult. In food packaging, these are still plastics that are single-use, but have the ability to be decomposed or compsted after use, rather than put in a landfill. There are observable benefits to bioplastics in the packaging industry, however more advancement is needed specifically in the food industry. Most bioplastics are considered “Generally Safe for Use” (Helanto 2019).

CONTROVERSY

The development and use of bioplastics has become a growing topic in the plastics and packaging industry as an option to improve the current climate crisis. Overall, there are slight benefits to producing bioplastics compared to synthetic plastics, however for the application of food packaging, may not be practical at the current level of development. In the future as the technology and bioplastics evolve, may become an undisputable alternative.

Currently, bioplastics are typically more expensive than synthetic plastics, however this is expected to diminish as they become more popular. There is also concern of the depletion of natural resources, as the cultivation of raw sources will put a strain on the natural and agricultural resources. Moral ethics come into play as many environmentalists dispute the idea of “should those crops be used to feed people and livestock rather than supplying potentially harmful plastics?”.

In addition, there is currently an insufficient waste management structure to allow for the separation and proper disposal of biodegradable materials at a national level in Canada. Most materials that can be recycled, composted or biodegraded are often sent to landfills as they are not accepted in the recycling facilities. Although many bioplastics claim that they degrade, in reality the plastic needs to be disposed of in very specific environmental conditions in order for the material to deteriorate completely, which cannot be achieved in a landfill. Due to this, bioplastics that are not sent to specialized recycling or composting facilities ultimately end up creating the same amount of waste pollution as synthetic plastic. Many companies are using the term ‘biodegradable’ as a selling feature of their product, however do not take into consideration the environmental effects after disposal of their packaging.

CONCLUSION

It is indisputable that there is a growing plastic waste crisis that exists in the world today, however as a consumer-based society in Canada, are not in a position to eliminate plastics from our supply chain as they offer several benefits in packaging. The development of bioplastics are generally a greener option compared to synthetic plastics when evaluating energy consumption and carbon emissions, however need to be disposed of properly in order to diminish the strain on plastic waste solution. More research is needed to undeniably consider bioplastics as a direct substitute for the application of single-use food plastic packaging, as there is little information available on the impact on food quality when bioplastics are used. The materials themselves are considered stable, however, very little testing has been done to compare these materials compared to traditional multi-layered packaging in a retail environment. As bioplastic continues to evolve and develop, it is likely that they will become more abundant in the food packaging industry, however are currently a viable alternative to completely substitute traditional plastic.

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