

PREPARATION OF BIOPLASTIC FROM POTATO STARCH AND CORN STARCH

Submitted in partial fulfillment of the requirements for the award of
Bachelor of Technology degree in Chemical Engineering

by

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**DEPARTMENT OF CHEMICAL ENGINEERING
SCHOOL OF BIO & CHEMICAL ENGINEERING**

SATHYABAMA

**INSTITUTE OF SCIENCE AND TECHNOLOGY
(DEEMED TO BE UNIVERSITY)**

Accredited with Grade "A" by NAAC

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MARCH-2021



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BONAFIDE CERTIFICATE

This is to certify that this Project Report is the bonafide work of **NIKHIL KUMAR (37190028)**, who carried out the project entitled "**PREPARATION OF BIOPLASTIC FROM POTATO STARCH AND CORN STARCH**" under our supervision from September 2020 to March 2021.

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ACKNOWLEDGEMENT

I am pleased to acknowledge my sincere thanks to Board of Management of SATHYABAMA INSTITUTE OF SCIENCE AND TECHNOLOGY for their kind encouragement in doing this project and for completing it successfully. I am grateful to them.

I convey my thanks to **Dr. D.PRABU, M.E., Ph.D., Dr. S.SATHISH, M.E., Ph.D., Head of the Department, Department Of Chemical Engineering** for providing the necessary support and details at the right time during the progressive reviews.

I would like to express my sincere and deep sense of gratitude to my Project Guide **Dr. D Venkatesan, M.Tech., Ph.D., Department Of Chemical Engineering** for his valuable guidance, suggestions and constant encouragement paved way for the successful completion of my project work.

I wish to express my thanks to all Teaching and Non-teaching staff members of the Department of Chemical Engineering who were helpful in many ways for the completion of the project.

ABSTRACT

Plastics are commonly used and useful almost in every industry today, including containers, packaging, computers, mobile phones and even the medical and automotive companies. Since their compositions can be chemically processed with some force and structure to achieve low reactivity, long-lasting substances and higher molecular weights, plastics are a viable choice. They are both long-lasting and cheap. But the decreasing availability of petroleum, including the contamination caused by petroleum-based plastics non-biodegradability, has sparked growing curiosity in the sector of bioplastics.

The aim of this report is to prepare a bioplastic film from different starch and comparing which bioplastic film performs better. The report also discusses about the Plastic, history of plastics and also the demerits of plastics. This report also include about bioplastics and about its history, different types of bioplastics, advantages of bioplastics over plastics, market share of bioplastics and also their applications.

Keywords : Plastic, bioplastic, starch.

TABLE OF CONTENT

CHAPTER NO.	TITLE	PAGE NO.
	ABSTRACT	V
	LIST OF FIGURES	VIII
	LIST OF TABLES	XI
1	INTRODUCTION	1
	1.1 PLASTICS	1
	1.1.1 HISTORY	1
	1.1.2 CLASSIFICATION OF PLASTIC	3
	1.1.3 PROBLEMS RELATED TO PLASTIC	4
	1.2 BIOPLASTICS	8
	1.2.1 HISTORY	9
	1.2.2 CLASSIFICATION OF BIOPLASTIC	12
	1.2.3 MARKET SHARE	16
	1.2.4 APPLICATIONS OF BIOPLASTIC	17
	1.2.5 BIOPLASTIC 'S ADVANTAGES	18
	1.2.6 DIFFICULTIES FOR BIOPLASTIC	20
2	LITERATURE SURVEY	21
3	AIM AND SCOPE OF THE STUDY	23
	3.1 AIM	23
	3.2 SCOPE	23
4	MATERIALS AND METHODS	24
	4.1 MATERIALS	24
	4.1.1 EQUIPMENTS REQUIRED	24
	4.1.2 RAW MATERIALS & CHEMICALS REQUIRED	28
	4.2 METHODOLOGY	32

	4.2.1 PROCEDURE TO PREPARE POTATO STARCH BIOPLASTIC	32
	4.2.2 PROCEDURE TO PREPARE CORN STARCH BIOPLASTIC	36
	4.3 CHARACTERIZATION OF BIOPLASTIC FILMS	38
	4.3.1 WATER ABSORPTION TEST	38
	4.3.2 ACID ABSORTION TEST	39
	4.3.3 BASE ABSORPTION TEST	39
	4.3.4 MOISTURE CONTENT TEST	39
	4.3.5 BIODEGRADABILITY TEST	40
5	RESULTS AND DISCUSSION	41
	5.1 POTATO STARCH BASED BIOPLASTIC FILM	41
	5.2 CORN STARCH BASED BIOPLASTIC FILM	47
6	SUMMARY AND CONCLUSION	55
	REFERENCES	56

LIST OF FIGURES

FIGURE NO.	DESCRIPTION	PAGE NO.
4.1	Weighting Machine	24
4.2	Glass Rod/Stirrer	25
4.3	Spatula	25
4.4	Measuring Cylinder	26
4.5	Petri Dish	26
4.6	Beaker/Measuring Cup	27
4.7	Cooking Pan	27
4.8	Corn Starch Powder	28
4.9	Potato Starch Powder	29
4.10	Universal Indicator	29
4.11	Distilled Water	30
4.12	Glycerin	30
4.13	White Vinegar	31
4.14	Sodium Hydroxide (NaOH)	31
4.15	Raw materials added together (Potato Starch Bioplastic)	34
4.16	After mixing thoroughly (Potato Starch Bioplastic)	34
4.17	After 5 minutes of heating (Potato Starch Bioplastic)	35
4.18	After 10 minutes of heating (Potato Starch Bioplastic)	35
4.19	Raw materials added together (Corn Starch Bioplastic)	36
4.20	After mixing thoroughly (Corn Starch Bioplastic)	37
4.21	After 5 minutes of heating (Corn Starch Bioplastic)	37
4.22	After 10 minutes of heating (Corn Starch Bioplastic)	38

5.1	Potato Starch Bioplastic Film(11.86 grams)	41
5.2	Water Absorption Studies : Bioplastic (Potato Starch) immersed in water	42
5.3	Weight (in g) of the Bioplastics (Potato Starch) after 24 hours immersion in water.	42
5.4	Acid Absorption Studies : Bioplastic (Potato Starch) immersed in acid	43
5.5	Weight (in g) of the Bioplastics (Potato Starch) after 24 hours immersion in acid	43
5.6	Base Absorption Studies : Bioplastic (Potato Starch) immersed in base	44
5.7	Weight (in g) of the Bioplastics (Potato Starch) after 24 hours immersion in base	44
5.8	Biodegradability Test : Determination Weight loss of the Bioplastic (Potato Starch) on day 10 of degradation	46
5.9	Corn Starch Bioplastic Film(10.88 grams)	47
5.10	Water Absorption Studies : Bioplastic (Corn Starch) immersed in water	48
5.11	Weight (in g) of the Bioplastics (Corn Starch) after 24 hours immersion in water	48
5.12	Acid Absorption Studies : Bioplastic (Potato Starch) immersed in acid	49
5.13	Weight (in g) of the Bioplastics (Corn Starch) after 24 hours immersion in acid	49
5.14	Base Absorption Studies : Bioplastic (Corn Starch) immersed in base	50

5.15	Weight (in g) of the Bioplastics (Corn Starch) after 24 hours immersion in base	50
5.16	Biodegradability Test : Determination Weight loss of the Bioplastic (Corn Starch) on day 10 of degradation	52
5.17	Final Product(1. Corn Starch Bioplastic Film, 2. Potato Starch Bioplastic Film)	54

LIST OF TABLES

TABLE NO.	DESCRIPTION	PAGE NO.
1.1	Comparing Petroplastics and Bioplastics	9
5.1	Data on Water Absorption Test for Potato Bioplastics	42
5.2	Data on Acid Absorption Test for Potato Bioplastics	43
5.3	Data on Base Absorption Test for Potato Bioplastics	44
5.4	Data on Moisture Content Test for Potato Bioplastics	45
5.5	Data on Biodegradability Test for Potato Bioplastics	46
5.6	Data on Water Absorption for Corn Bioplastics	48
5.7	Data on Acid Absorption Test for Corn Bioplastics	49
5.8	Data on Base Absorption Test for Corn Bioplastics	50
5.9	Data on Moisture Content Test for Corn Bioplastics	51
5.10	Data on Biodegradability Test for Corn Bioplastics	52
5.11	Comparing Potato Starch & Corn Starch Bioplastic Film	53

CHAPTER - 1

INTRODUCTION

1.1 PLASTICS

A plastic is a synthetic or semi-synthetic material made from a variety of organic polymers, such as polyethylene, that can be shaped into form when still flexible and then hardened to a solid or mildly elastic state. The term plastic comes from the Greek (plastikos), which means "ready to be shaped or moulded", and (plastos), which means "moulded". The plastics may be moulded, extruded, or pressed into solid structures of different shapes due to their plasticity. The majority of modern plastics are manufactured from petrochemicals extracted from fossil fuels such as natural gas or petroleum; however, newer manufacturing processes use recycled materials such as corn or cotton derivatives. The structure of a plastic consists of carbon which are chemically combined with hydrogen, oxygen and other non-metallic substances and in most cases they are fairly complex. Plastics have a wide variety of uses in all areas of life. They're used in everything from packaging, furniture, and fabrics to medical instruments and building materials.

Plastics manufacture is a big part of the chemical industry, and some of the world's leading chemical firms, such as BASF and Dow Chemical, have been active from the early days. The top 50 corporations' revenues totaled \$961.3 billion in 2014. The companies come from a total of 18 countries, with the United States accounting for more than half of the companies on the list.. Many of the top 50 plastics firms is located in only three countries: the United States (12), Japan (8), and Germany (6). Currently, the world uses more than 260 million tpa of plastics. Europe uses about 53 million tpa and, in particular, the UK produces about 5 million tpa of plastics.

1.1.1 History

Plastics have progressed through naturally organic products (like: shellac and gums) to chemically modified materials (like:, cellulose, milk proteins, natural rubber and gelatin) and finally to manufactured plastics (like: PVC, epoxy, and Bakelite).

Mesoamericans used natural rubber for hoops, bands, and figurines around 1600 BC. In the Middle Ages, treated cow horns were used as lantern screens. Milk proteins were treated with lye to create materials that mimicked the properties of horns. Many materials were published in the nineteenth century as chemistry advanced during the Industrial Revolution. Charles Goodyear's invention of vulcanization to harden natural rubber in 1839 accelerated the production of plastics.

Parkesine, the first man-made plastic, was invented by Alexander Parkes in 1855 and patented the next year. It was made from cellulose (the main component of plant cell walls) that had been dissolved in nitric acid. Parkesine was first exhibited at the 1862 International Exhibition in London, where it received a bronze medal for Parkes.

