Table of Contents

Abstract

Soft-plastic fishing lures consistently break off from the hooks of anglers, sinking to the bottom of waterways where they degrade into microplastics over time. The goal of the project is to develop an entirely biodegradable and edible fishing lure with similar physical properties and consumer appeal to traditional plastic-lures while reducing the ecological footprint associated with fishing. With this, a new biopolymer hydrogel recipe utilizing solely sodium alginate, calcium lactate, gelatin, vegetable glycerin, cornstarch, distilled water, and natural coloring (for cosmetics) to create the biodegradable lures. Experiments on these lures were directed towards mechanical performance (breaking point and sink time), visual properties, and degradation rate for the purpose of ensuring practicality and usability. These tests found statistical similarities in degradation, visual properties, and sink time, and a statistical increase in durability for the biodegradable lures. A secondary benefit to this lure/biopolymer hydrogel is that it is entirely edible for both fish and humans. The project also addresses the potential for commercial feasibility, including cost analysis and market viability of the biodegradable lures. A large drawback of other biodegradable fishing lures on the market is their reduction in performance or their significant increase in price. A pack of 10 of our lures costs around $1.70 to produce (including biodegradable packaging and not accounting for bulk purchase of goods). As an environmentally friendly alternative to traditional plastic lures, this product reduces plastic pollution in waterways without losing traditional lure performance and monetary attractiveness for anglers.

Problem

Synthetic soft-plastic fishing lures are a large contributor to water-bound microplastics. As a large number of anglers lose them on a regular basis, this leads to a significant build up in the amount that is constantly degrading into microplastics in saltwater and freshwater ecosystems alike.

Research Questions

Can a fishing lure made from a novel biopolymer hydrogel recipe maintain similar functionality and effectiveness of traditional soft plastic lures?

To what extent do biodegradable fishing lures influence a reduction of microplastics and biomagnification in aquatic ecosystems compared to traditional soft plastic lures?

Review of Literature

Fishing is an industry where environmentally friendly products have had a hard time becoming industry giants. Biodegradability usually comes with a reduction in performance, or a significant increase in price. Conventional plastic lures are non-biodegradable and take centuries to break down, adding to aquatic pollution and causing harm to marine life. One of the major ingredients in many available biodegradable lures is biopolymers, which are polymers that occur naturally in plants or animals. However, a less used material is a biopolymer hydrogel. These materials include a three dimensional network of polymers that create a gel-like material which are able to retain large amounts of water.

Originally, this project utilized the polysaccharides agar agar and xanthan gum to increase structure maintenance and flexibility. However, the addition of these two materials resulted in lures that were too brittle, and fell apart. These two materials were later replaced by gelatin.

Sodium alginate is a polysaccharide from brown seaweed. The chemical structure is composed of repeating units of guluronic acid (G) and mannuronic acid (M) that are linked together by β-glycosidic bonds. Each unit has a carboxyl group that can ionic bond with divalent cations, like calcium (Ca^{2+}) (Buenaflor et al., 2022). This binding of sodium alginate with calcium lactate causes crosslinking, creating a three-dimensional hydrogel network.

Calcium lactate is a calcium salt of lactic acid that is central to biopolymer hydrogel formation. It supplies calcium ions (Ca^{2+}), which react with the carboxyl groups of the alginate chains, displacing the sodium ions (Na^{+}). The exchange leads to ionic crosslinking in which the calcium ions link the alginate chains together to form a stiff, three-dimensional network (Buenaflor et al., 2022)..

The crosslinking process toughens the hydrogel, making it stronger and more resistant to degradation, yet still capable of retaining its flexibility. The addition of calcium lactate increases the structural integrity of the lure, making it functional and durable in water environments.

Gelatin is a biopolymer that is made from collagen, an animal tissue structure protein. The structure of gelatin comprises sequential amino acids, such as glycine, proline, and hydroxyproline. Amino acids permit gelatin to create hydrogen bonding between the chains of the polymers, and this plays an important role in gel formation (Derkach, Voron'ko, & Kuchina, 2022).

When gelatin is combined with water and cooled, it undergoes gelation, forming a thermo-reversible hydrogel (Derkach, Voron'ko, & Kuchina, 2022). This means that the gel can solidify when cooled and liquify when heated, which gives it the ability to mimic the flexibility and stretchability of traditional plastic lures. The addition of gelatin to the biopolymer hydrogel mix increases the elasticity of the lure, providing the required stretch and durability for effective use in fishing applications.

Vegetable glycerin is a polyol (sugar alcohol) with three hydroxyl (-OH) groups. Due to its structure, it is hydrophilic and can absorb water. When added to a biopolymer hydrogel, glycerin is a plasticizer that softens the material and makes it more flexible (Zhu, Samsudin, & Yhaya, 2022).

Glycerin disrupts the hydrogen bonding between polymer chains, creating a more flexible and elastic material (Chen et al., 2018). This is important for fishing lures, as it can stretch and compress without breaking, giving the wanted tactile sensation but being simple to handle on the hook.

Cornstarch is a polysaccharide made up of two polymers: amylose, a linear polymer of glucose, and amylopectin, a branched polymer of glucose. Starch molecules, upon heating in water, form a gel-like structure that adds structure and viscosity (Yu et al., 2021). In the lure, cornstarch adds structural integrity to the hydrogel, supporting its mechanical strength.

Biopolymer hydrogels are especially useful in producing biodegradable lures because they possess properties of flexibility, water absorption, and biodegradability. Sodium alginate and calcium lactate crosslinked polymer network produces a stable but supple structure similar to that of synthetic lures. The addition of gelatin increases the elasticity of the hydrogel, whereas glycerin makes the hydrogel more flexible and stretchable. The cornstarch consolidates the structure and guarantees the environmental degradation of the material with passage of time.

