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Development and Characterization of Biodegradable Bioplastic derived from Fish Scale Waste.

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ABSTRACT

Plastic pollution is a global environmental threat due to its non-biodegradable nature. This study successfully demonstrates the production of bioplastic from fish scales collected from local markets. Chitosan was extracted through the 3 processes of deproteinization; demineralization, deacetylation. In this project, development of biodegradable bioplastic film made from fish scales, which has several beneficial characteristics including heat tolerance, smooth texture, transparency, soft touch, tensile strength, and it is degradable in 3 days with water and 6 days with soil. The purpose of the degradability test was to determine whether the bioplastic that were produced would break down when exposed to soil microbes. The film's production costs are low and reasonably simple. Thus, the process called recycle of waste become environmentally friendly, economical, and healthy. Also, it reduces the usage of petroleum derived product by using bioplastics instead of plastic. For all that reason's bioplastic usage increased in our life.

Keywords: Bioplastic film, Fish scales, Chitin, Chitosan, Biodegradable.

INTRODUCTION

One of the most grievous problems, that our planet is facing today is the upheaval generated by excessive and impetuous use of single use plastics. Plastic seemed to create a drastic effect in day to day life. Plastics like polyethene, polyethylene terepthalate, polyethylene, polyvinyl chloride, polystyrene etc. are synthetic polymers that find immense applications in day to day life of mankind. Owing to their properties like stability, malleability and durability they are widely used in manufacturing commodities of commercial importance. The word bioplastic was derived from the Greek words "bios" meaning (life or living) and "plastikos" meaning for (moulding) and "plastos" meaning (moulded); the term plastics refers to a material's ductility during manufacture. Bioplastics are special types of biomaterials. This property accorded the material ability to be shaped into diverse forms for various uses. Plastics can be classified as conventional and bioplastics. Conventional plastics are those formed from fossil fuels such as coal, natural gas, crude oil; while bioplastics are those sourced from biomass/renewable organic sources such as grains, vegetables, potatoes, sugarcane, corn starch, soybean oil, hemp oil, milk, tapioca etc. – or microbial sources, rather than traditional petrochemical-derived plastics are called bioplastics and it can be biodegradable within short timeframe.

Fish scales are one type of fish waste that may be processed and used to create additional materials for the production of bioplastics, which is one strategy to minimize pollution and provide fisheries waste economic value. Chitin, the second most abundant biopolymer in nature after cellulose, is a linear polymer, i.e., a polysaccharide, sited in fungi cell walls and plankton, in crustacean and insect exoskeletons, under the form of ordered crystalline microfibrils. It appears as a yellowish powder, with a high molecular weight, insoluble in water and organic solvents. Moreover, fish scales are also a potential source of chitin, as recently demonstrated. The most important byproduct of chitin is chitosan, whose main advantage, compared to chitin, is its solubility. Chitosan may be used to create bioplastics. Because of its non-toxic and biodegradable hydrophobic qualities, chitosan is utilized as an extra ingredient in the production of bioplastics to enhance their qualities (Ramdhani and Firdhausi 2021). Chitosan is a derivative of chitin, which is one of the three most important and abundant polysaccharides on the planet, together with cellulose and starch. Chitosan, a biopolymer with the chemical formula C6H9NO3, is generated from chitin. Three procedures are typically used to separate chitosan from chitin: deproteination, demineralization, and deacetylation (Fadli et al, 2018). Chitosan has shorter chains that chitn, is soluble in acidic solutions, and has high biological and mechanical properties, such as being nontoxic, biocompatible, biodegradable and polyelectrolyte material that inhibits the growth of a wide variety of fungi, bacteria, and yeasts, which has allowed it to have applications in different areas such as cosmetics, agriculture, food, biomedicals, textiles (Pratiwi et al. 2014). The purpose of the degradability test was to determine whether the bioplastics that were produced would break down when exposed to soil microbes. The film's production costs are low and reasonably simple. After fish are cleaned, a lot of fish scales are thrown out incorrectly at the market or at home; as a result, fish waste is recycled and used.

METHODS

1. Collecting fish scales

The fish scales were collected from local fish market (Kasturba) in Bhopal.

