DEGRADATION OF BIOPLASTICS UNDER THE INFLUENCE OF SEVERAL ENVIRONMENTAL CONDITIONS

M. Rizwan[1], T. Jamal[2], A. Jamal[3] and I. S. Kokab[4]

[1] Government College University Lahore
[2]Department of Geography, Punjab University, Quid e Azam Campus, Lahore.
[3]Rifah International Islamic University, Lahore
[4]Punjab University, Lahore

ABSTRACT: The rising environmental risks that plastics bring led to the development of bio-plastics from renewable biomass resources. Glycerol is used to starch to create high-quality bioplastics. Plastics are fundamentally synthetic or synthetic-like materials that do not disintegrate. This study aims to investigate the degradation of bioplastics. Synthetic plastics are more damaging to the environment than bioplastics. Soil, compost, and water are just a few of the environments where the bio-plastics can degrade. The bioplastic components are buried in composite soil or loam sand in order to weigh them and take photographs of the breakdown activity. Different weather circumstances, such as temperature, humidity, rainfall, sunshine intensity, and sunlight duration, were recorded in order to study the impact of weather on the degrading activities. The comparison of the results showed that hydrophilic enzymes were used to carry out the bio-plastics' breakdown activity. After saturation, the initial regenerative material absorbs soil moisture, increasing weight by up to 87%. Following the start of the degradation process, the weight of the bio-plastics gradually decreased. Microorganisms from the soil that invade help the deterioration process. Rainfall, humidity, and the amount of sunlight all have an impact on the environment and how quickly bioplastics degrade. The rate at which bio-plastics degraded increased as a result of the soil's increased microbial activity brought on by the increased solar intensity.

Keywords: Bioplastic, Degradability and Purified Glycerol.

(Received 12.10.2022 Accepted 28.11.2022)

INTRODUCTION

Plastics are frequently used industrial products made from synthetic and semi-synthetic basic materials. Plastics either aren't biodegradable or decompose very slowly in the natural environment. Due to their affordability, adaptability, durability, moisture resistance, and light weight, they are frequently used in packaging, textiles, and electronic devices. Because it takes longer than a human lifetime for plastics to degrade, they are considered to be non-biodegradable. The degradation of the landscape's natural beauty is one of the environment's worst repercussions of plastics made from petroleum. Over time, plastics left in soil alter its makeup and wipe off its microbial community. Aquatic creatures, such as zooplanktons, mammals, fish, amphibians, and birds that depend on water for survival, are dying out as a result of plastic trash contamination. Birds, fish, turtles, and whales are just a handful of the animals that could be killed by ingesting plastic. Plastics offer the greatest threat to the food chain because, when disposed of improperly, they can clog sewage and drainage systems and encourage the growth of mosquitoes and other disease-carrying vectors underground. As a result, this barrier makes it more likely to flood and makes waste disposal a problem.

Therefore, there is an urgent demand for renewable or biodegradable packaging materials due to rising environmental risks. One significant effort to shorten the lifespan of plastics made from petroleum was to combine them with natural polymers, like starch. The petroleum plastics were transformed into bio-plastics through this blending. The development of bio-plastics has also utilised other polymers, such as cellulose, protein resins, and lignin [8]. Bio-plastics are also created using lipids and animal fats. The majority of the carbohydrates used to manufacture bioplastics are mostly sourced from plant tubers and grains. Starch is naturally cheap and abundant, but plasticizing improves its mechanical properties, particularly flexibility. Glycerol, a plasticizer, dissolves the hydrogen bonds that form between the monomers of the starch granules that make up a polymer. High-quality bio-plastics like Thermal plastic starch (TPS), Polylactic acid (PLA), Polycaprolactone, and Ecoflex, which are made of biodegradable polyesters, are produced using starch. As a byproduct of biodiesel production, glycerol has a number of uses in the pharmaceutical, polymer, food, and cosmetic industries. However, after being purified, it is dangerous to the environment if it is disposed of directly. The creation of less polluting, environmentally friendly bio-plastics is one of the main advantages of using glycerol plasticizer

Due to their propensity to degrade more quickly than petroleum-based plastics, bioplastics are presented as an alternative to non-renewable petroleum-based plastics. Bioplastics break down thanks to soil microbial activity. In the ideal environments of soil, microorganisms create enzymes that break down bioplastics.

