Biodegradable Plastics

Prisha Shah

duPont Manual High School

Abstract

The purpose of this project was to figure out what type of plastic would biodegrade the most underground by the end of the experiment. There are many types of biodegradable plastics in the world today, but not all of them actually biodegrade as quickly as they are said to biodegrade. That results in plastics being left in landfills and staying there for years and years, never biodegrading, therefore harming the environment. This experiment tests different biodegradable plastics and measures how quickly they biodegrade. 3 plastics were chosen, acetone, casein, and cornstarch. 15 plastics were created, 5 of each kind. The initial volumes were measured, then they were buried underground. The plastics were taken out 5 times over the course of 2 months to measure the change in volumes. It was hypothesized that the casein plastic would biodegrade the quickest, and the hypothesis was proven correct with the data. The data showed that out of all 3 plastics, casein biodegraded the most when placed underground. The data showed the casein plastics having an average mean of 5.53, cornstarch with a mean of 1.46, and acetone with a mean of zero. Casein biodegraded the most because it had the biggest mean out of all of them. This result suggests that the casein is made out of more organic materials than the rest of the plastics, therefore resulting in its quick biodegradation.

Keywords: biodegrade, plastics

Introduction

The current amount of carbon dioxide in the atmosphere is 412.5 parts per million as of 2021 and is projected to increase quickly. Excessive CO_2 causes a big problem because of the greenhouse effect. The greenhouse effect causes the CO_2 to trap heat from the sun in the atmosphere and heat the planet. This causes global warming, a huge issue that is greatly affecting the environment in negative ways. There are many sources that emit excessive amounts of Carbon Dioxide, one of them being landfills. High levels of methane and carbon dioxide are generated by the rotting trash dumped in the landfills. Examples of the materials dumped into landfills are food waste, plastic, paper, glass, and other common household products. Food waste (apple cores, leftovers, etc…) makes up over 24% of the waste that is dumped in landfills, and as it decomposes often creates a harmful order called methane, which is a powerful greenhouse gas. Plastic (tin cans, plastic bags) makes up 19% of the waste in landfills (EPA 2018). Plastic that is buried deep underground can leech harmful chemicals into the ground, affecting the nutrition in soil and making it harder for plants to find the minerals they need to survive. Glass takes over a million years to decompose and it serves no purpose in landfills, it is recyclable and a valuable resource considering many things that are made have some sort of glass in it. Landfills can also impact the ocean if the waste enters the water. Animals may attempt to eat the plastic, and end up dying because the waste gets stuck in their stomach. Seafood also gets impacted, as the food becomes toxic because of the toxic waste that the animal consumed. In addition to environmental impacts, landfills can also pose a problem for people living around them. As waste decomposes, it releases many harmful chemicals into the air, causing many health problems such as asthma, cholera, malaria, flu, and cough. People living around them would also

see many bugs and not as clean water, due to the toxic chemicals from landfills seeping into the water.

Biodegradable plastics are plastics that decompose into organic materials at a much faster rate than normal plastics. When these plastics are dumped into a landfill, they decompose very quickly and reduce the chance to pollute any of the surrounding areas. Furthermore, biodegradable plastics are recyclable, they can be used multiple times in multiple different ways. Biodegradable Plastics are eco-friendly and an exceptional alternative to current plastics.

Despite the many benefits of biodegradable plastics, they are not used as much in society. This is because modern biodegradable materials are expensive to manufacture and are not as strong as the traditional types of plastic. This experiment uses inexpensive biodegradable materials to create biodegradable plastic that can decompose in the environment fairly quickly compared to other types of plastic. It directly addresses the biggest problem of biodegradables, cost. The question of this experiment is ‘What materials can be used to create the fastest biodegrading plastic?’

This experiment tests alternatives to expensive biodegradable materials, and if it succeeds, can present new biodegradable plastics that decompose quickly and are affordable to create and use in daily life. Currently, biodegradable plastics are being created using green materials that are expensive to manufacture. The materials that are being used in this experiment are materials that are already used in daily life and relatively easy to manufacture, such as milk, corn starch, and paper.

