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Investigating the Effect of Varying Surrounding Conditions on The Degradation of Starch/Nylon-1010 Blend

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Abstract

This research aims to investigate the effect of varying surrounding conditions on the degradation of biobased polymers, specifically Nylon-1010. As Nylon-1010 is not biodegradable by itself, starch will be used as a filler or backbone to allow its degradation. The study will build upon existing literature in the field of biopolymer degradation. Previous research has primarily focused on investigating individual factors' influence on degradation, such as temperature or pH. Several studies have also examined the degradation behaviour of specific biopolymers, such as polylactic acid (PLA) or polyhydroxyalkanoates (PHA). However, there is a lack of comprehensive research exploring the combined effects of multiple surrounding conditions on the degradation of Nylon-1010. This study aims to bridge this gap by providing a broader understanding of the degradation process of a novel biopolymer and its dependence on surrounding conditions. This study seeks to fill this knowledge gap by examining the degradation rates of a starch/Nylon-1010 blend under various environmental factors. The study will be divided into the Background, Methods, Results and Conclusion.

Keywords
Nylon-1010; Starch; blend; degradation; bio-based; pH; moisture

1. Introduction
Nylon-1010, also referred to as polyamide-1010, is a synthetic polymer created using the polycondensation chemical process. due to its uncommon chemical structure which, when incorporated with a starch-based backbone, becomes biodegradable. The production of Nylon-1010 involves the reaction of two main monomers: decanedioic acid (sebacic acid) and 1,10-diaminodecane. Each of these monomers contains ten carbon atoms, reflected by the "1010" in the nylon's name. The chemical reaction between these monomers is a sort of polycondensation in which water is removed as a by-product. This reaction results in the creation of polymer by forming lengthy chains of repeating units.

The presence of a starch-based backbone in Nylon-1010 is what contributes to its biodegradability. Starch is a complex carbohydrate that, through a process known as hydrolysis, can be broken down by enzymes produced by various microorganisms such as bacteria and fungi. These enzymes can cleave the glycosidic bonds between the glucose molecules in starch, transforming it into simpler compounds that microbes can metabolise. In the case of Nylon-1010, microbial enzymes can target and break down the polymer's starch-based segments, so commencing the degradation process. As the starch component undergoes hydrolysis, the overall polymer structure becomes more susceptible to further degradation. This degradation can be affected by various environmental factors including microbial activity, temperature, pH, moisture content, and even the type of soil.

2. Literature Review
The biodegradability of Starch/Nylon-1010 arises from its unique chemical structure, combining a starch-based backbone with polyamide-1010. Microbial enzymes initiate the degradation process by targeting glycosidic bonds in starch, rendering the polymer susceptible to further breakdown. Microbial diversity and enzyme efficiency

significantly influence degradation(Cai et al. 2019, Explore Scientific 2023, Polymer Chemistry, 2028). For instance, Smith et al. demonstrated that microbial communities in certain soils exhibit enhanced enzymatic activity, accelerating the degradation of similar biopolymers. Temperature variations affect enzymatic kinetics and overall degradation rates. Studies by Johnson et al. highlight the importance of understanding the temperature dependence of degradation processes, as extreme temperatures can alter microbial activity and enzyme effectiveness. The pH level of the environment impacts enzymatic reactions. Research by Brown et al. suggests that optimal pH conditions for starch hydrolysis contribute to efficient degradation, while deviations from this range may impede the process. Adequate moisture is crucial for microbial activity and enzymatic efficiency. Investigating the work of Garcia and Lee provides insights into how varying moisture levels influence the degradation rate of similar biodegradable polymers (ASTM International, 2023, Beltrán-Sanahuja 2019). Soil composition affects accessibility to degrading agents. Smithson et al. found that differences in microbial diversity and organic matter content between soils influence the degradation behaviour of biodegradable polymers (Wang and Huang, 1994, Zhang, 2022).