Pretreatment, microorganisms, and the characteristics of the polymer all have an impact on the breakdown activity of bioplastics. Polymers' common characteristics include their molecular weight, mobility, kind of plasticizers, tactility, and crystallinity, to name a few. Since hydrophilic enzymes frequently dwell in moist surroundings, including humidity, the breakdown action usually takes place under optimum circumstances. The amylase enzyme, which breaks down starch, is secreted by a variety of species in soil, including bacteria, fungi, and worms.

This enzyme converts insoluble starch molecules into soluble byproducts, such as maltose and glucose, which are typically taken by microbial cells. Large polymers are broken down into monomers during breakdown by enzymes, which reduces viscosity and causes the product to liquefy. Following the breakdown of bonds, a process known as scarification produces various saccharides. When there is water, oxygen, heat, and light, the microbial activity of the soil increases.

As a result, bioplastics breakdown quickly in the presence of water. Paper bags are typically coated with bioplastics to improve their stability and absorb moisture and oil.

This study seeks to investigate the sequential deterioration, disintegration, and decomposition of bioplastics under different environmental circumstances.

MATERIALS AND METHODS

Study area: In 2020, this study was conducted in Karachi's coastline agricultural zone. This area experiences high temperatures and a humid climate in general. To obtain starch, cassava roots are collected in the fields.

Material and method: Glycerol is employed as a plasticizing agent when starch is used to make bioplastics, and acetic or hydrochloric acid is used to hydrolyze the plastics. The starch content of cassava root peels is high. Cassava roots were processed with 0.1 M NaCl to extract the peel using a whirling blender in order to produce starch cassava. Through the use of a muslin cloth, the homogenate was strained. The homogenate was baked for 24 hours at 60°C to dry it out. Glycerol was used to plasticize starch. There are two types of glycerol: pure glycerol made from vegetable oil and analytical glycerol (AG) that can be found locally.

Reagents: Different reagents were used in addition to glycerol, including Acetic acid, NaCl, HCl, and AG glycerol. 35g of starch was mixed with 450ml of distilled water, 15g of 0.1M acetic acid, and 10ml of glycerol to generate a mixture for plasticization. After that, this mixture was heated to 120 c for 45 minutes in an 850 ml beaker. This liquid was chilled before being placed in a tray. The mixture was spread out on the tray using a rod. The tray was heated once more for 18 hours at 60 °C. The dried substance was referred to as bioplastics, and it was broken up into smaller pieces for use in laboratories.

Burying of bioplastics: The initial component weights of the bioplastics were determined before burial. Weekly photos were taken and weight measurements of buried bioplastics were made in order to gauge the impact of decomposition. Three different methods were used in the lab to break down bioplastics. The first method involves putting the bioplastics into a 250 ml beaker at room temperature after soaking them in 100 ml of distilled water. The second method involved burying the bioplastics three inches deep in the soil. Each week, roughly 6 cc of water were added to maintain the soil moist. The third tactic involved monitoring bioplastics in their natural environment. After that, these bioplastics were covered in polyester and buried 30 cm deep in the soil. Precipitation, temperature, and humidity effects of changing weather are also highlighted.

Table 1: Reagents used in Bioplastic Samples.

Samples	Starch (g)	Water (ml)	Acid	Glycerol
Bioplastic 1	35	450	HCL	Analytical Grade (AG)
Bioplastic 2	35	450	HCL	purified glycerol
Bioplastic 3	35	450	Acetic acid	purified glycerol

RESULTS

In Table 2, three bioplastics' disintegration times are listed. When decomposition began, bioplastics underwent a physical change. Due to water absorption, which also darkened the colour of the bioplastics, their thickness increased. The bioplastics then broke down into smaller pieces until they were totally destroyed. The bacteria can cling to the bioplastic parts and digest starch because of the disintegration. The bioplastics had decomposed into very minute, fragile components by the sixth week.