2. Cleaning and washing

The collected fish scales were washed and cleaned thoroughly with water and salt to remove their - dirt, blood, mucus, and residual tissue.

3. Drying

After the washing, dry the fish scales under the sunlight for 7-8 hours to evaporate excess water. Then, dry the scales in a hot air oven at around 80°C until they are completely dry.

4. Grinding and sieving

Grind the dried fish scales into a fine powder using a grinder. Then, sieve the powder to ensure a consistent particle size like 45μm.

5. Chitosan Extraction:

- **Deproteinization:** FS Powder was stirred in 3.5% NaOH at 65°C for 2 hours to remove proteins.
- **Demineralization:** The residue was treated with 3.5% HCL at 400 rpm for 1 hour to remove minerals.
- **Deacetylation:** Chitin was treated with 40% NaOH at 100°C for 1 hour to obtain chitosan.

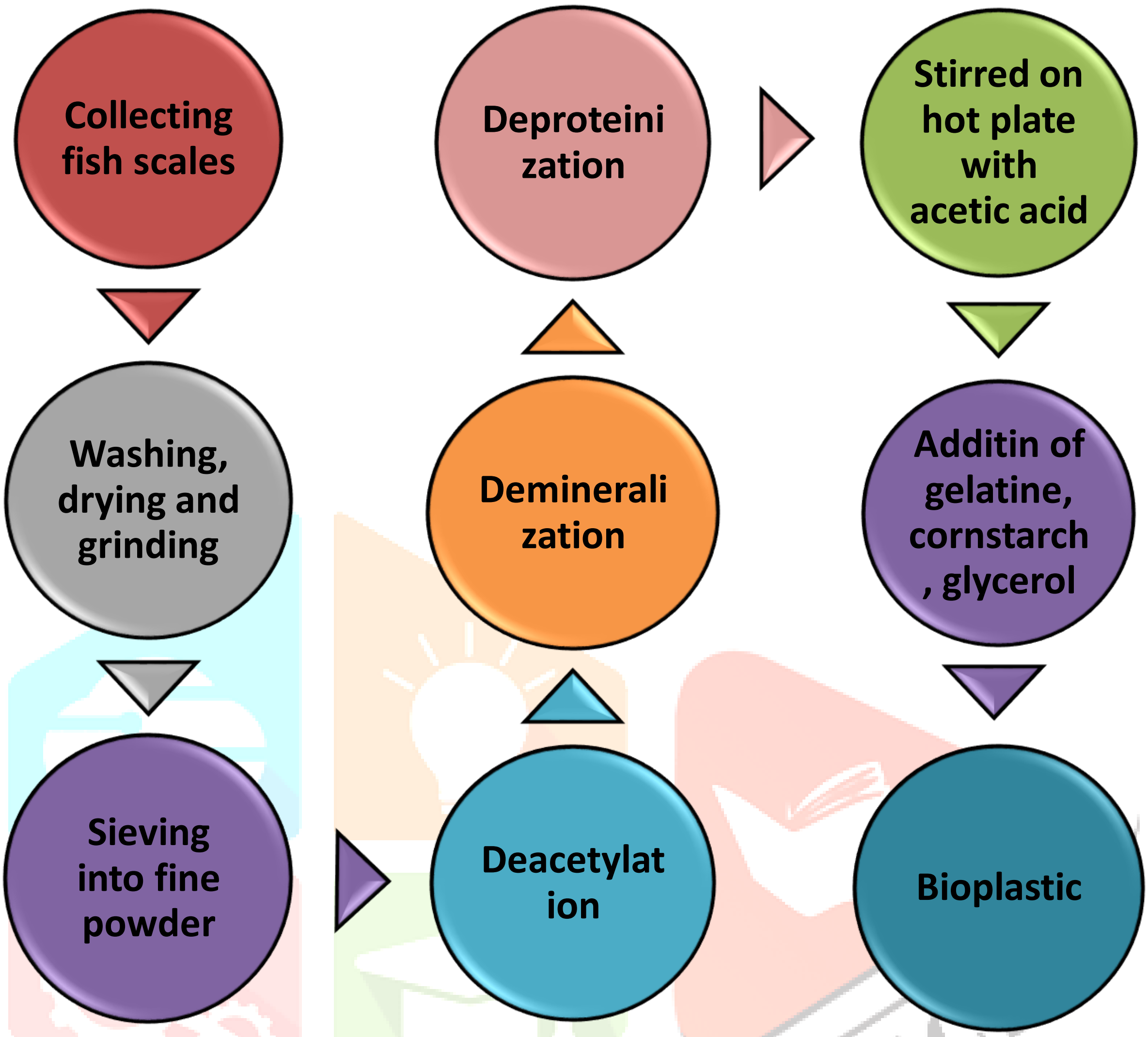
6. Bioplastic production

Chitosan were dissolved in 1% acetic acid and stirred at 60°C/200 rpm for 1 hour to create bioplastics. Then, adding 5 grams of gelatine, 5 grams of corn starch and 5 ml of glycerol was used as a plasticizer and stirred again at 60°C for half an hours until it was quite thick. The solution is then printed on aluminum foil, plastic tray or Petri-dish and allowed to dry at sunlight for 4-5 hours. Then, dry at room temperature for 24 hours. If you want to add color in bioplastic, you can use food color 4-5 drops; this is optional. After this the Bioplastic film is comes out.

MATERIALS

Fish scales Sodium hydroxide (NaOH), HCL, Acetic acid, Gelatine, Corn Starch, and Glycerol.

METHODOLOGY



RESULTS

Table 1: Bioplastic composition

S. no.	Chitosan	Acetic acid 1%	Gelatin	Corn starch	Glycerol
Sample 1	15 gram	100 ml	5 gram	5 gram	5 ml
Sample 2	5 gram	50 ml	2 gram	2 gram	2 ml
Sample 3	5 gram	50 ml	2 gram	2 gram	2 ml
Sample 4	2 gram	25 ml	1 gram	1 gram	1 ml