Though biopolymer hydrogels have been used in many different fields, using them in biodegradable fishing lures is quite new. Most studies have been directed at creating single-use plastics or wholly synthetic materials for fishing gear. Yet, blending natural biopolymers such as sodium alginate, gelatin, and cornstarch into a hydrogel presents a new, environmentally friendly way to address plastic pollution in bodies of water. This study opens the door to eco-friendly fishing lures that have the same durability, flexibility, and water retention capacity of plastic lures but are biodegradable.

Hypothesis

Fishing lures made with edible and biodegradable materials will degrade faster than traditional plastic soft lures while maintaining the same functionality, reducing microplastic levels and biomagnification in aquatic ecosystems.

Methodology

The first priority of this project is to develop a promising recipe that is able to maintain shape once set, stretch without breaking, and return to its original shape when stretched. The following methods were used for each iteration of the lure:

[Information Rescinded], [Figure 1 Rescinded]

After finishing the optimization of the lure for desirable traits, several comparison functionality tests were conducted. These tests compared my biodegradable fishing lures to traditional synthetic soft-plastic lures. The following information details the methodology of these comparison test:

Comparison Test No.1:

Average Time of Descent (10") in Water Comparison

Procedure -

- This experiment was chosen to ensure the buoyancy of the two lures was similar, as many fish bites occur within seconds of when the lure drops in the water
- Fill a five-gallon fish tank until 10” is fully submerged (~the top of the tank)
- Set a camera up which is constantly recording and able to see the top and bottom of the tank
- Obtain 30 biodegradable lures and 30 plastic lures that are the same size (5”) and weight (10.4 grams)
- Hold each lure at the very top of the tank, release, allow lure to hit bottom, then retrieve

- Repeat until all 60 tests are completed
- Replay video and measure time dropped and and subtract that from the time the lure reached the bottom for each lure

Control Group: Plastic lure

Experiment Group: Biodegradable lure

Independent Variable: Lure type

Dependent Variable: Descent time

Control Variables: Lure size, lure weight, descent size, water conditions, camera position

Comparison Test No. 2:

Average Light Transmission Comparison

Procedure -

- The scattering of light through soft plastic lures is a large attractor to fish, this test was conducted to see whether the biodegradable lures had similar attractability
- Set a flashlight up on a tripod directly across from a lumen meter
- Make the room completely dark besides the flashlight, so the lumen meter is only reading the flashlight
- Record the initial lumens from the flashlight

- Place a biodegradable lure 3 inches in front of the light, and record the emitted lumens
- Do the same with a plastic lure
- Repeat with 30 of each type of lure
- Calculate transparency percentage by taking lumens recorded for each trial over initial lumens
- Calculate average for each lure type

Control Group: Flashlight with no lure in front of it

Experiment Group: Biodegradable lure

Independent Variable: Lure type

Dependent Variable: Transparency Percentage

Control Variables: Light source, distance between lumen meter and light source, angle of light exposure, temperature/humidity, measurement method, lure color (green pumpkin)

Comparison Test No. 3:

Average Breaking Force Comparison

Procedure -

- This experiment was chosen to test whether the biodegradable lure had similar strength to the soft plastic lures
- Obtain 30 biodegradable lures and 30 plastic lures that are the same size (5”) and weight (10.4 grams)
- On a digital newton meter, attach a pristine conditioned lure in the center
- Clamp the newton meter to a table to ensure direction of force is uniform

- Pull on the lure linearly until the lure breaks
- Record the Newton value in which the lure broke.
- Repeat until all 60 tests are completed

Control Group: Plastic lure

Experiment Group: Biodegradable lure

Independent Variable: Lure type

Dependent Variable: Breaking force

Control Variables: Lure size, lure shape, point of hook insertion, measurement device, speed of applied force, angle of force, original lure condition

Besides these three comparison tests, a biodegradability comparison test was conducted to determine how fast the finalized recipe for the biodegradable lures completely broke apart in the water compared to a synthetic soft-plastic lure. However, only one biodegradable lure and one synthetic lure were compared in this test, so no statistical conclusions can be made in relation to this test detailed below:

Biodegradability Test

Procedure -

- Obtain 1 biodegradable lure and 1 plastic lure that are the same size (5”) and weight (10.32 grams)

- Fill a single 37 liter tank with 18 liters of water, and place river pebbles on the bottom of the tank to simulate a riverbed.
- Install aquarium water circulation pumps on opposite sides of the tank to simulate moving water
- Place each lure in the tank, and after 24 hours measure the weight of the lures

<u>Control Group</u>: Plastic lure

<u>Experiment Group</u>: Biodegradable lure

<u>Independent Variable</u>: Lure type

<u>Dependent Variable</u>: Degradation rate

<u>Control Variables</u>: water temperature, water pH, lure weight, lure size, and light exposure

To measure the functional groups acting in the finalized recipe, an IR spectroscopy was conducted:

IR Spectroscopy

<u>Procedure</u> -

- Obtain 3 samples of the optimized biopolymer hydrogel material
- Place the material under in the IR spectrometer and run test
- Analyze and compare results

