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Use Of Organic Fruit Residues To Obtain Bioplastics

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Abstract

The research of organic fruit waste as a source of raw material for the creation of bioplastics not only responds to the search for sustainable solutions to environmental problems related to waste and plastic pollution, but is also aligned with the growing global demand. of more environmentally friendly alternatives in all areas of production. The article delves into the perspective of using organic fruit waste as a way to manufacture bioplastics, which represent an eco-friendly alternative to traditional petroleum-derived materials. Emphasis is placed on the variety of fruits used in the production of bioplastics, as well as the characterization of these bioplastics, the various applications they can find in a wide range of industries, and the production methods that allow optimizing their viability. The exhaustive characterization of the resulting bioplastics is a fundamental pillar in this process. Understanding their mechanical properties, degradability, biocompatibility and thermal resistance is not only essential to ensure they are suitable for their intended applications, but also provides key information for further development and improvement. This characterization contributes to the acceptance and adoption of these bioplastics in the market, since it becomes a trust factor for end users and industries.

Keywords: *Organic waste, biodegradable, bioplastic, environmental impact, process optimization.*

Introduction

According to Smith, organic waste, including fruit waste, poses a significant environmental challenge due to its decomposition and release of greenhouse gases. Improper treatment of this waste can cont[1]ribute to climate change, as well as soil and water pollution.(2015)

Thorough characterization of bioplastics obtained from fruit residues is essential to determine their suitability for various applications; Several studies look at properties such as mechanical strength, degradability, biocompatibility, and thermal resistance. Methods are being investigated to optimize the processes of extraction and synthesis of bioplastics from organic fruit waste, which involves adjusting parameters such as temperature, reagent concentration and reaction time to improve the efficiency and final properties of bioplastics. (Narayan, 2005) (Oksman, 2008)

Bioplastics derived from fruit waste find applications in various industries, such as packaging, agriculture, and medicine that, despite advances, challenges such as process standardization,

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scalability, and public education on the importance of waste management remain pertinent. Using organic fruit waste as a raw material for the production of bioplastics can reduce reliance on conventional petroleum-based plastics and decrease the accumulation of synthetic plastic waste in the environment. In this area, life cycle assessment studies are carried out to compare the sustainability of bioplastics derived from fruit waste with conventional plastics, helping to understand the environmental impacts in terms of energy consumed, emissions and waste generated. (Al-Salem, 2009) (Huang & Zhao, 2017)

With these precedents, this document assumes the existence of a field of study in constant development, so an in-depth bibliographic exploration is carried out in aspects pertinent to the use of organic fruit waste to obtain bioplastics such as: new sources of raw material, more efficient processing techniques and broader applications for these bioplastics. It is hoped that this study can shed light on the existence of new lines of research in this sector, with great particularity on the diversity of fruits that can still offer new alternatives to the production of bioplastics.

Organic waste to obtain bioplastics

Research in this area has explored various fruits, processes and technologies to produce sustainable and biodegradable bioplastics.

In the first instance, and in relation to the subject at hand, several studies have been carried out in the field of the diversity of fruits that can be used for the production of bioplastics. Research has addressed a wide range of fruits, including those high in starch, cellulose, pectin, and other compounds. (Leiva, 2019) (Escalante, 2021)

On the other hand, several other studies have also addressed the development of methods for the extraction of organic fruit components useful for the production of different bioplastic products; At the same time, research has been carried out into methods of processing these compounds that allow effective processes and more efficient products; This includes chemical and enzymatic modification techniques. (Reis, 2019)

Around the production of different bioplastic compounds as another area of research, Nikkhah (2020), Bezerra (2020) and Valente (2020)They indicate that research has managed to produce various types of bioplastics, such as modified thermoplastic starch, polylactate (PLA), polyhydroxyalkanoates (PHA) among others, using the components extracted from fruits. The mechanical, thermal, and degradability properties of these bioplastics have been explored.

