

**PRODUCTION OF BIOPLASTIC FROM SWEET LIME PEEL AND  
ITS CHARACTERIZATION**

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**(20PBT001)**

**THESIS SUBMITTED TO**

**AVINASHILINGAM INSTITUTE FOR HOME SCIENCE AND HIGHER  
EDUCATION FOR WOMEN, COIMBATORE-641043**

**IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE  
DEGREE OF MASTER OF SCIENCE IN BIOTECHNOLOGY**

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**CERTIFICATE**

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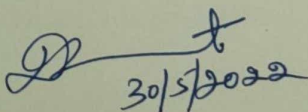
**Avinashilingam Institute for Home Science and Higher Education for Women**

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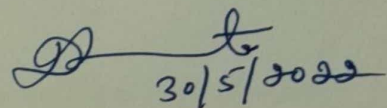
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## ACKNOWLEDGEMENT

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## **INTRODUCTION**

## 1. INTRODUCTION

All living and non-living things that occur naturally on earth are included in the natural environment. The built environment, which includes places and components that are heavily influenced by humans, contrasts with the natural environment. Environment is the biotic and abiotic surrounding of an organism or population, and encompasses the variables that have an influence in their survival, development and evolution.

All living things that have survived have had to adapt to their surroundings. Temperature, light, humidity, soil nutrients, and other variables all have an impact on any species in any environment. Some long-term changes to our planet's history have been substantial, such as the addition of oxygen to the atmosphere. This technique involved anaerobic bacteria breaking down carbon dioxide and using it as a carbon source.

Pollution occurs when toxins are introduced into the natural environment and cause harm. Chemical substances or energy, such as noise, heat, or light, can pollute the environment. Pollutants are either foreign substances/energies or naturally occurring pollutants that contribute to pollution. Pollution is frequently classified as either point source or nonpoint source.

A single identifiable source of air, water, thermal, noise, or light pollution is referred to as a point source of pollution. A point source is distinguished from other pollution source geometries by its small size. The sources are called point sources because they can be modelled as a mathematical point to ease analysis in mathematical modelling.

Pollution from dispersed sources is referred to as nonpoint source pollution (NPS). Pollution can cause serious difficulties in global geochemical cycles as well as the long-term viability of human and other creatures. Despite the fact that other organisms are affected by natural changes, humans are the primary perpetrator. A variety of hazardous compounds can enter the natural environment through a variety of natural and/or anthropogenic activities, disrupting biological systems and causing a slew of negative environmental changes (Kampa *et al.*, 2008). Large megalexes have been built in many urban locations that are not sustainable and have issues with waste management, heat islands, growing pollution, and crowding due to population growth, among other things (William *et al.*, 2011). CO<sub>2</sub> is hazardous to pregnant

women and can harm the foetus if they are exposed. Similarly, automobiles (Markert *et al.*, 2011)

The term “plastic” is derived from the Greek word “plastikos” meaning fit for molding, and “plastos” meaning molded. It refers to the material’s malleability or plasticity during manufacture that allows it to be cast, pressed, or extruded into a variety of shapes, such as films, fibers, plates, tubes, bottles, boxes, and much more. Plastic is the general common term for a wide range of synthetic or semi-synthetic materials used in a huge, and growing, range of applications. (Orezzoli *et al.*, 2018).

Plastics are derived from organic products, the same as wood, paper or wool. The materials used in the production of plastics are natural products such as cellulose, coal, and natural gas, salt and, of course, crude oil. (Orezzoli *et al.*, 2018).

The two major processes used to produce plastics are called polymerization and polycondensation, and they both require specific catalysts. In a polymerization reactor, monomers like ethylene and propylene are linked together to form long polymers chains. Each polymer has its own properties, structure and size depending on the various types of basic monomers used. (Gironi *et al.*, 2011).

Plastics are used in practically every area of our daily lives. Plastic is utilised in the production of daily items including beverage containers, toys, and furniture. Plastics' ubiquitous use necessitates proper waste management. Plastics are most commonly found in containers and packaging (e.g., soft drink bottles, lids, shampoo bottles), but they are also present in both durable and nondurable goods (e.g., appliances, furniture) (e.g. diapers, trash bags, cups and utensils, medical devices).

The use of plastics is widespread within our society; this is primarily due to the favourable thermal and mechanical properties of plastics making it a stable and durable material. The extensive global use of plastics has contributed heavily to environmental pollution; as plastics are not always properly discarded or recycled and consequently persist within the environment. The manufacturing processes required to produce plastic also creates large quantities of chemical pollutants. In recent years there has been a shift in public opinion, with people becoming more ecologically aware. The shift in public opinion and political influence combined with the increasing price of oil, has driven industries to investigate biodegradable alternatives to plastic, which are not manufactured using petrochemical

methods. Materials produced from synthetic polymers are widely used for a diverse range of applications in modern society. The production of biodegradable alternatives with greater compatibility in the environment is necessary if the applications continue to grow.



**Figure 1 Land Pollution**

According to the Marrickville Council of Australia, up to 100,000 whales, turtles, and birds die each year as a result of plastic in their habitat. Plastic bags not only harm our natural ecosystems, but they have also been linked to the deaths of many animals, primarily due to suffocation when consumed.

Not only animals, but also infants and small children have been reported to have died as a result of plastic bags. Children frequently seal their lips and nostrils with plastic bags because they are thin and airtight. Suffocation and, in some situations, death can occur if they are not being watched by an adult.

Plastic bags have long been known to harm the environment. It can take up to 1000 years for a single plastic bag to decompose fully. This allows the bags to linger in the environment for longer, resulting in a large build-up on the natural landscape (much more than degradable materials like paper). To put it another way, the more plastic bags used, the higher the risk of environmental harm.

Plastic bags are incredibly long-lasting. Plastic bags will most likely make up the majority of the pollutants. To put it another way, plastic bags have resulted in a significant increase in pollution levels.

Plastic bags are not renewable, which is one of their major drawbacks. This is because they are made of petrochemicals, which are a non-renewable energy source. It is possible to recycle them, although not as easily as paper bags. Plastic bags have the potential to survive hundreds of years.

Bioplastics are plastics made from renewable biomass sources like corn starch and vegetable fats and oils. In either anaerobic or aerobic settings, biodegradable bioplastics can degrade. Plastic is a huge contaminant on the planet. Bioplastic is being developed to replace synthetic plastic and to reduce pollution. The majority of degraded organic waste used to make bio plastic is microorganisms and algae.



**Figure 2 Bioplastic Products**

Bio-plastic has not been widely employed because large-scale manufacture of the material in industry is prohibitively expensive. Developed countries such as North America, Japan, and Western Europe dominated bioplastics production during the twentieth century. According to the findings of this study, Brazil will become one of the world's leading bioplastics manufacturers by 2013. In 2013, the demand for bioplastics in Japan will be six times more than 178000 metric tonnes. By 2013, China intends to create 100,000 metric tonnes of bioplastics. In Southeast Asia, the bioplastics market is still in its infancy. According to BCC's research, the market value of bioplastics has surpassed \$1 billion. (Shreema, 2014)

Thus the present study was focused on the following objectives,

- To synthesize, characterize and optimize mosambi peel based bioplastic.
- To optimize operating process variable specifically peel powder concentration, concentration of glycerol, drying temperature and residence time for hydrolysis
- To investigate the characteristic of the synthesized bioplastics produced (FTIR test, XRD Analysis , solubility, swelling test and biodegradability of the produced bio film)

This study provides two key benefits that can be used as advice and input for future research in actual experiments. Its practical usefulness includes the ability to employ the research's optimised process parameters to synthesis a higher-quality bioplastic from sweet lime peel, and it may be used as a base for scaling up sweet lime peel-based bioplastic manufacturing. Another advantage is that this research can be used as a starting point for future studies. It can be used as a starting point for study into strategies to increase the quality of bioplastic as well as research into bioplastic manufacturing from trash in general.

## **REVIEW OF LITERATURE**

## **2. REVIEW OF LITERATURE:**

### **2.1 PLASTIC**

A plastic is a synthetic or man-made polymer that resembles natural resins found in trees and other plants in many respects. Plastics are defined as "any of numerous complex organic compounds created by polymerization, capable of being moulded, extruded, cast into various shapes and films, or pulled into filaments and used as textile fibres," according to Webster's Dictionary. (Patil, 2018).