The hypothesis for this experiment is ‘ If a casein plastic is buried underground for 2 months then it will biodegrade the fastest because the plastic contains the most biodegradable materials. To measure which material degraded the fastest, at the end of the experiment I will

place all the plastic on a scale to measure how much it degraded. The one that has lost the most weight, or is fully degraded is the fastest degrading plastic. The 3 types of plastics that are being created for this experiment include Paper/Acetone Plastic, Casein Plastic, and a biodegradable cornstarch bag. The paper/acetone plastic is created out of nail polish remover and paper. Nailpolish remover is made up of Isopropyl acetone, methyl ethyl ketone, and n-methyl-pyrrolidone, all 3 of these chemicals have been proven to be biodegradable and decompose relatively quickly. Acetone takes an average of 22 days to decompose underground, and paper takes 2 - 6 weeks to decompose, Casein (Milk) plastic is made out of Milk and Vinegar. Milk is made out of biodegradable materials that take only a few days to decompose and Vinegar takes 2 - 3 days to completely biodegrade. Cornstarch Plastic is created out of Cornstarch, Vinegar, and Water. Cornstarch takes a few months to biodegrade.

Methodology

This experiment was conducted in the kitchen and backyard of a 2 story home with an adult supervising. The materials gathered for this experiment include 1 cup of whole milk, 1 teaspoon of vinegar or lemon juice, a saucepan (or stove), and a strainer. These materials were needed to create the first plastic (casein plastic). To create the second plastic (cornstarch plastic), the materials needed were a container, cornstarch, water, glycerin, and vinegar. To create the 3rd plastic (Paper Plastic) the materials needed were nail polish remover (acetone), A mason jar, paper, and gloves. The first plastic created was the casein plastic. First, the cup of whole milk was placed in a saucepan and kept on low heat on the stove. It was constantly checked to make sure that the milk was not boiled. Next, the vinegar was added, a few tablespoons at a time, and then mixed together for a few minutes. Lastly, the mixture was taken off the stove and strained, the excess at the bottom was the casein plastic. Then, the plastic was placed in the freezer to harden for 2 - 3 hours. The next plastic made was the cornstarch plastic, First, 1 tablespoon of cornstarch was added to the container, then 4 tablespoons of water. The 2 things were mixed together until the cornstarch dissolved. Once the mixture has dissolved, add 1 tablespoon of glycerin and 1 tablespoon vinegar, then mix them together. Once the mixture is ready, place over low heat and stir it together. Once the mixture was lump-free, it was removed from the stove and placed on a kitchen countertop. Then the plastic was left to dry for a day. The 3rd plastic to be created was the paper/acetone plastic. First, acetone was poured into the jar, then the paper was broken into smaller pieces and pushed to the bottom of the jar. The paper was pushed in to jar for 3- 5 minutes until it was taken out and molded in a sphere. Then it was left out for about a day to dry. Once all 3 plastics were dry, they were measured to see how much they weighed, and then placed into separate holes in the house's backyard and buried 6 inches deep. Every day, the

plastic was taken out and placed on weight for measuring. Once one plastic was fully dissolved, the experiment was completed. Then, all the steps to make the plastic were repeated multiple times to create 5 different batches of plastic. The data was recorded and analyzed using statistical methods.

Data & Results

Raw Data:

Cornstarch Plastic: Table: 1

	Cornstarch 1	Cornstarch 2	Cornstarch 3	Cornstarch 4	Cornstarch 5
Trial 1 (Initial)	10.8 cm^3	9.45 cm^3	13.72 cm^3	2.88 cm^3	10.4 cm^3
Trial 2	9.5 cm^3	9 cm^3	12.7 cm^3	2.88 cm^3	9.5 cm^3
Trial 3	9 cm^3	8.1 cm^3	10.34 cm^3	2 cm^3	9.32 cm^3
Trial 4	9 cm^3	7.5 cm^3	10 cm^3	2 cm^3	9 cm^3
Trial 5	8.7 cm^3	6.5 cm^3	7.5 cm^3	2 cm^3	8 cm^3