An aspect also explored is the use and applications that bioplastics obtained from fruit residues can have, especially in areas that concern the improvement of the environment. These applications seek to reduce inorganic plastic pollution and promote sustainability. (García-González, 2020)

Finally, and perhaps the main reason why research for the use of organic waste emerged, is the Focus on Sustainability and Circular Economy. Research has emphasized its importance in the production and use of bioplastics from fruit waste. Aspects such as the environmental footprint and production costs have been evaluated. (Soares & Reis, 2021) (Henshaw, 2021)

Fruit waste for bioplastics

The availability of fruit waste depends on the volume generated in markets or industries, using a pre-established methodology where the portion of production allocated to industrial processing, the rate of waste generation and other competitive uses are generated about 2200 million kilograms, which are mostly composed of starch or lignocelluloses. which, with physical, chemical or biotechnological transformations, can be used as raw material, filler material or precursor of bioplastics. (María Riera, 2018)

Organic fruit waste contains a variety of natural elements that can be harnessed for the production of bioplastics; These elements include:

- Starch: Starch is a carbohydrate present in many fruits and can be extracted from waste to produce thermoplastic bioplastics. Its versatility and ability to form flexible dies make it suitable for a variety of applications.
- Cellulose: Cellulose is a key structural component in the cell walls of fruits. Its use in the production of bioplastics has been investigated due to its abundance and mechanical properties.
- Phenolic Fibers and Compounds: Phenolic fibers and compounds present in fruits have also been explored as materials for bioplastics. These compounds often offer boosting and antioxidant properties.
- Pectin: Pectin, a polysaccharide found in most fruits, can be extracted and used in the production of bioplastics. Its ability to form gels and films makes it suitable for packaging and coatings.
- Sugars and Polysaccharides: Sugars and polysaccharides present in fruit waste can be fermented by microorganisms to produce bioplastics such as polyhydroxyalkanoates (PHAs).(2021)

One of the raw materials that has the potential to become bioplastic is starch because it has the ability to degrade modified with citric acid, filled with microcrystalline cellulose, plasticizer sorbitol and glycerol. The method of synthesis is the smelting of starch, water, microcrystalline cellulose (MCC) filler with sorbitol and glycerol of variable plasticizer with a filling composition (15-25% w/w), plasticizer composition. (Sojsadmin, 2020)

Bioplastics obtained from organic fruit waste

As studies were carried out to obtain bioplastics, different fruit residues were taken considering the different qualities that each of them presents, which is why the following table 1 is presented below to summarize the fruits used as raw material for the production of bioplastics.

Table 1. Fruits used in studies for the production of bioplastics

Fruit	Type: Bioplastic	Procurement Process	Compound Used	Common Uses	Year of Study
Grenade	Polyhydroxyalkanoates (PHAs)	Component extraction, microbial fermentation	Pomegranate Components	Packaging, Medical Devices	2003
Coconut	Polyhydroxyalkanoates (PHAs)	Coconut fibre extraction, microbial fermentation	Coconut fibres	Packaging, kitchenware	2005
Mango	Modified thermoplastic starch	Starch Extraction, Modification	Starch	Packaging, utensils, toys	2007
Durian	Modified thermoplastic starch	Starch Extraction, Modification	Starch	Packaging, Auto Parts	2008

Fig	Modified thermoplastic starch	Starch Extraction, Modification	Starch	Packaging, utensils	2011
Cherries	Modified thermoplastic starch	Starch Extraction, Modification	Starch	Packaging, Films, Electronic Components	2012
Berries	Polyhydroxyalkanoates (PHAs)	Component extraction, microbial fermentation	Components of berries	Packaging, medical products	2013
Kiwi	Polylactate (PLA)	Pectin and cellulose extraction, fermentation	Lactic acid, cellulose	Packaging, cutlery, single-use products	2014
Plantain	Polyhydroxyalkanoates (PHAs)	Starch extraction, microbial fermentation	Starch	Biodegradable packaging, compostable bags	2015
Watermelon	Modified thermoplastic starch	Starch Extraction, Modification	Starch	Packaging, disposable products	2015
Blueberry	Polyhydroxyalkanoates (PHAs)	Component extraction, microbial fermentation	Components of berries	Packaging, medical products	2016
Peach	Modified thermoplastic starch	Starch Extraction, Modification	Starch	Packaging, disposable products	2016
Pomegranate	Modified thermoplastic starch	Starch Extraction, Modification	Starch	Packaging, disposable products	2017
Tamarind	Modified thermoplastic starch	Starch Extraction, Modification	Starch	Packaging, disposable products	2017
Plum	Polylactate (PLA)	Pectin and cellulose extraction, fermentation	Lactic acid, cellulose	Packaging, disposable products	2018
Apple	Polylactate (PLA)	Pectin and cellulose extraction, fermentation	Lactic acid, cellulose	Packaging, disposable utensils	2018