#### **2.1.1 HISTORY AND WORLDWIDE USE OF PLASTICS**

Natural plastics and man-made plastics are the two major categories in which plastics have evolved. Natural plastics have been used by humans for many years for diverse reasons. Egyptians, for example, preserved their deceased by soaking burial wrappings in natural resins. Natural plastics, on the other hand, were in low supply and difficult to shape. Scientists began to search for more efficient methods and trustworthy plastic source materials as a result of these and other limitations. (Cucci *et al.*, 2008).

In 1862, British scientist Alexander Parkes introduced Parkesine, the first man-made plastic. In 1909, an American chemist named Leo Hendrik Baekeland developed Bakelite, the first totally synthetic man-made material (Cucci *et al.*, 2008).

When Giulio Natta developed Polypropylene in 1954, commercial production of the resin began in 1957, the development of plastics or polymers accelerated. It is the most frequently used thermoplastic on the planet. Celluloid for billiard balls, polyvinyl chloride (PVC), which is used in various industries, and viscose (rayon) for clothes were among the important natural/synthetic polymers developed throughout the nineteenth century. (Neal *et al.*, 2009)

In the first half of the twentieth century, the development of modern plastics exploded, with at least 15 new polymer types produced. Plastics have had a lot of success as a material; they've proven to be adaptable in a variety of types and forms, including natural polymers, modified natural polymers, thermosetting plastics, thermoplastics, and, more recently, biodegradable polymers. (Neal *et al.*, 2009)

The history of plastic products manufacturing in Ethiopia has a 50 years long journey, “Currently there are a total of 350 plastic manufacturing companies in Ethiopia producing 12 categories of products ranging from automotive tire to the latest wood and plastic blend home partitions and PVC made tiles and small household furniture,” said Eng. Yonas Abate, Plastic and Rubber Industries Development Director at the state-owned Ethiopian Chemical and Construction input Industries Development Institute. (Andualem, 2017)

Plastics are a valuable resource for civilization, as they often provide functionality that other materials cannot simply or affordably replace. The majority of plastics are durable and can survive for hundreds of years. They've replaced metals in most manufactured goods' components, including computers, vehicle parts, and refrigerators, and in the process, they've made them cheaper, lighter, safer, stronger, and easier to recycle. (Yates, 2013) Plastics have mostly replaced paper, glass, and cardboard in packaging, lowering costs and cutting carbon emissions while also better protecting the objects they protect. (Goodall, 2011)

About 4% of the world's oil production is converted into plastics for use in products as varied as shopping bags and the external panels of cars. Another few percent is used in processing industries because oil-based plastics require substantial amounts of energy to manufacture. Each kilo gramme of plastic typically requires 20 kilowatt hours of energy in the manufacturing process, more than the amount needed to make steel of the same weight. Almost all this comes from fossil sources.

Changing lifestyles have dictated the need for foods that offer convenience to the consumer in a countless of ways, such as minimizing preparation time, easy opening of the container and single service, while also offering high quality throughout an extended shelf life. Plastic packaging has responded to these demands, and creativity with plastics has been limited only by the imagination of the designer. (Andualem, 2017)

### **2.1.2 Problems Associated With Plastics**

Despite their many uses and desirable properties, petroleum based conventional plastics have many disadvantages. The major reasons for looking at alternatives to plastics are because of the following drawbacks: (Prasad *et al.*, 2014)

## **A. Production problems**

Plastics are made from petroleum, natural gas, or comparable materials. They are converted to a polymer resin, which is then moulded and fashioned into the desired product. Plastics, on the other hand, add to oil dependency as a petroleum by-product, and as it is widely acknowledged that oil will not be available indefinitely, this leads to a future raw material issue. (Janusz *et al.*, 1994)

## **B. Plastic recycling**

Despite the fact that many types of plastics could potentially be recycled, only a small amount of plastic actually enters the recycling process. PET (polyethylene terephthalate) is the most often recycled plastic, which is used in soft drink bottles. PET bottles are recycled at a rate of 15 to 27 percent per year. High-density polyethylene (HDPE), which is used in shampoo bottles, milk jugs, and two-thirds of rigid plastic containers, is another form of plastic that is often recycled. HDPE plastic is recycled at a rate of about 10% per year. (Prasad *et al.*, 2014) These numbers reveal that the vast majority of plastics generated are not recycled, posing a serious concern as long as production continues uninterrupted.

## **C. Landfilling**

Plastic bags, in particular, end up in landfills in large quantities. Because waste space is becoming increasingly scarce and plastics are non-biodegradable, landfills face unique challenges.

The problem is exacerbated by a report (Zero Waste America, 1988-2008) that indicated 82 percent of the studied landfill cells had leaks, with 41% having a leak larger than 1 square foot.

Furthermore, these leaks can only be detected if they reach landfill monitoring wells. Both ancient and new landfills are frequently located near major bodies of water, making leak detection and cleanup challenging. All of these factors indicate that dumping plastics in landfills is not a long-term solution. (Prasad *et al.*, 2014)

## **D. Incineration**

Plastic incineration has been supported by some industry authorities as a form of

disposal. Pyrolysis, which is a related process, converts plastics into a hydrocarbon soup that may be reused in oil and chemical refineries. Incineration and pyrolysis, on the other hand, are more expensive than recycling, use more energy, and result in serious air pollution.

Despite recent strengthening of emission rules for waste incineration power plants, the EPA noted in 2007 that the waste-to-energy process still "creates considerable emissions, including trace levels of harmful air pollutants."

Incinerators are a major producer of 210 distinct dioxin compounds, as well as mercury, cadmium, nitrous oxide, hydrogen chloride, sulphuric acid, fluorides, and particulate matter small enough to stay in the lungs permanently. (Woody, 2007)

### **E. Effects on biodiversity**

Wildlife, human health, and the environment are all negatively impacted by plastic litter. Scientists have reported 267 species of animals (including invertebrate groups) that have been injured or killed as a result of plastic pollution, either directly or indirectly. Poisoning from plastic ingestion, asphyxia from entanglement in plastic nets, and other factors all contribute to these issues.

Millions of tonnes of plastic bottles, bags, and trash in the world's oceans are degrading and leaching chemicals, posing a hazard to marine life and humans. Large amounts of plastic have been discovered in the stomachs of some marine creatures, such as sea turtles. Because the plastic obstructs the animal's digestive tract, it usually starves. Occasionally, little pieces of plastic are unintentionally dropped. (Chris, 2010)

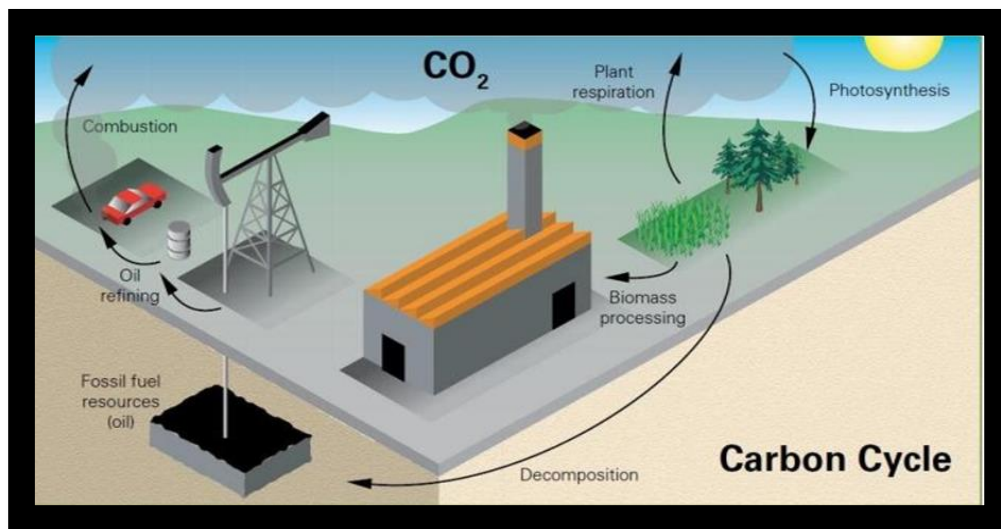
### **F. Carbon cycle**

When a plant grows, it absorbs carbon dioxide, and when it decomposes, it releases carbon dioxide back into the atmosphere — it's a closed loop cycle. We disturb the natural cycle when we extract fossil fuels from the planet, releasing carbon dioxide into the atmosphere faster than natural processes can remove it. As a result, carbon dioxide levels in the atmosphere are rising. Furthermore, because fossil fuels take millions of years to create, they are nonrenewable resources. To put it another way, we are depleting fossil resources faster than they can be replenished.

When we use fossil fuels to manufacture things like plastics, we contribute to

environmental imbalances by depleting valuable fossil resources thereby increasing the carbon footprint of the world.