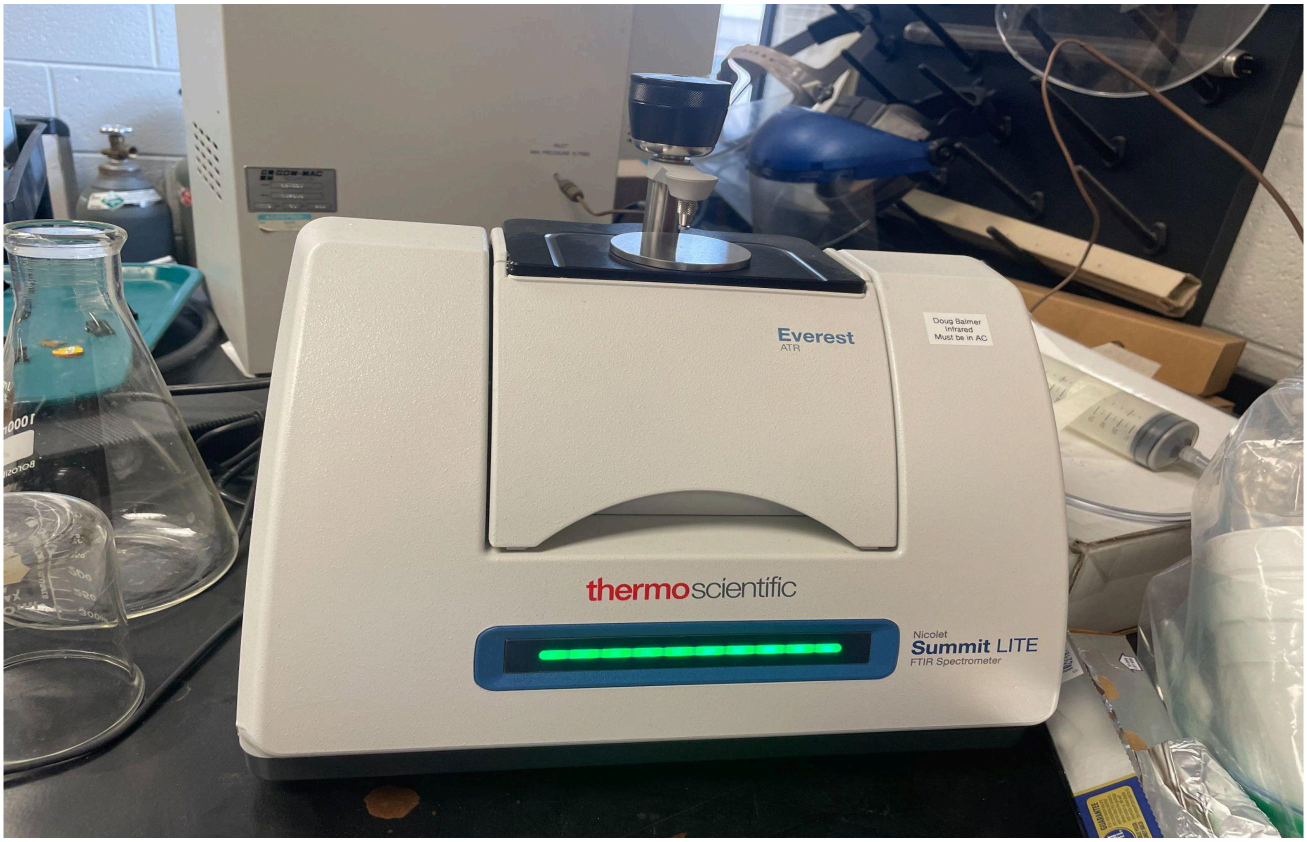

Figure 2. Photo Taken by Finalist

Results & Discussion

After each biopolymer hydrogel iteration and lure creation, visual observations were recorded:

[Information Rescinded]

Figure 3. Photo taken by Finalist

Comparison Test No.1:

Average Time of Descent (10") in Water Comparison

Statistical Analysis:

H_0: There is no significant difference in the average time of descent between biodegradable and plastic lures.

H_a: There is a significant difference in the average time of descent between biodegradable and plastic lures.

$df = 58$, $t^* = 0.54$, $p = 0.593$

Because the p value of .593 is greater than a .05 significance level, we fail to reject the null hypothesis. What this shows is that there is not a significant difference between average time of descent between biodegradable and traditional plastic lures. This shows the way in which biodegradable lures made of the biopolymer hydrogel are able to function in a manner similar to that of traditional plastic lures. Specifically, this shows that the biodegradable lures sink at a similar speed to that of plastic lures.

(Data on next Page)