About 1860, John Wesley Hyatt developed a cellulose derivative, which set off the development of artificial plastics or polymers. His invention was later patented as Celluloid and went on to become a commercial success, with products ranging from dental plates to men's collars being made from it. Auguste Trillat, a French chemist, found a way to insolubilize casein (milk proteins) by immersing it in formaldehyde in 1893, resulting in galalith.

Bakelite was the world's first entirely synthetic resin, invented in 1907 in New York by Leo Baekeland, who also coined the word plastics. Nobel laureate Hermann Staudinger, regarded as "the father of polymer chemistry," and Herman Mark, known as "the father of polymer physics," have also contributed to the materials science of plastics.

In 1920, a significant advance occurred in the manufacture of plastic materials. According to German chemist Hermann Staudinger, plastics are made up of very

large molecules bound together by tight chemical bonds. During the 1920s and 1930s, several new plastic materials were produced, including , methyl methacrylate (known as Lucite or Plexiglas), nylon and polytetrafluoroethylene (marketed as Teflon in 1950).

Nylon was developed by Wallace H. Carothers of DuPont, but it was rejected as possessing little usable properties because it was a sticky substance with no structural integrity in its early form. Soon, Julian Hill, a DuPont chemist, noticed that nylon threads were very solid and had a silky look when stretched out, and discovered that they could be useful as a fibre.

Improvements in chemistry during World War I resulted in an influx in new varieties of plastics, with mass manufacturing starting in the 1940s and 1950s. Polystyrene (first developed in the 1930s by BASF) and polyvinyl chloride (first created in 1872 but commercially produced in the late 1920s) were among the first examples of the wave of new polymers . Durite Plastics, Inc. was the first company to produce phenol-furfural resins in 1923. Imperial Chemical Industries (ICI) researchers Reginald Gibson and Eric Fawcett discovered polyethylene in 1933.

Plastics were being used in place of metal in items like equipment and protective jackets, as well as in certain high-temperature equipment. In 1953, a German chemist named Karl Ziegler invented polyethylene, and the next year, an Italian chemist named Giulio Natta invented polypropylene. These are two of the most widely used plastics today.

1.1.2 Classification Of Plastic

Based on their Physical Properties, the plastics are categorized into two types:

A) Thermoplastic

A thermoplastic, also known as thermosoftening plastic, is a plastic polymer substance that softens or becomes moldable at a high temperature before solidifying when cooled.

Thermoplastics are made up of chemically independent macromolecules which have a basic molecular structure. They are softened or melted when heated, then moulded, formed, welded, and solidified after cooling. Heating and cooling processes can be repeated several times, allowing for reprocessing and recycling.

Examples Of Thermoplastics are : Acrylic, Nylon, Acrylonitrile butadiene styrene (ABS), Polybenzimidazole, Polylactic acid (polylactide), Polyoxymethylene (POM), Polyether ether ketone(PEEK), Polycarbonate (PC), Polyetherimide (PEI), Polyether sulfone (PES), Polyethylene(PE), Polypropylene (PP), Polyvinyl chloride (PVC), Polystyrene, Polytetrafluoroethylene (PTFE)or Teflon, etc.

B) Thermosetting plastic

A thermosetting plastic, also known as a thermoset, is a polymer that cures from a soft rigid or viscous liquid prepolymer or resin to become irreversibly hardened. Curing a thermosetting resin converts it into a plastic or elastomer (rubber) by forming covalent bonds between individual polymer chains, resulting in crosslinking or chain extension. The density of crosslinks varies depending on the monomer or prepolymer combination and the crosslinking mechanism. Curing is caused by heat or sufficient radiation, and it may be intensified by applying high pressure or combining with a catalyst.

Prior to curing, the starting material for thermosets is typically malleable or liquid, and it is often built to be shaped into the final form. In comparison to thermoplastic polymers, which are typically manufactured and circulated in the form of pellets and formed into the finished product form by melting, pressing, or injection moulding, thermoset polymers cannot be melted for reshaping once hardened.

Examples of Thermosetting plastics are: Bakelite, Fiberglass (a fiber-reinforced polymer composite), Melamine, Polyester resin, Silicone resin, Polyurethane, Epoxy resin, Vulcanized rubber, etc.

1.1.3 Problems related to plastics

Since the 1950s, one billion tonnes of plastic waste has been discarded, according to one report. Others report that humans have produced 8.3 billion tonnes of plastic, of which 6.3 billion tonnes are waste and about 9% is recycled.

According to the Ocean Conservancy, China, Philippines, Indonesia, Vietnam and Thailand, throw more plastic into the oceans than the rest of the world combined. According to a study The Pearl, Amur, Indus, Pink, Yangtze, Nile, Hai, Ganges, Mekong, and Niger rivers "transport 88 percent to 95 percent of the global [plastics] load into the sea,".

Despite their many applications and favourable properties, petroleum-based traditional plastics have a number of drawbacks. The following risks are the primary reasons for considering alternatives to plastics:

A) Production Of Plastics

Plastics are manufactured from petroleum, natural gas, or other related materials. They are converted to a polymer resin, which is then moulded and formed into the desired product. Plastics made from crude oil require 7.9 to 13.7 kWh/lb of energy. Plastics, on the other hand, are a petroleum by-product that contributes to energy dependence, and it is widely acknowledged that oil will not be around forever. This leads to a potential future raw material shortage.

B) Microplastics

According to the US National Oceanic and Atmospheric Administration (NOAA) and the European Chemicals Agency, microplastics are pieces of some kind of plastic that are less than 5 mm in length. Clothes, cosmetics, and manufacturing practises are just a couple of the ways they get into natural environments.

Some plastic fragments or particles that are already 5.0 mm in size or less before entering the atmosphere are called primary microplastics. Examples of Primary Microplastics are : plastic pellets, microbeads, and Clothing microfibers. Secondary microplastics are formed as larger plastic materials degrade (break down) in the atmosphere due to natural weathering processes. Examples of Secondary Microplastics are : Plastic bags, fishing nets, Water and soda bottles.

Plastics, especially microplastics, are becoming more prevalent in the food chain. Microplastics were first discovered in the guts of seabirds in the 1960s, and their

proportions have steadily increased since then. Microplastics have a high likelihood of incorporation into, ingestion, and deposition in the bodies and tissues of many animals because plastics degrade very slowly (mostly hundreds or thousands of years).

C) Plastics decomposition

Plastics account for about ten percent of all discarded waste. Though most common plastics are not readily biodegradable, they do undergo polymer degradation by a number of methods, the most important of which is typically photo-oxidation. Because of the salty atmosphere and drying influence of the water, polymers take even longer to dissolve in the water, which leads to the accumulation of plastic waste in some habitats. Recent experiments have shown, that plastics in the ocean disintegrate faster than previously believed, as a result of rain, exposure of the sun, and other environmental factors, releasing harmful chemicals like bisphenol A. But the decomposition has slowed as a result of the increasing amount of plastics in the water. The decomposition rates of many plastic items have been forecast by the Marine Conservancy: a foam plastic cup would take 50 years to dissolve, a plastic bottle keeper will take 400 years, a disposable diaper will take 450 years, and fishing line will take 600 years.

D) Recycling of Plastic

The method of recovering scrap or waste plastic and reprocessing it into usable items is known as plastic recycling. Despite the fact that multiple kinds of plastics could theoretically be recycled, only a small amount of plastic currently enters the recycling process. Less than 10% of plastic has ever been recycled due to intentionally misleading symbols on plastic containers and various technological challenges. PET (polyethylene terephthalate) is the most often recycled plastic that is found in soft drink bottles. About 15 to 27 percent of the PET bottles are recycled every year. High-density polyethylene (HDPE), which is used in milk jugs, shampoo bottles and two-thirds of rigid plastic containers, is another form of plastic that is commonly recycled. About 10% of HDPE plastic is recycled yearly. Recycling can serve to minimise the volume of plastic in the waste stream since nearly all plastic is non-biodegradable. This is critical, for example, in order to reduce the nearly 8 million metric tonnes of waste plastic that reach the ocean

each year. Owing to the difficulties of recycling, a large volume of plastic obtained for recycling is recycled in various ways, such as by garbage incineration, or is not processed at all.

E) Disposal of Solid Waste/ Landfill Disposal

Plastic bags, in fact, end up in landfills in huge numbers. Since landfill space is becoming increasingly inadequate and plastics are non-biodegradable, landfills face various challenges. A survey showed that 82 percent of the surveyed landfill cells had leaks, with 41% getting a leak greater than 1 square foot. Furthermore, these spills can only be detected once they enter landfill testing wells. Both old and new landfills are often located near vast bodies of water, rendering leak detection and cleaning challenging.

F) Incineration

Plastic incineration has been promoted by some company officials as a method of disposal. Pyrolysis, which is a related procedure, turns plastics into a hydrocarbon broth that can be reused in oil and chemical refineries. Incineration and pyrolysis, on the other hand, are more costly than recycling, use more electricity, and result in serious air emissions. Incinerators are a large source of 210 various dioxin contaminants, as well as cadmium, mercury, hydrogen chloride, fluorides, sulphuric acid, nitrous oxide, and particulate matter small enough to stay in the lungs indefinitely. Controlled high-temperature incineration at temperatures above 850°C for two seconds, followed by selective additional heating, is commonly used in municipal solid waste incineration to break down toxic dioxins and furans generated by burning plastic. This is essential because the unregulated incineration of plastics releases polychlorinated dibenzo-p-dioxin, a carcinogen. The dilemma exists because the heat quality of the waste stream varies. Plastic is usually burned in the open air at lower temperatures, and poisonous fumes are normally released.

G) Changes in the climate

A recent study on the effect of plastic on climate change was released by the Center for International Environmental Law in 2019. According to the study, plastic will emit 850 million tonnes of carbon dioxide (CO₂) into the atmosphere in 2019.

Annual pollution will exceed 1.34 billion tonnes by 2030 if existing patterns persist. Plastic will contain 56 billion tonnes of greenhouse gas emissions by 2050, accounting for up to 14% of the world's remaining carbon budget. Plastics have a mixed effect on global warming. Petroleum is used to make most plastics. While biodegradable plastics have caused methane pollution, if it is incinerated, it raises carbon emissions; if it is disposed of in a landfill, it becomes a carbon sink. Plastic, as opposed to glass or aluminium, is lighter and therefore may consume less energy. For eg, using PET plastic instead of glass or metal to package drinks saves 52 percent on transportation electricity.

1.2 BIOPLASTICS

Bioplastics are plastics that are manufactured from natural materials (plants such as potatoes, corn, sugar, rice, tapioca, and algae) and are entirely or partly bio-based, as well as biodegradable or compostable. Using microorganisms, bioplastic can be manufactured from plant by-products as well as recycled plastics (such as water bottles and other containers). Sugar derivatives such as cellulose, sugar, and lactic acid are widely used to produce bioplastics. Plastics made from petroleum or natural gas are known as fossil-fuel plastics. Bioplastics accounted for around 0.2 percent of the overall polymer industry(300 million tons) in 2014. . Despite the fact that bioplastics are not economically feasible, research on the subject continues.