These problems can be overcome. All the major oil-based plastics have substitutes made from biological materials. The polyethylene in a shopping bag can be made from sugar cane and the polypropylene of food packaging can be derived from potato starch. Plastics are irreplaceable and will all eventually be made from agricultural materials. (Thompson *et al.*, 2009)



**Figure 3 Carbon Cycle (Chris, 2010)**

## 2.2 Bioplastic

A bioplastic is a plastic that is made partly or wholly from polymers derived from biological sources such as sugar cane, potato starch, corn starch, banana peel starch or the cellulose from trees, straw and cotton. (Chen, 2014)

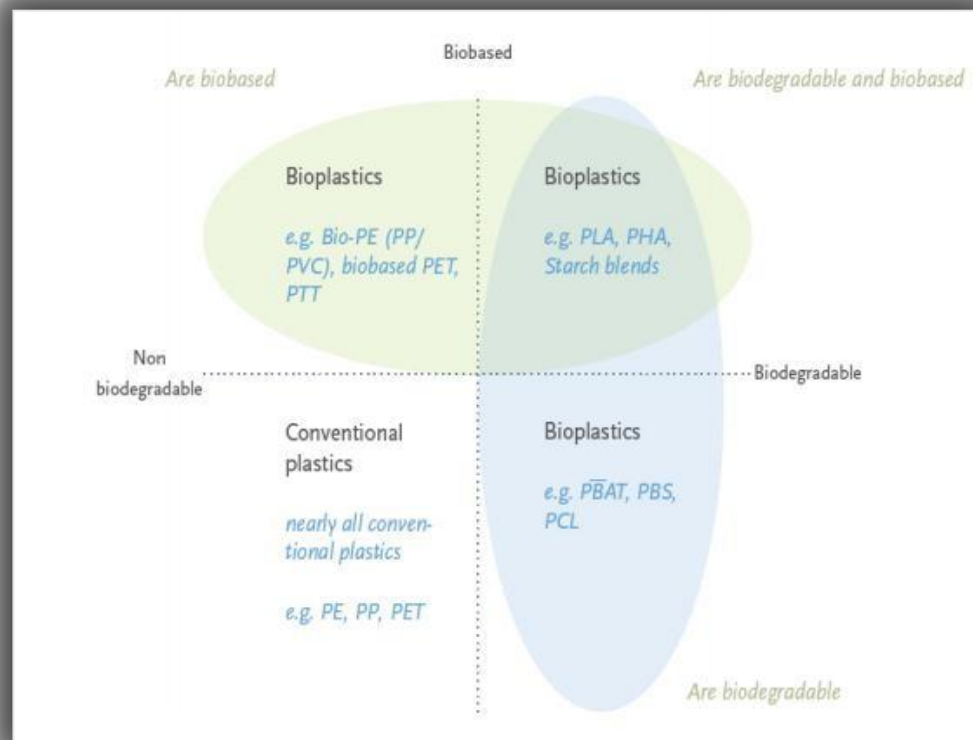
Bioplastics are usually derived from sugar derivatives, including starch, cellulose, and lactic acid but can also be made from agricultural by-products and also from used plastic bottles and other containers using microorganisms. Common plastics (petro based polymers) are derived from petroleum or natural gas. Not all bioplastics are biodegradable or biodegrade more readily than commodity fossil-fuel derived plastics. (Chua *et al.* 1999)

Bioplastics is a broad term used to describe a range of plastic materials that are either

biodegradable or derived from renewable resources or both. Some bioplastics degrade in the open air, others are made so that they compost in an industrial composting plant, aided by fungi, bacteria and enzymes. Others mimic the robustness and durability of conventional plastics such as polyethylene or PET. Bioplastics can generally be directly substituted for their oil-based equivalent. Indeed, they can generally be made to be chemically identical to the standard industrial plastics. (Buchholz, 2012)

Generally bioplastic materials can be grouped according to their properties as follows:

- **Bio-based and biodegradable bioplastics:** These are manufactured from renewable resources, such as plant biomass, will decompose in certain environments. Disposable items such as packaging, drink bottles, single-use food containers, and silverware can all benefit from these materials. They are more environmentally friendly since they conserve fossil fuel resources and, when properly disposed of, promote plant growth.
- **Bio-based and long-lasting (non-biodegradable) bioplastics:** These are manufactured from renewable resources but are intended to last longer (for example, carpet fibres and interior car panels). These materials are more sustainable when they are made from renewable resources. In addition, employing them to replace metal components in automobiles reduces vehicle weight, which improves fuel economy.
- **Petrochemical-based and biodegradable bioplastics:** There are some petrochemical-based plastics that can be biodegraded by the microbes in the soil, compost or oceans. (Buchholz, 2012)



**Figure 4 Broad categories of Bioplastics (Buchholz, 2012)**

### 2.2.1 Development of Bioplastics

Galalith, the first bio-based plastic, was developed by German chemists in 1897. Galalith is a bioplastic made from milk that is commonly found in buttons. Following a German scientist's discovery of bioplastics, scientists began to develop a variety of bioplastics from various raw materials with enhanced heat resistance and plastic properties. Some of the important discoveries are mentioned in Table 2-1 with a brief explanation. (Jouhara *et al.*, 2017)

The petroleum crisis of the mid-1970s brought renewed interest in finding alternatives to petroleum-based products. The rise of molecular genetics and recombinant DNA technology.

After that time further spurred research, so that by the beginning of the 21st century the structures, methods of production, and applications for numerous types of bio-based plastics had become established.

Bio-based plastics that were either in use or under study included PHB and

polyhydroxyalkanoate (PHA), both of which are synthesized within specialized microbes, as well as polylactic acid (PLA), which is polymerized from lactic acid monomers produced by microbial fermentation of plant-derived sugars and starches. (Lackner, 2015)

<b>Year</b>	<b>Bioplastic Discovery or Development</b>	<b>Brief Description</b>
1862	Parkesine - Alexander Parkes	At the Great London Exhibition, Alexander Parkesine displays Parkenisine, the first plastic. Parkesine is made from nitrocellulose. (White, 1998)
1897	Galalith - German chemists	Still produced today, Galalith is a milk-based bioplastic that was created by German chemists in 1897. Galalith is primarily found in buttons. (Raschka <i>et al.</i> , 2013)
1907	Bakelite - Leo Baekeland	Leo Baekeland invented Bakelite, which received the National Historic Chemical Landmark for its non-conductivity and heat-resistant properties. It is used in radio and telephone casings, kitchenware, firearms and many more products. (Pathak <i>et al.</i> , 2014)
1912	Cellophane - Jacques E. Brandenberger	Brandenberger invents Cellophane out of wood, cotton, or hemp cellulose. (Raschka <i>et al.</i> , 2013)
1920s	Polylactic ACid (PLA) -Wallace Carothers	Wallace Carothers finds Polylactic Acid (PLA) plastic. PLA is incredibly expensive to produce and is not mass-produced until 1989. (Whiteclouds, 2018)
1926	Polyhydroxybutyrate (PHB) -	Maurice Lemoigne invents polyhydroxybutyrate
1930s	Soy bean-based bioplastic car - Henry Ford	The first bioplastic car was made from soy beans by Henry Ford.

1983	Biopal - Marlborough Biopolymers	The first bioplastics company, Marlborough Biopolymers, is started which uses a bacteria-based bioplastic called biopal.
1989	PLA from corn - Dr. Patrick R. Gruber; Matter-bi - Novamount	The further development of PLA is made by Dr. Patrick R. Gruber when he figures out how to create PLA from corn.  The leading bioplastic company is created called Novamount. It uses matter-bi, a bioplastic, in multiple different applications.
1992	PHB can be produced by Arabidopsis thaliana (a small flowering plant)	It is reported in Science that PHB can be produced by the plant Arabidopsis thaliana. (Poirier <i>et al.</i> , 1992)
2007	Mirel (100% biodegradable plastic) by Metabolic inc. is market tested	Metabolix inc. market tests its first 100% biodegradable plastic called Mirel, made from corn sugar fermentation and genetically engineered bacteria. (DiGregorio, 2009)
2012	Bioplastic is developed from seaweed	A bioplastic is developed from seaweed proving to be one of the most environmentally friendly bioplastics based on research published in the journal of pharmacy research A bioplastic is developed from seaweed proving to be one of the most environmentally friendly bioplastics based on research published in the journal of pharmacy research (Rajam <i>et al.</i> , 2018)
2013	Bioplastic made from blood and a cross-linking agent which is used in medical procedures	A patent is put on bioplastic derived from blood and a crosslinking agent like sugars, proteins, etc.(iridoid derivatives, diimidates, diones, carbodiimides, acrylamides, dimethylsuberimidates, aldehydes, Factor XIII, dihomobifunctional NHS esters, carbonyldiimide, glyoxyls, proanthocyanidin, reuterin). This invention can be applied by using the