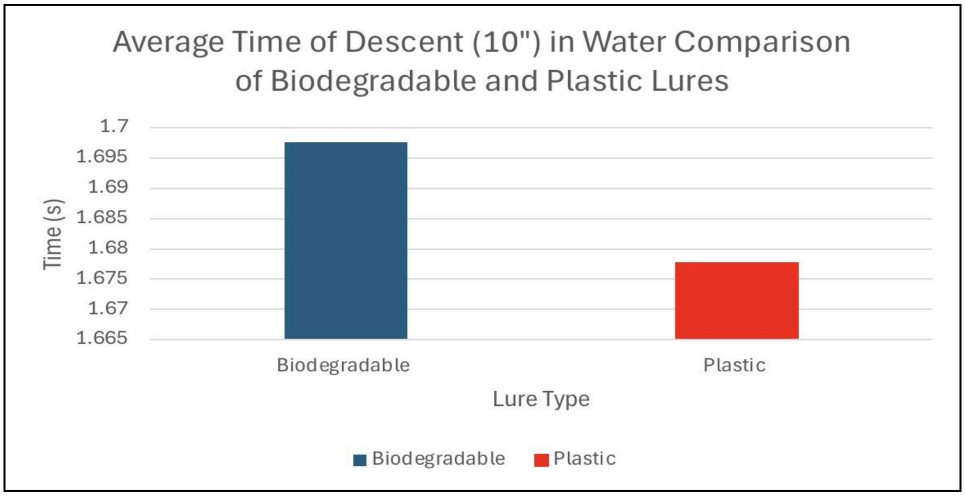

Figure 4. Graph created by Finalist using Excel

Type of Lure	Trial #	initial Weight (Closest .1g)	Sink Time (10")
Biodegradable	1	10.4	1.57
Biodegradable	2	10.4	1.68
Biodegradable	3	10.4	1.8
Biodegradable	4	10.4	1.71
Biodegradable	5	10.4	1.63
Biodegradable	6	10.4	1.88
Biodegradable	7	10.4	1.66
Biodegradable	8	10.4	1.55
Biodegradable	9	10.4	1.71
Biodegradable	10	10.4	1.78
Biodegradable	11	10.4	1.45
Biodegradable	12	10.4	1.53
Biodegradable	13	10.4	1.74
Biodegradable	14	10.4	1.76
Biodegradable	15	10.4	1.88
Biodegradable	16	10.4	1.64
Biodegradable	17	10.4	1.69
Biodegradable	18	10.4	1.62
Biodegradable	19	10.4	1.87
Biodegradable	20	10.4	1.51
Biodegradable	21	10.4	1.68
Biodegradable	22	10.4	1.7
Biodegradable	23	10.4	1.54
Biodegradable	24	10.4	1.89
Biodegradable	25	10.4	1.84
Biodegradable	26	10.4	1.82
Biodegradable	27	10.4	1.59
Biodegradable	28	10.4	1.67
Biodegradable	29	10.4	1.75
Biodegradable	30	10.4	1.79
Plastic	1	10.4	1.78
Plastic	2	10.4	1.95
Plastic	3	10.4	1.89
Plastic	4	10.4	1.71
Plastic	5	10.4	1.65
Plastic	6	10.4	1.76
Plastic	7	10.4	1.77
Plastic	8	10.4	1.56
Plastic	9	10.4	1.73
Plastic	10	10.4	1.55
Plastic	11	10.4	1.65
Plastic	12	10.4	1.5
Plastic	13	10.4	1.63
Plastic	14	10.4	1.73
Plastic	15	10.4	1.64
Plastic	16	10.4	1.55
Plastic	17	10.4	1.61
Plastic	18	10.4	1.51
Plastic	19	10.4	1.58
Plastic	20	10.4	1.71
Plastic	21	10.4	1.59
Plastic	22	10.4	1.81
Plastic	23	10.4	1.72
Plastic	24	10.4	1.65
Plastic	25	10.4	1.63
Plastic	26	10.4	1.75
Plastic	27	10.4	1.53
Plastic	28	10.4	1.67
Plastic	29	10.4	1.69
Plastic	30	10.4	1.83

Figure 5. Data Table created by Finalist using Excel

Comparison Test No. 2:

Average Light Transmission Comparison

Statistical Analysis:

H_0: There is not a significant difference between average transparency percent in biodegradable and plastic lures.

H_a: There is a significant difference between average transparency percent in biodegradable and plastic lures.

df = 58, t* = 0.42, p = 0.68

Because the p value of .68 is greater than a .05 significance level, we fail to reject the null hypothesis. What this shows is that there is not a significant difference between average transparency percentage between biodegradable and traditional plastic lures. This shows another aspect of how biodegradable lures are able to display similar properties to that of synthetic soft-plastic lures.

(Data on next Page)

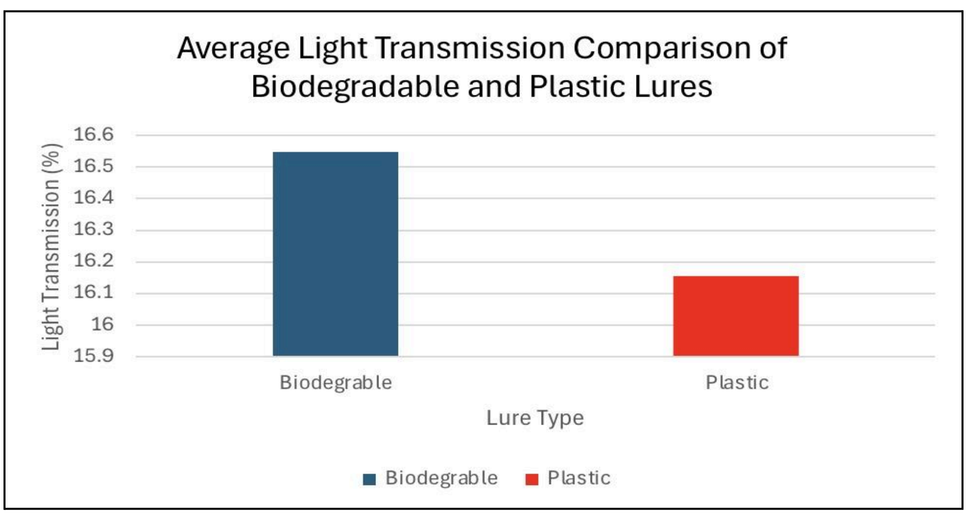

Figure 6. Graph created by Finalist using Excel

Type of Lure	Trial #	Lumens	Light Transmission %
Biodegradable	1	7.4	16.44444444
Biodegradable	2	5.6	12.44444444
Biodegradable	3	5.4	12
Biodegradable	4	8.1	18
Biodegradable	5	7.3	16.22222222
Biodegradable	6	9.6	21.33333333
Biodegradable	7	7.5	16.66666667
Biodegradable	8	7.1	15.77777778
Biodegradable	9	8.3	18.44444444
Biodegradable	10	6.7	14.88888889
Biodegradable	11	8.8	19.55555556
Biodegradable	12	7.8	17.33333333
Biodegradable	13	8.3	18.44444444
Biodegradable	14	6.3	14
Biodegradable	15	7.7	17.11111111
Biodegradable	16	7.1	15.77777778
Biodegradable	17	6.9	15.33333333
Biodegradable	18	9.1	20.22222222
Biodegradable	19	8.1	18
Biodegradable	20	8.1	18
Biodegradable	21	5.7	12.66666667
Biodegradable	22	6.8	15.11111111
Biodegradable	23	8.3	18.44444444
Biodegradable	24	8.5	18.88888889
Biodegradable	25	7.3	16.22222222
Biodegradable	26	9	20
Biodegradable	27	5.4	12
Biodegradable	28	6.3	14
Biodegradable	29	7.8	17.33333333
Biodegradable	30	7.1	15.77777778
Plastic	1	6.7	14.88888889
Plastic	2	5.3	11.77777778
Plastic	3	9.6	21.33333333
Plastic	4	9.6	21.33333333
Plastic	5	7.5	16.66666667
Plastic	6	5.7	12.66666667
Plastic	7	9.3	20.66666667
Plastic	8	6.6	14.66666667
Plastic	9	6.9	15.33333333
Plastic	10	9	20
Plastic	11	5.9	13.11111111
Plastic	12	6.4	14.22222222
Plastic	13	10.1	22.44444444
Plastic	14	6.7	14.88888889
Plastic	15	6.3	14
Plastic	16	6.5	14.44444444
Plastic	17	7.8	17.33333333
Plastic	18	7.9	17.55555556
Plastic	19	8.3	18.44444444
Plastic	20	8	17.77777778
Plastic	21	6.1	13.55555556
Plastic	22	8	17.77777778
Plastic	23	7	15.55555556
Plastic	24	5.9	13.11111111
Plastic	25	6.7	14.88888889
Plastic	26	9.3	20.66666667
Plastic	27	5.3	11.77777778
Plastic	28	5.3	11.77777778
Plastic	29	6.1	13.55555556
Plastic	30	8.3	18.44444444