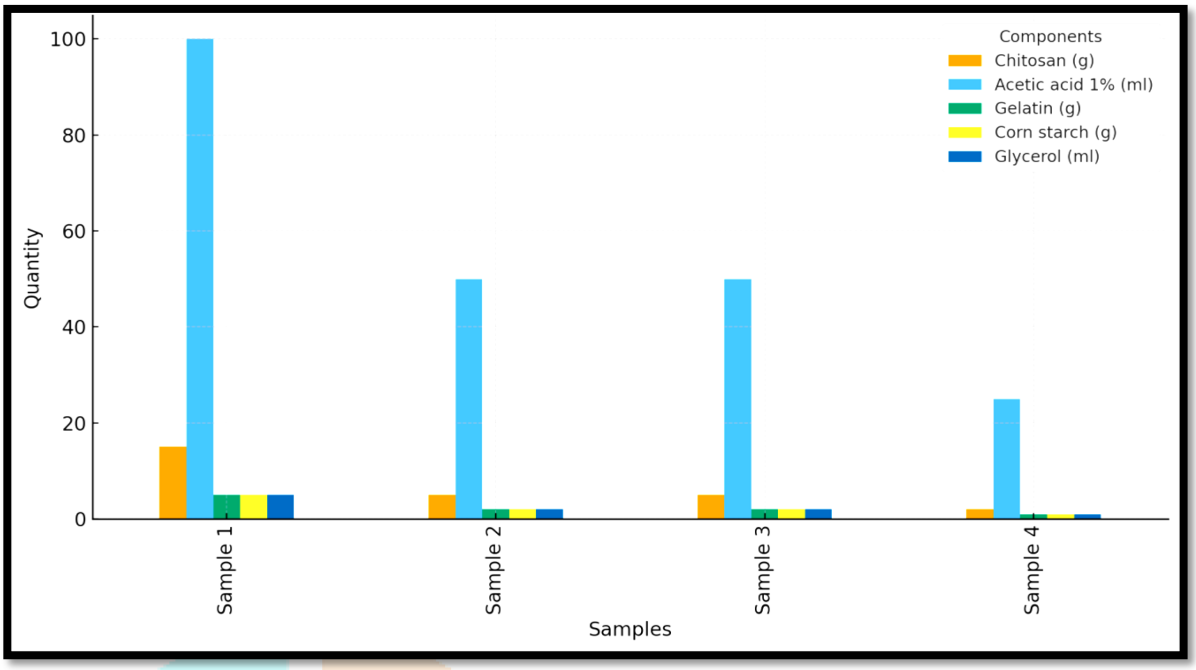


Chart 1: Graph showing the Bioplastic composition

Table 2: Weight & Shape

Chitosan	Weight	Shape	Length & Width
15 gram	6.70 gram	Square	6 X 6
5 gram	10.30 gram	Rectangle	L- 22, W- 9
5 gram	8.10 gram	Circle	D- 14.2 cm
2 gram	4.50 gram	Circle	D- 8.5 cm

Table 3: Film thickness

Film	Thickness
15 gram (Square)	3.5 mm
5 gram (Rectangle)	1 mm
5 gram (Circle)	1 mm
2 gram (Circle)	1 mm

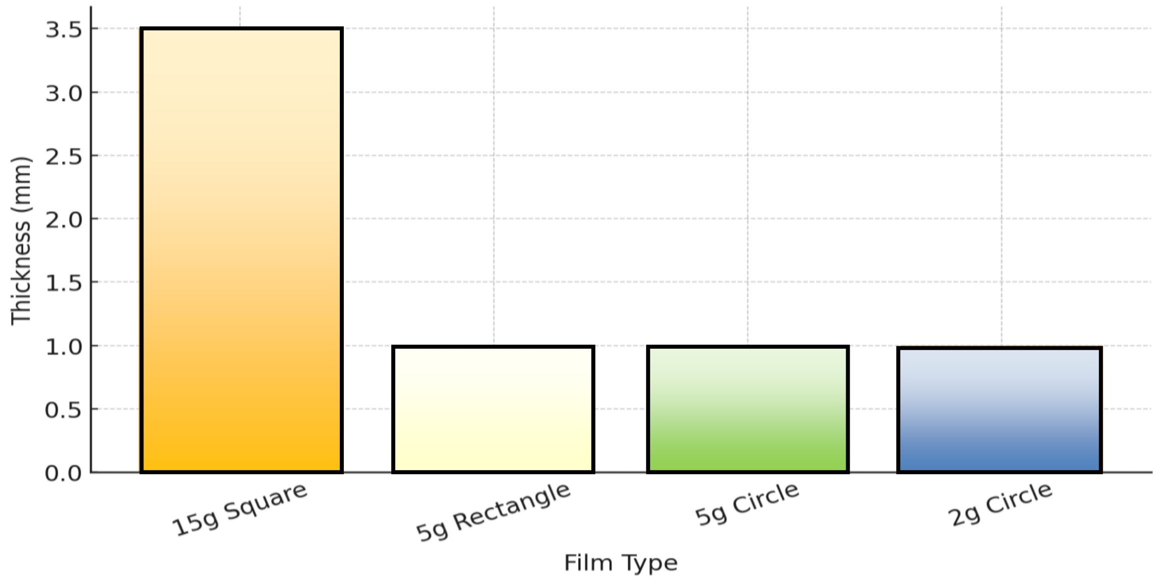


Chart 2: Graph showing the Film thickness

Table 4: Tensile & Flexibility table

Film	Initial length	Final length	Breaking point
15 gram	4 cm	6 cm	6.5 cm
5 gram (R)	4 cm	5.5 cm	6 cm
5 gram (C)	4 cm	7.5 cm	8 cm
2 gram	4 cm	7 cm	7.5cm