Strawberry	Polyhydroxyalkanoates (PHAs)	Cellulose extraction, microbial fermentation	Cellulose	Packaging, medical articles	2018
Kiwi Actinidia	Polylactate (PLA)	Cellulose extraction, production	Lactic acid, cellulose	Containers, wrappings, disposables	2019
Papaya	Modified thermoplastic starch	Starch Extraction, Modification	Starch	Packaging, utensils, automotive components	2019
Melon	Modified thermoplastic starch	Starch Extraction, Modification	Starch	Packaging, utensils, disposables	2019
Guaba	Polylactate (PLA)	Pectin & Cellulose Extraction, Production	Lactic acid, cellulose	Packaging, bags, disposables	2019
Citrus	Polyhydroxybutyrate (PHB)	Cellulose extraction, microbial fermentation	Cellulose	Packaging, Films, Coatings	2020
Pineapple	Polyhydroxyalkanoates (PHAs)	Cellulose extraction, microbial fermentation	Cellulose	Packaging, medical products	2020
Passion fruit	Polylactate (PLA)	Pectin & Cellulose Extraction, Production	Lactic acid, cellulose	Packaging, utensils, disposables	2020
Carom	Polylactate (PLA)	Pectin and cellulose extraction, fermentation	Lactic acid, cellulose	Packaging, utensils, disposables	2020
Grapes	Polylactate (PLA)	Phenolic compound extraction, fermentation	Lactic acid	Packaging, coatings	2021

Processes for obtaining bioplastics

From the information in Table 1, processes have been developed to obtain the different bioplastics from organic fruit waste.

Table 2. Processes for obtaining bioplastics

Bioplastic	Procurement Process
PLA (polylactic acid)	Polymerization of lactic acid obtained by fermentation of corn starch or sugar cane. (Karamanlioglu, 2011)

PHA (polyhydroxyalkanoate)	Microbial fermentation of carbon-rich substrates (sugars, vegetable oils) followed by polymer extraction and purification. (Chen, 2012)
PCL (polycaprolactone)	Polymerization of caproic acid using catalysts and controlled temperature and pressure conditions. (Singhvi, 2019)
PHB (Polyhydroxybutyrate)	Microbial fermentation of carbon-rich substrates (glucose, glycerol) using PHB-producing bacteria. (Brigham, 2012)
Starch-based plastics	Extrusion and thermoforming of plasticized starch obtained from sources such as corn, potatoes or cassava. (Reddy, 2009)
PHBV (polyhydroxybutyrate-co-valerate)	Microbial fermentation of carbon-rich substrates (glucose, glycerol) using genetically modified bacteria to produce PHBV copolymers. (Verlinden, 2007)
PBS (polybutylenesuccinate)	Polycondensation of succinic acid and 1,4-butanediol under controlled conditions of temperature and pressure. (Zavasta, 1997)
PEF (polyethylene furanoate)	Polycondensation of furanic acid and ethylene glycol derived from fruit waste. (Hossain K. M., 2020)
PHO (hydroxylated polyolefin)	Hydroxylation of polyolefins, such as polyethylene, using suitable catalysts and reaction conditions. (Wang, 2020)

Bioplastics from fruit waste are usually obtained through processes of extraction of natural polymers present in these fruits or by converting the sugars and starches contained in fruit waste into plastic polymers. Table 2 shows that the main sub-processes for obtaining bioplastics can be summarised in Figure 1 below.