Figure 7. Data Table created by Finalist using Excel

Comparison Test No. 3:

Average Breaking Force Comparison

Statistical Analysis:

H_0: There is not a significant difference between average breaking force in biodegradable and plastic lures.

H_a: There is a significant difference between average breaking force in biodegradable and plastic lures.

df = 58, t* = 48.82, p = 8.309e-49

Because the p value of 8.309e-49 is much smaller than a .05 significance level, we reject the null hypothesis. What this shows is that there is a significant difference between average breaking force between biodegradable and traditional plastic lures. Specifically, this shows that the biodegradable lures have a higher breaking point than plastic lures.

(Data on next Page)

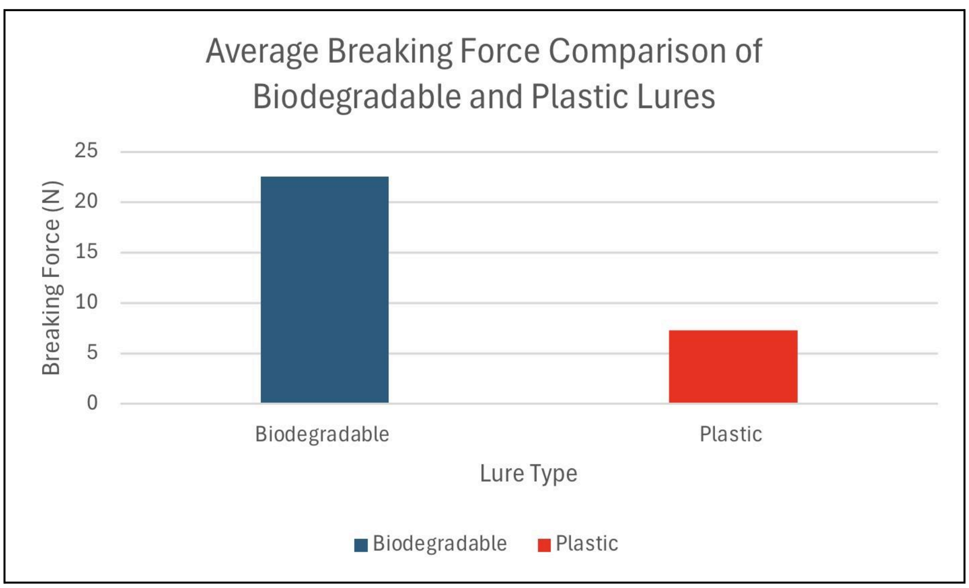

Figure 8. Graph created by Finalist using Excel

Type of Lure	Trial #	initial Weight (Closest .1g)	Breaking Force (N)
Biodegradable	1	10.4	23.1
Biodegradable	2	10.4	25.29
Biodegradable	3	10.4	21.44
Biodegradable	4	10.4	20.94
Biodegradable	5	10.4	25.08
Biodegradable	6	10.4	23.47
Biodegradable	7	10.4	21.76
Biodegradable	8	10.4	22.61
Biodegradable	9	10.4	23.42
Biodegradable	10	10.4	22.88
Biodegradable	11	10.4	22.14
Biodegradable	12	10.4	21.02
Biodegradable	13	10.4	24.74
Biodegradable	14	10.4	22.32
Biodegradable	15	10.4	21.08
Biodegradable	16	10.4	22.91
Biodegradable	17	10.4	24.64
Biodegradable	18	10.4	23.2
Biodegradable	19	10.4	22.04
Biodegradable	20	10.4	24.95
Biodegradable	21	10.4	24.26
Biodegradable	22	10.4	21.54
Biodegradable	23	10.4	22.57
Biodegradable	24	10.4	23.96
Biodegradable	25	10.4	23.07
Biodegradable	26	10.4	21.94
Biodegradable	27	10.4	21.72
Biodegradable	28	10.4	20.43
Biodegradable	29	10.4	21.18
Biodegradable	30	10.4	23.7
Plastic	1	10.4	7.48
Plastic	2	10.4	6.91
Plastic	3	10.4	4.18
Plastic	4	10.4	8.15
Plastic	5	10.4	7
Plastic	6	10.4	9.22
Plastic	7	10.4	8.64
Plastic	8	10.4	6.67
Plastic	9	10.4	8.41
Plastic	10	10.4	6.6
Plastic	11	10.4	7.52
Plastic	12	10.4	8.06
Plastic	13	10.4	8.77
Plastic	14	10.4	7.48
Plastic	15	10.4	7.97
Plastic	16	10.4	7.26
Plastic	17	10.4	7.22
Plastic	18	10.4	7.71
Plastic	19	10.4	9.43
Plastic	20	10.4	7.08
Plastic	21	10.4	7.97
Plastic	22	10.4	8.38
Plastic	23	10.4	7.61
Plastic	24	10.4	7.13
Plastic	25	10.4	8.54
Plastic	26	10.4	7.34
Plastic	27	10.4	8.82
Plastic	28	10.4	6.81
Plastic	29	10.4	7.89
Plastic	30	10.4	8.21

Figure 9. Data Table created by Finalist using Excel

Biodegradability Test

Due to the sample size being one, no statistical conclusions can be made about the degradability of either lure type. However, this test does provide a starting point for understanding this biopolymer hydrogel's degradation behavior. An experiment with a larger sample would be required to draw any conclusions about both lure types, which is why this test is simply a starting point.