		bioplastic astissue, cartilage, tendons, ligaments, bones, and being used in stem cell delivery. (Campbell, 2004)
2014	Bioplastic made from vegetable waste	It is found in a study published in 2014 that bioplastics can be made from blending vegetable waste (parsley and spinach stems, the husks from cocoa, the hulls of rice, etc.) with TFA solutions of pure cellulose creates a bioplastic. (Bayer, <i>et al.</i> , 2014)
2016	Car bumper made from banana peel bioplastic	An experiment finds that a car bumper that passes regulation can be made from nano-cellulose based bioplastic biomaterials using banana peels (Hossain <i>et al.</i> , 2016)
2017	Bioplastics made from lignocellulosic resources (dry plant matter)	A new proposal for bioplastics made from Lignocellulosics resources (dry plant matter).(Brodin <i>et al.</i> , 2017)
2018	Bioplastic furniture, bio-nylon, packaging from fruit	Many developments occur including Ikea starting industrial production of bioplastics furniture (Barret, 2018).
2019	Five different types of Chitin nanomaterials- Korea Research Institute of Chemical Technology	Five different types of Chitin nanomaterials were extracted and synthesized by the 'Korea Research Institute of Chemical Technology' to verify strong personality and antibacterial effects. When buried underground, 100% biodegradation was possible within 6 months (Tran, 2019)

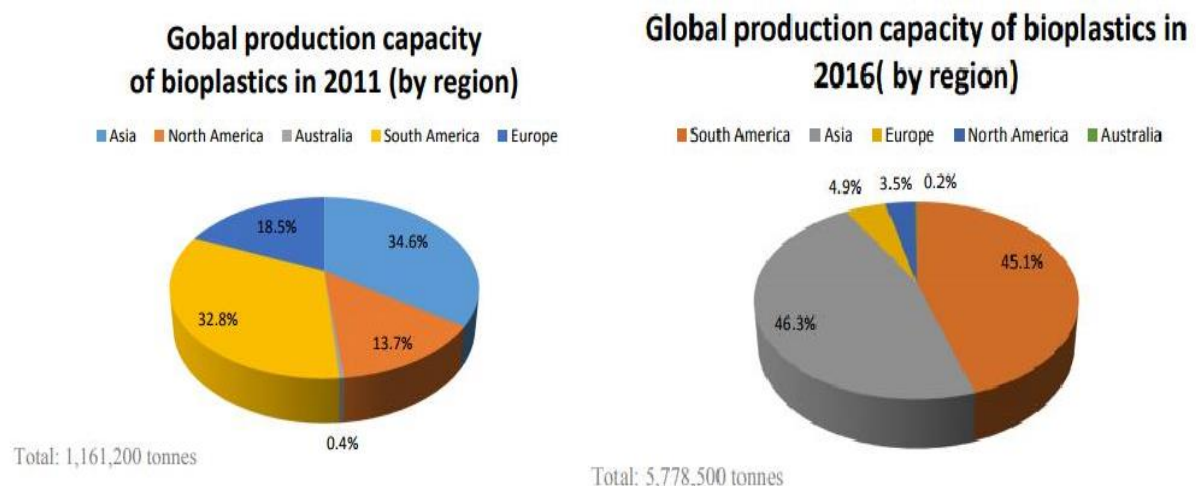
## 2.2.2 The World Plastic Industry and the Role of Bioplastic

The annual output of the world’s plastics industry is about 300 million tonnes a year. (Weiss, 2012) This number has grown by a few per cent per year over the last decade. The bioplastics industry is much smaller, it only represents approximately 0.2% of the global polymer market, but the growth rate of bioplastics is much higher. Most sources suggest that this part of the plastics industry is growing at least 20% a year. Not even the most fervent advocates of the bioplastics suggest that they will quickly replace all oil-derived compounds though most people expect rapid growth to continue. (Künkel, 2016)

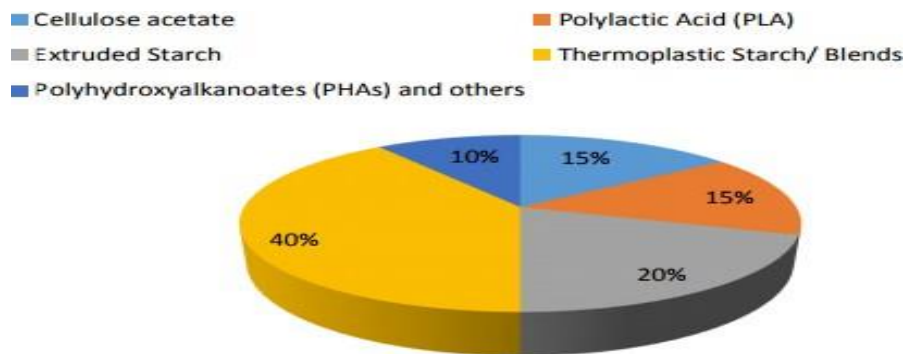
### 2.2.3 Market Size

Growing demand for more sustainable solutions is reflected in growing production capacities of bioplastics: in 2011 production capacities amounted to approximately 1.2 million tonnes. Market data of “European Bioplastics” forecasts the increase in the production capacities by fivefold by 2016 – to roughly 6 million tons. (Mohanty *et al.*, 2013)

The factors driving market development are both internal and external. External factors make bioplastics the attractive choice. This is reflected in the high rate of consumer acceptance. Moreover, the extensively publicized effects of climate change, price increases of fossil materials, and the increasing dependence on fossil resources also contribute to bioplastics being viewed favorably. (Reddy *et al.*, 2013)



**Figure 5 Global production of bioplastic by region (Mohanty *et al.*, 2013)**



**Figure 6 Bioplastics Market Share (Mohanty et al., 2013)**

### 2.2.3 Advantages of bioplastic

#### a) Major Consumer Goods Brands and Bioplastics

Over the last five years many of the world's largest consumer good companies have begun to employ bioplastics in the packaging of their products. Examples include Coca Cola's use of a mixture of a conventional plastic and bioplastic in its soft drink bottles (petroleum PET and up to 30% plant-based equivalent), Proctor and Gamble's bioplastic shampoo packaging and Nestle's adoption of a bioplastic top for his Brazilian milk products and 30 other upcoming projects and Sun Chip, a subsidiary of PepsiCo's Frito-Lay snacks unit. (Ottman, 2011)

These companies are among the biggest consumer goods companies in the world, with operations in almost every country. All of them appear to be committed to an increase in the use of bioplastic packaging for their products. Their reasons are simple: these businesses are watching the actions and attitudes of their customers who are increasingly concerned about the use of fossil fuel resources and, particularly, about indestructible litter. Bioplastics are important in helping consumer goods companies present their brands in a favorable light. Recyclable or compostable packaging made from biological materials can be used to make their products more environmentally friendly in the eyes of consumers. Although bioplastics may be more expensive per kilo of packaging, the extra cost is more than outweighed by the benefits seen by purchasers. The client lists of the major bioplastic suppliers include most of the largest and best-known consumer goods companies, ranging from the Shiseido cosmetics brand to Ecover, the Belgian cleaning products company. (Ottman, 2011)

## **b) The value of the reduction in landfill/expensive preparation for recycling**

Some bioplastics are as robust and durable as their oil-based equivalents. Others will rapidly break down in commercial composting plants. These rapidly biodegradable plastics have high value in some circumstances such as when plastics become inevitably mixed with other streams of compostable waste and would otherwise need to be hand separated. For example, quantities of plastic material are used in greenhouse applications. A productive application for bioplastics is the ties that hold tomato vines to the support wires in commercial greenhouses. After the crop is concluded, the waste organic material, including the ties and other plant-based plastics such as the small pots in which plants are grown as seedlings, can be quickly and efficiently cleared and taken to be composted. Conventional plastics would have to be separated by hand at great expense and usually then sent to an incinerator or landfill. . (Martien, 2017)

A bioplastic mulch that will dissolve in the soil over the winter is much better because it saves time and money but also adds to the carbon content of the soil, helping to maintain fertility. In other important agricultural uses, such as for trimmer cord (“weedwacker“ in the US, full biodegradability means that small pieces of plastic filament do not persist in the environment. As disposal sites fill up around the world, the need either to recycle plastics or to compost them can only increase, adding further buoyancy to bioplastic sales. (Martien, 2017)

In a similar move, municipalities around the world collecting food waste from homes are now often providing compostable plastic bags into which the food goes prior to collection. Householders benefit from easier and more hygienic storage of the waste. The municipality can collect the bag and does not have to separate it from the waste food before the composting process begins. While these bags are not as strong as the equivalent standard polyethylene bag, they perform their functions well.

