

Replacement of Polyethylene Microbeads with Sustainable Biodegradable Alternatives

Abstract:

In our project, we investigated the potential of several biodegradable plastics prepared from sustainable materials as alternatives to environmentally damaging industry standards such as polyethylene and polypropylene.

- We prepared calcium alginate, starch plastic prepared with acetic acid and starch plastic prepared with hydrochloric acid in our school laboratory.
- We carried out preliminary tests which could indicate whether these plastics were suitable for use in cosmetic and personal care products. Each test was repeated 3 times.
- We determined the effect of each test on the microbeads with two variables; average bead size and mass change.
- It was evaluated if there was a significant difference recorded in the microbead samples before and after testing with the use of t-tests.
- This helped us conclude how suitable our microbeads would be in cosmetic products in the future.

Introduction:

- Microbeads are tiny, man-made plastic beads which can fulfil a huge range of functions in products such as scrubbing, cleansing and exfoliating.
- They have been included in all sorts of different personal care products such as shampoo, facial wash and toothpaste.
- Recent research has uncovered the potentially detrimental effects of these microbeads. Their harmful effects begin in the ocean, where they can be ingested by freshwater and marine species. This uptake can cause adverse consequences such as reduced nutrition and energy reserves. These microbeads can then pass on to humans through trophic transfer.
- These shocking discoveries have led many countries to propose bans on microbead products, but many companies are looking for alternatives.
- One possible solution proposes the production of biodegradable plastic alternatives, which could biodegrade in waste water treatment plants before even entering the ocean.

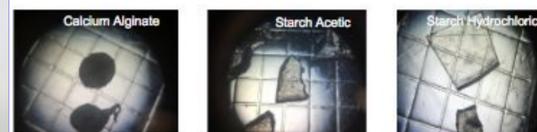
Experimental Methods:

- Preparing Biodegradable Plastics

We prepared three types of biodegradable plastics to conduct tests on in the lab; calcium alginate, starch plastic prepared with hydrochloric acid, and starch prepared with acetic acid starch microbeads.

- Physical Property Tests

The beads' physical properties were recorded with the aid of a microscope. The average size of each microbead type was recorded using 200 beads with reference to a slide of 1mm x 1mm squares. The colour and texture of each microbead type was also noted.



- pH Stability Tests

Samples of mass 0.05g of each microbead type were placed in buffers of pH 2,4,7,9,10 and 13 at room temperature (18°C) and 37°C and left in the buffers for a period of 2 weeks.

- Solubility Tests

The solubility of each microbead type in samples of water, oil, and face wash was tested by placing 0.3g of each microbead type in 7.5ml of each solvent for 2 weeks.

- Thermal Oxidative (Heat Cycle) Tests

0.1g samples of each microbead type were placed in an oven for 24 hours at 37°C. They were then placed in a freezer for 24 hours at -15°C. This was repeated over 10 days as a preliminary test to determine the shelf life of each sample

- Photostability tests

The beads were split into samples of 0.1g which were placed on a UV light over the course of a month.

- Microbiological Tests

We conducted these tests in a sterilized area with a Bunsen burner. An inoculating loop was sterilised using ethanol and a Bunsen burner and it was used to prepare 3 agar petri dishes of each microbead type. These were left to grow over the course of a month.

Results:

In the table below are some of the physical properties which were noted and recorded.

- The mass and average bead size of each sample after tests had been carried out were recorded
- We wanted our t-tests to show that the beads had no significant differences with a p-value of greater than 0.05 as this would mean our beads withstood the tests.
- Ultimately, we were comparing our recordings with our controls. We found a correlation between the size and mass change of the microbeads so for space purposes we have only included the mass in grams.