Bioplastics are divided into two groups:

A) Biodegradable Plastics

There are plastics that decompose into organic matter and gases such as CO₂ over a period of time and can be composted.

B) Bio based Plastic

The word "bio-based" refers to a substance or product that is (partially) made from biomass (plants). Bioplastics are made from biomass derived from plants such as cellulose, sugarcane, or rice. It's worth noting, though, that biodegradation is related to a material's chemical composition rather than its resource base. In other

words, 100% biodegradable plastics may be non-biodegradable, while 100% fossil-based plastics may biodegrade.

Table 1.1 : Comparing Petroplastics and Bioplastics

	PETROPLASTICS	BIOPLASTICS
Renewable	No	Yes or partly
Sustainable	No	Yes
Polymer Range	Extensive	Limited but growing
Usage of Fossil Fuels	Relatively high	Usually Low
GHG emissions	Relatively high	Usually Low
Breaking down in the environment	Polymer Oxidation will degrade some of them	Biodegradable and/or compo-stable
Usage of Arable land	None	Currently low

1.2.1 History

Event Date	Event
1 st Jan, 1862	Alexander Parkes (1813-1890), a chemist and inventor, demonstrated Parkesine, a moldable substance made of cellulose nitrate and wascalles, at the Great International Exhibition in London. Parkes founded the Parkesine Company in Hackney Wick, London, in response to the overwhelming public interest in Parkesine. Commercially, though, it was not a big hit.
8 th Aug, 1869	Following the demise of Parkesine, a new bioplastics brand emerged. John Wesley Hyatt invented a system for the manufacture of solid bioplastic in 1869 in order to find a new substitute for billiard balls other than ivory. Celluloid was the substance that he was able to patent.
28 th Mar, 1907	Petroleum plastics were discovered. The start of a long journey that will inevitably lead to a dead end.
1907	Bakelite was patented by Leo Baekeland and has been

	designated as a National Historic Chemical Landmark due to its non-conductivity and heat resistance. It can be used in radio and telephone casings, as well as kitchenware, weapons, and a number of other items.
1912	Cellophane is made by Brandenberger using cellulose from hemp, wood or cotton.
8 th Sep, 1924	Henry Ford attempted to pursue other non-food applications for agricultural surpluses in the 1920s. Ford started producing bioplastics for use in the production of cars. Interior trim,dashboards, and Steering wheels were all made of bioplastics. Since then, Ford has been using them.
1920s	Plastic made of Polylactic Acid (PLA) is discovered by Wallace Carothers. PLA is extremely costly to manufacture, and it was not mass-produced until 1989.
1926	Polyhydroxybutyrate (PHB), the very first bioplastic made from bacteria, is invented by Maurice Lemoigne.
12 th Jun, 1933	E.W. Fawcett and R.O. Gibson, two chemists, found polyethylene by mistake in 1933. The computer they were using to experiment with ethylene and benzaldehyde sprung a leak, and all that was left was polyethylene. The polymerization mechanism was discovered by them, and they were credited with it.
1940-1945	Plastic usage grew during World War II, when it was used in many wartime materials. Between 1940 and 1945, the United States tripled the production of plastics (in general, not just bioplastics) thanks to government investment and oversight.
13 th Aug, 1941	In 1941, Henry Ford introduced the first plastic sedan. The chassis and portions of this vehicle is made of 14 different bioplastics. There was a lot of curiosity, but WWII broke out shortly after, and everyone's focus was distracted.

1950s	Amylomaize (corn with a higher than 50% amylose content) was successfully bred, and industrial bioplastics applications began to be investigated.
1970s	Bioplastics have grown in popularity as a result of the environmental revolution.
1983	Marlborough Biopolymers, the very first bioplastics firm, is created, using biopal, a bacteria-based bioplastic.
1989	Dr. Patrick R. Gruber advances the invention of PLA when he discovers how to make PLA from rice. Novamount, the leading bioplastics firm, is founded. Matter-bi, a bioplastic, is used by Novamount in a number of applications.
1992	PHB can be developed by the plant <i>Arabidopsis thaliana</i> , according to Science.
Late 1990s	The BIOFLEX film was created from the synthesis of TP starch and BIOPLAST by BIOTEC's research and manufacturing. Blown film extrusion, flat film extrusion, and injection moulding lines are all forms of BIOFLEX film.
2001	Metabolix inc. acquires Monsanto's biopol company (formerly Zeneca), which produces bioplastics from plants.
2005	NatureWorks, a joint venture between Cargill and Dow Chemicals, is re - branded as the largest PLA manufacturer.
2007	Metabolix Inc. is putting the first 100 percent biodegradable plastic, Mirel, on the market, which is manufactured from corn sugar fermentation and genetically modified bacteria.
2012	According to studies published in the journal of pharmaceutical research, a bioplastic made from seaweed has shown to be one of the most

	environmentally sustainable bioplastics.
2013	Bioplastic extracted from blood with a crosslinking agent such as proteins, sugars or other molecules is patented. This invention will be used to create cartilage, tendons, bones, muscle and ligaments , as well as to deliver stem cells.
2014	Bioplastics could be produced by combining vegetable waste (cocoa husks, rice hulls, parsley and spinach roots etc.) with TFA solutions of pure cellulose, according to a report published in 2014.
2016	An analysis proves that a car bumper constructed from nano-cellulose based bioplastic biomaterials and banana peels will pass regulatory requirements.
2017	A recent bioplastics proposal based on lignocellulosic resources.
2018	Many changes arise, such as Ikea beginning industrial manufacturing of bioplastics furniture, Project Effective concentrating on swapping nylon with bio-nylon , and the very first fruit-based packaging
2019	The 'Korea Research Institute of Chemical Technology' isolated and synthesised five separate forms of Chitin nanomaterials to validate high personality and antimicrobial effects. Within 6 months of being buried underground, 100 percent bio degradation was probable.

1.2.2 Classification Of Bioplastic

If we talk of bioplastics, we're talking about a diverse group of bio-based polymers with a wide spectrum of properties and applications. As new products are found, the list continues to grow. The most commonly used bioplastics are:

A) Starch-based Plastics

The most commonly used bioplastic is thermoplastic starch, which accounts for around half of the bioplastics industry. Starch is a low-cost, plentiful, and

renewable resource. Gelatinizing starch and solution processing can be used to create a basic starch bioplastic film at home. Pure starch can trap moisture, making it an ideal material for the pharmaceutical industry to use in the manufacture of drug capsules. Pure starch-based bioplastic, on the other hand, is brittle. Plasticizers including sorbitol, glycerol and glycol should be applied to the starch such that it can be treated thermo-plastically. Through changing the concentrations of these ingredients, the properties of the resulting bioplastic (also known as "thermoplastic starch") may be adjusted to individual requirements. Solution casting, compression moulding, injection moulding, and extrusion are examples of traditional polymer manufacturing methods that can be used to transform starch into bioplastic. The amylopectin/amylose ratio has a major impact on the properties of starch bioplastic. In general, starch with a high amylose content has stronger mechanical properties. High-amylose starch, on the other hand, is less processible due to its higher melting viscosity and gelatinization temperature.

Starch-based films (used mostly for packaging) are biodegradable and compostable items made from starch mixed with thermoplastic polyesters. These films are often used in consumer goods packaging, such as bubble wrap and magazine wrappers. These films are often used in food packaging as bakery or vegetable and fruit bags. Composting bags of these films are used to store agricultural waste selectively. Films consisting of starch can also be used as a paper.

Nanocomposites based on starch have been extensively studied, exhibiting enhanced thermal stability, moisture tolerance, mechanical properties and gas barrier properties.

B) Protein-based Plastics

Bioplastics may be produced from proteins from a variety of sources. For instance, casein, wheat gluten and milk have excellent potential as a raw material for different biodegradable polymers. In addition, soy protein is known to be another type of bioplastic. Soy proteins are used in the manufacture of plastics for over a hundred years. For instance, the original Ford car body components were built of soy-based plastic. Because of their water sensitivity and comparatively high cost, soy protein-based plastics pose challenges. As a result, combining soy protein

with some already-available biodegradable polyesters increases water resilience and reduces costs.

C) Cellulose-based Plastics

The cellulose esters (such as cellulose acetate and nitrocellulose) and its derivatives, such as celluloid, are the most popular cellulose bioplastics. When cellulose is highly modified, it can become thermoplastic. For instance, cellulose acetate is a costly material that is hardly used for packaging. Due to their lower hydrophilicity than starch, cellulosic fibres applied to starches can enhance gas permeability, water resistance and mechanical properties. Using a technique known as hot pressing, a group at Shanghai University were able to create a new organic plastic based on cellulose.

D) Aliphatic Polyesters

Aliphatic biopolyesters mainly includes :

- ❖ PHV (polyhydroxyvalerate),
- ❖ PHH (polyhydroxyhexanoate),
- ❖ PLA (polylactic acid),
- ❖ PHA (polyhydroxyalcanoate),
- ❖ PHB (poly-3-hydroxybutyrate),
- ❖ Polyamide 11 (PA11)

They're both susceptible to hydrolytic deterioration to varying degrees, so they can be combined with several other compounds.

I. Poly-3-hydroxybutyrate(PHB)

Poly-3-hydroxybutyrate (PHB), a biopolymer, is a polyester made by bacteria who treat glucose, corn starch, waste water or glucose. It has properties that are identical to the petroplastic polypropylene. The amount of PHB generated is rising. The sugar industry in South America, for instance, has planned to scale up PHB production to an industrial level. The physical features of PHB are what set it apart. It can be made into a clear film with the melting point of over 130 degrees Celsius and is completely biodegradable.

II. Polylactic acid (PLA)

PLA (polylactic acid) is a clear plastic made from dextrose or maize. On the surface, it looks like traditional petrochemical-based bulk plastics like Polystyrene(PS). It has the added benefit of degrading into nontoxic substances. Unfortunately, its thermal robustness, barrier properties and impact strength are all lacking. PLA and PLA blends are used for the plastic packaging industry to make plastic bags, containers, film, bottles and fabrics, in the shape of granulates with different properties. PLA is perhaps the most commonly used plastic filament which is used for fused deposition at home.

III. Polyhydroxyalkanoates(PHA)

Polyhydroxyalkanoates are straight polyesters formed by bacteria fermenting sugar or lipids in nature. They are formed by the bacteria in order to store carbon, power and energy. The polyester is processed and refined via bacteria in industrial processing by controlling sugar fermentation environments. Here in this family, over than 150 different monomers can be mixed to create materials with a wide range of applications and properties. PHA is a biodegradable material that is more ductile and less porous than most plastics. In the medical sector, this plastics are commonly used.