## **C Litter**

The best understood advantage of biodegradable bioplastics lies in the reduction of permanent litter. Plastic single use shopping bags are the most obvious example of how plastics can pollute the environment with huge and unsightly persistence. A large fraction of the litter in our oceans is of disposable plastic bags. Cities and countries around the world are taking action against the litter, sometimes by banning non-degradable plastic bags entirely. Italy has

decided to block the use of non-biodegradable single use shopping bags from the beginning of 2012. The city of Portland, Oregon has just (July 2011) joined several dozen US municipalities in banning most plastic bags. These legislative changes represent a clear trend as politicians respond to the irritation over the persistence of plastic bag litter in the world's seas, rivers and rural and urban environments. (Chen, 2014)

Some places will continue to allow plastic bags that are genuinely biodegradable and meet the published standards for compostability. Biodegradable bioplastic bags will be allowed in Italy, providing a huge boost to the European market for these products not least because until now the country has been the largest European market for single use shopping bags. (Chen, 2014)

#### **D. Bioplastics demand will continue to grow**

Continued research and development in bioplastics is creating high quality products for a wide variety of industries. Now that the benefits of biologically sourced plastics are well-understood, their market share is likely to rise sharply. The three drivers of growth – the importance of brand image to consumer goods companies, the value of joint composting and the reduction of litter – will provide the spur for continued growth in bioplastics across the world. (Kasterine, 2012)

#### **E. The carbon footprint of plastics**

Calculating the greenhouse gas reductions arising from the use of bioplastics is a complex and controversial area. But it is nevertheless important to try to quantify the benefits from making plastics from biological materials in order to encourage further debate and research.

The first point to make is that the carbon footprint of a bioplastic is crucially dependent on whether the plastic permanently stores the carbon extracted from the air by the growing plant. A plastic made from a biological source sequesters the CO<sub>2</sub> captured by the plant in the photosynthesis process. If the resulting bioplastic degrades back into CO<sub>2</sub> and water, this sequestration is reversed. But a permanent bioplastic, made to be similar to polyethylene or other conventional plastics, stores the CO<sub>2</sub> forever. Even if the plastic is recycled many times, the CO<sub>2</sub> initially taken from the atmosphere remains sequestered. (Goodall, 2011)

Plastics derived from biological sources still require additives such as plasticizers to provide the product with the desired properties. Bioplastics, on the other hand, do not contain bisphenol A, an endocrine disruptor that is thought to leach from plastics. Most countries have not yet outlawed bisphenol A since it is swiftly eliminated by most animals, including humans. However, given the high amounts of continued exposure to this dangerous chemical from traditional plastics, consumers may choose to avoid it and switch to safer bioplastic alternatives. (Kasterine, 2012)

### **2.2.5 Disadvantage of bio plastic**

They are generally two or three times more expensive than the major conventional plastics such as polyethylene or PET. This disadvantage will tend to diminish as bioplastics manufacturing plants become larger and benefit from economies of scale. When the local biological feedstock is particularly cheap, as it is in Brazil, large bio- polyethylene plants may already be close to being cost-competitive with oil-based alternatives. But more generally, the crude oil for a kilo of plastic costs around €0.20 but the corn, a key source of feedstocks for bioplastics currently costs about twice this amount.

- Their physical properties aren't always an exact match for the comparable polymer. The differences are often minor, such as the biological version's slightly different texture, but in rare circumstances, the bioplastic cannot replace the conventional plastic. However, for the most significant plastic, polythene, the bio-based product is identical to the oil-based product.
- Bioplastics have the potential to compete in a wide range of market categories. Bioplastics are projected to make significant inroads into traditional plastics' market dominance in some circumstances, while struggling in others. Biodegradable plastics can replace around 45 percent of overall sales of oil-based plastics in horticulture and 25% of those used in catering, according to Novamont, the biggest Italian bioplastics manufacturer. Others believe these figures are too low.
- Bioplastics vs. food in a variety of situations Bioplastics provide a number of advantages over traditional goods. Despite their current limited function, there is a critical issue that needs to be addressed now and in the future. Many bioplastics are now manufactured from sugars and starches extracted from crops that would otherwise be grown for food. The bioplastics sector, like the liquid biofuels industry, must decide

whether the rise of bioplastics would reduce the amount of land available for food production or boost the motivation to clear wooded areas to make more arable land. Approximately 300,000 hectares are used to grow the crops that are processed into plastics by the industry. If all of today's plastics were manufactured from this material

- Finally, we need to consider the impact of improved recycling. We are stressing the importance of the recycling of non-biodegradable plastics, because whether from oil or from plant matter. Because the world needs to be more economical in its use of its scarce resources. Whether this is the oil used for most plastics or the starches, sugars and cellulose for biological plastics, we cannot afford to continue to throw away three quarters of the plastic we use. (Gironi *et al.*, 2010)

### 2.2.6 Classification of bioplastics

The Flowing diagram shows an attempt to classify the biodegradable polymers into two groups and four different families. The main groups are

- The agro-polymers (polysaccharides, proteins, etc.)
- The bio polyesters (biodegradable polyesters) such as poly lactic acid (PLA), poly hydroxylalkanoate (PHA), aromatic and aliphatic co polyesters. (Reddy *et al.*, 2013)

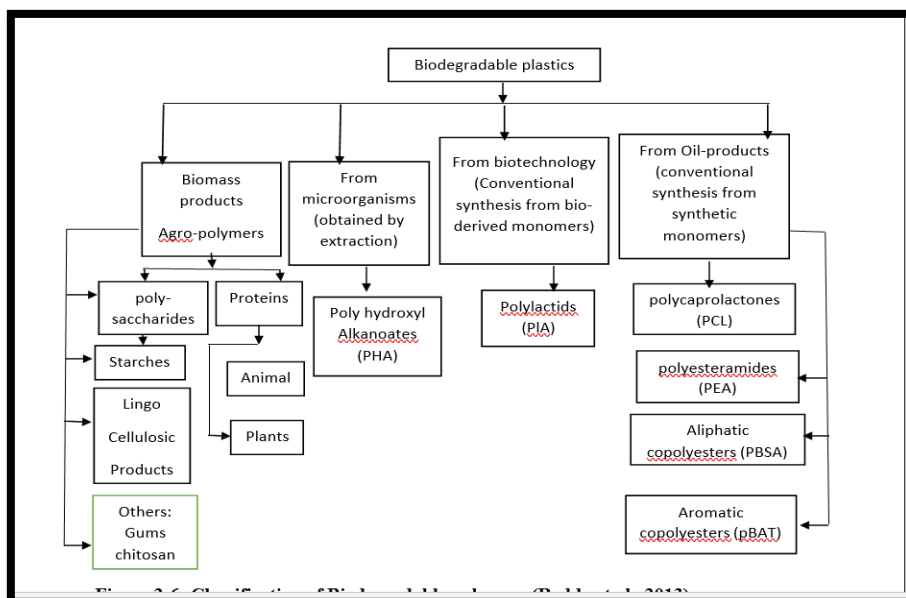


Figure 6 Classification of Biodegradable polymers (Reddy *et al.*, 2011)

## 2.3 Bioplastic Types

Bioplastics come in a variety of forms and are made from a variety of raw ingredients. Each variety of bioplastic differs from the others in terms of the raw ingredients used, as well as qualities like as strength, biodegradability, and transparency. The following are some of the most common bioplastics:

### 2.3.1 Starch-Based Plastics

The most extensively used bioplastic is thermoplastic starch, which accounts for nearly half of the bioplastics market. At home, you can make simple starch bioplastic. Pure starch can absorb moisture, making it an ideal material for the pharmaceutical industry to use in the creation of medicine capsules. Sorbitol and glycerin, as well as other flexibilizers and plasticizers, can be used to make the starch thermo-plastic. By altering the proportions of these ingredients, the features of the resulting bioplastic (also known as "thermo-plastical starch") can be adjusted to individual applications. (Mehta *et al.*, 2014)

To make starch/polylactic acid, starch/polycaprolactone, or starch/Ecoflex blends, starch-based bioplastics are frequently combined with biodegradable polyesters. These mixtures are biodegradable and utilised in industrial applications. (Sherman, 2008)

Due to the origin of its raw material, starch is cheap, abundant, and renewable. Starch based plastics are complex blends of starch with compostable plastics such as Polylactic acid, Polybutylene Adipate Terephthalate, Polybutylene Succinate, Polycaprolactone, and Polyhydroxyalkanoates.