Trial #	Biodegradable Weight (g)	Plastic Weight (g)
0	10.32	10.32
1	17.81	10.3
2	18.72	10.39
3	17.51	10.45
4	15.69	10.34
5	13.74	10.43
6	11.46	10.44
7	10.91	10.45
8	9.79	10.45
9	8.34	10.44
10	6.52	10.43
11	4.92	10.41
12	3.38	10.39
13	2.05	10.45
14	0.58	10.42
15	0	10.45

Figure 10. Data Table created by Finalist using Excel

What can be seen here is that the single biodegradable lure took 15 days to become completely dissolved in the water. The hydrogel works for the first 2 days, significantly increasing the weight of the lure as it takes on large amounts of water. With this, the lure then begins to break down, and after reaching a max weight on the second day, the lure begins to break down. The plastic lure saw essentially no difference in weight, showing how the biopolymer hydrogel lure will not sit on the bottom of water ways, but will instead biodegrade.

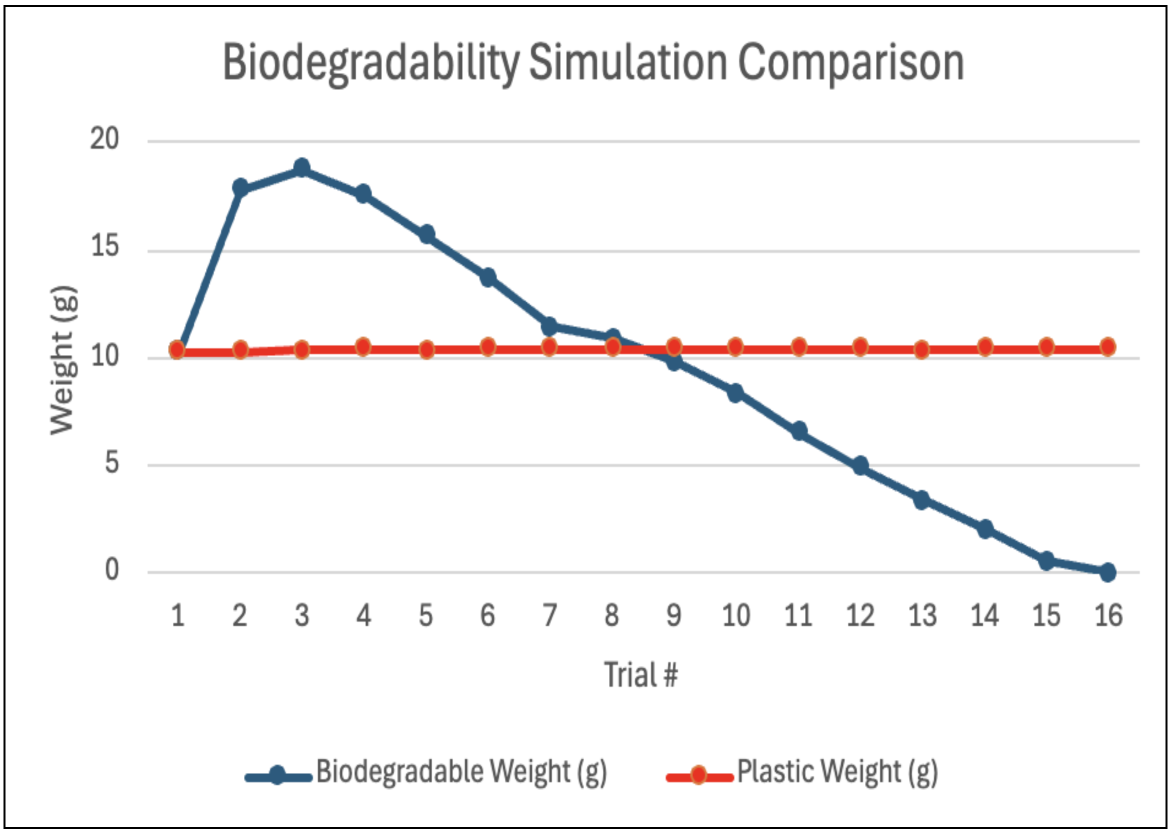

Figure 11. Graph created by Finalist using Excel

IR Spectroscopy

The FTIR analysis determines several major peaks that signify the chemical composition of the biopolymer hydrogel. The major peak at 3273.986 cm^{-1} is for O-H or N-H stretching, suggesting gelatin or vegetable glycerin presence. A peak at 1653.736 cm^{-1} is related to carbonyl

(C=O) stretching, likely sodium alginate and gelatin-related. The 1552.920 cm^{-1} peak shows N-H bending in amides, consistent again with the presence of gelatin. A second peak at 1037.996 cm^{-1}, showing C-O stretching, is a typical functional group found in polysaccharides such as sodium alginate or cornstarch. Together, these spectral signals affirm the chemical makeup of the biopolymer hydrogel, with the occurrence of the key functional groups in agreement with its known content.