Change in Bioplastic Weight: Bioplastics that were buried over time changed in weight. The basic trend of breakdown involves weight gain, further alterations in bioplastics caused by soil organisms, and weight loss once bioplastics completely disintegrate. The bioplastics' first weight gain is caused by a hydrophilic enzyme that starts the breakdown process by absorbing water into them. Because starch is hydrophilic, its weight varies depending on the soil's moisture level, which in turn depends on many environmental factors like rain. The bioplastics are totally broken down by soil microorganisms after moisture absorption. Since both the starch itself and the enzyme that breaks down it are hydrophilic and moisture is also necessary for microbial activity in soil, moisture concentration has a substantial impact on how quickly bioplastics degrade. After three weeks, microorganisms begin to break down the bioplastics, which results in a reduction in the weight of the bioplastics. All of these bioplastics were entirely broken down within 10 weeks: the first one was consumed by worms, the second by termites, and the third by fungi. Bioplastics hydrolyzed with local glycerol or acetic acid did not significantly differ in weight from each other, in contrast to those hydrolyzed with HCL.

Table 2: weekly physical changes in weights of bioplastics under the influence natural environment.

Change in weight	Week 1	Week 2	Week 3	Week 4	Week 5
Bioplastic 1	8.03g	11.57 g	12.19g	12.5g	7.06
Bioplastic 2	8.03g	18.74g	19.05g	17.06g	16.89g
Bioplastic 3	8.03g	9.09g	10.94g	9.14g	5.48g

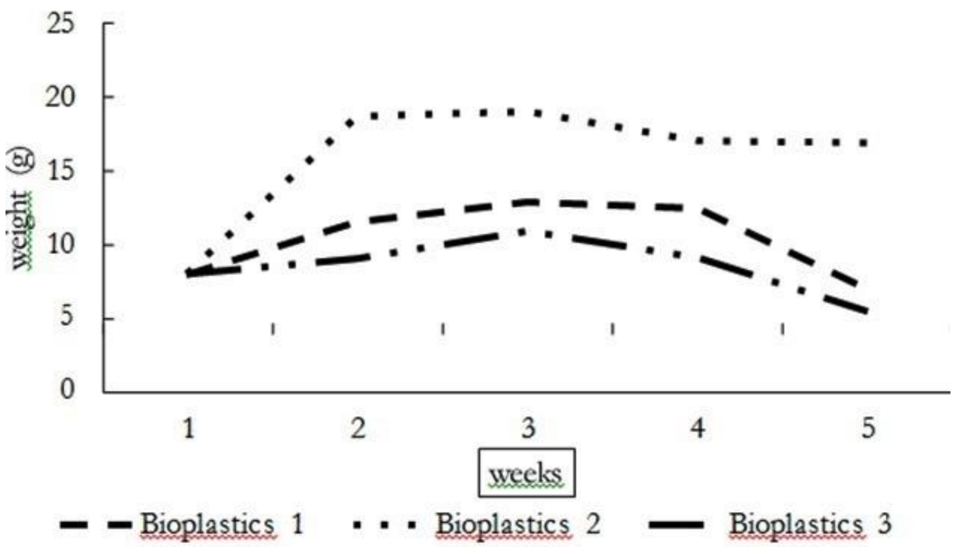

Figure 1: Weight change of the bioplastic after five weeks of deterioration.

Strong acid like HCL requires a lot of moisture content to break down into water and free ions, which could be why the weight of bioplastics varies so much.

Effect of Weather on Bioplastic Degradation: Over the course of the 10 weeks of decomposition, the average temperature varied from 20 to 43 degrees Celsius, there were 0 to 12 hours of sunshine on average, 0 to 43 millimetres of rain on average, and 61.5% to 84.5% relative humidity. Because rain increases the amount of water in the soil and hastens the breakdown of bioplastics, it directly affects the weight variations of bioplastics. The first bioplastic's weight variation is significantly influenced by temperature, but sunshine only has a favourable relationship with the third bioplastic. While the relationship between the weight of bioplastics and relative humidity was the opposite.

