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Production of bio-plastic from potato starch

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Abstract
Plastics are hazardous to environment as they are as they are not decomposable because they are derivatives of strongly bonded long chain petrochemical based materials. However bio plastics can be seen as the solution to the problem. Bio plastics are made from biomass derived from plants such as cellulose, sugarcane, or rice. Starch is a natural biopolymer having mainly two types of polymer glucose. In this research work bio plastic is made using potato starch as its abundant and easily available. However, poor physico-mechanical properties like low tensile tear strength, high stiffness, elongation at break and poor moisture stability are observed in most of the starch-based materials. Development of starch-based bio plastic properties is being endeavoured by starch alteration. The physical and mechanical properties of the biodegradable plastic have been improved through some well-designed processes. Raw materials and chemicals used for production of potato starch based bio plastic are Potato, distilled water, PVA, Acetic Acid, Lecithin and glycerine. Different composition of the above ingredients were used to make bio degradable bio plastic.

Keywords: Bio plastic, starch, properties, biodegradable

Introduction
Bioplastics are plastics that are manufactured from natural materials (plants such as potatoes, corn, sugar, rice, tapioca, and algae) and are entirely or partly biobased, 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% 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 CO_2 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.

Classification of Bioplastic
a) Starch-based Plastics
b) Protein-based Plastics
c) Cellulose-based Plastics
d) Aliphatic Polyesters
e) Organic Polyethylene
f) Lipid derivative polymers

Review of Literatures: McGlashan, S., & Halley, P. *et al.* (2003) [9] Starch can be stored in the different organs of plants such as in the root of cassava plant, the stem pith of sago, the tuber of the potato, and the seeds of corn, rice, and wheat. This starch can be collected by crushing or grinding the tubers or seeds and then mixing it up with the water in order to collect the starch as sediment. This organic starch can then be used in order to make biodegradable plastics by going through various complicated processes.

Fakhoury *et al.* (2012) [10] There has been increased interest in the development of biodegradable films because the environmental damage from conventional plastic packaging is increasingly evident.

The main advantages of starch-based biodegradable plastic are its abundance of raw materials and easy manufacturing process with low cost. During the photosynthesis process, starch is produced in the plants as the reserve food supply.

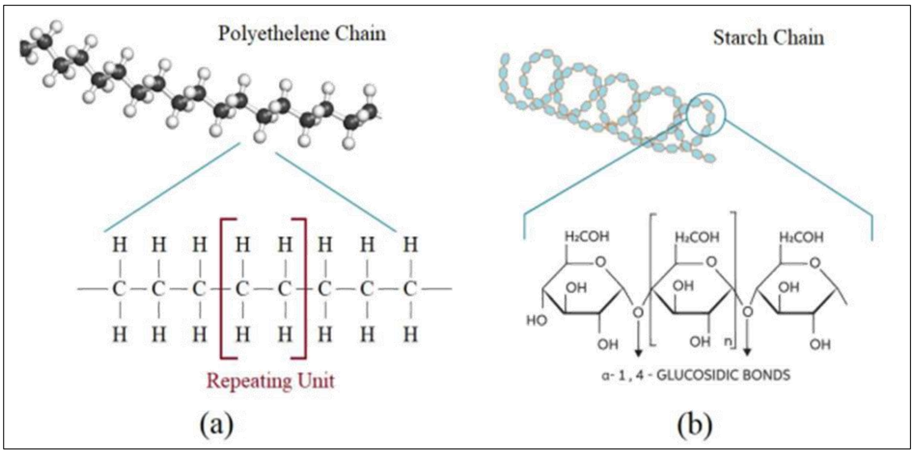

Fig 1: Structural Framework of polyethelene and starch chain

Yaradoddi, J.S., Banapurmath, N.R., Ganachari, S.V. *et al.* (2020) [11] The use of agriculture waste-derived carboxymethyl cellulose (CMC) mainly is to reduce the cost involved in the development of the film, at present commercially available CMS is costly.

Materials and Methods

Raw materials and chemicals used for production of potato starch based bio plastic are Potato, distilled water, PVA, Acetic Acid, Lecithin and glycerine. Machineries used in formation of bio plastic is Magnetic stirrer, Desiccator, Hot air oven, Grinder and electronic weighing balance and the Equipment's required are stirrer/ glass rod, spatula, measuring cylinder, petri dish, beaker and white laminate sheets.