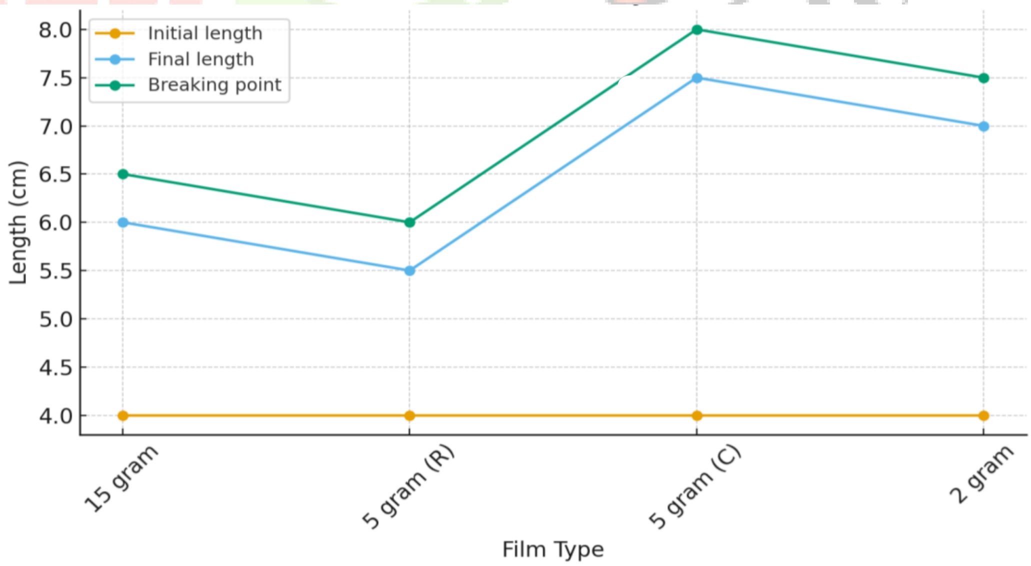


Chart 3: Graph showing the Tensile & Flexibility of Bioplastic film

5. Biodegradable test

- **Degradation with Water**

1st day **after 3rd day**

The bioplastic product was tested by burying small pieces in water for 3 days. Surprisingly, the product was able to be degraded in less than 3 days.

- **Degradation with Soil**

1st day **3rd day** **6th day**

The bioplastic product was tested by burying small pieces in soil for 1 week. Surprisingly, the product was able to be degraded in less than 7 days. Bioplastic film completely degrades in 6th day.

6. pH measurement

WATER

SOIL

The product was tested by dissolving small pieces in the water and soil. Then, measured by the pH paper. It was almost Neutral (pH~7).

7. Effect of Sunlight

The bioplastic film was tested by being placed in; exposed to sunlight for 1 week.

Before 1 week **After 1 week**

DISCUSSION

1. Dried fish scales

The fish scales are collected & cleaned in fresh water. The fish scale dried under the sunlight to evaporate excess water. Then, the fish scale was dried in the hot air oven at 160°C to remove the moisture present in it. But even after drying the fish scales, moisture kept coming back again and again. Therefore, before grinding, the fish scales were kept in a hot air oven at 160°C for 2 hours every time. After grinding fish scales sieved with a 45µm mesh. Then, we obtain the fish scale in fine powder form. The grinding process has been done, but fish scale was shrinked.

2. Deproteinization method

The process of separating chitin from fish scales powder there are involved 2 steps: deproteination and demineralization. For 2 hours, FS powder is combined and agitated in a 3.5% NaOH solution. Fish scales/NaOH solution 1:10 (m/v) was stirred in a magnetic stirrer with hot plate at 400 rpm/65°C/2 hrs. After this step, the mixture was highly alkaline. The main challenge was neutralizing the residue. We had to wash it multiple times with distilled water until the pH reached ~6.8.

3. Demineralization method

After that, the deproteination product was demineralized. The deproteinized powder is combined and agitated in a 3.5% HCL solution 1:5 (m/v) was stirred in a magnetic stirrer with hot plate at 400rpm/65°C/1 hrs. Then, neutralize the precipitate. The precipitate was washed 2 to 3 times with distilled water until the pH reached ~6.8.

4. Deacetylation method

Separating chitosan from chitin involves: Deacetylation. Chitin was dissolve in 40% NaOH at a ratio of 1:5 (m/v).

We performed deacetylation with 40% (concentration of NaOH solution implied) because we analyzed that 50% is not suitable for precipitate; sometimes the 50% NaOH turn into a jelly form, it can take a longer time to dry, does not neutralize quickly, which causes problems in forming chitosan and also create a problem in forming the bioplastic film. So, that's the reason we performed the deacetylation method with 40%. Stirred in magnetic hot plate at 100°C with 400 rpm for 1 hour. Then, neutralize the precipitate. The precipitate was washed 2 to 3 times with distilled water until the pH reached ~6.8.