These complex blends improve water resistance as well as processing and mechanical properties. (Eric *et al.*, 2014)

Starch-based films (mostly used for packaging purposes) are made mainly from starch blended with thermoplastic polyesters to form biodegradable and compostable products. These films are seen specifically in consumer goods packaging of magazine wrappings and bubble films. In foodpackaging, these films are seen as bakery or fruit and vegetable bags. Composting bags with this films are used in selective collecting of organic waste. (Eric *et al.*, 2014)

### 2.3.2 Cellulose-Based Plastics

Cellulose bioplastics are mainly the cellulose esters, (including cellulose acetate and nitrocellulose) and their derivatives, including celluloid. Cellulose can become thermoplastic when extensively modified. An example of this is cellulose acetate, which is expensive and therefore rarely used for packaging. However, cellulosic fibers added to starches can improve mechanical properties, permeability to gas, and water resistance due to being less hydrophilic than starch .

A group at Shanghai University was able to construct a novel green plastic based on cellulose through a method called hot pressing (Murphy *et al.*, 2009)

### 2.3.3 Protein-Based Plastics

Bioplastics can be made from proteins from different sources. For example, wheat gluten and casein show promising properties as a raw material for different biodegradable polymers. (Brian *et al.*, 2008)

Additionally, soy protein is being considered as another source of bioplastic. Soy proteins have been used in non-bioplastic plastic production for 100 years.

There are difficulties with using soy protein-based plastics due to their water sensitivity and relatively high cost. Therefore, producing blends of soy protein with some already-available biodegradable polyesters improves the water sensitivity and cost (Zhang *et al.*, 2006)

### 2.3.4 Aliphatic biopolyester

The aliphatic bio polyesters are mainly polyhydroxyalkanoates (PHAs) like the poly-3-hydroxybutyrate (PHB), polyhydroxyvalerate (PHV) and polyhydroxyhexanoate (PHH).

#### **Polylactic acid (PLA)**

Polylactic acid (PLA) is a transparent plastic produced from corn or dextrose. Superficially, it is similar to conventional petrochemical-based mass plastics like PS. It has the distinct advantage of degrading to nontoxic products.

Unfortunately it exhibits inferior impact strength, thermal robustness, and barrier properties (blocking air transport across the membrane).

PLA and PLA blends generally come in the form of granulates with various properties, and are used in the plastic processing industry for the production of films, fibers, plastic containers, cups and bottles. PLA is also the most common type of plastic filament used for home fused deposition modeling. (Andreas, 2016)

### **Poly-3-hydroxybutyrate**

The biopolymer poly-3-hydroxybutyrate (PHB) is a polyester produced by certain bacteria processing glucose, corn starch or wastewater. Its characteristics are similar to those of the petro plastic polypropylene. PHB production is increasing. The American sugar industry, for example, has decided to expand PHB production to an industrial scale. PHB is distinguished primarily by its physical characteristics. It can be processed into a transparent film with a melting point higher than 130 degrees Celsius, and is biodegradable without residue. (Knights, 2011)

### **Polyhydroxyalkanoates**

Polyhydroxyalkanoates are linear polyesters produced in nature by bacteria fermentation of sugar or lipid. They are produced by the bacteria to store carbon and energy. In industry production the polyester is extracted and purified from the bacteria by optimizing the conditions for the fermentation of sugar. More than 150 different monomers can be combined within this family to give materials with extremely different properties. PHA is more ductile and less elastic than other plastics, and it is also biodegradable. These plastics are being widely used in the medical industry. (Justyna et al., 2016)

# *Experimental Procedures*

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### **3. EXPERIMENTAL PROCEDURE**

The present study entitled **Synthesis of bioplastic from Sweet lime peel, its characterization and application in the formulation of a chocolate wrapper** was focused on preparing bio-plastic from sweet lime peel, studying its characteristics and using it to prepare chocolate wrapper. The experimental procedures below are discussed under the following headings:

3.1 Collection of sweet lime peel.

3.2 Preparation of the extract

3.3 Formulation of Bioplastic

3.4 FTIR Analysis

3.5 XRD Analysis

3.6 Assessment of Stability and degradability studies

3.6.1 Swelling test

3.6.2 Solubility test

3.6.3 degradation test

**3.7 Application of bioplastic as a chocolate wrapper**

#### **3.1 Collection of Sweet lime peel**

The sweet lime peel waste was collected from local juice shops in Coimbatore and washed with tap water.

#### **3.2 Preparation of the extract**

The sweet lime peels were dried in a room temperature at 37 °C for two to three days. The dried sweet lime peels were weighed and grounded using mixer and the sweet lime peel must be blended well in order to get a fine powder without any clumps

### **3.3 Formulation of bioplastic**

The formulation of bioplastic with peel was done by the method given by Roxana Gheorghita *et al.*, (2020) and the details are given in Appendix I

### **3.4 FTIR analysis**

The bioplastic formed was subjected to FTIR analysis as described by Deepika (2020) the details are given in Appendix II

### **3.5 XRD analysis**

The bioplastic formed was subjected to XRD analysis described by Jayachandra *et al.*,(2016) by the method depicted in Appendix III

## **3.6 ASSESSMENT OF STABILITY AND DEGRABILITY OF BIOPLASTIC**

### **3.6.1 Swelling test**

The bioplastic formed was subjected to Swelling test described by Jayachandra *et al.*,(2016) shown in Appendix IV

### **3.6.2 Solubility test**

The bioplastic formed was subjected to Solubility test described by Rizwana *et al.*, (2020) and the details are given in Appendix V

### **3.6.3 Degradation test**

The bioplastic formed was subjected to Degradation test described by Garima *et al.*, (2015) and this is given in Appendix VI

## **3.7 APPLICATION OF BIOPLASTIC AS A CHOCOLATE WRAPPER:**

The formed bioplastic was moulded into a chocolate wrapper.

## **RESULTS AND DISCUSSIONS**

#### 4. RESULTS & DISCUSSIONS

The present study entitled **Synthesis of bioplastic from sweet lime peel, its characterization and its application in the formulation of a chocolate wrapper** was focused on the following on collecting the peel waste, formulating it into bioplastic and characterizing it using FTIR and XRD analysis and performing swelling, solubility and degradation tests.

Environmental pollution has existed for ages, but it grew more significant in the nineteenth century as industry developed. Industries, radioactive compounds, and garbage dumping in oceans and on land all pose a severe threat to the environment and surroundings but they can be minimized or utilised. Organic materials such as crude oil, natural gas and others are used to make plastic. Some harmful chemicals, such as acetone, methylene, chloride, styrene, benzene, sulfuroxides, nitrogen oxides, methanol and other volatile organic compounds, are routinely emitted during the manufacture of plastics. These poisonous acids pollute the environment severely.

Plastic is the most serious environmental threat since it is not biodegradable. Every environmentalist and wildlife conservationist is concerned about them. We are throwing plastics into the ocean, which has resulted in a disaster for the organisms who dwell there. The main component of plastic is a polymer (polypropylene/polystyrene), which can leach into water and enhance water toxicity. Aquatic organisms confuse the plastic items that float on the surface of water for food and feast on them, resulting in death.

Plastic is a huge contaminant on the planet. As a result, bioplastic is being developed to replace synthetic plastic and reduce pollution. Biodegradable bioplastics are made from renewable biomass sources such as vegetable fats and oils, corn starch and can degrade in either anaerobic or aerobic environments.

The agents are microorganisms and algae which primarily decompose organic waste to produce bioplastic. New par, Thus the present investigation has been chosen to synthesize bioplastic from mosambi peels characterizing by FTIR and XRD and do the solubility, swelling tests .

The findings of the present study are discussed under the following headings.

#### **4.1 Sweet lime paste from sweet lime peel**

#### **4.2 Bioplastic from sweet lime paste**

#### **4.3 Characterization of synthesized bioplastic**

##### **4.3.1 FTIR analysis of synthesized bioplastic from sweet lime peel**

##### **4.3.2 XRD analysis of synthesized bioplastic from sweet lime peel**

##### **4.3.3 Swelling test results of synthesized bioplastic from sweet lime peel**

##### **4.3.4 Solubility test results of synthesized bioplastic from sweet lime peel**

##### **4.3.5 Degradation test results of synthesized bioplastic from sweet lime peel**

#### **4.4 Application of bioplastic as a chocolate wrapper**

#### **4.1 Sweet lime paste from sweet lime peel**

The Sweet lime paste made from sweet lime peels was orangish brown in hue, as shown in figure 7.