Rainfall & Sunshine Hours Contribution to Degradation: The onset of the decomposition of bioplastics was heralded by low rainfall totals, or 2.3mm. During the first two weeks, bioplastic weight increased while rainfall volume declined. When the amount of rain increased by 0.05mm after two weeks, the weight of bioplastics dramatically increased. After four weeks, the weight started to decrease as a result of a decrease in rainfall and precipitation rate. Rain increases the moisture level of the soil, hastening the degradation of bioplastics. Rainfall therefore provides the perfect environment for hydrophilic enzymes to degrade bioplastics. The rate of weight loss slowed down as the amount of rainfall sharply decreased from the fourth to the seventh week. When larger components broke down, smaller ones offered high volume to surface ratios for absorbing moisture.

The sun's rays have an impact on the soil's microbial activity and help break down biological molecules and biological activity. The decrease in sunlight results in a rise in the weight of bioplastics. Moderate sunlight speeds up the decomposition of bioplastics in soil by promoting the hydrophilic enzymes, which leads to an increase in bioplastic decomposition.

Laboratory Degradation Trend for Bioplastics in Water: During the first three weeks, the weight of bioplastics absorbed in water rose. From the fourth to the eighth week, the substrate entirely dissolved and decomposed, the weight of the bioplastics decreased.

Table 3: Weekly physical changes in weights of bioplastics when the substrate is completely dissolved.

Change in weight	Week 5	Week 6	Week 7	Week 8	Week 9
Bioplastic 1	7.06g	6.28g	5.09g	4.95g	4.06
Bioplastic 2	16.89g	12.74g	11.05g	10.06g	8.89g
Bioplastic 3	5.48g	5.09g	4.94g	3.95g	3.18g

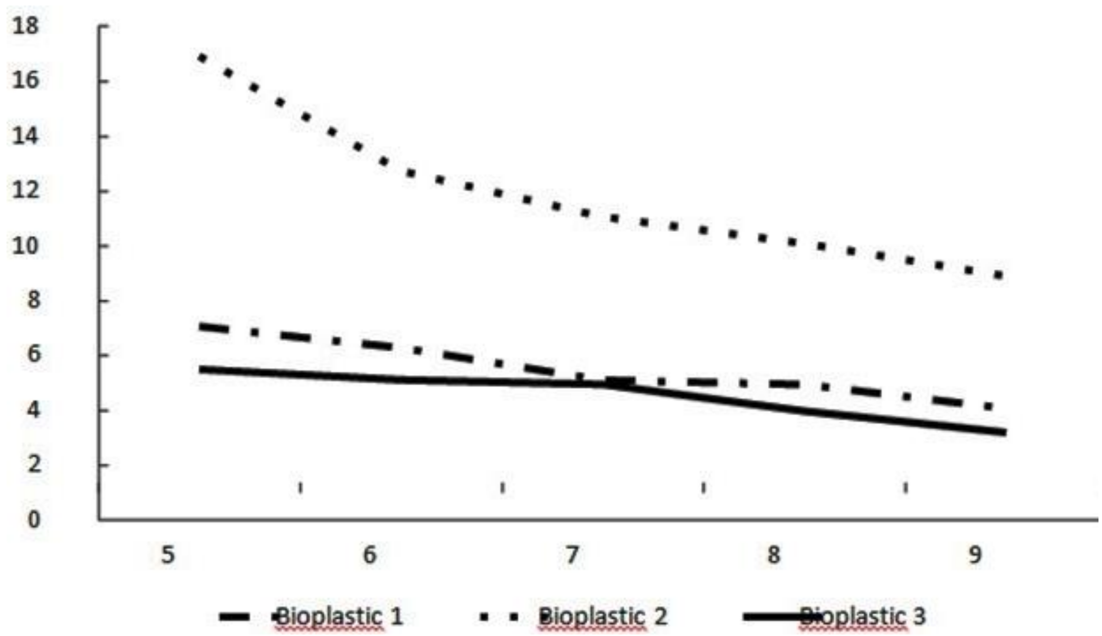

Figure 2: Change in Bioplastic weight from five weeks of degradation period.