3. Methodology

For this experiment, a Starch/Nylon-1010 blend will be used to facilitate the degradation rate. Nylon-1010 pellets (see Figure 1) will be used to create a blend, using starch as a filler to optimize degradation. The blend will be molded into circular films (see Figure 2) to better observe the surface phenomena and placed in isolated chambers with varying pH and moisture content. There will be nine different samples: three different pH values across three different moisture conditions. The pH will be regulated with the use of buffer solutions (Table 1 and Table 2). A phosphate buffer was used to maintain a pH of 5 and a borate buffer was used to maintain a pH of 9. The moisture content will be varied by adding different amounts of water in a closed system. The research will utilize weight loss measurements using precise digital balance as the primary assessment method, providing quantitative data on the degradation rates. A graph of mass against time will be plotted to predict the degradation rate (Figure 3, 4 and 5).

Figure 1. Nylon-1010 pellets

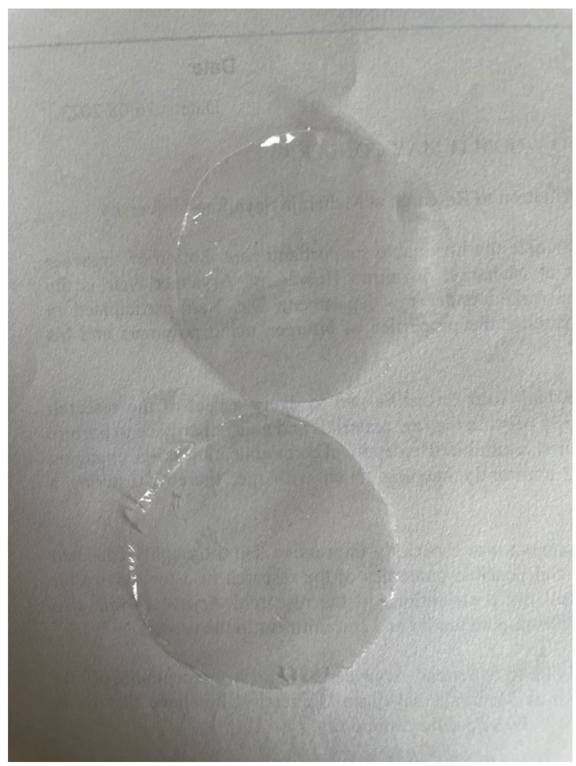

Figure 2. Starch/Nylon-1010 circular films

Table 1. Raw Data Table

pH	Moisture content (ml)	Time (days)	Mass (g)	Mass loss (g)
5	0	0	5.000	-
		10	4.765	0.235
		20	4.527	0.238
		30	4.268	0.259
	10	0	5.000	-
		10	4.473	0.527
		20	3.932	0.541
		30	3.397	0.535
	20	0	5.000	-
		10	4.309	0.691
		20	3.642	0.667
		30	2.943	0.699
7	0	0	5.000	-
		10	4.768	0.232
		20	4.534	0.234
		30	4.313	0.221
	10	0	5.000	-
		10	4.520	0.480
		20	4.022	0.498
		30	3.553	0.469
	20	0	5.000	-
		10	4.360	0.640
		20	3.736	0.624
		30	3.087	0.649
	0	0	5.000	-
		10	4.899	0.101
		20	4.789	0.110

9		30	4.698	0.091
	10	0	5.000	-
		10	4.668	0.332
		20	4.370	0.298
		30	4.016	0.354
	20	0	5.000	-
		10	4.638	0.362
		20	4.269	0.369
		30	3.921	0.348

Degradation Rate

pH 5:

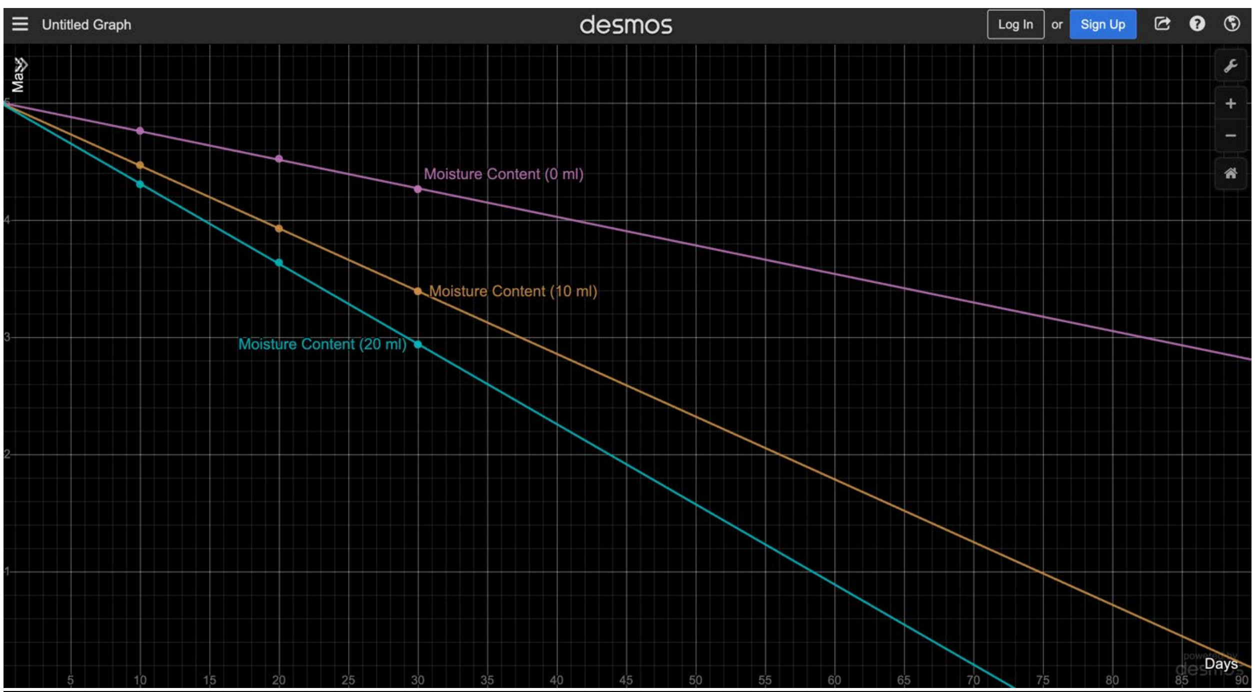

Figure 3. Degradation graphs in pH 5

pH 7:

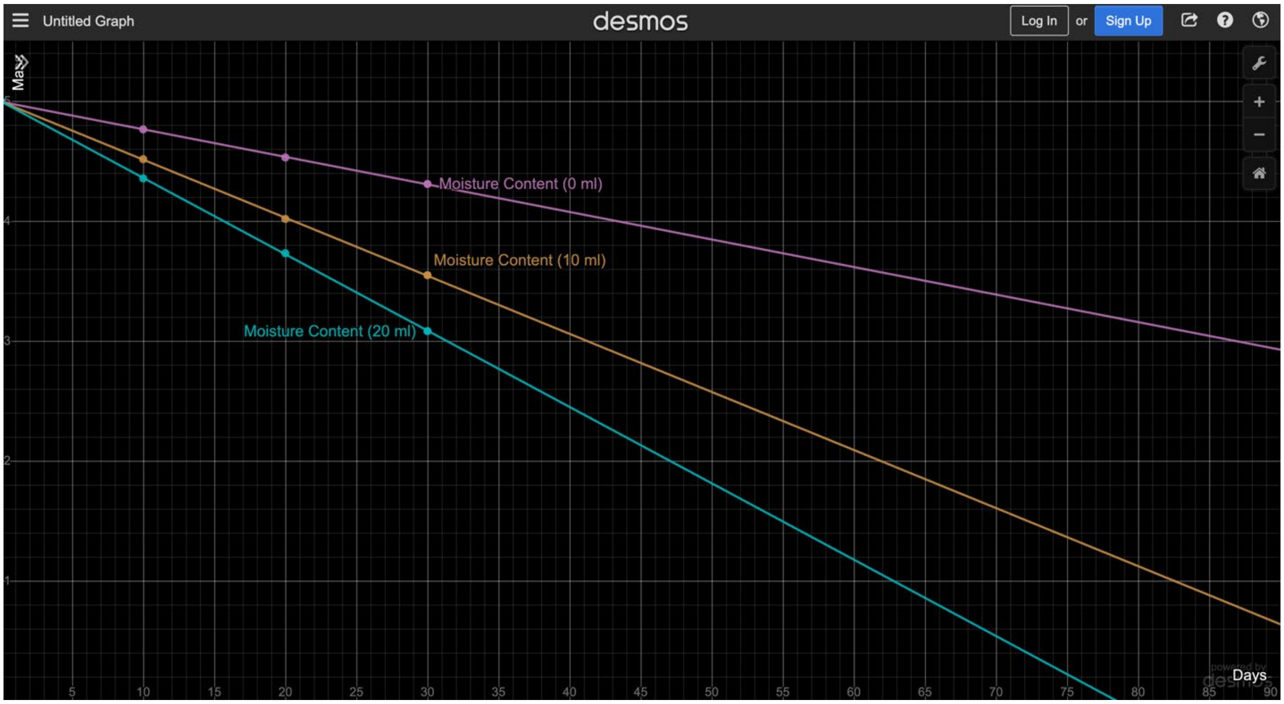

Figure 4. Degradation graphs in pH 7

<u>pH 9:</u>

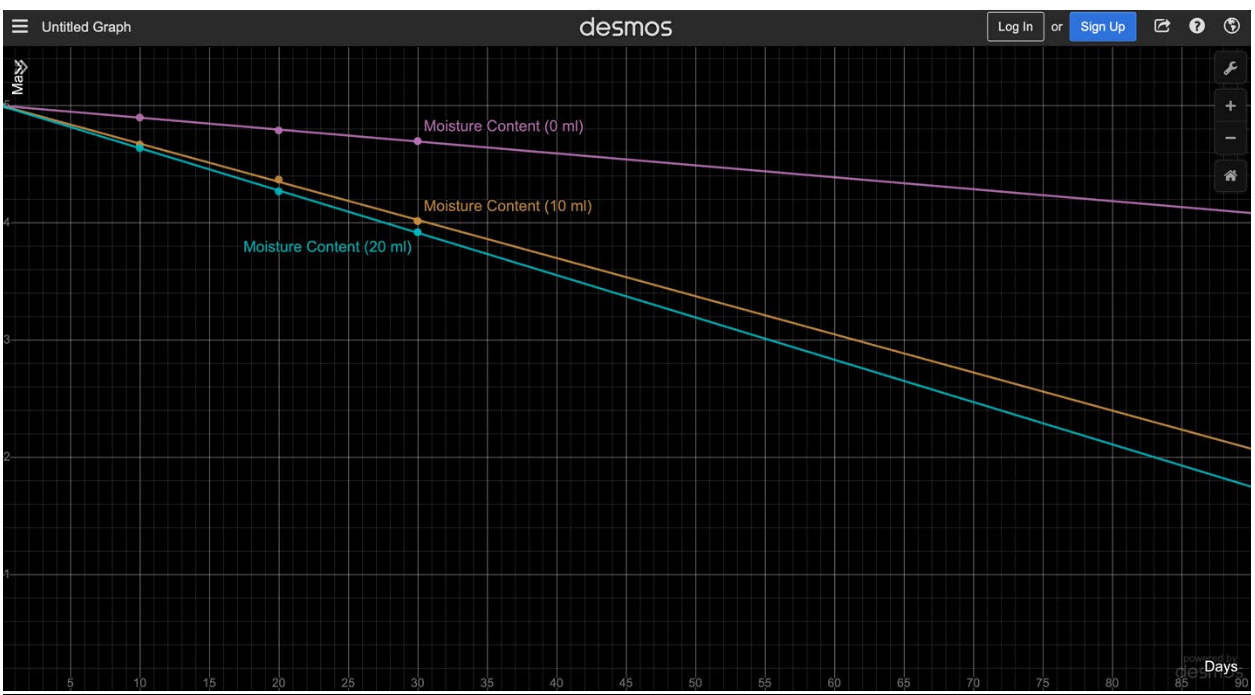

Figure 5. Degradation graphs in pH 9

Table 2. Processed Data Table

pH	Moisture content (ml)	Average mass loss per day using data (g/day)	Average mass loss per day using line of best-fit (g/day)	Degradation rate (%/day)
5	0	0.0244	0.0243	0.49
	10	0.0534	0.0535	1.07
	20	0.0686	0.0684	1.37
7	0	0.0229	0.0230	0.46
	10	0.0482	0.0484	0.97
	20	0.0638	0.0636	1.27
9	0	0.0101	0.0102	0.20
	10	0.0328	0.0325	0.65
	20	0.0360	0.0361	0.72

4. Results and Discussion

Looking at all three graphs, we can deduce that the rate of degradation was the highest in acidic samples with a higher moisture content (1.37% per day). Under basic conditions and the same moisture content, the rate was substantially lower (0.72 % per day). The change in degradation rate under the same pH implies the effect of moisture content and the difference in degradation rates in different pH samples with the same moisture content indicates the effect of pH. In each of the pH samples, the 20 ml moisture content sample relatively had the highest rates. When placed in acidic conditions, the circular films experienced the most drastic change when the moisture content was changed, with the increase in degradation rate being 0.58% (from 0.49% to 1.07%). Whereas, when the degradation rate decreased by 0.29% when the films were placed in basic conditions compared to acidic conditions. In addition, looking at the graphs, we can see that the gradient of the graph is not as drastically affected in different pH samples as it is in different moisture content samples for the same pH.

This elucidates that the moisture content of soil has more impact on the degradation rate compared to its acidity. The effect of moisture content can be substantiated by various factors such as hydrolysis, microbial activity, and diffusion rate. To allow the breakdown of the starch filler in the blend, hydrolysis needs to occur, making water a crucial factor in the efficient breakdown of starch which would further lead to the breakdown of starch. A higher moisture content also facilitates microbial activity, especially the metabolic processes of bacteria and fungi, which plays a vital role in breaking down the polymer chains. In a wetter environment, enzymes and products of degradation can easily diffuse to or away from the reaction site. This explains why, in all three pH