IV. Polyamide 11(PA11)

Polyamide is a natural oil-derived biopolymer. It's also called by the brand name Rilsan B, which is sold by Arkema. Polyamide is a kind of technological polymer that is non-biodegradable. It has similar properties as of PA 12, but it emits less greenhouse gases and uses less fossil fuels in the manufacturing process. It also outperforms PA 12 in terms of thermal tolerance. Electrical cord antitermite sheathing, catheters, control fluid umbilicals, automotive fuel lines, mobile system parts, lightweight oil and gas rods, pneumatic airbrake tubes and athletic gear are few of the examples where Polyamides are used.

E) Organic Polyethylene

Ethylene is the fundamental building block (monomer) of Polyethylene. Ethylene are chemically identical to and can be obtained through ethanol, and is made from plant feed stocks including corn or sugar cane instead of fossil fuels. Bio-derived

polyethylene are physically and chemically similar to conventional polyethylene; it is non-biodegradable but recyclable.

F) Lipid derivative polymers

Animal and plant fats and oils have been used to build a variety of bioplastic groups. Polyesters, epoxy resins, polyurethanes and a range of many other polymers with properties similar to crude oil-based materials have been developed. The recent invention of olefin metathesis has made it possible to transform a large range of fuel sources into biomonomers and polymers at a low cost. There is big scope for growth in this region, with the rising development of conventional vegetable oils and also low-cost microalgae-derived oils.

1.2.3 Market share

Bioplastics were once too costly to be seen as a viable alternative to petroleum-based plastics. Bioplastic costs are becoming more competitive with standard plastics due to lower temperatures used to manufacture bioplastics and a more reliable supply of biomass, as well as the rising cost of crude oil. It's difficult to quantify the overall size of the market of bioplastics due to complexity and uncertain meanings, but estimates placed global capacity at 327,000 tonnes. Market growth for much more sustainable solutions is reflected in the bioplastics global demand, which reached approximately one million tonnes in 2011. Market statistics from "European Bioplastics" predicts a fivefold rise in production capacity by 2016 – to approximately six million tonnes.

Business growth is influenced by both internal and external factors. Bioplastics are appealing because of external factors. Furthermore, the widely publicised impacts of global warming, price rises in carbon materials, and a growing reliance on fossil fuels all lead to bioplastics' favourable perception.

According to Ceresana, the global bioplastics industry will generate sales of around US\$2.8 billion in 2018, representing yearly growth rates of 17.8 percent. Bioplastics are intended to help protect the environment, solve the waste crisis, reduce dependency on fossil raw resources, and improve the reputation of plastic goods. In 2010, Europe was the main exporter of bioplastics, accounting for nearly 35% of total exports, led by North America and Asia-Pacific.

The market shares of the various world areas will adjust drastically during the next eight years. Ceresana predicts that two countries would have a major impact on the bioplastics industry. Asia-Pacific would increase its percentage of bioplastics production due to rapid growth in production and consumption. As a response, Asia-Pacific will almost catch up to North America and Europe in terms of economic growth. Furthermore, South America will experience solid growth, owing to major increases in production in Brazil.

1.2.4 Applications of Bioplastic

A. Horticulture and agriculture

- ❖ Bioplastics can be transformed into entirely blurred or translucent films which provide the perfect growing conditions while also supplying soil nutrients for future years.
- ❖ Ploughing mulching films into the ground after using it, rather than retrieving them from the field, washing them off, and restoring them for recycling, is more realistic and increases the operation's economics.
- ❖ Bioplastics have been established as a solution to forest waste, providing a protective barrier that allows young trees to survive. Early in the growth process, protection from vermin and a harsh atmosphere is guaranteed, but as the tree matures, the material can bio-disintegrate. On maintained woods, unsightly waste is eliminated, and collection expenses are minimized.
- ❖ Horticulturists are increasingly using bioplastics to create usable plant holders that are solid, water tolerant, come in a variety of shades, and disintegrate naturally in to the biomass.

B. Hygiene and Personal Care

- ❖ Bioplastics can be used to produce most personal care products, such as razors and toothbrushes. The bioplastics' matte finish assures that the plastic razor does have a strong grip and offers a smooth shave. Moisture, fatigue, thermal and temperature testing for goods in this field have all yielded satisfactory results.

- ❖ Bioplastics, on the other hand, can also be blown into opaque, smooth bottles for shampoos and lotions. Caps made of bioplastic may be injection or pressure moulded to match.
- ❖ These are use and throw items; if bioplastics could be used in place of plastic, the issue of plastic as a net trash can be greatly reduced.

C. Automobile and Electronic Devices

- ❖ NEC, a Japanese multinational, successfully created and introduced a flame-retardant bio-plastic that could be used in electronic gadgets in 2009. Because of its high heat resistance and thermal stability. NEC's new bioplastic is among the globe's most environmentally safe fire resistant plastics used for packaging electronic equipment.
- ❖ In another instance, Mitsubishi Plastics, Inc. accomplished in increasing the heat resistant of polylactic acid by mixing together with other biodegradable plastics and filler, and the resulting plastic packaging was used to produce a modern version of Sony Corp.'s Walkman.
- ❖ Back in the 1920s, Ford Motor Company was the first car company in the world to use bioplastics in the production of car components.
- ❖ They were recently included in the cover for the spare tyre in Toyota's latest iteration, the Raum. Polylactic acid (PLA) is a bioplastic extracted from natural like sugarcane and sweet potatoes.

D. Packaging

- ❖ Bioplastics can be made into waterproof and fat-resistant film for a range of environmentally friendly packaging and packing solutions.
- ❖ For retailers, being able to recycle unsellable perished food items with their packaging at a low cost instead of having to remove the contents from the packaging at a high cost is also a huge benefit.
- ❖ PLA is the most commonly utilized bioplastic in the food sector, including uses in fresh produce, dried foods like beef, fruit drinks, yoghurt, pasta and potato chips.

1.2.5 Bioplastic 's Advantages

A. Degradation Time

Standard plastics take millions of years to decay, and they remain in the atmosphere for decades, wreaking havoc on the ecosystem, especially on the sea bed. The development of natural ecosystems is hampered by these plastics, which ruin them.

On the other hand, bioplastics, decay in a fraction of the time. For certain bioplastics, this decay may be done at home, and perhaps even for those that need special conditions, the time taken to decay fully is significantly reduced. This relieves a lot of the burden on our current landfill.

B. Environmental-friendly

Standard plastics are petroleum-based plastics that rely on an inefficient source of energy: fossil fuels. Obtaining fossil fuels also has a huge negative effect on the atmosphere.

On the other hand, bioplastics, are made entirely of biomaterials such as , plants, trees and even garbage, and are totally biodegradable. As a result, bioplastics are produced from 100% renewable energy sources.

During the processing of plastics, contamination takes place; for instance, PVC plants may emit dioxins, which are recognised carcinogens that bio-accumulate in wildlife and humans and are related to health and immunity system disabilities.

Burning fossil fuels raises the amount of CO₂ in the environment which raises the global temperature (greenhouse effect). Scientists have discovered a link between the CO₂ levels in the environment and a rise in the rate of severe storms, hurricanes, and volcanism.

C. Less Energy Utilization

Industries do use fossil fuels to make bioplastics, but many bioplastics use much less fuel. Polylactic acid, for instance, takes less energy to manufacture than most other plastics.

D. Toxicity

Few plastics decay quickly in the seas, releasing extremely toxic chemicals into the water causing harm to wildlife and humans via the food chain.

There are no contaminants or pollutants in bioplastics, so they are absolutely clean. These plastic degrades and is dissolved into the soil in an environmentally friendly manner. Such benefits of bioplastics are critical, as the hazardous plastic burden on the planet is the and will create a slew of issues for coming generations if it continues at this pace.

1.2.6 Difficulties for Bioplastic

A. Environmental Affect

Starch-based bioplastics are usually derived from crops such as potatoes, corn, maize and so forth. This puts enormous strain on agricultural plants which must meet the demands of an ever-increasing population. Crops must be produced in order to produce plastics, which can result in deforestation.

Bioplastics are usually made from plants such as rice, soyabeans, potatoes and corn. These plants are frequently genetically engineered to enhance resilience to diseases insects and pests, as well as to increase production . This activity, however, poses a significant environmental risk since these crops can be harmful to both humans and animals.

B. Misinterpretations

Even though compostable plastics are thought to be good for the atmosphere they can damage the eco - system in certain respects. Greenhouse gases such as carbon dioxide and methane are emitted in vast quantities at landfill areas as they degrade.

Some bioplastics require particular criteria to biodegrade; these requirements may not be accessible at all landfills, or customers may not have accessibility to landfills; in such situations, it is critical to develop bioplastics that are biodegradable in a regular soil manure.

C. Cost

Bioplastics are an emerging technology that will take additional study and developments to become known. In terms of cost, bioplastics are not equivalent to plastics.

CHAPTER - 2

LITERATURE SURVEY

The standard method for the production of starch-based bioplastics is defined by the Royal Society of Chemistry. This includes using an acid to hydrolyze the starch. The thermal, rheological, and physiological properties of acid hydrolyzed starch were defined by Abdorreza et al (2011) in their paper.

This claim is also supported by Karntarat Wuttisela et al's paper (2008). The amylose composition of starch is what causes it to become plastic. Plasticizers are used to make the bioplastic products more flexible and mouldable.

Thawien Bourtoom of Thailand's Prince of Songkla University addresses the impact of common forms of plasticizers and its influence on bioplastic film characteristics such as elongation at break, water vapour absorption and tensile power in his paper (2007).

In their article, Nanou Peelman et al. (2013) address the uses of bioplastics, particularly in the packaging industries where biobased materials used as an element in (food) packaging products are discussed, various techniques for enhancing barrier qualities of biobased packaging and mechanical characteristics and permeability properties of multi-layered biobased plastics are also addressed.

Veeran Gowda Kadajji (2011) Department of Pharmaceutical Sciences, Western University of Health Sciences, Pomona, CA 91766, USA discusses pharmaceutical developments in his article. In the pharmaceutical companies, water soluble polymers are used.

The chemical structure of coconut kernel powder as a filler substance has indeed been explored in a paper by C.J. Ewansiha in (2012) Chemistry Department, College of Education, P.M.B 003, Igueben, Nigeria. This paper investigated the proximate research and mineral compositions of coconut shells.

J. Olumuyiwa Agunsoye (2012) Department of Metallurgical and Materials Engineering, University of Lagos, Lagos, Nigeria, explored the shell powdered applied on polymer matrix compound.

K. Kanimozhi (2014) of Periyar University's Department of Chemistry in Salem, Tamilnadu, India, addressed the testing of bioplastic formulation in an article. She identified the different steps of FTIR spectroscopy study of bioplastics shape and composition.

CHAPTER - 3

AIM AND SCOPE OF THE STUDY

3.1 AIM

To compare the potato starch-based bioplastic film and corn starch- based bioplastic film by performing different experiments on them. Also, to find out which bioplastic film is better.

The objective of this experiments are :

- i. To check the pH of the produced bioplastics films.
- ii. To compare the Water Absorption Test.
- iii. To compare the Acid Absorption Test
- iv. To compare the Base Absorption Test
- v. To compare the Moisture Content.
- vi. To perform Biodegradability Test on the bioplastic films.