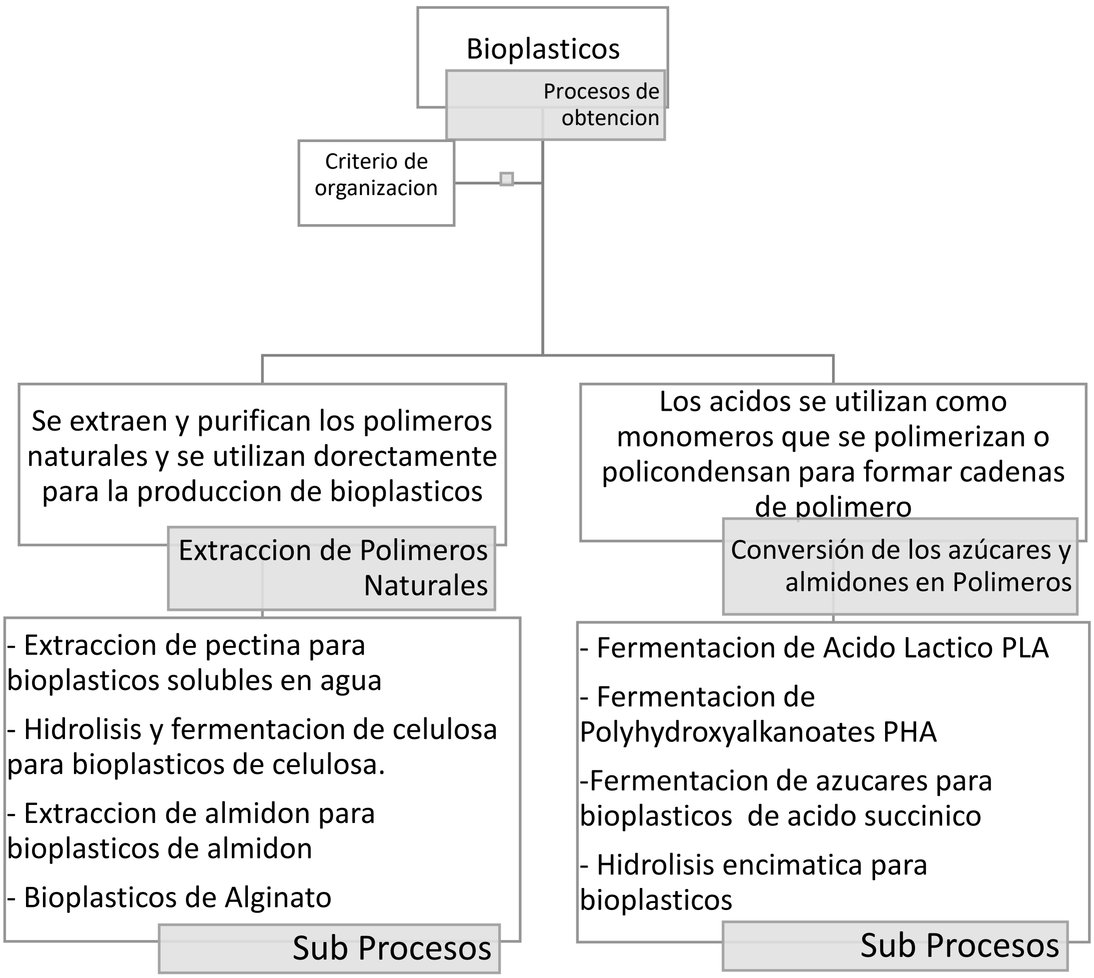

Figure 1. Organization of processes for obtaining bioplastics

The extraction of pectin for the production of bioplastics usually involves the separation and purification of pectin present in fruits and other plant materials. There are several methods and techniques to carry out this process, however, the three most important ones can be deduced from Figure 1, namely, "extraction", "hydrolysis" and "fermentation" as the main processes in obtaining the material necessary for the production of bioplastics from organic fruit waste.
The first process is the "extraction" of biomaterial from organic fruit waste. As it involves the use of different types of fruits, the extraction process is carried out in different ways as follows:

- **Hot Water Extraction**: This is one of the simplest and most widely used methods. Pectin is extracted by heating the fruit with hot water. Heat helps break the bonds between pectin molecules and other components of the fruit. Then, the extract is filtered and concentrated. (Willats, 2016)
- **Extraction with Citric Acid or Citric Acid and Salts**: In this method, an acidic solution, such as citric acid or a combination of citric acid and salts, is used to extract the pectin. Citric acid dissolves pectin and separates it from other components of the

fruit. Subsequently, a precipitation process is carried out to obtain the pectin in solid form. (Wikiera, 2019)

- **Enzymatic extraction**: Enzymatic extraction involves the use of enzymes, such as pectinase, to break down the pectin structure in fruit. This process is gentle and specific, allowing for efficient extraction of pectin with high purity. (Hinz, 2009)
- **Microwave Extraction**: Microwave pectin extraction uses microwave energy to heat and speed up the extraction process. This method can be faster than conventional hot water extraction. (Šimović, 2016)
- **Ultrasound-Assisted Extraction**: Ultrasound-assisted extraction uses ultrasonic waves to break down the cellular structures of the fruit and facilitate the release of pectin. This method can increase extraction efficiency and reduce processing times. (Aljawish, 2020)
- **High Pressure Extraction**: High-pressure extraction involves the use of hydrostatic pressure to separate the pectin from the fruit. The high pressure allows for efficient extraction at room temperature and maintains pectin quality. (Zhao, 2021)
- **Precipitation Extraction of Alcohol**: In this method, alcohol (usually ethanol or methanol) is used to precipitate the pectin from the extractor solution. Pectin is collected in solid form after precipitation (Ahmed, 2018)