Different methodologies adopted for the preparation of plastic film from potato starch

To formulate bioplastic film from potato starch

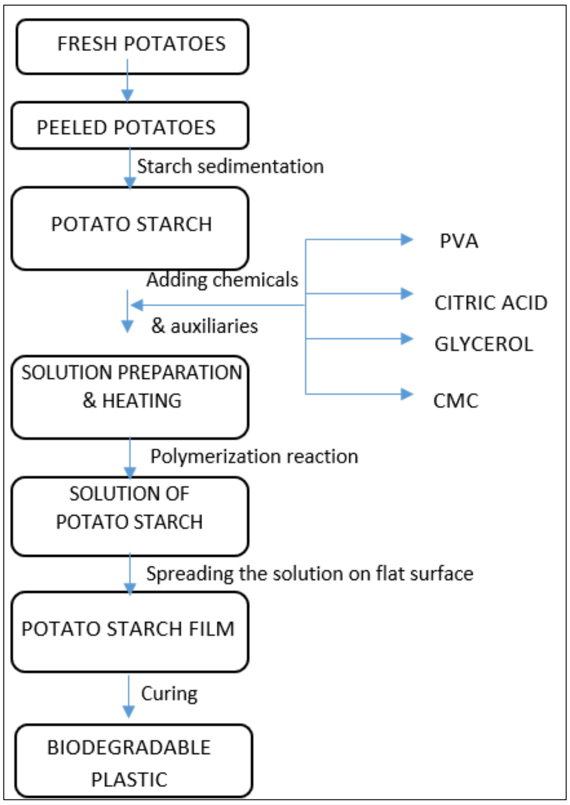

Fig 2: Process flow chart of potato-starch based biodegradable plastic preparation

Formulation of bioplastic from potato starch

Begin by taking distilled water and pouring it into a beaker. Add potato starch to the water, and then place the beaker on a hot plate, maintaining a temperature of about 100 °C. As the mixture heats, add all the necessary chemicals and vigorously stir the solution at 300 rpm for approximately 40-45 minutes. Once the solution achieves the desired thickness, carefully pour it onto a flat sheet. Finally, transfer the sheet into a hot air oven set at a temperature of approximately 55°C, and leave it to dry for a duration of 24 hours.

Method I

1. Add 3 g of potato starch to the beaker, followed by 20 ml of vinegar, 2 ml of glycerin, and 30 ml of water. Mix everything well.
2. Turn on the heating plate and set it to 70 °C.
3. Heat the mixture for 25-30 minutes.
4. Once it reaches a thick consistency, transfer it onto a glass film placed on a cold sheet.
5. Put the flat sheet with the mixture into a hot air oven set to 60 °C to dry.

Method II

1. Weigh out 10 g of potato starch.
2. Measure 60 ml of water, 5 ml of glycerin, and 2 ml of white vinegar.
3. Mix all the ingredients together in a beaker. Use the stirring rod or a spoon to stir the mixture so that all the ingredients are combined without any lumps.
4. Transfer the mixture into a glass beaker if you plan to use a magnetic hot plate or a saucepan. Continuously monitor the liquid as it heats and stir it throughout the process, observing for bubbles and the transition from an opaque to a translucent liquid. It should also become noticeably thicker.
5. Carefully pour the mixture into a petri dish or saucer, spreading it out evenly using a spoon or stirrer.
6. Place the dish in a warm location to allow it to dry.

Method III

1. Measure out 5 g of potato starch in a beaker.
2. Add 70 ml of distilled water to the beaker.
3. Incorporate 3.3 ml of citric acid.
4. Introduce 3.3 ml of glycerin.
5. Enhance the mixture with 2 drops of food coloring to make it more attractive.
6. Gradually heat the mixture, starting from low and gradually increasing to medium-high.
7. Once the solution thickens, let it continue heating for another 5 minutes on medium-high heat.
8. Allow the mixture to cool for a few minutes.
9. Grease a Petri plate with a small amount of oil. This will make it easier to remove the plastic once it's dry.

Method IV

1. Measure out 4.5 grams of potato starch in a beaker.
2. To this add 2.3 g of citric acid.
3. Add about 3.3 g of glycerol and mix it all together.
4. Add 2 g of lecithin and blend it well.
5. Add 70 ml 0f distilled water and stir at 200 rpm.
6. Place the beaker on the hot plate at 90 degrees Celsius at 500 rpm for 30-40 minutes.
7. Once the solution gets the right consistency (honey-like consistency), turn off the hot plate.
8. Grease a Teflon sheet with a little bit of oil. This will make it easy to remove the plastic once it's dry.
9. Scoop the mixture into the sheet and spread it out.
10. Stick the sheet into the oven at 65°C for 12 hours.
11. Carefully scrap off the sheet from the Teflon sheet.