Acetone Plastic: Table 2

	Acetone 1	Acetone 2	Acetone 3	Acetone 4	Acetone 5
Trial 1 (Initial)	1.8 cm^3	2.5 cm^3	2.6 cm^3	1.56 cm^3	1.6 cm^3
Trial 2	1.8 cm^3	2.5 cm^3	2.6 cm^3	1.56 cm^3	1.6 cm^3
Trial 3	1.8 cm^3	2.5 cm^3	2.6 cm^3	1.56 cm^3	1.6 cm^3
Trial 4	1.8 cm^3	2.5 cm^3	2.6 cm^3	1.56 cm^3	1.6 cm^3
Trial 5	1.8 cm^3	2.5 cm^3	2.6 cm^3	1.56 cm^3	1.6 cm^3

Casein Plastic: Table 3

	Casein 1	Casein 2	Casein 3	Casein 4	Casein 5
Trial 1 (Initial)	13.8 cm^3	14.25 cm^3	12.56 cm^3	15.02 cm^3	15.75 cm^3
Trial 2	10.5 cm^3	11.2 cm^3	8.75 cm^3	12.25 cm^3	11.26 cm^3
Trial 3	5.5 cm^3	10.5 cm^3	7.5 cm^3	8.5 cm^3	9.8 cm^3
Trial 4	4.5 cm^3	5.25 cm^3	4.38 cm^3	7.5 cm^3	7.88 cm^3
Trial 5	4.5 cm^3	7.5 cm^3	2 cm^3	4 cm^3	4 cm^3

Fig.1

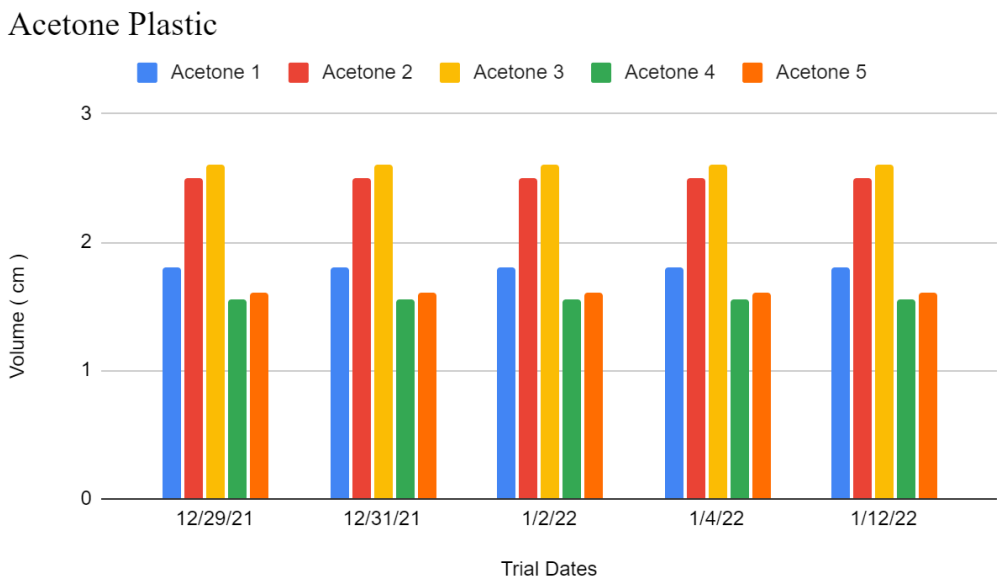


Fig 2:

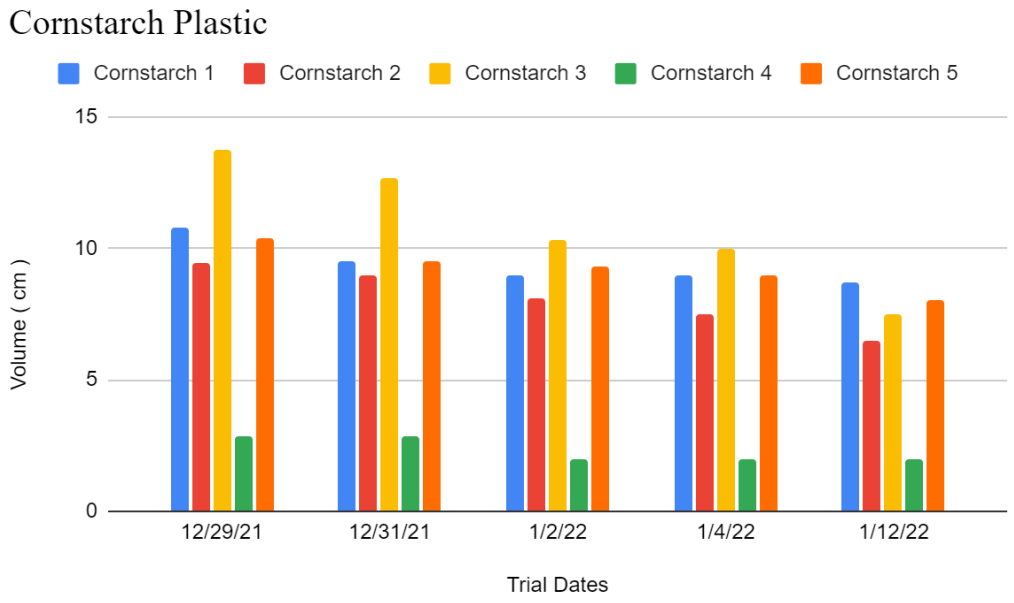
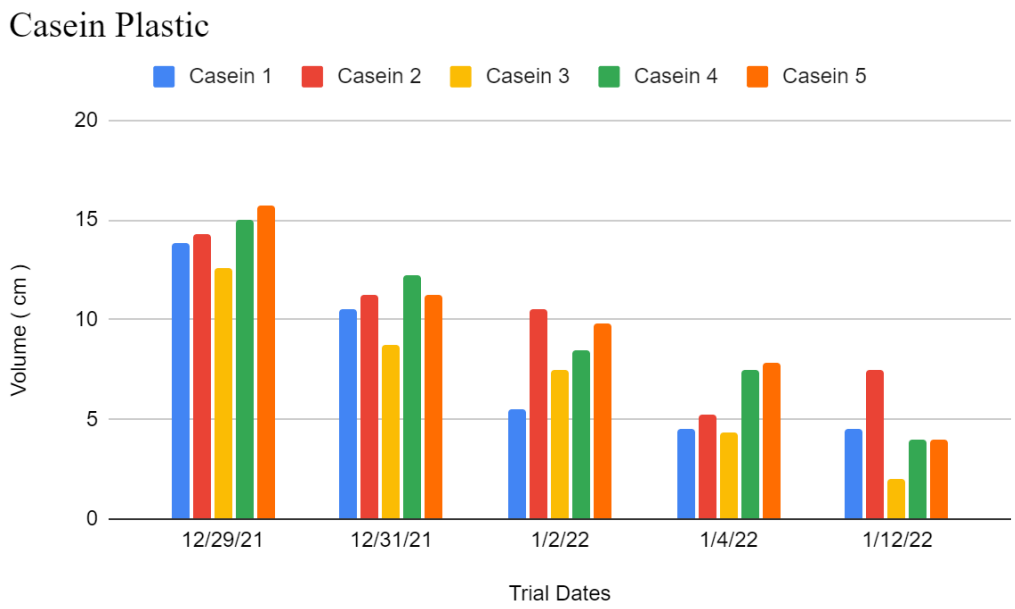


Fig 3:



Tables 1, 2, and 3 show the raw data for the experiment, they show the exact values of the plastic in each trial. Fig 1 shows the change in volume for the plastic acetone in each trial, Fig 2 shows the change in cornstarch in each trial, and Fig 3 shows the change in the casein plastic in each

trial. The independent variable was the different types of plastic and the hypothesis for this experiment was that the casein plastic would biodegrade the fastest, therefore have the steepest slope. The dependent variable in this experiment was the rate of biodegradation of each plastic. Each trial is a volume check I made at different time intervals, there is no coordination between the time intervals in the trails.

Table 4:

Acetone (Change in Volume):

	1	2	3	4	5
12/29/21	0	0	0	0	0
12/31/21	0	0	0	0	0
1/2/22	0	0	0	0	0
1/4/22	0	0	0	0	0
1/12/22	0	0	0	0	0

Table 5:

Cornstarch (Change in Volume);

	1	2	3	4	5
12/29/21	0	0	0	0	0
12/31/21	1.3	0.45	1.02	0	0.9
1/2/22	1.8	1.35	3.38	0.88	1.08
1/4/22	1.8	1.95	3.72	0.88	1.4
1/12/22	2.1	2.95	6.22	0.88	2.4

Table 6:

Casein (Change in Volume (cm)):