Below are the three iterations of the FTIR scan, confirming the chemical makeup of the biopolymer hydrogel is consistent:

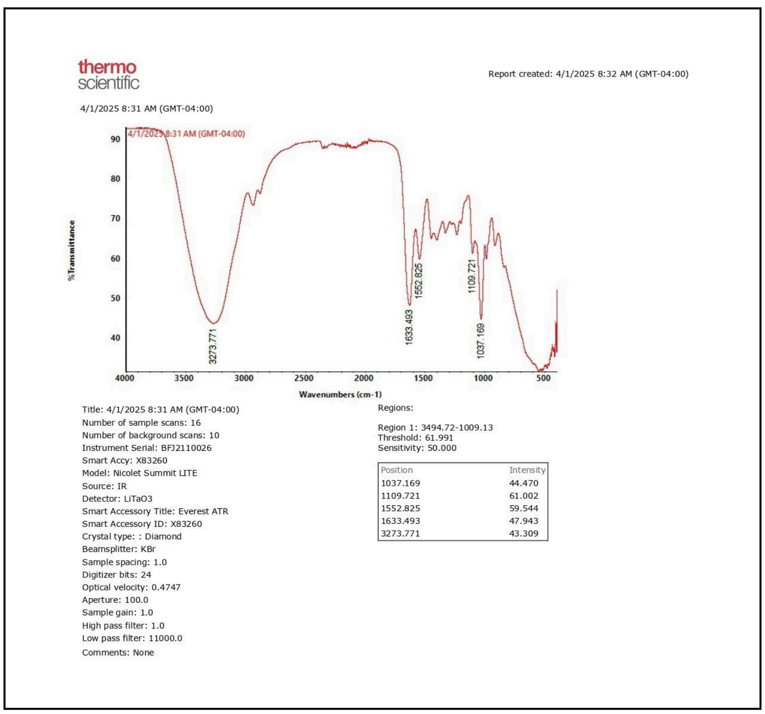

Figure 12. Spectrum acquired by Finalist using IR Spectrometer.

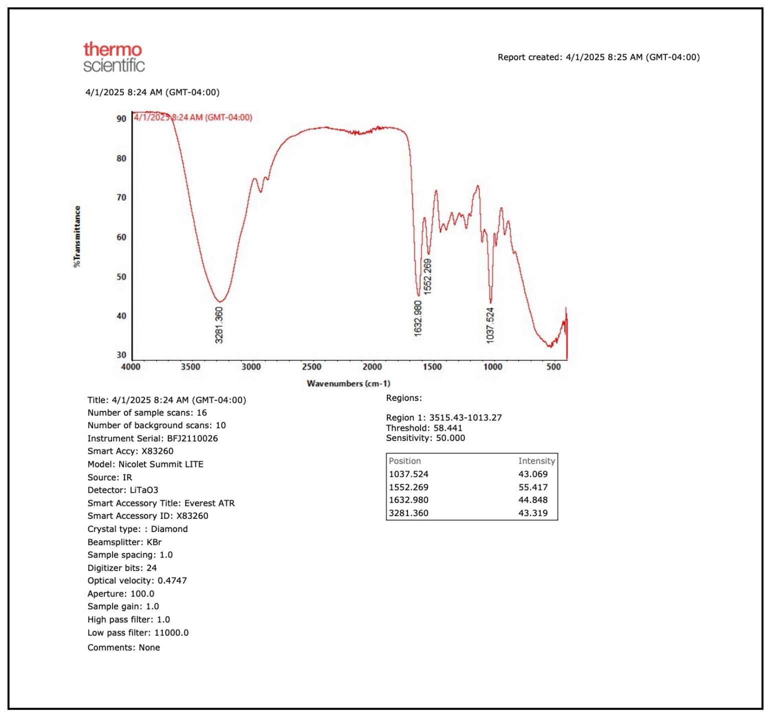

Figure 13. Spectrum acquired by Finalist using IR Spectrometer.

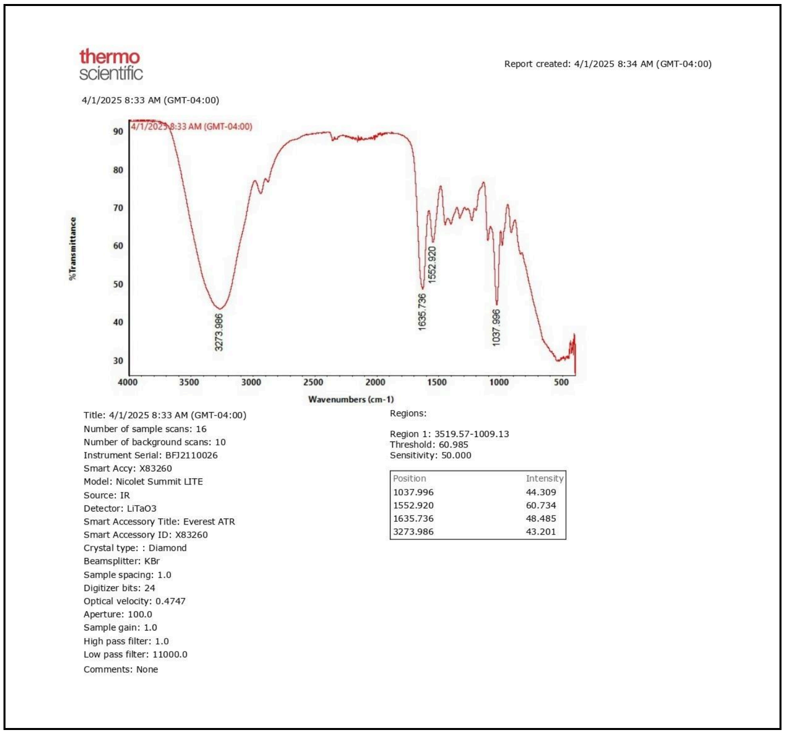

Figure 14. Spectrum acquired by Finalist using IR Spectrometer.