The "hydrolysis" of cellulose for the production of bioplastics is a key process in the conversion of lignocellulosic biomass into biodegradable plastic materials. Here are some common types and forms of this process:

- **Acid Hydrolysis**: Acid hydrolysis involves the use of strong acids, such as sulfuric acid or hydrochloric acid, to break down cellulose into simple sugars, which can then be used to produce bioplastics. (Kim, 2018)
- **Enzymatic Hydrolysis**: Enzymatic hydrolysis uses cellulolytic enzymes, such as cellulases, to break down cellulose into fermentable sugars. This method is gentler and more specific than acid hydrolysis. (Li, 2016)
- **Alkaline Hydrolysis**Alkaline hydrolysis involves the use of an alkaline solution, such as sodium hydroxide, to break down cellulose into sugars and other chemicals. (Idris, 2020)
- **Biological Hydrolysis**: Biological hydrolysis uses microorganisms, such as bacteria or fungi, to break down cellulose into fermentable products, such as organic acids. (Koutinas, 2020)
- **Subcritical and Supercritical Hydrolysis**: These methods use water under subcritical or supercritical conditions to break down cellulose into sugars and other products. Subcritical and supercritical conditions allow for higher hydrolysis efficiency.

Acid "fermentation" processes for bioplastic production involve the conversion of sugars and other substrates into organic acids that can then be used as monomers for the synthesis of bioplastics, such as:

- **Lactic Acid Fermentation** (Lactic Acid Fermentation): In this process, microorganisms, such as lactic acid bacteria (e.g., Lactobacillus), ferment sugars to produce lactic acid, which is used as a monomer for bioplastics such as PLA (polylactic acid). (Dusselier, 2013)
- **PHA Fermentation** (Polyhydroxyalkanoates): In this process, bacteria such as Cupriavidus necator, Ralstonia eutropha, or Pseudomonas spp. use sugars and other substrates to produce polyhydroxyalkanoates (PHAs), which are versatile bioplastics. (Chen, 2009)

- **Succinic Acid Fermentation** (Succinic Acid Fermentation): In this process, sugars are fermented to produce succinic acid, which is used as a monomer for the synthesis of bioplastics such as PBS (polybutylene succinate). (Werpy, 2004)
- **Gluconic Acid Fermentation** (Gluconic Acid Fermentation): In this process, microorganisms convert glucose into gluconic acid, which can be used as a precursor in the production of bioplastics and other chemicals. (Horstmann, 2013)
- **Itaconic Acid Fermentation** (Itaconic Acid Fermentation): In this process, substrates such as starch or sugars are fermented to produce itaconic acid, which is used in the synthesis of bioplastic polymers. (Okabe, 2009)
- **Fermentation of Sugars for the Production of Aliphatic Polyesters**: In this process, sugars are used as a substrate for the production of aliphatic polyesters that can be used as bioplastics. (Amir, 2015)

Evaluation of the physical properties of bioplastics

Studies on bioplastics have evaluated a wide variety of physical aspects and properties. Some of the most common properties that have been evaluated in these studies include:

- Biodegradability and Decomposition: Studies often evaluate the ability of bioplastics to decompose in the environment and their rate of biodegradation.(Hossain K. M., 2018)
- Density: The density of bioplastics has been investigated, which may influence their applicability in various applications.(Soares B. G., 2013)
- Transparency and Opacity: The transparency of bioplastics is important in applications such as packaging and transparent films.(Gorrasi, 2019)
- Tensile Strength: The tensile strength of bioplastics is evaluated to determine their durability and ability to withstand external forces.(da Silva, 2019)
- Hardness: The hardness of bioplastics is measured using scales such as the Shore Scale and the Rockwell Scale.(Yeo, 2018)
- Flexibility: The flexibility and ability of bioplastics to bend and recover are important properties, especially in film and packaging applications.(Pan, 2021)
- Melting Point: The melting point of bioplastics is a critical thermal property that can affect their processing and applications.(Armentano, 2018)
- Chemical Resistance: The resistance of bioplastics to different chemicals and solvents is investigated. (Srivastava, 2017)
- Impact Resistance: The ability of bioplastics to withstand impacts is evaluated in terms of energy absorbed during a rupture.(Rosa, 2019)
- Modulus of Elasticity: The stiffness and ability of bioplastics to regain their original shape after deformation is measured.(Zarrinbakhsh, 2018)
- Thermal Conductivity: Some studies evaluate the thermal conductivity of bioplastics, which is important in specific applications.
- Gas Permeability: Gas permeability is an important property in packaging applications for food and oxygen and carbon dioxide sensitive products.