Method V

1. Measure out 5 grams of potato starch in a beaker.
2. Add 2.3 grams of citric acid and 1 grams of Carboxymethyl Cellulose to the beaker.
3. Incorporate approximately 3.3 grams of glycerol and mix everything together.
4. Add 70 ml of distilled water and stir at 200 rpm.
5. Place the beaker on the hot plate at 90 degrees Celsius and set it to 500 rpm for 30-40 minutes.
6. Once the solution reaches the desired consistency (honey-like consistency), turn off the hot plate.
7. Grease a Teflon sheet with a small amount of oil. This will make it easier to remove the plastic once it's dry.
8. Scoop the mixture onto the sheet and spread it out.
9. Insert the sheet into the oven at 65 degrees Celsius for 12 hours.
10. Carefully scrape the mixture off the Teflon sheet.

Method VI

1. Measure out 4.5 grams of potato starch in a beaker.
2. Add 1.3 grams of citric acid and 2 grams of Carboxymethyl Cellulose to the beaker.
3. Incorporate approximately 3.3 grams of glycerol and 1 g of PVA and mix everything together.
4. Add 70 ml of distilled water and stir at 200 rpm.
5. Place the beaker on the hot plate at 90 degrees Celsius and set it to 500 rpm for 30-40 minutes.
6. Once the solution reaches the desired consistency (honey-like consistency), turn off the hot plate.
7. Grease a Teflon sheet with a small amount of oil. This will make it easier to remove the plastic once it's dry.
8. Scoop the mixture onto the sheet and spread it out.
9. Insert the sheet into the oven at 65 degrees Celsius for 12 hours.
10. Carefully scrape the mixture off the Teflon sheet.

Biodegradability Test -Soil Burial Test (Standard Method – ASTM D5338)

The specimen was cut into pieces of 4.0 cm^2. Found near the roots of plants which are rich in nitrogenous bacteria, 500 g of soil (having slight moisture content) was collected and stored in a container. One sample was buried inside the soil at a depth of 2 cm and another buried at a depth of 3 cm for 15 days under the conditions of the room. The weight of the specimen was measured before and after the testing. The biodegradability test was measured by Equation:

$$\text{Weight Loss (\%)} = \frac{(W_0 - W)}{W_0} \times 100,$$

Where W_0 and W are the weights of samples before and after the test.

Results and Discussion

In order to find out the best combination for creating plastic form potato starch five different methods were experimented and tested out. All five methods are given in the Table 1. The weight per litre ratio of Potato starch, the weight per litre ratio of Acetic acid (0.8 M), glycerin PVA $[CH_2CH(OH)]_n$ and CMC were at different combinations.

Table 1: Different methods for Biodegradable Plastic preparation

Chemicals Used	I	II	III	IV	V	VI
Distilled water (ml)	30	60	70	70	70	70
Potato starch (g)	3	10	5	4.5	5	4.5
Citric acid (g)/Vinegar (ml)	2 V	5 V	3.3 C	2.3 C	2.3 C	1.3 C
Glycerol (ml)	2	5	3.3	3.3	3.3	3.3
Lecithin (g)	-	-	-	2	-	-
CMC (g)	-	-	-	-	1	2
PVA (g)	-	-	-	-	-	1

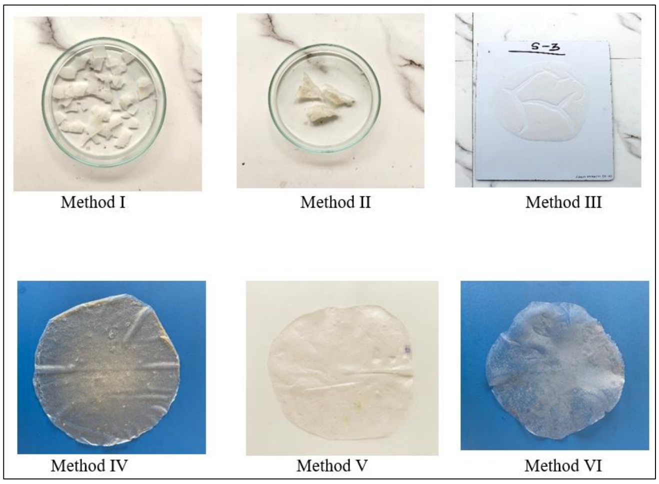

Fig 3: Result showing plastic film of different methods

Among the six different methods of bioplastic formulation, the first method yielded brittle plastic that broke into small pieces rather than forming a film.
In the next formulation, film became crystallized.
In another composition, the plastic failed to form a proper film, exhibiting visible cracks.
In the fourth formulation, introduction of lecithin, a natural emulsifier known for its excellent functional properties, such as low water vapor permeability, high flexibility, and opacity. However, this formulation displayed a high-water absorption rate.
Subsequently, addition of Carboxymethyl cellulose (CMC), a hydrophobic derivative of cellulose, enhance the hydrophobicity and strength of the carboxylate starch film.
Ultimately, on the sixth method. Introduction of polyvinyl alcohol (PVA), a biodegradable, non-toxic, and water-soluble polymer improved the plastic's strength and properties.