5. Production of Bioplastic film

Chitosan were dissolved in 1% acetic acid and stirred at 60°C/200 rpm for 1 hour to create bioplastics. Then, adding 5 grams of gelatine (gelatine can be used in fish scale bioplastics because it is a good film-forming agent with properties like biocompatibility, biodegradability, and mechanical strength), 5 grams of corn starch (corn-starch is added to bioplastic because it can improve their mechanical properties and biodegradbility, it acts as a base material to create a film, which can be reinforced with fish scale powder to increase its strength, while also making the final product more biodegradable and environmentally friendly) and 5 ml of glycerol was used as a plasticizer (glycerol is used as a plasticizing agent to make the material flexible, less brittle, and easier to process, it can increase material flexibility and plasticity). Stirred again at 60℃ for half an hour until it was quite thick. The solution is then printed on aluminum foil, plastic tray or Petri-dish and allowed to dry at sunlight for 4-5 hours. We analyzed that there is no need to put the bioplastic in the oven; it is drying at room temperature or with sunlight alone. Then, dry at room temperature for 24 hours. If you want to add color in bioplastic, you can use food color 4-5 drops; this is optional. After this the Bioplastic film is comes out.

➢ Functional properties

Film thickness

The determination of bioplastic thickness is important as well to estimate the barrier properties of a packaging system (Durai *et al.,* 2008). The observed thickness of the bioplastic sheets obtained was less than 1 cm.

Tensile & Flexibility

The tensile strength test determined the quality of bioplastics (Dasumiati *et al.*, 2019) in this project the high tensile strength about 7.5 cm. Tensile strength is crucial for bioplastic because it measures their ability to withstand pulling forces, ensuring they are strong enough for real-world use (life packaging, films) without tearing or breaking.

Degradation test with water

The biodegradability of bioplastic product was tested by burying small pieces in water for 3 days. Surprisingly, the product was able to be degraded in less than 3 days. The water solubility of bioplastic films was entirely dependent on polymer structure and intermolecular bonds (Kaewprachu and Rawdkuen, 2014). Glycerol is hydrophilic in nature and is used as a plasticizer to ensure bioplastic solubility. In addition, its hydrophilic nature increases the mobility of the peptide chains and contributes to solubility (Ekrami and Emam-Djomeh, 2014).

Degradation test with soil

The biodegradability of plastic in the soil was determined using a biodegradability test. After three days, only a few crumbs remained and surprisingly, the product was able to be degraded in less than 7 days it can proved the biodegradation of the film. The bioplastic made from fish scales degraded in less than 1 week was due to the properties of fish scales, which contain biodegradable compounds such as glycerol, gelatin, and corn starch which have chemical properties that make them biodegradable (Patwary *et al.,* 2020).