Bead Type	Average Bead Size	Opacity	Texture
Calcium Alginate	1.05mm	Opaque	Smooth, Hard
Starch-HCl	0.93mm	Translucent	Smooth, Easily Cut
Starch-CH ₃ COOH	1.04mm	Translucent	Smooth, High Elasticity

pH Tests at Room Temperature (18°C)

Ca Alginate	Control	pH 2	pH 4	pH 7	pH 9	pH 10	pH 13
Test 1	0.05g	0.07g	0.11g	3.14g	0.08g	0.07g	n/a
Test 2	0.05g	0.05g	0.39g	3.29g	0.07g	0.1g	n/a
Test 3	0.05g	0.05g	0.14g	3.31g	0.07g	0.08g	n/a
t-test		0.8	0.35	0.00038	0.022	0.083	n/a

We found there to be no significant difference at pH 2,4 and 10. At pH 13 the beads dissolved.

Starch HCl	Control	pH 2	pH 4	pH 7	pH 9	pH 10	pH 13
Test 1	0.05g	0.04g	0.07g	0.04g	0.05g	0.04g	0.03g
Test 2	0.05g	0.04g	0.08g	0.05g	0.06g	0.03g	0.04g
Test 3	0.05g	0.05g	0.06g	0.04g	0.06g	0.05g	0.04g
t-tests		0.3	0.1	0.3	0.3	0.38	0.07

There was no significant difference in any buffer.

Starch CH ₃ COOH	Control	pH 2	pH 4	pH 7	pH 9	pH 10	pH 13
Test 1	0.05g	0.04g	0.03g	0.03g	0.02g	0.04g	n/a
Test 2	0.05g	0.05g	0.04g	0.05g	0.02g	0.05g	n/a
Test 3	0.05g	0.05g	0.03g	0.03g	0.01g	0.04g	n/a
t-tests		0.8	0.045	0.3	0.01	0.3	n/a

There was a significant difference in buffers 4 and 9. They dissolved in pH 13.

Light Intensity Tests

Ca Alginate	Control	Experiment
Test 1	0.1g	0.11g
Test 2	0.1g	0.09g
Test 3	0.1g	0.13g
t-tests		0.48

No significant difference.

Heat Cycle Tests

Ca Alginate	Control	Experiment
Test 1	0.1g	0.05g
Test 2	0.1g	0.06g
Test 3	0.1g	0.05g
t-tests		0.053

No significant difference.

Starch HCl	Control	Experiment
Test 1	0.1g	0.08g
Test 2	0.1g	0.07g
Test 3	0.1g	0.05g
t-tests		0.23

No significant difference.

Starch CH ₃ COOH	Control	Experiment
Test 1	0.1g	0.07g
Test 2	0.1g	0.06g
Test 3	0.1g	0.07g
t-tests		0.007

A significant difference was noted.

Starch HCl	Control	Experiment
Test 1	0.1g	0.08g
Test 2	0.1g	0.07g
Test 3	0.1g	0.05g
t-tests		0.063

No significant difference.

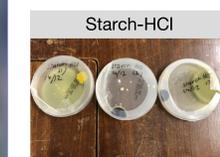
Starch CH ₃ COOH	Control	Experiment
Test 1	0.1g	0.07g
Test 2	0.1g	0.06g
Test 3	0.1g	0.07g
t-tests		0.007

A significant difference was noted.

Microbiological Stability Tests



- Test 1 – Large circular fungal colony, white with yellow centre
- Test 2 – No significant growth noted
- Test 3 – Hair-like strands, small, white and cream bacterial colonies



- Test 1 – Green and white fungus, yellow stringy bacteria
- Test 2 – Creamy yellow bacteria, green and black fungus
- Test 3 – Green and white fungus, creamy and shiny bacteria, and dark brown fungus



- Plate 1 – Green/grey fungi and white, wispy fungi
- Plate 2 – Green and white fungi, yellow shiny bacteria, white bacteria
- Plate 3 – Green and white fungi, yellow shiny bacteria

pH Tests at 37°C

Ca Alginate	Control	pH 2	pH 4	pH 7	pH 9	pH 10	pH 13
Test 1	0.05g	0.09g	0.1g	1.38g	0.07g	0.11g	n/a
Test 2	0.05g	0.08g	0.08g	1.3g	0.06g	0.09g	n/a
Test 3	0.05g	0.08g	0.07g	1.36g	0.06g	0.07g	n/a
t-tests		0.094	0.063	0.00034	0.057	0.074	n/a

We observed that the calcium alginate had no significant difference in pH 2,4,9, and 10. They dissolved in pH 13.