Biodegradability Test

Microorganisms such as bacteria and fungi present in the soil can absorb and metabolize the bioplastic as a source of energy and all that remains are CO_2, water, salts and biomass.

$$\text{Weight Loss (\%)} = \frac{(W_0 - W)}{W_0} \times 100$$

Where, W_o is the initial weight of sample before burial and w is the final weight after burial
Day wise weight of the bioplastic sample is recorded and at the end of sixth day it is found out that weight of plastic remains was 0.112g
By using the data recorded in the table 2 and by using the formula above, the biodegradability is being calculated.

Table 2: Biodegradability of bio plastic

Days	Weight (g)
Day1	1.151
Day2	0.972
Day3	0.823
Day4	0.648
Day5	0.453
Day6	0.112

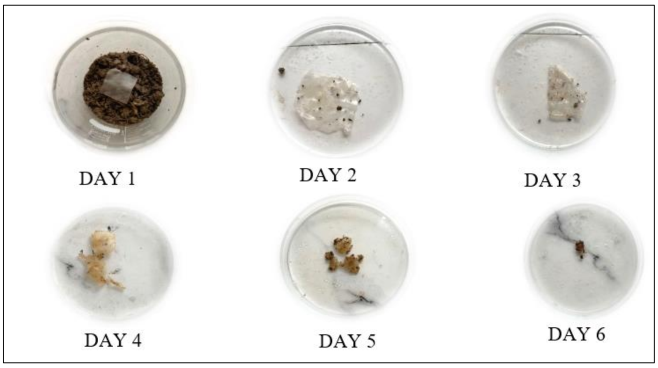

Fig 4: Daily record of bio plastic sample

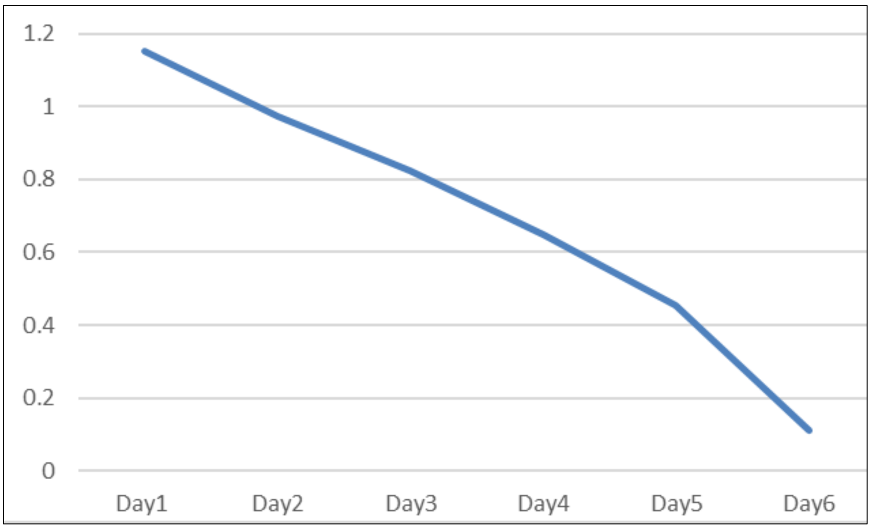

Fig 5: Graph showing biodegradability

By using the formula,

Weight Loss (%) = $\frac{(W_0 - W)}{W_0} \times 100$,

$= \frac{(1.151 - 0.112)}{0.151} \times 100$

= 90.26%

Biodegradability of 90.26% was achieved in 6 days for the sample placed in the soil at a depth of 3 cm.

Conclusion

After extracting starch and gaining insights into the chemical composition and machinery involved in bio plastic formation, we devised strategies to explore how the constituents combined. To determine the optimal combination, we developed and tested six different methods, ultimately settling on the sixth method, which incorporated polyvinyl alcohol, significantly enhancing the bio plastic's strength and quality. Starch-based plastics offer versatility, finding applications in bags, packaging, food containers, compostable waste collection bags, crockery, and cutlery. Emphasizing the biodegradation capability, our research demonstrated that the plastic degraded within just seven days, marking a significant achievement in developing a new biodegradable plastic. Nonetheless, further research is needed to explore new properties and expand its versatility.

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