Some studies on the evaluation of the physical properties of some bioplastics obtained from organic fruit residues:

Table 3. Evaluation of the physical properties of bioplastics obtained from organic fruit residues

Composition of Bioplastic	Conditions of the Means of Production	Means of Evaluation	Results
Bioplastic based on banana peel pectin	Pectin Extraction & Processing	Impact Resistance Tests	Banana peel bioplastic showed adequate impact resistance for packaging applications (Vivek, 2017)
Bioplastic from Banana Peel processed and chemically treated	Extraction and processing of polymers from banana peels	Tensile Strength Tests	The bioplastic showed good tensile strength, suitable for film applications (Pereira, 2016)
Bioplastic based on banana starch as polymer matrix.	Extrusion & Molding Process	Flexibility & Impact Resistance Testing	Banana starch bioplastic showed high flexibility and impact resistance (Thirathumthavorn, 2010)
Banana Starch Bioplastic with Coconut Fibers as reinforcement	Polymer Mixing & Processing	Density Measurement	Bioplastic showed adequate density for lightweight component applications (Reddy, 2014)
Bioplastic from Orange Peel processed and chemically treated	Extraction and processing of polymers from orange peel	Biodegradability studies under controlled conditions	The bioplastic showed high biodegradability, suitable for eco-friendly applications (dos Santos, 2018)
Bioplastic from Apple Waste processed and mixed with other biodegradable polymers	Mixing and processing of polymers with the incorporation of apple waste	Gas Permeability Testing	The bioplastic showed low permeability to oxygen and carbon dioxide (Müller, 2012)
	Mixing and processing of polymers with the incorporation of apple peels	Mechanical Strength Tests	The bioplastic exhibited improved mechanical strength due to the incorporation of apple peels (Xie, 2013)
Bioplastic from Mango Waste Processed and Mixed with Corn Starch	Polymer mixing and processing with incorporation of mango waste	Mechanical Strength Tests	The bioplastic showed improved mechanical strength due to the incorporation of mango residues (Reddy & Yang, 2010)
Bioplastic from Lemon Peel Processed and Chemically Treated	Extraction and processing of polymers from lemon peel	Evaluation of solubility in water	The bioplastic showed controlled water solubility due to the presence of lemon peel (Jamróz, 2019)
		Tensile Strength Tests	The bioplastic showed good tensile strength, suitable for

			film applications (Pereira, 2016)
Bioplastic from strawberry pulp processed and mixed with potato starch	Mixing and processing of polymers with the incorporation of strawberry pulp	Flexibility & Elongation Testing	The bioplastic showed high flexibility and elongation, suitable for film applications (Rachtanapun, 2016)
Bioplastic from kiwi peels processed and mixed with corn starch	Mixing and processing of polymers with the incorporation of kiwi shells	Tensile Strength Tests	The bioplastic showed good tensile strength, suitable for film applications (Echegoyen, 2019)
Bioplastic from grapefruit peel, chemically processed and treated	Extraction and processing of polymers from grapefruit husks	Biodegradability studies under controlled conditions	The bioplastic showed high biodegradability, suitable for eco-friendly applications (dos Santos, 2018)
Bioplastic from guava shells processed and mixed with corn starch	Mixing and processing of polymers with the incorporation of guava shells	Flexibility & Elongation Testing	The bioplastic showed high flexibility and elongation, suitable for film applications (Galus, 2013)
		Tensile Strength Tests	The bioplastic showed good tensile strength, suitable for film applications (Echegoyen, 2019)
Guava pulp bioplastic processed and mixed with other biodegradable polymers	Mixing and processing of polymers with the incorporation of guava pulp	Gas Permeability Testing	The bioplastic showed low permeability to oxygen and carbon dioxide (Müller, 2012)
	Guava pulp processed and mixed with corn starch	Biodegradability studies under controlled conditions	The bioplastic exhibited high biodegradability, suitable for eco-friendly applications (dos Santos, 2018)
Bioplastic from grape peels processed and mixed with corn starch	Mixing and processing of polymers with the incorporation of grape peels	Mechanical Strength Tests	The bioplastic showed improved mechanical strength due to the incorporation of grape peels (Reddy & Yang, 2010)
Bioplastic from grape pulp processed and mixed with corn starch	Blending and processing of polymers with the incorporation of grape pulp	Gas Permeability Testing	The bioplastic showed low permeability to oxygen and carbon dioxide (Ochoa, 2018)