## Figure 7 Sweet Lime Peel Powder

### 4.2 Bioplastic from Sweet lime paste

The result of formation of bioplastic film from sweet peel is shown in figure 8. It is from the plate that the bioplastic formed was orangish brown in colour.



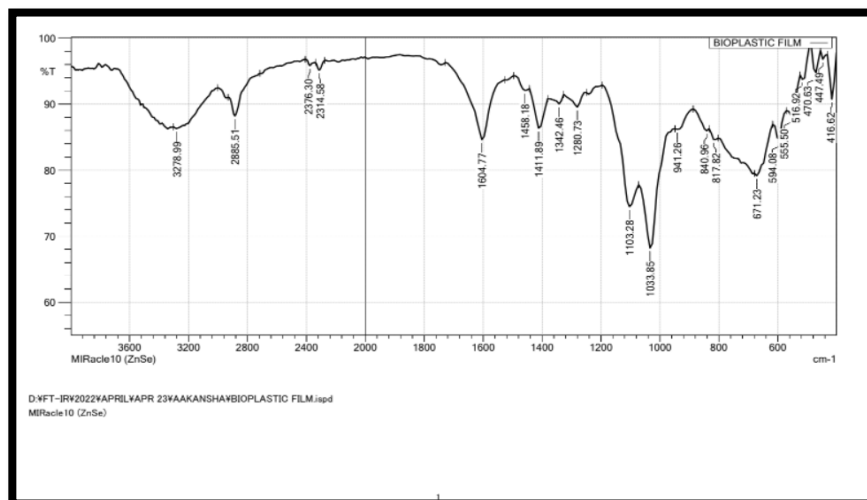
Figure 8 Formation of Bioplastic

### 4.3 Characterization of synthesized bioplastic

#### 4.3.1 FTIR analysis of synthesized bioplastic from Sweet lime peel:

The synthesized bioplastic material was further characterized by using FTIR analysis.

FTIR spectroscopy reveals the interactions between different components and changes in chemical compositions of the mixtures. FTIR measurements for synthesized bioplastic film were carried out to identify the possible biomolecules present in the bioplastic. Figure 9 shows the graph obtained after the FTIR analysis.



### Figure 9 Graphical representation of FTIR

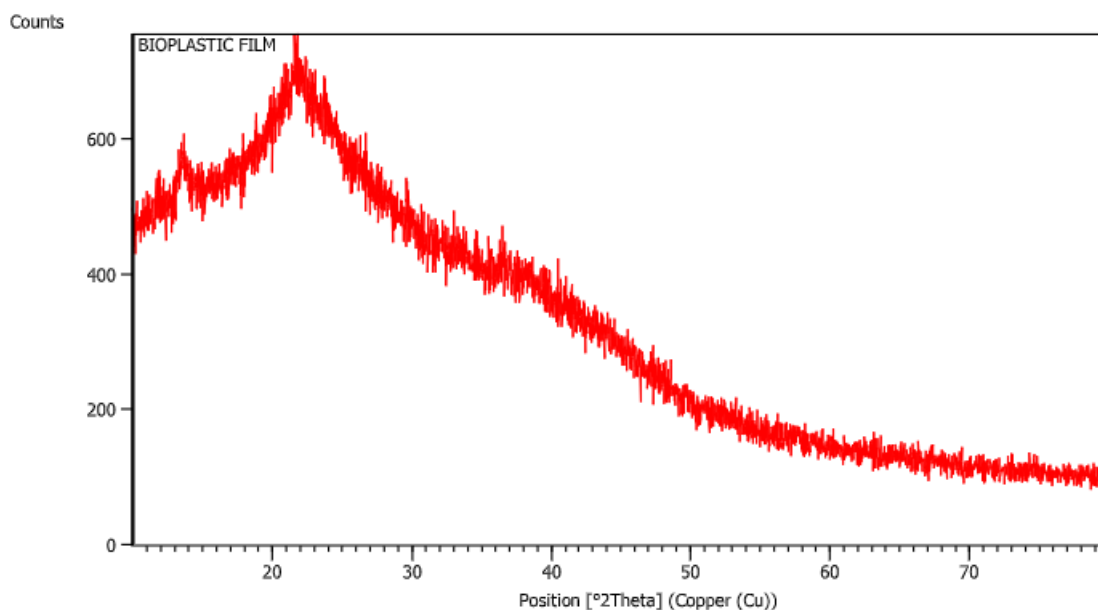
From the figure 9, it can be seen that the FTIR spectrum of the sample obtained at a wavelength in the range of 400-4000  $\text{cm}^{-1}$ , also showed that the peak 1103.28  $\text{cm}^{-1}$  was due to primary amine that produce 2 N-H stretching absorptions, peak at 14518.18  $\text{cm}^{-1}$  was attributed to the alkane C-H bonds. Stretching at 2885.51  $\text{cm}^{-1}$  was due to carboxylic O-H stretching. Peak at 1604.77  $\text{cm}^{-1}$  was attributed to C=O stretch.

Fazdil *et al.*,(2021) reported that the FTIR spectrum of bioplastic made from orange peels showed similarity with bioplastic made from sweet lime peel in fingerprinting peaks indicating the presence of pectin.

Yaradoddi *et al.*,(2016) stated that the FTIR spectrum of bioplastic made from fruit waste materials also showed similarity but a little difference in peaks, indicating the similar organic compounds present.

#### 4.3.2 XRD analysis of synthesized bioplastic from Sweet lime peel

X-ray diffraction, or XRD, is a technique for analysing the atomic or molecular structure of materials. It is non-destructive, and works most effectively with materials that are wholly, or part, crystalline. Figure 10 reveals the XRD Analysis of synthesized bioplastic from sweet lime peel.



### Figure 10 Graphical representation of XRD

The x-ray diffraction patterns of the bioplastic prepared from sweet lime peel showed a high degree of crystallinity. The crystalline structure of the biopolymer was reduced crystalline when it was heat-treated at 180<sup>0</sup>C, giving x-ray diffraction patterns similar to that of a typical crystalline material.

Similar patterns for corn starch with banana pseudo stem fiber made bioplastics have been reported by Hermansyah *et al.*,(2014).

Natural bioplastic also showed a semi-crystalline results on its x-ray diffraction pattern, which confirmed that treated biopolymer and untreated biopolymer were crystalline and semi crystalline in nature respectively. This was also reported by Jayachandra *et al.*(2016).

#### 4.3.3 Swelling test results of synthesized bioplastic from Sweet lime peel

The findings of a bioplastic (sweet lime) swelling test are displayed in figure 11 and table 1.



Figure 11 Swelling test results

The study found that when the sample was soaked in chloroform and methanol, there was little change in weight, but when it was retained in water medium, there was a little rise in

weight. The findings of the swelling test demonstrate that the bioplastic material has a low quantity of engorgement in water.

The results obtained are similar to bioplastic formed from banana peel and potato starch. Since there is a low amount of engorgement in water which is more desirable to be a bioplastic material, stated by Rizwana *et al.*,(2020) and Jayachandra *et al.*,(2016)

**TABLE 1 Swelling Test Data**

s.no	sample	Solvent medium	Quantity (ml)	Initial weight (gms)	Final weight (gms)	Difference In Weight (gms)
1.	Synthesized bioplastic	Distilled water	5	0.25	0.27	0.2
2.		chloroform	5	0.25	0.31	0.6
3.		methanol	5	0.25	0.26	0.1

#### 4.3.4 Solubility test of synthesized bioplastic from Sweet lime peel

The solubility of the bioplastic substance was investigated. The solubility test was used to determine the persistence of these bioplastic composites. The sample was divided into little bits and analysed. It was placed into various test tubes containing various Ammonia, acetic acid, acetone, and sulphuric acid are examples of solvents together with ethyl alcohol The *ewek* acid, polar solvent, non-polar solvent, and solvent were decided

The results of solubility test of bioplastics were shown in (Figure 12 and table 2).