3.2 SCOPE

Many other experiments and analysis which I couldn't perform can be performed on both the bioplastics films like Scanning Electron Microscopy(SEM), Protein Contents, Fourier Transform Infrared Spectroscopy(FTIR), Mechanical Properties, Thermal Properties.

CHAPTER - 4

MATERIALS AND METHODS

4.1 MATERIALS

4.1.1 Equipments Required

- A. Weighing Machine
- B. Stirrer/Glass Rod
- C. Spatula
- D. Measuring Cylinder
- E. Petri Dish
- F. Beaker/Measuring Cup
- G. Cooking Pan



Fig:4.1 : Weighting Machine



Fig:4.2 : Glass Rod/Stirrer



Fig:4.3 : Spatula



Fig:4.4 : Measuring Cylinder



Fig:4.5 : Petri Dish

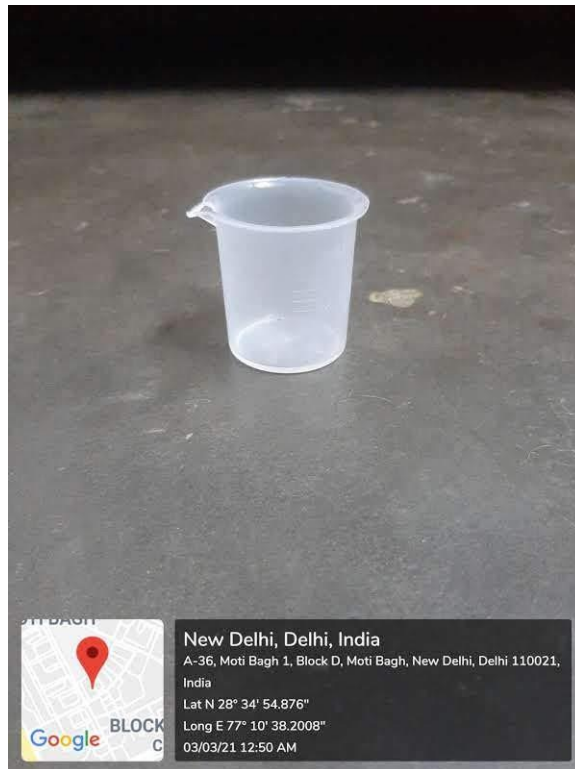


Fig:4.6 : Beaker/Measuring Cup



Fig:4.7 : Cooking Pan

4.1.2 Raw Materials & Chemicals Required

- A. Corn Starch Powder
- B. Potato Starch Powder
- C. Universal Indicator
- D. Distilled Water
- E. Glycerin
- F. White Vinegar/0.1M Hydrochloric Acid
- G. 0.1M Sodium Hydroxide(NaOH)



Fig:4.8 : Corn Starch Powder

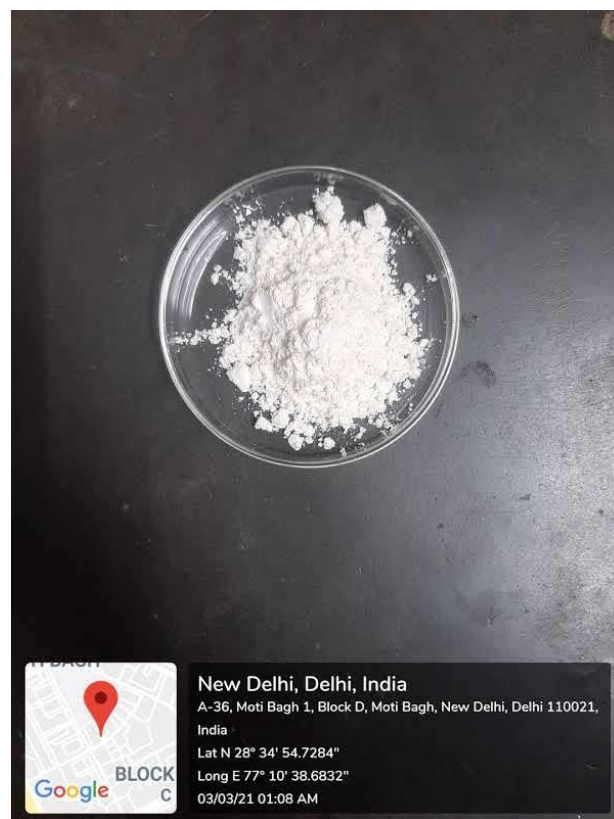


Fig:4.9 : Potato Starch Powder



Fig:4.10 : Universal Indicator



Fig:4.11 : Distilled Water



Fig:4.12 : Glycerin



Fig:4.13 : White Vinegar



Fig:4.14 : Sodium Hydroxide (NaOH)

4.2 METHODOLOGY

4.2.1 Procedure to Prepare Potato Starch Bioplastic Film

A. Potato Preparation

The potatoes had to be smashed and ground so the starch grains could be extracted from the destroyed cells. To begin, potato starch had to be extracted through a series of steps that included weighting, cleaning, peeling, and chopping up the potatoes, slurring sliced potatoes, and finally filtering.

- i. **Weighting** : To start, the chosen potatoes were weighed to determine their initial mass. The overall weight of potatoes used for the extraction was roughly 1.127 kilogram. The impurities of the potatoes were measured by the difference in weight before and after washing.
- ii. **Cleaning** : The potatoes were then thoroughly cleaned with water to eliminate any undesirable items such as soil, dirt and dust. Since certain impurities have weights and proportions that are identical to starch, cleaning them thoroughly is the best way to get rid of them.
- iii. **Peeling** : After cleaning, potatoes were properly peeled by hand with a peeler. One of the factors for the starch granules and pulp being lost is the unnecessary peeling of the potato. Loosing a significant volume of starch granules because of peeling can induce changes in both chemical and physical characteristics.
- iv. **Chopping** : The peeled potatoes were then carefully chopped by using a knife into smaller sizes. Again, chopping should be done with precautions, to prevent any damage to starch granules.
- v. **Slurring** : Put the chopped potatoes in a blender and add some cold water to it. The ratio of the chopped potato to cold water is 1:10.

B. Extraction Of the Starch

- ❖ After blending, drain the liquid into a beaker using the coffee strainer having left the potato behind.
- ❖ Now add 100 ml of water, then grind and strain once more.
- ❖ After that, set aside for 5 to 10 minutes to allow the solution to settle in the beaker.
- ❖ Remove the water from the beaker, leave the white layer that should have accumulated at the bottom of the beaker suggesting that the starch had already collected.
- ❖ Now, stir in about 100 mL of distilled water to the collected starch.
- ❖ Allow to settle again before pouring the water out and having left the starch behind.
- ❖ The beaker containing starch was dried in a microwave oven until it became powdered and then measured.

C. Preparation Of Bioplastic Film Using Potato Starch

- ❖ In a container, 5 grams of dried potato starch powder is mixed with 50 ml distilled water.
- ❖ Now add 4 ml of Glycerol and 6 ml of White Vinegar.
- ❖ The mixture was thoroughly mixed after being stirred.
- ❖ After that, the solution was heated on a low-medium flame for 10-15 minutes, until an opaque gel was developed.
- ❖ Draw the solution in beaker out of the flame, and test the Potential of Hydrogen(pH) of solution using an universal pH indicator.
- ❖ If the Universal Indicator turns red, it shows the presence of acid in solution.
- ❖ As a result, introduce 6 mL of 0.1M Sodium hydroxide(NaOH) to neutralise the solution and thoroughly mix the solution.
- ❖ Finally, the solution was laid out on a petri dish.
- ❖ To solidify, the solution is kept to dry in the room temperature.



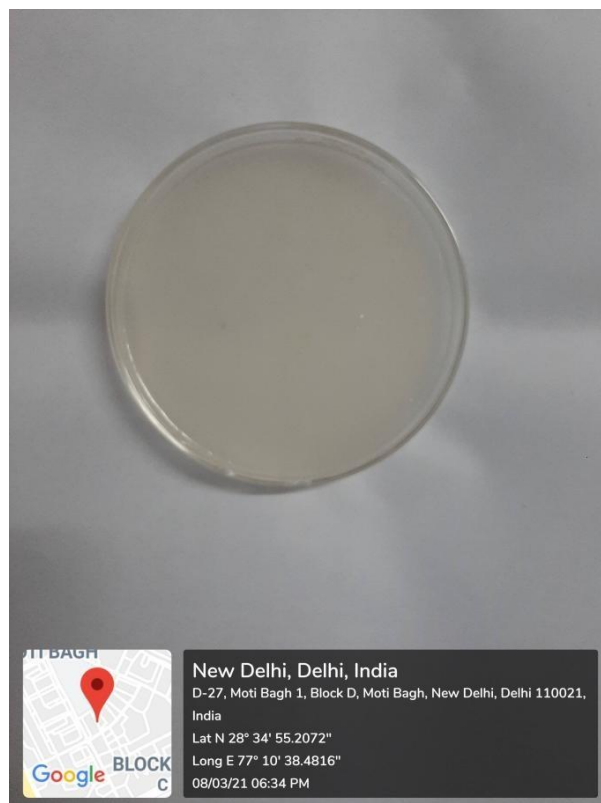
Fig:4.15 : Raw materials added together (Potato Starch Bioplastic)



Fig:4.16 : After mixing thoroughly (Potato Starch Bioplastic)



**Fig:4.17 : After 5 minutes of heating
(Potato Starch Bioplastic)**



**Fig:4.18 : After 10 minutes of
heating (Potato Starch Bioplastic)**

4.2.2 Procedure to Prepare Corn Starch Bioplastic Film

For this experiment, I took a ready-made Corn starch powder of Desire company.

- ❖ In a container, 5 grams of dried corn starch powder is mixed with 50 ml distilled water.
- ❖ Now add 4 ml of Glycerol and 6 ml of White Vinegar.
- ❖ The mixture was thoroughly mixed after being stirred.
- ❖ After that, the solution was heated on a low-medium flame for 10-15 minutes, until an opaque gel was developed.
- ❖ Draw the solution in beaker out of the flame, and test the Potential of Hydrogen(pH) of solution using an universal pH indicator.
- ❖ If the Universal Indicator turns red, it shows the presence of acid in solution.
- ❖ As a result, introduce 6 mL of 0.1M Sodium hydroxide(NaOH) to neutralise the solution and thoroughly mix the solution.
- ❖ Finally, the solution was laid out on a petri dish.
- ❖ To solidify, the solution is kept to dry in the room temperature.