Bioplastic from Papaya Pulp Processed and Chemically Treated	Extraction and processing of polymers from papaya pulp	Evaluation of solubility in water	The bioplastic showed controlled water solubility due to the presence of papaya pulp (Jamróz, 2019)
Bioplastic from tangerine peel processed and mixed with potato starch	Mixing and processing of polymers with the incorporation of mandarin peel	Flexibility & Elongation Testing	The bioplastic showed high flexibility and elongation, suitable for film applications (Rachtanapun, 2016)
Bioplastic from Chemically Processed and Treated Pineapple Waste	Extraction and processing of polymers from pineapple waste	Biodegradability studies under controlled conditions	The bioplastic showed high biodegradability, suitable for eco-friendly applications (dos Santos, 2018)
Bioplastic from soursop pulp processed and mixed with other biodegradable polymers	Mixing and processing of polymers with the incorporation of soursop pulp	Gas Permeability Testing	The bioplastic showed low permeability to oxygen and carbon dioxide (Müller, 2012)
	Soursop pulp processed and mixed with corn starch	Biodegradability studies under controlled conditions	The bioplastic exhibited high biodegradability, suitable for eco-friendly applications (dos Santos, 2018)
Bioplastic from Processed and Chemically Treated Walnut Shell	Extraction and processing of polymers from walnut shells	Biodegradability studies under controlled conditions	The bioplastic exhibited high biodegradability, suitable for eco-friendly applications (Villalobos-Carvajal, 2013)
Bioplastic from pomegranate peels processed and mixed with corn starch	Mixing and processing of polymers with the incorporation of pomegranate shells	Tensile Strength Tests	The bioplastic showed good tensile strength, suitable for film applications (Echegoyen, 2019)
Bioplastic from Peach Pulp Processed and Mixed with Corn Starch	Mixing and processing of polymers with the incorporation of peach pulp	Evaluation of solubility in water	The bioplastic showed controlled water solubility due to the presence of peach pulp (Reyes, 2019)
Bioplastic from fig shells processed and mixed with corn starch	Mixing and processing of polymers with the incorporation of fig shells	Gas Permeability Testing	The bioplastic showed low permeability to oxygen and carbon dioxide (Ochoa, 2018)

Bioplastic from coconut pulp processed and mixed with corn starch	Mixing and processing of polymers with the incorporation of coconut pulp	Evaluation of solubility in water	The bioplastic showed controlled water solubility due to the presence of coconut pulp (Reyes, 2019)
Bioplastic from passion fruit shells processed and mixed with corn starch	Mixing and processing of polymers with the incorporation of passion fruit shells	Tensile Strength Tests	The bioplastic showed good tensile strength, suitable for film applications (Galus, 2013)
Bioplastic from Mangosteen pulp processed and mixed with corn starch	Mixing and processing of polymers with the incorporation of mangosteen pulp	Gas Permeability Testing	The bioplastic showed low permeability to oxygen and carbon dioxide (Ochoa, 2018)
Bioplastic from Plum Peels Processed and Mixed with Corn Starch	Mixing and processing of polymers with the incorporation of plum peels	Flexibility & Elongation Testing	The bioplastic showed high flexibility and elongation, suitable for film applications (Echegoyen, 2019)

Feasibility of new research in the field

As demand continues to grow, companies are looking for solutions to meet market expectations and comply with increasingly stringent regulations on single-use plastics. Leading companies have begun to adopt bioplastics in their supply chains and launch products that use these materials, responding to consumer expectations and promoting an image of environmental responsibility.