The results of the study revealed that the material was insoluble in water which makes it more eligible to be a bioplastic material. It was also insoluble in acetone (polar solvent), ethyl

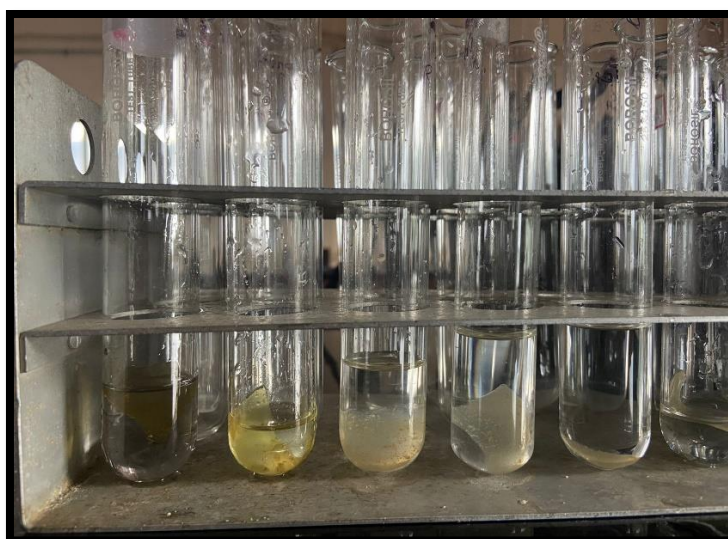
alcohol (nonpolar solvent), acetic acid (polar solvent) and partially soluble in ammonia (polar solvent) and completely soluble in sulphuric acid (strongly acidic solvent).

Solubility plays a major role in selecting a sustainable biomaterial for bioplastic because if the material is soluble in water and other solvents then it cannot be accounted as bioplastic.

Results from the solubility test showed similarity with bioplastic made banana peel and orange peel and the material is insoluble in water and other organic solvents which makes it more efficient to produce bioplastic at low cost also stated by Jayachandra *et al.*,(2016) and by Hermansyah *et al.*,(2014).

**TABLE 2 Solubility Test Data**

s.no	Solvents used	Solubility test		
		Insoluble	Partially soluble	Completely soluble
1.	Ammonia		Yes	
2.	Acetic acid	Yes		
3.	Acetone	Yes		
4.	Sulphuric acid			Yes
5.	Ethyl alcohol		Yes	



**FIGURE 12 Solubility Test Results**

#### 4.3.5 Degradation test of synthesized bioplastic from Sweet lime peel :

The Sweet lime peel bioplastic was weighed and buried under the soil for 10 days to check the degradation of the bioplastic and values were recorded and noted in table 3.

**Table 3 Degradation Test Data**

Number of days	Observations for degradation	
	Wt. of Sweet lime peel bioplastic (mpb)	Observation
Day 1	10 gms	No degradation
Day 3	8.7 gms	Degradation starts
Day 5	5.2 gms	mpb degrading slowly
Day 7	4.9 gms	Rate of degradation slows down
Day 9	3 gms	Degradation continues

As we can see the degradation starts from day3 and the degradation slows by day 5 and by day 7 rate of degradation slows down and continues. It took 16 days for the bioplastic to degrade which makes it more effective when compared to normal plastic.

Sweet lime peel has a degradation similar to banana peel degradation and potato starch bioplastic degradation as stated in Rizwana *et al.*,(2020), Jayaram *et al.*,(2015) with a complete degradation difference of 2-3 days making it efficient.

#### **4.4 APPLICATION OF BIOPLASTIC AS A CHOCOLATE WRAPPER:**

The formed bioplastic was moulded into a chocolate wrapper as given in figure 13



**Figure 13 Bioplastic Chocolate Wrapper**

#### **Highlights of the study**

- This bioplastic is designed in such a way for handling by small scale, locally managed composting and recycling systems.
- This is a better alternative and efficient in replacement of the commercially available chocolate wrapper.
- This bioplastic has high durability, flexibility, gloss, holding capacity which makes it more structured.

## **SUMMARY AND CONCLUSION**

## SUMMARY & CONCLUSION

The amount of plastic waste increases every year and the exact time needed for its biodegradation is unknown. Ecological awareness has impelled the development of new biodegradable materials.

Bio-plastics can be defined as plastics made of biomass such as corn and sugarcane. These substances have been increasingly highlighted as means for saving fossil fuels, reducing CO<sub>2</sub> emission and plastic wastes. Biodegradability of bio plastics has been widely publicized in society and the demand for packaging is rapidly increasing among retailers and the food industry at large scale.

Population growth has led to the accumulation of massive volume of non-degradable waste materials across our planet. The accumulation of plastic waste has become a major concern in terms of the environment. Conventional plastics not only take many decades during decomposition, but also produce toxins while degradation. Hence, there is need to produce plastics from materials that can be readily eliminated from our biosphere in an “eco-friendly” fashion. Bioplastics are natural biopolymers synthesized and catabolized by various organisms. These get accumulated as storage materials in microbial cells under stress conditions. However, the high production cost and the availability of low-cost petrochemical-derived plastics led to bioplastics being ignored for a long time.

The present study was focused on the utilization of Sweet lime peels waste as a natural source for the production of bioplastic. The bioplastic formed using sweet lime peel was flexible and had a good quality. Its solubility, swelling and degradation test showed good results. The peak development and presence of compounds were investigated using FTIR and XRD analysis. The durability of the bioplastic formed was determined. Bioplastic was moulded into a chocolate wrapper as an application.

The results of the present study are summarised below:

1. The peaks of the various chemical compounds were studied using FTIR analysis. The peak's configuration indicates the presence of compounds present in sweet lime peel.

2. The degradation tests showed that the bioplastic degrades at a good and a faster rate which makes it more effective when compared to normal plastic.

3. The swelling test confirmed that the bioplastic formed has a low quantity of engorgment in water, which makes it more appealing.

4. The solubility test revealed that the bioplastic formed is insoluble in water which makes it more eligible to be a bioplastic material and more efficient to produce bioplastic at low cost.

5. XRD analysis showed that the bioplastic material possess a high crystalline structure and gave information on the chemical composition.

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# *Appendices*

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## **APPENDICES**

### **APPENDIX I**

#### **FORMULATION OF BIOPLASTIC FROM MOSAMBI PEELS**

Roxana Gheorghita *et al.*, ( 2020)

##### **REAGENTS:**

1. Sweet lime peel
2. Sodium Alginate powder
3. Glycerol
4. Gelatin
5. Distilled water

##### **PROCEDURE:**

- Weighed about 25gms of Sweet lime peel powder along with 27.5 gms of sodium alginate powder.
- To the measured components add 15 ml of glycerol and 2-4 gms of gelatin.
- To the mixture added 500ml of distilled water.
- Stirred the mixture continuously keeping it on a boiling water bath to get an uniform consistency.
- Poured in the petri plate and allowed it to dry for 2 hours at 120<sup>0</sup>C in hot air oven. Once the bioplastic has dried, it can be scrapped out.

## **APPENDIX II**

### **FTIR ANALYSIS**

Deepika, (2020)

The formed bioplastic from Sweet lime peel was taken to FTIR analysis. A small piece was placed on a diamond window of the spectrophotometer under standard room temperature.

A32 scans with a resolution of 4cm was adopted. The available spectrum ranges was 600 cm-1 to 3600 cm-1

## **APPENDIX III**

### **XRD ANALYSIS**

Jayachandra *et al.*,(2016)

To get an insight into the structure of bioplastic formed by using Sweet lime peel, powder XRD patterns were recorded using an X-ray diffractometer using the Cu K-beta (30 kV, 100 mA) radiation. Data were recorded during 2 $\theta$  range of 10°-80° under continuous scan mode using the scan rate of 4°/min.

## **APPENDIX IV**

### **SWELLING TEST**

Jayachandra *et al.*,(2016)

Swelling study is generally conducted to check whether developed material retains the original properties when it was formed during the preparations. 0.25gms of samples were prepared were taken in the test tube to check the protuberance and other morphological changes, it was carried out on the medium containing 5ml of various solvents such as water, chloroform and methanol medium. Where the deliberated samples were kept in the medium for about 2 hours and the results were recorded accordingly.

## **APPENDIX V**

### **SOLUBILITY TEST**

Rizwana *et al.*, (2020)

The solubility test was carried out to check persistence the bioplastic formed from Sweet lime peels . The sample was cut into small pieces and was inserted into different test tubes containing different solvents – ammonia, acetic acid, acetone, sulphuric acid and ethyl alcohol of 5ml . The solvents were chosen in such a way that the activity of material with parameters like high acidic solvent, polar solvent, non-polar solvent and weak acid

## **APPENDIX VI**

### **DEGRADATION TEST**

Garima *et al.*, (2015)

The bioplastic was weighed and buried under the soil for about 10 days. Checked for the degradation every alternate days, checked the weight and noted down the value.