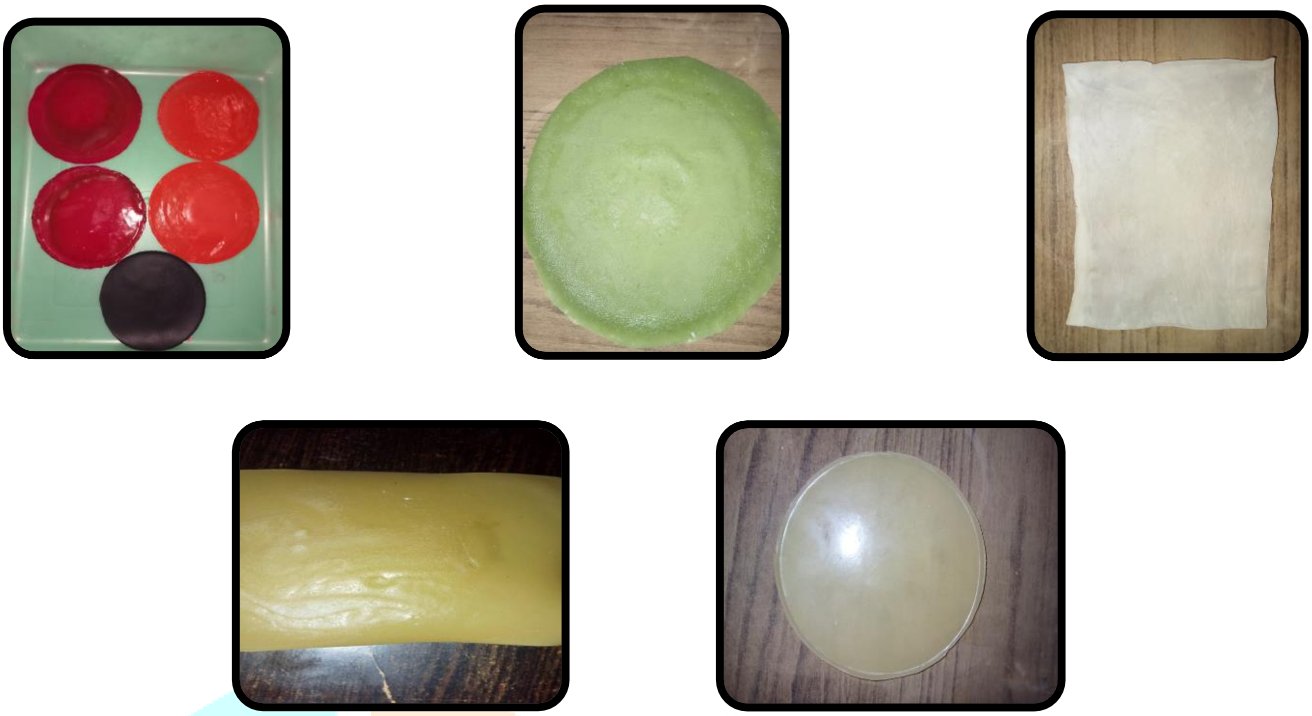
pH measurement (water, soil)

The product was tested by dissolving small pieces in the water and soil. Then, measured by the pH paper. It was almost Neutral (pH~7). Soil and water pH testing is crucial during bioplastic degradation because the breakdown process releases organic acids and other compounds that alter pH levels, affecting microbial activity, nutrient availability, and overall soil/water health; significant pH shifts (towards acidic or alkaline) can stress plants, change nutrient cycles, and even releases toxic intermediates, making pH a key indicator of environmental impact, note studied in (Adele Folino *et al.,* 2023), (Xiangzhou Yuan *et al.,* 2025) and nature.

Effect of sunlight

To observe the effect of heat on the bioplastic, the method were used: Expose the bioplastic to sunlight for 1 week outside the lab, the bioplastic was not affected but there is a slight effect on the film's elasticity – it is stretching less than before. This test helps determine how quickly and effectively bioplastics will degrade in the outdoor environment. Exposure to sunlight can cause bioplastics to fade (discoloration), become brittle, or lose their mechanical properties. Testing ensures that the material remains safe and effective for its intended use. (Al Abri, Jehan *et al*., 2025).

Overall, the evidence shows that bioplastics made from fish scales are a more environmentally friendly and biodegradable substitute.



These are the final samples of Bioplastic Film

CONCLUSION

Plastic is a product that is widely used in our daily lives due to its affordability and practicality. However, because plastic is non-renewable and difficult to degrade, it poses a hazard to the environment. This study successfully demonstrated the immense potential of utilizing waste fish scales as a sustainable and renewable raw material for the production of biodegradable bioplastic films. The developed bioplastic primarily composed of extracted chitosan and blended with glycerol as a plasticizer, exhibited favorable characteristics, including rapid biodegradability (achieving~56% degradation in seven days) and adequate mechanical strength for specific applications like single-use packaging. This innovative approach offers a viable solution to mitigate the environmental burden caused by both synthetic plastics and fish processing waste, aligning perfectly with the goals of a circular economy. The fish scales, an abundant and underutilized waste from the fish processing industry. The collagen and hydroxyapatite present in fish scales provide excellent film-forming properties and mechanical strength, making them a sustainable alternative to conventional petroleum-based plastics. The bioplastic produced from fish scales exhibited favorable physical and chemical characteristics, such as flexibility, tensile strength, and biodegradability, indicating its potential for various applications in packaging and other eco-friendly products.

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