In comparison to the first two types of bioplastics, the third kind hydrolyzed with acetic acid and disintegrated more quickly. The bioplastics that had been bathed in deionized water showed no discernible alterations.

Pure glycerol-based bioplastics decompose more quickly, according to bioplastics laboratory experiments. These studies demonstrate that hydrolyzing agents and glycerol purity have an impact on how quickly bioplastics break down in any media.

DISCUSSION

Bioplastics are plastics created from renewable plant-based resources. Both natural resources and chemical synthesis in laboratories can be used to create these polymers. Starch is one of the main biological compounds used in the creation of bioplastics. Bioplastics have the advantage over plastics based on petroleum in that they can disintegrate more quickly than bioplastics based on petroleum. Understanding the pattern of degradation is vital to comprehend the duration and conditions necessary for plastics to decompose as well as to gain knowledge of the materials used in the production of plastics with a desired rate of decomposition. The hydrolysis of bioplastics starts the decomposition process, which is followed by the dissolution of polymers into monomers that are ingested by microbes. The worms, bacteria, fungi, and other soil creatures all contribute to the microbial activity of the soil. The soil organisms, which may or may not be visible to the naked eye, aid in the decomposition process. Microbial activity begins in the second week after the substrate weight increases, and it causes the weight to drop.

In comparison to enzymatic breakdown, the natural process of decomposition is more efficient.

Different soil types have different microorganisms and compositions to aid in decomposition. In damp, permeable soil that is home to more bacteria, the pace of decomposition doubles. First-generation bioplastics degrade quickly and have a short assimilation time. Additionally, the microbes decline when the substrate loses moisture. Reduced rainfall lowers the soil's moisture content and slows the process of decomposition.

The pace of breakdown is also influenced by the mechanical qualities of bioplastics. High tensile strength bioplastics degrade at a slower rate. But regardless of the mechanical strength of the bioplastics, the rate of degradation in water was the same.

Conclusion: Plastics made from petroleum are dangerous for the environment because they take so long to degrade. Therefore, starch should be employed as a quick degrading raw material while making bioplastics. Because starch is hydrophilic, it breaks down more quickly in water than it does in soil. The bioplastics can also break down in a few weeks in soil that is healthy, well-drained, and home to a variety of microorganisms. Under the microbiological activity of soil, bioplastics made from starch derived from cassava peel and plasticized with glycerol can disintegrate fully in ten weeks. The degrading activity of bioplastics is also impacted by several environmental variables.

Conflicts of Interest: The author/s declare no conflicts of interest regarding the publication of this paper.

REFERENCES

Crawford, C.B. and Quinn, B. Plastic Production, Waste and Legislation. In: Crawford, C.B. and Quinn, B., Eds., Microplastic Pollutants, Elsevier Science, Amsterdam,pp:39-56,2017.

Mark, H.F. and Bikales, N.M. Degradation. In: Encyclopedia of Polymer Science and Technology, John Wiley & Sons, Inc., Hoboken, pp: 1-44, 2005.

Gross, M. Plastic Waste Is All at Sea. Current Biology, Vol 23, issue 4, pp: R135- R137, 2013.

Jambeck, J.R., Geyer, R., Wilcox, C., et al. Marine pollution. Plastic waste inputs from land into the ocean, Science, Vol 347, issue 6223, pp: 768-771, 2015.

Derraik, J.G.B. The Pollution of the Marine Environment by Plastic Debris: A Review. Marine Pollution Bulletin, Vol 44, issue 9, pp: 842-852, 2002.

Webb, H.K., Arnott, J., Crawford, R.J. and Ivanova, E.P. Plastic Degradation and Its Environmental Implications with Special Reference to Poly(ethylene terephthalate). Polymers (Basel), Vol 5, issue 1, pp: 1-18, 2013.