	1	2	3	4	5
12/29/21	0	0	0	0	0
12/31/21	3.3	3.05	3.81	2.77	4.49
1/2/22	8.3	3.75	5.06	6.52	5.95
1/4/22	9.3	9	8.18	7.52	7.87
1/12/22	9.3	6.75	10.56	11.02	11.75

Tables 4, 5 and 6 show how the plastics volumes changed in each trial. Table 4 shows how the acetone plastic changed its volume over time, Table 5 shows how the cornstarch plastic changed its volume over time and Table 6 shows how the casein plastic changed its volume over time. These 3 tables differ from the raw data tables because they do not show raw data, they show the rate of biodegradation each plastic faced throughout the experiment.

Table 7:

Statistics of Change in Volume:

Acetone		Cornstarch		Casein	
Mean	0	Mean	1.4584	Mean	5.53
Variance	0	Variance	2.122830667	Variance	14.18528333
SD	0	SD	1.456993709	SD	3.766335531
1 SD	0	1 SD	0.0014 - 2.915	1 SD	1.764 - 9.296
2 SD	0	2 SD	0- 4.37	2 SD	0 - 13.062
3 SD	0	3 SD	0- 5.827	3 SD	0 - 16.828
Number	5	Number	5	Number	5
T-Test vs Cornstarch	t = -3.85648	T-Test vs Acetone	t = -3.85648	T-Test vs acetone	t = -5.65689
	p<.05		p<.05		p < .00001
	Significant		Significant		Significant
T-Test vs Casein	t = -5.65689	T-Test vs Casein	t = 5.04119	T-Test vs Cornstarch	t = 5.04119
	p < .00001		p < .00001		p < .00001
	Significant		Significant		Significant

Table 7 contains the descriptive statistics of the change in volume (which can be seen in Tables 4, 5 and 6). The mean of the plastic acetone is 0 because the plastic had not biodegraded at all during the experiment, so variance and standard deviation also remained 0. The mean of the plastic cornstarch is 1.4584 cm^3 & the mean of the plastic casein is 5.53. The means show that casein biodegraded more than all 3 of the plastics. The hypothesis was proven correct. The Standard Deviation of the cornstarch plastic is 1.456993709 & the standard deviation of the casein plastic is 3.766335531. There were 5 trials conducted on each of the plastics. The t-test for acetone vs casein shows a t of -5.65689 & a p<.0001. This is significant for the experiment because it supports that casein biodegraded faster than acetone. The t-test for acetone vs cornstarch showed t = -3.85648 & p<.05. This is also significant. The t-test for acetone vs

cornstarch showed t = 5.04119 & p < .00001. This is also significant. Overall, this experiment supported the original hypothesis of the casein plastic biodegrading the most out of all the other plastics.

Fig 4:

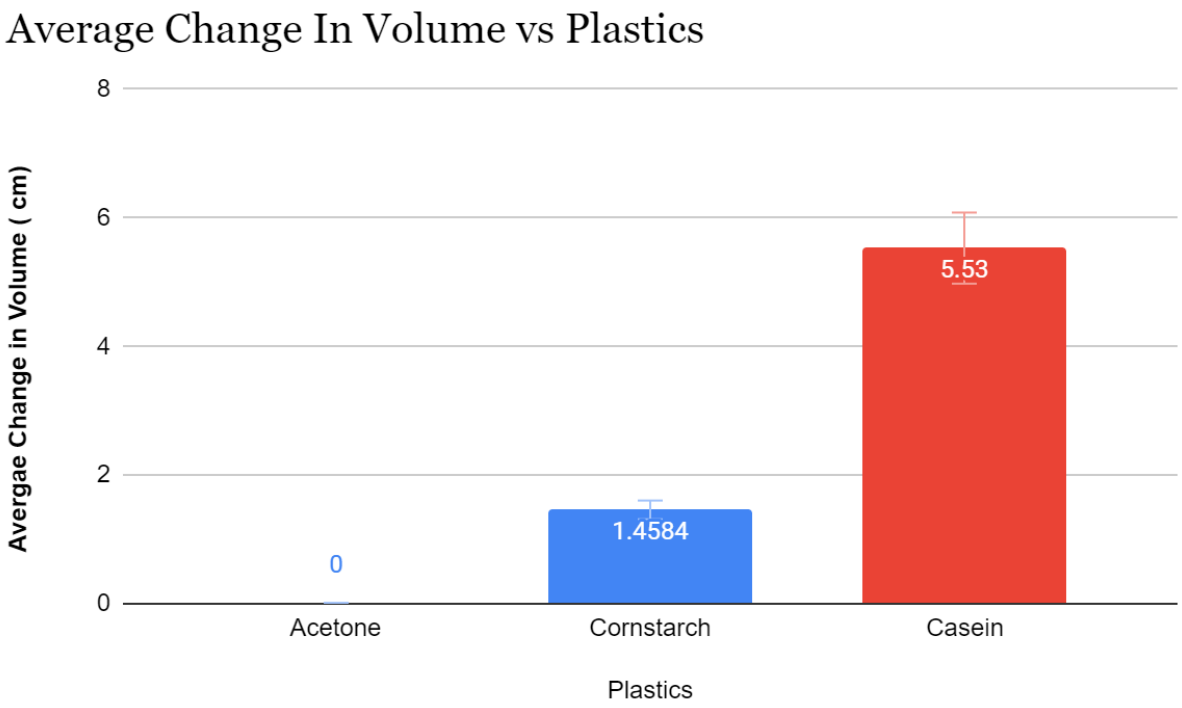


Fig 4 shows the average change in volume for all 3 plastics as a whole. Acetone is 0 because it experienced no change, cornstarch had a change of 1.4584, and casein had the most change with a value of 5.53. The gaps between all 3 of the plastics were very large and significant.

Conclusion

The purpose of this project was to figure out what type of plastic would biodegrade the most underground by the end of the experiment. 15 individual plastics were created, 5 plastics of each of the 3 types of plastics. The change in the volumes of the plastics was measured and compared to each other. It was hypothesized that the casein plastic would biodegrade the quickest due to the casein plastic being made mostly of organic materials. If this were true, more casein plastics could be integrated into daily life, reducing the average person's carbon footprint and being overall more environmentally friendly. Overall, the hypothesis was supported. The data showed the casein plastic decreased at a much steeper slope than the other plastics. The t-test between acetone and cornstarch resulted in $t=-3.85648$, $p<.05$. This result is somewhat significant, but not as much as the others. The t-test between acetone and casein was $t = -5.65689$, $p < .00001$. This result is quite significant. The t-test between cornstarch and casein was $t = 5.04119$, $p < .00001$. This result is also significant. In conclusion, the casein plastic biodegraded more than the other plastics by a significant amount.

The likely explanation for this trend is the fact that casein is made out of organic materials that bio decomposes faster than other products used in plastics. Casein Plastic is made out of milk & vinegar. When milk is added to the vinegar, the pH of the milk changes. The pH change causes the casein molecules to unfold and reorganize into a long chain. Each individual Casein plastic is a monomer and the long chain that is created is a polymer. The polymer can then be molded, making it into plastic. In general, polymers are easier to biodegrade than monomers or other forms of plastic. The acetone plastic didn’t decompose at all, this is due to the fact that the main ingredient in acetone plastic is paper, and paper is made of cellulose. Cellulose is biodegradable, but since it needs to be mixed with other non-biodegradable materials to be

used in plastic, it is not as easy to biodegrade as some other plastics. Cornstarch is biodegradable, but it is not efficient due to the fact that it is made with a lot of extra chemicals and products that hinder its ability to break down as quickly as other biodegradable plastics.

There was a chance of error when measuring the volume of the plastics, there was a strong possibility that there was some inaccuracy in the measurements, or the measurements might not have been as accurate as hoped. Another source of error might have been the amount of water runoff the plastics were subjected to. The samples closest to the house may have been exposed to more water, while others may have been exposed to less. The difference in the amount of water runoff could contribute to one biodegrading less or more than another.

There are several ways this experiment could be expanded upon. One possible way is creating more plastics. The more plastics there are, the less likely there is for an outlier to have a greater impact on the results. Instead of 5 plastics for each type, maybe there should be 10 or 15. Another way is including other types of biodegradable plastics other than the 3 already tested, such as vegetable or fruit-based plastics. Lastly, the plastics could also be buried in a different environment other than in a backyard, for example outside of a park or a lake.

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