Fig:4.19 : Raw materials added together (Corn Starch Bioplastic)



***Fig:4.20 : After mixing thoroughly
(Corn Starch Bioplastic)***



***Fig:4.21 : After 5 minutes of
heating (Corn Starch Bioplastic)***



**Fig:4.22 : After 10 minutes of heating
(Corn Starch Bioplastic)**

4.3 CHARACTERIZATION OF BIOPLASTIC FILMS

4.3.1 Water Absorption Test :

The bioplastic film was cut into a fixed weight to get a sample. After that, the sample was dried in a microwave oven at 60 degrees celsius to eliminate any remaining moisture. Then the dried sample is placed inside a glass containing 50 ml of distilled water for 24 hours. Weight the sample before placing in distilled water and after 24 hours. The equation for determining water absorption is :

$$\text{Water Absorption(WA)\%} = \frac{(\text{Final Weight(Wb)} - \text{Initial Weight(Wa)})}{\text{Initial Weight(Wa)}} \times 100$$

Where, WA- Water Absorption

Wa- Initial Weight of the sample(dry)

Wb- Final Weight of the sample(after 24 hrs in distilled water)

4.3.2 Acid Absorption Test :

The bioplastic film was cut into a fixed weight to get a sample. After that, the sample was dried in a microwave oven at 60 degrees celsius to eliminate any remaining moisture. Then the dried sample is placed inside a glass containing 50 ml of white vinegar for 24 hours. Weight the sample before placing in white vinegar and after 24 hours. The equation for determining acid absorption is:

$$\text{Acid Absorption(AA)\%} = \frac{(\text{Final Weight(Wd)} - \text{Initial Weight(Wc)})}{\text{Initial Weight(Wc)}} \times 100$$

Where, AA- Acid Absorption

Wc- Initial Weight of the sample(dry)

Wd- Final Weight of the sample(after 24 hrs in white vinegar)

4.3.3 Base Absorption Test :

The bioplastic film was cut into a fixed weight to get a sample. After that, the sample was dried in a microwave oven at 60 degrees celsius to eliminate any remaining moisture. Then the dried sample is placed inside a glass containing 50 ml of Sodium Hydroxide(NaOH) for 24 hours. Weight the sample before placing in Sodium Hydroxide and after 24 hours. The equation for determining base absorption is :

$$\text{Base Absorption(BA)\%} = \frac{(\text{Final Weight(Wf)} - \text{Initial Weight(We)})}{\text{Initial Weight(We)}} \times 100$$

Where, BA- Base Absorption

We- Initial Weight of the sample(dry)

Wf- Final Weight of the sample(after 24 hrs in sodium hydroxide)

4.3.4 Moisture Content Test :

The moisture content was measured by calculating the weight reduction of bioplastic films. The bioplastic film was cut into a fixed weight to get a sample. To obtain a moisture free dry product, the sample is dried in a microwave oven at 110 degrees Celsius. The equation for determining the weight loss is given as :

$$\text{Moisture Content(MC)\%} = \frac{(\text{Initial Weight}(W_o) - \text{Final Weight}(W_i))}{\text{Initial Weight}(W_o)} \times 100$$

Where, MC- Moisture loss

W_o - Initial Weight of the sample

W_i - Final Weight of the sample(after drying in microwave oven)

4.3.5 Biodegradability Test :

The bioplastic film was cut into a fixed weight to get a sample. Around 500 grams of soil is collected and collected in a pot.

Using the Universal Indicator the pH of the soil was found out to be 7.7.

Both the samples of bioplastic films were buried in the soil at depth of 6 cm for 10 days under the room conditions. The weight of the samples were measured on the first day and on the tenth day. The equation for determining the weight loss is given as :

$$\text{Percent Weight Loss, (\%W)} = \frac{(\text{Initial Weight}(W_x) - \text{Final Weight}(W_y))}{\text{Initial Weight}(W_x)} \times 100$$

Where, W- Weight Loss

W_x - Initial Weight of the sample

W_y - Final Weight of the sample(after 10days)

CHAPTER - 5

RESULTS AND DISCUSSION

5.1 POTATO STARCH BASED BIOPLASTIC FILM

- ❖ The total amount of Bioplastic film obtained as the final product is 11.86 grams .
- ❖ The Bioplastic film formed is whitish in colour, highly dense and solid.
- ❖ Thickness of the obtained bioplastic film was found out to be 0.23 cm
- ❖ The diameter of the obtained bioplastic film was found out to be 8.29 cm.

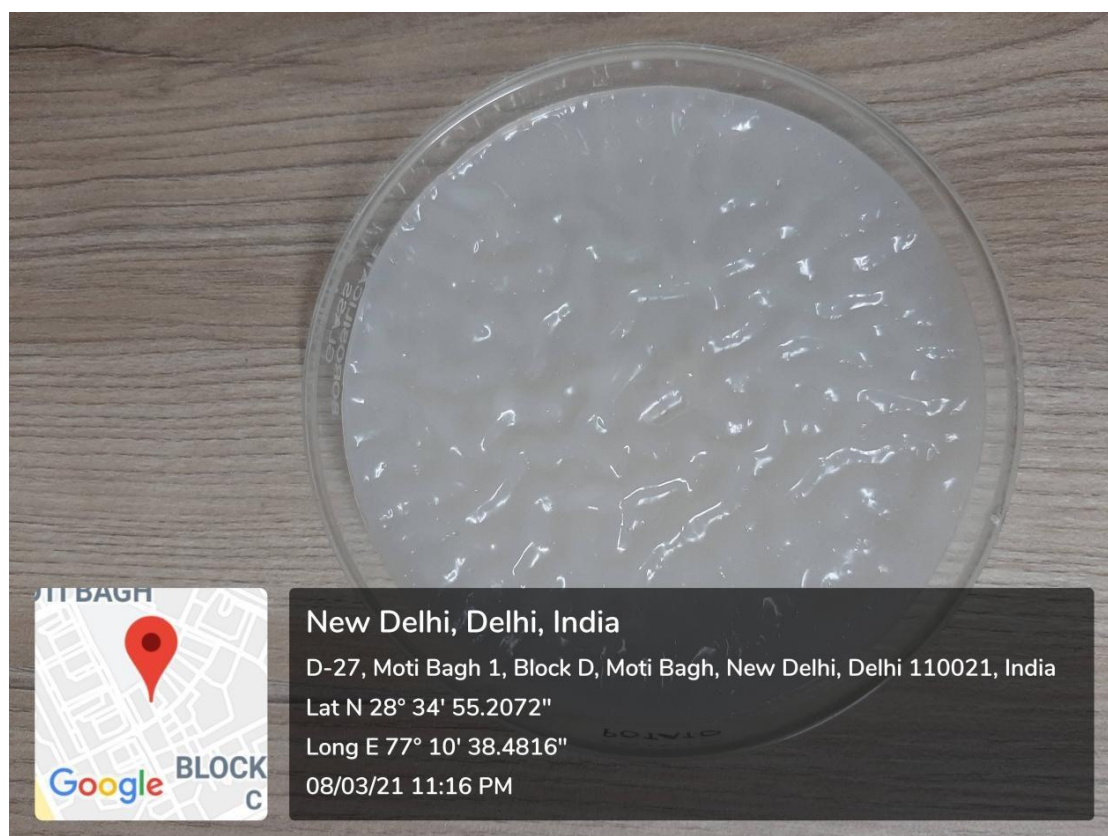


Fig:5.1 : Potato Starch Bioplastic Film(11.86 grams)

I. Water Absorption Test :

Table 5.1: Data on Water Absorption Test for Potato Bioplastics

Initial Weight (Wa) (in grams)	Weight at 12 hours (in grams)	Weight at 24 hours(Wb) (in grams)	Absorption Value in (%)
3.23	4.49	4.69	45.201

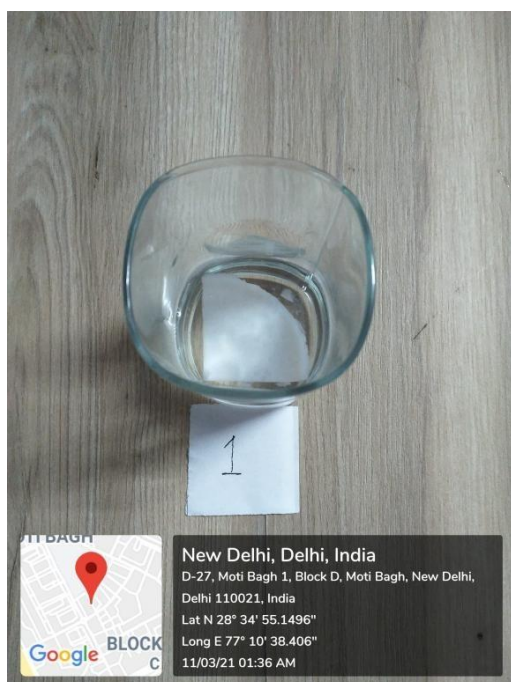


Fig:5.2 : Water Absorption Studies : Bioplastic (Potato Starch) immersed in water



Fig:5.3 : Weight (in g) of the Bioplastics (Potato Starch) after 24 hours immersion in water.

As per my experiment the obtained values are :

Weight of the Initial sample, Wa = 3.23 grams

Final Weight of the sample(after 24 hrs in distilled water), Wb = 4.69 grams

So, the Water Absorbed in 24 hours is given as :

$$\text{Water Absorption(WA)\%} = \frac{(\text{Final Weight(Wb)} - \text{Initial Weight(Wa)})}{\text{Initial Weight(Wa)}} \times 100$$

$$\text{Water Absorption(WA)\%} = \frac{(4.69 - 3.23)}{3.23} \times 100$$

$$\text{Water Absorption(WA)\%} = \frac{1.46}{3.23} \times 100$$

$$\text{Water Absorption(WA)\%} = 0.45201 \times 100$$

Water Absorption(WA)%= 45.201%

Therefore, the percent water absorbed by the potato starch based bioplastic film in 24 hours is 45.201%.

II. *Acid Absorption Test :*

Table 5.2: Data on Acid Absorption Test for Potato Bioplastics

Initial Weight (Wc) (in grams)	Weight at 12 hours (in grams)	Weight at 24 hours(Wd) (in grams)	Absorption Value in (%)
3.23	4.76	4.92	52.322



Fig:5.4 : Acid Absorption Studies : Bioplastic (Potato Starch) immersed in acid



Fig:5.5 : Weight (in g) of the Bioplastics (Potato Starch) after 24 hours immersion in acid

As per my experiment the obtained values are :

Weight of the Initial sample, Wc = 3.23 grams

Final Weight of the sample(after 24 hrs in White Vinegar), Wd =4.92 grams

So, the Acid Absorbed in 24 hours is given as :

$$\text{Acid Absorption(AA)\%} = \frac{(\text{Final Weight(Wd)} - \text{Initial Weight(Wc)})}{\text{Initial Weight(Wc)}} \times 100$$

$$\text{Acid Absorption(AA)\%} = \frac{(4.92 - 3.23)}{3.23} \times 100$$

$$\text{Acid Absorption(AA)\%} = \frac{1.69}{3.23} \times 100$$

$$\text{Acid Absorption(AA)\%} = 0.52322 \times 100$$

$$\text{Acid Absorption(AA)\%} = 52.322\%$$

Therefore, the percent acid absorbed by the sample bioplastic film in 24 hours is 52.322%.