Starch HCl	Control	pH 2	pH 4	pH 7	pH 9	pH 10	pH 13
Test 1	0.05g	0.01g	0.01g	0g	0.02g	0.02g	0.01g
Test 2	0.05g	0.02g	0.01g	0.01g	0.03g	0.02g	0g
Test 3	0.05g	0.02g	0.03g	0.01g	0.03g	0.01g	0.01g
t-tests		0.0099	0.038	0.0059	0.02	0.0099	0.0059

There was a significant difference in all the buffers.

Starch CH ₃ COOH	Control	pH 2	pH 4	pH 7	pH 9	pH 10	pH 13
Test 1	0.05g	0.02g	0.02g	0.01g	0.01g	0.02g	0.03g
Test 2	0.05g	0.03g	0.02g	0.01g	0.03g	0.04g	0.04g
Test 3	0.05g	0.03g	0.04g	0.02g	0.02g	0.02g	0.04g
t-test		0.02	0.073	0.0082	0.035	0.073	0.057

There was a significant difference in buffers 2,7, and 9.

Solubility Tests

Ca Alginate	Control	Water	Oil	Facewash
Test 1	0.3g	0.31g	0.23g	0.88g
Test 2	0.3g	0.3g	0.2g	0.57g
Test 3	0.3g	0.33g	0.27g	0.61g
t-tests		0.27	0.29	0.011

No significant difference was found in the water and oil. The beads expanded considerably in the facewash.

Starch HCl	Control	Water	Oil	Facewash
Test 1	0.3g	0.27g	0.29g	0.04g
Test 2	0.3g	0.28g	0.27g	0.08g
Test 3	0.3g	0.23g	0.26g	0.12g
t-tests		0.42	0.13	0.011

No significant difference in water and oil. Significant difference in the facewash.

Starch CH ₃ COOH	Control	Water	Oil	Facewash
Test 1	0.3g	0.29g	0.22g	0.05g
Test 2	0.3g	0.27g	0.23g	0.13g
Test 3	0.3g	0.29g	0.25g	0.08g
t-tests		0.13	0.01	0.006

No significant difference noted in water. Significant difference in oil and facewash.



Recommendations:

- In the future we intend to;
 - Test more biodegradable options such as PLA (Polylactic Acid) and various biodegradable plastic blends which could be more suitable for microbead use.
 - Look at the chemical makeup of our starch plastics to help us attain the correct plastic resilience
 - Prepare smaller beads with a more uniform size
 - Obtain more knowledge on the microbiological growth found in our petri dishes. We have contacted Dr. Helen Steele, who did her PhD in plant-microbe symbiosis, for help on this topic

Conclusion:

- We can conclude that our starch microbeads prepared with HCl exhibited the most promising results as being alternatives
- Our calcium alginate microbeads had swelled in pH 7 and the facewash.
- The Starch-HCl microbeads withstood room temperature pH tests in all of the buffers, which indicates that they would be suitable for storage. They also withstood solubility tests in water and oil. They also exhibited no significant differences in the light intensity and heat cycle tests.
- We concluded that our starch CH₃COOH microbeads were unsuitable.
- In future research we hope to vary the amount of glycerin used in the Starch-HCl microbeads and blend our calcium alginate microbeads with PLA (polylactic acid). We believe that this would help us overcome these problems and withstand our tests.

With future experimentation and further research, we believe that our Starch-HCl and calcium alginate microbeads have great potential as biodegradable alternatives to polyethylene microbeads. It is crucial that a solution to this problem continues to be developed, as microbeads produced from materials such as polyethylene harm marine life, pollute our environment, and end up in our food. In a day and age where people are becoming more aware of pollution and its negative effects on the environment, we must do as much as we can to fight against the negative ramifications of using polyethylene microbeads in our everyday routines.