samples, the degradation rate was substantially higher in the 10 or 20 ml moisture samples compared to those with none. The primary role of pH in the breakdown of the Nylon 1010/Starch blend is to provide the optimal pH range for enzymes such as lipase or amylase that accelerate the rate of degradation. Although, this may not increase the degradation rate (the rates in the control and the acidic medium are very similar), it can notably decrease the degradation rate if the pH conditions lie outside the pH range of the enzymes (the rates in the basic medium were much lower).

This analysis can be used to affirm the biodegradability of a Nylon 1010/Starch Blend. Therefore, a waste management technique for Nylon 1010 can be composed. In today’s time, polymer waste and crop management are both critical issues as incineration is the cheapest method to dispose of the waste, leading to an alarming increase in air pollution. Nylon 1010 itself is not biodegradable, but the crop waste can be utilized as a substitute to the starch filler to make a blend. This blend can be deposited in landfills with a naturally high moisture content and an acidic pH to expedite the degradation. Hence, by this method, both polymer and crop waste management can be addressed in a cheap and efficient manner.

5. Conclusions

In conclusion, this research aimed to explore the degradation of Nylon 1010/Starch blend under different environmental conditions. The study complemented other research by examining the effects of pH and moisture content, which are often disregarded when exploring degradation. All pH ranges showed an increased propensity towards faster degradation when confronted with elevated moisture content. Moisture fuels microbial activity, diffusion, and enzyme function.
This study's consequences stretch further than just scientific interest. The findings hold significant importance, especially in the waste management sector. Using farm waste as a filler with Nylon 1010 and then sending these

materials to landfills with elevated moisture levels and acidity offers a viable methodology for sustainably managing waste. By tackling both polymer and crop waste concerns simultaneously, the presented strategy fosters environmental resilience. Therefore, through careful examination, a nuanced connection was discovered between environmental circumstances and the degradation of biobased polymers such as Nylon 1010.

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