III. Base Absorption Test :

Table 5.3: Data on Base Absorption Test for Potato Bioplastics

Initial Weight (We) (in grams)	Weight at 12 hours (in grams)	Weight at 24 hours(Wb) (in grams)	Absorption Value in (%)
3.23	5.11	5.14	59.133



Fig:5.6 : Base Absorption Studies : Bioplastic (Potato Starch) immersed in base



Fig:5.7 : Weight (in g) of the Bioplastics (Potato Starch) after 24 hours immersion in base

As per my experiment the obtained values are :

Weight of the Initial sample, $W_e = 3.23$ grams

Final Weight of the sample(after 24 hrs in Sodium hydroxide), $W_f = 5.14$ grams

So, the Base Absorbed in 24 hours is given as :

$$\text{Base Absorption(BA)\%} = \frac{(\text{Final Weight}(W_f) - \text{Initial Weight}(W_e))}{\text{Initial Weight}(W_e)} \times 100$$

$$\text{Base Absorption}_{(BA)}\% = \frac{(5.14 - 3.23)}{3.23} \times 100$$

$$\text{Base Absorption}_{(BA)}\% = \frac{1.91}{3.23} \times 100$$

$$\text{Base Absorption(BA)\%} = 0.59133 \times 100$$

$$\text{Base Absorption(BA)\%} = 59.133\%$$

Therefore, the percent base absorbed by the sample bioplastic film in 24 hours is 59.133%.

IV. Moisture Content Test :

Table 5.4: Data on Moisture Content Test for Potato Bioplastics

Initial Weight (W_o) (in grams)	Final Weight (W_i) (in grams)	Moisture removed (in %)
4.62	2.984	35.41

As per my experiment the obtained values are :

Weight of the Initial sample, $W_o = 4.62$ grams

Final Weight of the sample(after drying in microwave oven), $W_i = 2.984$ grams

So, the Moisture removed after drying is given as :

$$\text{Moisture Content(MC)\%} = \frac{(\text{Initial Weight}(W_o) - \text{Final Weight}(W_i))}{\text{Initial Weight}(W_o)} \times 100$$

$$\text{Moisture Content}_{(MC)}\% = \frac{(4.62 - 2.984)}{4.62} \times 100$$

$$\text{Moisture Content}_{(MC)}\% = \frac{1.636}{4.62} \times 100$$

$$\text{Moisture Content(MC)\%} = 0.3541 \times 100$$

$$\text{Moisture Content(MC)\%} = 35.41\%$$

Therefore, the percent of moisture removed from the sample bioplastic film is 35.41%

V. Biodegradability Test :

Table 5.5: Data on Biodegradability Test for Potato Bioplastics

Initial Weight (W _x) (in grams)	Final Weight (W _y) (in grams)	Weight loss (in %)
11.68	7.58	35.10



Fig:5.8 : Biodegradability Test : Determination Weight loss of the Bioplastic (Potato Starch) on day 10 of degradation

As per my experiment the obtained values are :

Weight of the Initial sample, W_x= 11. 68 grams

Final Weight of the sample(after 10 days), W_y= 7.58 grams

So, the weight loss after 10 days is given as :

$$\text{Percent Weight Loss, (\%W)} = \frac{(\text{Initial Weight(W}_x) - \text{Final Weight(W}_y))}{\text{Initial Weight(W}_x)} \times 100$$

$$\text{Percent Weight Loss, (\%W)} = \frac{(11.68 - 7.58)}{11.68} \times 100$$

$$\text{Percent Weight Loss, (\%W)} = \frac{4.1}{11.68} \times 100$$

$$\text{Percent Weight Loss, (\%W)} = 0.3510 \times 100$$

$$\text{Percent Weight Loss, (\%W)} = 35.10\%$$

Therefore, the weight loss by the sample bioplastic film in 10 days is 35.10%.

5.2 CORN STARCH BASED BIOPLASTIC FILM

- ❖ The total amount of Bioplastic film obtained as the final product is 10.88 grams .
- ❖ The Bioplastic film formed is pure white in colour, dense and solid.
- ❖ Thickness of the obtained bioplastic film was found out to be 0.21 cm.
- ❖ The diameter of the obtained bioplastic film was found out to be 8.35 cm.



Fig:5.9 : Corn Starch Bioplastic Film(10.88 grams)

I. Water Absorption Test :

Table 5.6: Data on Water Absorption for Corn Bioplastics

Initial Weight (Wa) (in grams)	Weight at 12 hours (in grams)	Weight at 24 hours(Wb) (in grams)	Absorption Value in (%)
3.23	4.86	5.47	69.35



Fig:5.10 : Water Absorption Studies : Bioplastic (Corn Starch) immersed in water



Fig:5.11 : Weight (in g) of the Bioplastics (Corn starch) after 24 hours immersion in water.

As per my experiment the obtained values are :

Weight of the Initial sample, Wa = 3.23 grams

Final Weight of the sample(after 24 hrs in distilled water), Wb = 5.47 grams

So, the Water Absorbed in 24 hours is given as :

$$\text{Water Absorption(WA)\%} = \frac{(\text{Final Weight(Wb)} - \text{Initial Weight(Wa)})}{\text{Initial Weight(Wa)}} \times 100$$

$$\text{Water Absorption(WA)\%} = \frac{(5.47 - 3.23)}{3.23} \times 100$$

$$\text{Water Absorption(WA)\%} = \frac{2.24}{3.23} \times 100$$

$$\text{Water Absorption(WA)\%} = 0.6935 \times 100$$

Water Absorption(WA)%= 69.35%

Therefore, the percent water absorbed by the corn starch based bioplastic film in 24 hours is 69.35%.

II. Acid Absorption Test :

Table 5.7: Data on Acid Absorption for Corn Bioplastics

Initial Weight (Wc) (in grams)	Weight at 12 hours (in grams)	Weight at 24 hours(Wd) (in grams)	Absorption Value in (%)
3.23	5.24	5.88	82.043



Fig:5.12 : Acid Absorption Studies : Bioplastic (Corn Starch) immersed in acid



Fig:5.13 : Weight (in g) of the Bioplastics (Corn starch) after 24 hours immersion in acid

As per my experiment the obtained values are :

Weight of the Initial sample, Wc = 3.23 grams

Final Weight of the sample(after 24 hrs in White Vinegar), Wd =5.88 grams

So, the Acid Absorbed in 24 hours is given as :

$$\text{Acid Absorption(AA)\%} = \frac{(\text{Final Weight(Wd)} - \text{Initial Weight(Wc)})}{\text{Initial Weight(Wc)}} \times 100$$

$$\text{Acid Absorption(AA)\%} = \frac{(5.88 - 3.23)}{3.23} \times 100$$

$$\text{Acid Absorption(AA)\%} = \frac{2.65}{3.23} \times 100$$

$$\text{Acid Absorption(AA)\%} = 0.82043 \times 100$$

$$\text{Acid Absorption(AA)\%} = 82.043\%$$

Therefore, the percent acid absorbed by the sample bioplastic film in 24 hours is 82.043%.

III. Base Absorption Test :

Table 5.8: Data on Base Absorption for Corn Bioplastics

Initial Weight (Wa) (in grams)	Weight at 12 hours (in grams)	Weight at 24 hours(Wb) (in grams)	Absorption Value in (%)
3.23	4.82	5.30	64.086

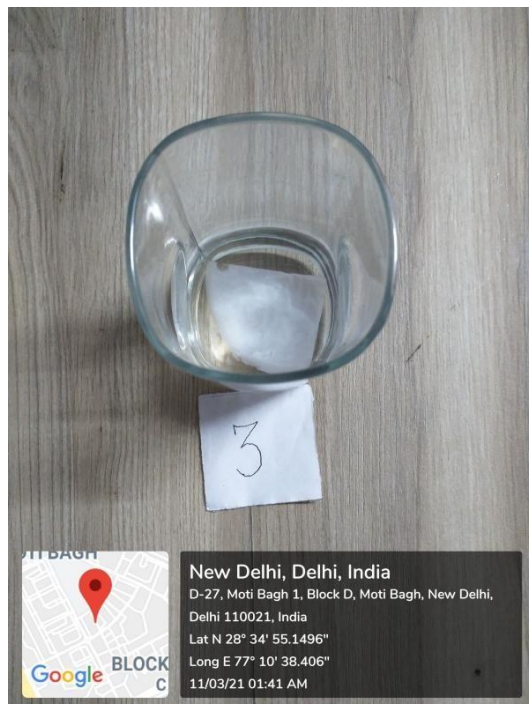


Fig:5.14 : Base Absorption Studies : Bioplastic (Corn Starch) immersed in base



Fig:5.15 : Weight (in g) of the Bioplastics (Corn starch) after 24 hours immersion in base

As per my experiment the obtained values are :

Weight of the Initial sample, $W_e = 3.23$ grams

Final Weight of the sample(after 24 hrs in Sodium hydroxide), $W_f = 5.30$ grams

So, the Base Absorbed in 24 hours is given as :

$$\text{Base Absorption(BA)\%} = \frac{(\text{Final Weight}(W_f) - \text{Initial Weight}(W_e))}{\text{Initial Weight}(W_e)} \times 100$$

$$\text{Base Absorption(BA)\%} = \frac{(5.30 - 3.23)}{3.23} \times 100$$

$$\text{Base Absorption(BA)\%} = \frac{2.07}{3.23} \times 100$$

$$\text{Base Absorption(BA)\%} = 0.64086 \times 100$$

$$\text{Base Absorption(BA)\%} = 64.086\%$$

Therefore, the percent base absorbed by the sample bioplastic film in 24 hours is 64.086%.

IV. Moisture Content Test :

Table 5.9: Data on Moisture Content Test for Corn Bioplastics

Initial Weight (W_o) (in grams)	Final Weight (W_i) (in grams)	Moisture removed (in %)
4.34	2.67	38.47

As per my experiment the obtained values are :

Weight of the Initial sample, $W_o = 4.34$ grams

Final Weight of the sample(after drying in microwave oven), $W_i = 2.67$ grams

So, the Moisture removed after drying is given as :

$$\text{Moisture Content(MC)\%} = \frac{(\text{Initial Weight}(W_o) - \text{Final Weight}(W_i))}{\text{Initial Weight}(W_o)} \times 100$$

$$\text{Moisture Content(MC)\%} = \frac{(4.34 - 2.67)}{4.34} \times 100$$

$$\text{Moisture Content (MC)\%} = \frac{1.67}{4.34} \times 100$$

$$\text{Moisture Content (MC)\%} = 0.3847 \times 100$$

$$\text{Moisture Content (MC)\%} = 38.47\%$$

Therefore, the percent of moisture removed from the sample bioplastic film is 38.47%.