Demirbas, A. Biodegradable Plastics from Renewable Resources. Energy Sources, Part A: Recovery, Utilization, and Environmental Effects, Vol 29, issue 5, pp: 419- 424, 2007.

Lorcks, J. Properties and Applications of Compostable Starch-Based Plastic Material. Polymer Degradation and Stability, Vol 59, pp: 245-249, 2002.

Sagnelli, D., Hebelstrup, K.H., Leroy, E., et al. Plant-Crafted Starches for Bioplastics Production. Carbohydrate Polymers, Vol 152, issue 5, pp: 398-408, 2016.

Ashter, S.A. Types of Biodegradable Polymers. In: Ashter, S.A., Ed., Introduction to Bioplastics Engineering, William Andrew, Amsterdam, Vol 8, issue 4, pp: 81-151, 2016.

Zhou, X., Yang, R., Wang, B. and Chen, K. Development and Characterization of Bilayer Films Based on Pea Starch/Polylactic Acid and Use in the Cherry Tomatoes Packaging. Carbohydrate Polymers, pp: 222, 2019.

Harma, A.K. Biopolymers in Drug Delivery. Biopolymers Research, Vol 1, issue 1, pp: 1-2, 2017.

Shah, A.A., Hasan, F., Hameed, A. and Ahmed, S. Biological Degradation of Plastics: A Comprehensive Review. Biotechnology Advances, Vol 26, issue 3, pp: 246-265, 2008.

Müller, C.M.O., Laurindo, J.B. and Yamashita, F. Composites of Thermoplastic Starch and Nanoclays Produced by Extrusion and Thermopressing. Carbohydrate Polymers, Vol 89, issue 2 pp: 504-510, 2012.

Singh, J., Dartois, A. and Kaur, L. Starch Digestibility in Food Matrix: A Review. Trends in Food Science & Technology, Vol 21, issue 4, pp: 168-180, 2010.

Emadian, S.M., Onay, T.T. and Demirel, B. Biodegradation of Bioplastics in Natural Environments. Waste Management, Vol 59, pp: 526-536, 2017.

Nuwamanya, E., Baguma, Y., Wembabazi, E. and Rubaihayo, P. Comparative Study of the Physicochemical Properties of Starches from Root, Tuber and Cereal Crops. African Journal of Biotechnology, Vol 10, issue 56, pp; 12018-12030, 2011.

Nanda, M., Yuan, Z., Qin, W., Poirier, M.A. and Xu, C. Purification of Crude Glycerol Using Acidification: Effects of Acid Types and Product Characterization. Austin Journal of Chemical Engineering, vol 1, issue 1, pp: 1004, 2015.

Abolibda, T.Z. Physical and Chemical Investigations of Starch Based Bio-Plastics. Thesis, University of Leicester, Leicester, Vol 29, Vol 479, pp: 2-29, 2015.

Smirnova, J., Fernie, A.R. and Steup, M. Starch

Degradation. In: Nakamura, Y., Ed., Starch: Metabolism and Structure, Springer, Berlin, pp: 239-290, 2015.

Rudnik, E. and Briassoulis, D. Degradation Behaviour of Poly (lactic acid) Films and Fibres in Soil under Mediterranean Field Conditions and Laboratory Simulations Testing. Industrial Crops and Products, Vol 33, pp: 648-658, 2011.

Fettke, J., Hejazi, M., Smirnova, J., Hochel, E., Stage, M. and Steup, M. Eukaryotic Starch Degradation: Integration of Plastidial and Cytosolic Pathways. Journal of Experimental Botany, Vol 60, issue 10, pp: 2907-2922, 2009.

Hoshino, A., Sawada, H., Yokota, M., Tsuji, M., Fukuda, K. and Kimura, M. Influence of Weather Conditions and Soil Properties on Degradation of Biodegradable Plastics in Soil. Soil Science and Plant Nutrition, Vol 47, issue 1, pp: 35-43, 2001.