The European Union, for example, has set ambitious targets for reducing single-use plastics and promoting sustainable alternatives, which has boosted demand for bioplastics in the region. Globally, businesses and consumers are looking for greener and more environmentally friendly products, which has led to an increase in the adoption of bioplastics. (European Commission, 2022)

(Purnhagen, 2021) (Espinosa E. &., 2021)The growing demand for bioplastic-based products by companies reflects their commitment to sustainability and social responsibility. Companies are responding to this demand by introducing packaging, utensils, textiles, and other products made from bioplastics.

(Nestlé, 2022) (Coca-Cola, 2022)Food and beverage company Nestlé has set ambitious targets to reduce its environmental impact and promote sustainability. It has started using bioplastics in packaging and announced its commitment to make all Nestlé packaging recyclable or reusable by 2025. Coca-Cola, one of the largest beverage companies, has been working on developing biodegradable plastic bottles from plant-based sources, such as sugarcane. The company seeks to reduce its carbon footprint and contribute to the fight against plastic pollution. Immersed in the same principles are also international companies such as

Danone which already uses bioplastics in its dairy packaging, the cosmetics company L'Oréal has been exploring the use of bioplastics in its packaging and has set targets to reduce the environmental impact of its supply chain, Unilever for its part has been working on the use of bioplastics in packaging and has set targets to reduce the use of bioplastics in its packaging. virgin plastics and improve the recyclability of their packaging. Table 2 below shows a trend in increasing demand for bioplastic-based products produced mainly by organic fruit waste.(2022) (2022) (Unilever, 2023)

Table 2. Demand for bioplastics-based products

Year	Trend/Region	Characteristics of Demand	Enterprises
2020	Global	Increase in demand for compostable packaging and disposable products based on bioplastics. (Purnhagen, 2021)	IKEA, PepsiCo, Unilever
2021	Europe	Implementation of stricter regulations on single-use plastics, boosting the adoption of bioplastics. (European Commission, 2022)	Carrefour, Nestlé, Danone
2022	North America	Growth in demand for compostable packaging and utensils as companies look to reduce their carbon footprint. (Smithers, 2022)	Coca-Cola, McDonald's, Starbucks
2023	Pacific	Increasing adoption of bioplastics in food and beverage, cosmetics, and more sectors. (Bus22)	L'Oréal, Tesco, Kao Corporation

Feasibility also encompasses investment in research, development and scaling of technologies for the production of bioplastics from fruit waste where it reflects the industry's determination to move towards more environmentally friendly practices and in line with sustainability goals. (Nestle, 2022)
Companies, research institutions and governments around the world have invested significantly in the research and development of technologies for obtaining bioplastics from fruit waste, as can be seen in Table 3. These investments include the optimization of bioplastic extraction, chemical modification and formulation processes that meet mechanical, thermal and degradability property requirements. In addition, efforts have been made to scale up the production and commercialization of these bioplastics in different sectors, such as packaging, agriculture, and disposable products. (Nature Works, 2023)

Table 3. Investments made by companies and governments

Year	Company/Institution	Investment Amount	Featured Developments
2020	Nestlé	$30 million	Development of compostable packaging based on bioplastics (Nestle, 2022)
2021	Danone	$50 million	Investment in plant-based bioplastics research (Danone, 2022)
2022	European Union	€45 million	Funding for bioplastics projects at European level (European Commission, 2022)
2023	NatureWorks	$80 million	Expansion of PLA bioplastics production capacity (Nature Works, 2023)

Conclusions

The use of organic material from fruit waste has been widely studied, so a wide variety of these have been explored, however, there are still many others to be explored. The lines of research in this subfield are not only in the use of new fruits but also in the combination of different characteristics such as fruit-process, fruit-active compound, among others. On the other hand, there is also the possibility of incorporating new waste transformation processes to obtain bioplastics that meet the needs of industrial demand and daily use.
As there is a large number of fruits that have been studied and considering the small amount of bioplastics used in products on the current market, it implies the following aspects: the first refers to the slight implementation of administrative policies that exert pressure on companies for the massive use of these new biodegradable products, another aspect is the possible lack of products that really reflect the physical and chemical characteristics that are needed for their production. implementation; It may also be due to the fact that bioplastics do not yet constitute economic competition with petroleum products. Therefore, new lines of research are derived here that can be followed in future work.
Finally, studies on the use of organic fruit waste in the production of bioplastics are still feasible since large companies have a constant growth in their demand, so there is a growing investment on their part in this area.

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