V. Biodegradability Test :

Table 5.10: Data on Biodegradability Test for Corn Bioplastics

Initial Weight (W _x) (in grams)	Final Weight (W _y) (in grams)	Weight loss (in %)
12.76	8.540	33.07

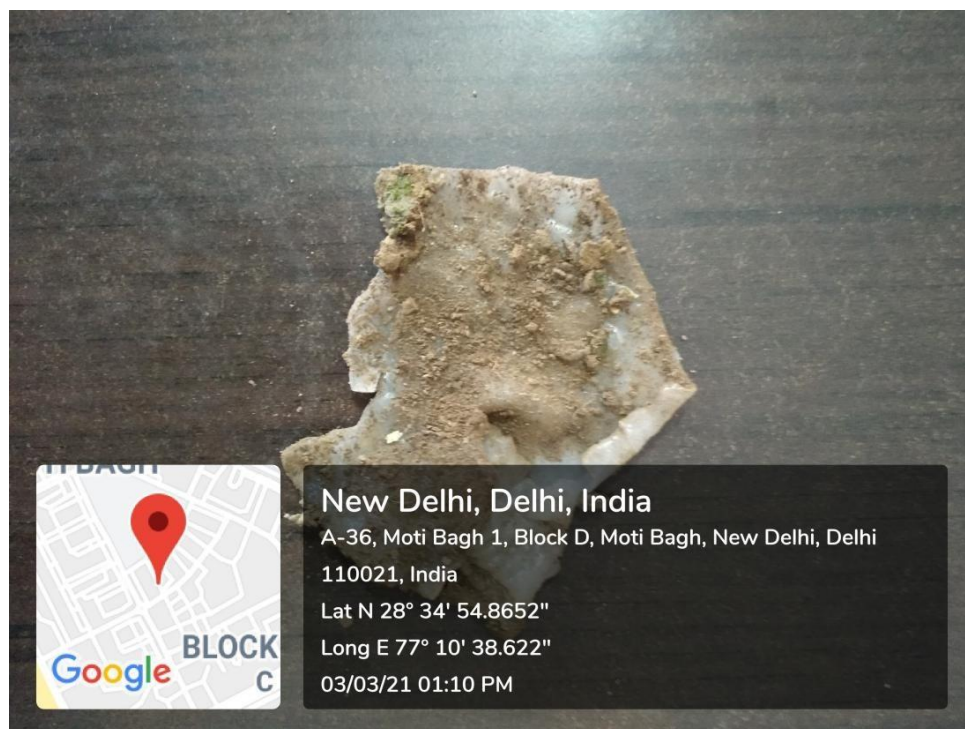


Fig:5.16 : Biodegradability Test : Determination of Weight loss of the Bioplastic (Corn Starch) on day 10 of degradation

As per my experiment the obtained values are :

Weight of the Initial sample, W_x= 12.76 grams

Final Weight of the sample(after 10 days), Wy= 8.540 grams

So, the weight loss after 10 days is given as :

$$\text{Percent Weight Loss, (\%W)} = \frac{(\text{Initail Weight}(W_x) - \text{Final Weight}(W_y))}{\text{Initail Weight}(W_x)} \times 100$$

$$\text{Percent Weight Loss, (\%W)} = \frac{(12.76 - 8.540)}{12.76} \times 100$$

$$\text{Percent Weight Loss, (\%W)} = \frac{4.22}{12.76} \times 100$$

$$\text{Percent Weight Loss, (\%W)} = 0.3307 \times 100$$

$$\text{Percent Weight Loss, (\%W)} = 33.07\%$$

Therefore, the weight loss by the sample bioplastic film in 10 days is 33.07%.

Table 5.11: Comparing Potato Starch & Corn Starch Bioplastic Film

Characterization	Potato Starch Bioplastic Film	Corn Starch Bioplastic Film
Water Absorption Test (in %)	45.201	69.35
Acid Absorption Test (in %)	52.322	82.043
Base Absorption Test (in %)	59.133	64.086
Moisture Content Test (in %)	35.41	38.47
Biodegradability Test (in %)	35.10	33.07



Fig:5.17 : Final Product(1. Corn Starch Bioplastic Film, 2. Potato Starch Bioplastic Film)

CHAPTER - 6

SUMMARY AND CONCLUSION

This present study involved the preparation of Bioplastic Film from two different sources. The first Bioplastic Film was prepared using Potato Starch and the second Bioplastic Film was prepared using Corn Starch. In this study the Bioplastic was obtained using White Vinegar instead of Hydrochloric Acid. The Other materials used in the preparation of bioplastic films are Glycerin, Sodium Hydroxide and Starch powder.

All the experiments and preparations were performed at Moti Bagh-I, New Delhi. The Potato Starch Powder was prepared at home on the other hand the corn starch powder was bought ready-made. Both the Bioplastic film had the neutral pH.

To check which Bioplastic film is better, several experiments like Water Absorption Test, Acid Absorption Test, Base Absorption Test, Moisture Content Test and Biodegradability Test were performed on both the films. After experimenting, it was found that the Corn Starch Bioplastic Film is better than potato starch bioplastic film. But, the Potato Starch Bioplastic Film degrades faster than that of the Corn Starch Bioplastic Film.

REFERENCES

Andreas Künkel, Johannes Becker, Lars Börger, Jens Hamprecht, Sebastian Koltzenburg, Robert Loos, Michael Bernhard Schick, Katharina Schlegel, Carsten Sinkel, Gabriel Skupin and Motonori Yamamoto (2016). Ullmann's Encyclopedia of Industrial Chemistry. Weinheim: Wiley-VCH. pp. 1–29. doi:10.1002/14356007.n21_n01.pub2

Avérous, Luc; Pollet, Eric (2014), "Nanobiocomposites Based on Plasticized Starch", Starch Polymers, Elsevier, pp. 211–239, doi:10.1016/b978-0-444-53730-0.00028-2, ISBN 9780444537300

Benvenuto, Mark A. (2018-01-20). "26 Biofuels and bioplastics". doi:10.1515/spark.32.27.

Brodin, Malin; Vallejos, María; Opedal, Mihaela Tanase; Area, María Cristina; Chinga-Carrasco, Gary (September 2017). "Lignocellulosics as sustainable resources for production of bioplastics – A review". *Journal of Cleaner Production*. **162**: 646–664. doi:10.1016/j.jclepro.2017.05.209. ISSN 0959-6526.

Cate, Peter (January 2017). "Collaboration delivers better results". *Reinforced Plastics*. **61** (1): 51–54. doi:10.1016/j.repl.2016.09.002. ISSN 0034-3617.

Corn and Rice Starch-Based Bio-Plastics as Alternative Packaging Materials. <https://doi.org/10.3390/fib7040032>

Floros, Michael; Hojabri, Leila; Abraham, Eldho; Jose, Jesmy; Thomas, Sabu; Pothan, Laly; Leao, Alcides Lopes; Narine, Suresh (2012). "Enhancement of thermal stability, strength and extensibility of lipid-based polyurethanes with cellulose-based nanofibers". *Polymer Degradation and Stability*. **97** (10): 1970–1978. doi:10.1016/j.polymdegradstab.2012.02.016.

Meier, Michael A. R.; Metzger, Jürgen O.; Schubert, Ulrich S. (2007-10-02). "Plant oil renewable resources as green alternatives in polymer science". *Chemical Society Reviews*. 36 (11): 1788–802. doi:10.1039/b703294c. ISSN 1460-4744. PMID 18213986

Preparation and characterization of natural corn starch-based composite films reinforced by eggshell powder Bingxue Jiang, Shuai Li, Yuanyuan Wu, Jingxin Song, Shanshan Chen, Xinxin Li Pages 1045-1054 | Received 09 Apr 2018, Accepted 04 Jul 2018, Published online: 04 Dec 2018 <https://doi.org/10.1080/19476337.2018.1527783>

Pillai, Prasanth K. S.; Floros, Michael C.; Narine, Suresh S. (2017-07-03). "Elastomers from Renewable Metathesized Palm Oil Polyols". *ACS Sustainable Chemistry & Engineering*. 5 (7): 5793–5799. doi:10.1021/acssuschemeng.7b00517.

Raschka, Achim; Carus, Michael; Piotrowski, Stephan (2013-10-04), "Renewable Raw Materials and Feedstock for Bioplastics", *Bio-Based Plastics*, John Wiley & Sons Ltd, pp. 331–345, doi:10.1002/9781118676646.ch13, ISBN 9781118676646

Song, J. H.; Murphy, R. J.; Narayan, R.; Davies, G. B. H. (2009-07-27). "Biodegradable and compostable alternatives to conventional plastics". *Philosophical Transactions of the Royal Society B: Biological Sciences*. 364 (1526): 2127–2139. doi:10.1098/rstb.2008.0289. ISSN 0962-8436. PMC 2873018. PMID 19528060.

Tran, Thang Hong, Nguyen, Hoang-Linh, Hwang, Dong Soo, Lee, Ju Young, Cha, Hyun Gil, Koo, Jun Mo, Hwang, Sung Yeon, Park, Jeyoung, Oh, Dongyeop X. (2019). "Five different chitin nanomaterials from identical source with different advantageous functions and performances". *Carbohydrate Polymers*. Elsevier Science B.V., Amsterdam. 205 (– [2019]): 392–400. doi:10.1016/j.carbpol.2018.10.089. ISSN 0144-8617. PMID 30446120

Vert, Michel (2012). "Terminology for biorelated polymers and applications (IUPAC Recommendations 2012)" (PDF). Pure and Applied Chemistry. 84 (2): 377–410. doi:10.1351/PAC-REC-10-12-04. S2CID 98107080

White, J. L. (December 1998). "Fourth in a Series: Pioneers of Polymer Processing Alexander Parkes". International Polymer Processing. 13 (4): 326. doi:10.3139/217.980326. ISSN 0930-777X. S2CID 137545344

https://en.wikipedia.org/wiki/Bioplastic#Biodegradation_of_Bioplastics

<https://en.wikipedia.org/wiki/Plastic>

<https://jprsolutions.info/files/ms-file-5b482cd492f7a6.80201486.pdf>

<https://projectblue.blob.core.windows.net/media/Default/Research%20Papers/Cereals%20and%20Oilseed/pr450-final-project-report.pdf>

http://www.ipme.ru/e-journals/MPM/no_34420/MPM344_09_nandiyanto.pdf

https://www.researchgate.net/publication/272351686_Bioplastics-utilization_of_waste_banana_peels_for_synthesis_of_polymeric_films

https://www.researchgate.net/publication/330845696_Synthesis_and_Testing_of_Corn_Starch_Based_Biodegradable_Plastic_and_Composite

https://www.researchgate.net/publication/332318543_Corn_and_Rice_Starch-Based_Bio-Plastics_as_Alternative_Packaging_Materials

<https://www.slideshare.net/EngrRabaijaz/final-project-47011822>

<https://www.slideshare.net/Pichaimuthumpm/thesis-of-bio-plastics>

https://www.theseus.fi/bitstream/handle/10024/335541/Van_Le.pdf?sequence=2&isAllowed=y