On top of these tests, the biopolymer hydrogel was compared with 99% glycerol to confirm the presence of glycerol in the final product.:

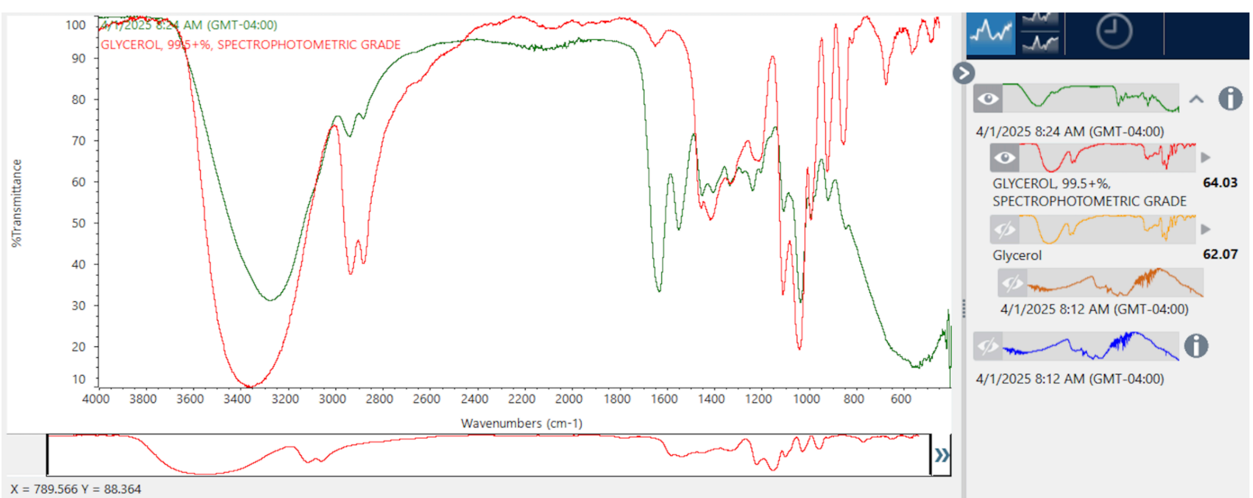

Figure 15. Spectrum acquired by Finalist using IR Spectrometer.

The FTIR overlay of this spectrum shows a correlation between the pure glycerol (red) and the sample (green), confirming the presence of glycerol in the hydrogel formulation. Both spectra have a broad strong peak around 3270–3300 cm^{-1}, corresponding to O-H stretching of glycerol. Moreover, the overlapping peaks in the fingerprint area, between 1000–1100 cm^{-1}, also support the presence of C-O stretching vibrations typical of glycerol's three hydroxyl groups. The co-alignment of these significant functional group absorptions between the sample and the glycerol reference consistently supports the confirmation that glycerol is included in the biopolymer hydrogel composition.

Conclusion

Throughout the development of this project, xanthan gum and agar agar were substituted for gelatin (the final lure's main biopolymer). The thermo-reversibility of gelatin allows for money to be saved in production, as the lure mixture can be remelted and poured. On top of this, the gelatin became the lure's main body, with the other ingredients adding preferred characteristics, like added strength, flex, and hydrogel water-retention. The xanthan gum was frequently fish-eyed and did not disperse properly throughout the mixture, and the agar agar was not providing adequate structure to the physical lure. These issues led to gelatin being used as a substitute, which is used in the final lure recipe.

The biopolymer hydrogel produced in this work provides similar functionality to traditional synthetic soft-plastic lures but with improved strength and durability. Not only does the new biopolymer hydrogel recipe enable the lure to maintain its shape, it also allows for the lure to stretch and flex, mimicking the natural action of live bait in the water the same way familiar plastic lures do. The lure's memory effect retains the lure in its original form after use, so the lure is an easy choice for fishermen. Optically, the lure allows a statistically equal amount of light to pass through to standard plastic lures, and has the same descent rate in water, so that its effectiveness is not lost.

Practically speaking, the attraction is made from an inexpensive, abundant, and highly scalable biopolymer material which can be easily molded using injection molding. With this flexibility, one can make many different types of lures for many different types of fish. Due to this fact, the target market for these lures is broad, ranging from recreational fishermen to professionals. At a reasonable price of $10 for a pack of 10, the bait offers an ecologically beneficial option for customers yet maintains a competitive market position. Additionally, the business model supports nearly a 500% profit margin, which leaves room for plenty of financial maneuvering in terms of expansion and growth.

A related finding is that this lure is made of entirely edible materials, so anglers lost in the wilderness with a pack of biopolymer hydrogel lures will be able to consume the lures for sustenance. This finding builds upon the already strong feasibility for this lure to become a staple in anglers' tackleboxes.

In addition to its business attractiveness, the creation of this biopolymer hydrogel is a crucial step toward advancing more eco-friendly fishing practices. With its biodegradable engineering and easy manufacturing process, the new lure has a strong chance in making its way into the hands of many anglers. By introducing the lures at the forefront and making them easily accessible to people, the overall objective is to shift anglers towards a more shared and ecologically friendly means of fishing. This biopolymer hydrogel material and lure, while maintaining and improving functionality, has the potential to reduce the harm associated with plastic fishing lures and the toxic microplastics they release.

References

Agricultural Marketing Service. (2010, January 19). *Glycerine technical report*. U.S. Department of Agriculture. https://www.ams.usda.gov/sites/default/files/media/Glycerine%20TR.pdf

Amazon. (n.d.). *Biodegradable compostable shipping packaging envelopes*. Amazon. https://www.amazon.com/dp/B08P7CB98M

Appenzeller, P., Hecher, F., & Sack, R. (2019). *Quite a patch: Size of the Great Pacific Garbage Patch in*. Plastic Atlas. Wikimedia Commons. https://commons.wikimedia.org/wiki/File:Plastic_Atlas_-_%27Quite_a_patch%27_-_Size_of_the_Great_Pacific_Garbage_Patch_in_comparison_(4.5_times_the_size_of_Germany).png

Buenaflor, J., Lydon, C., Zimmerman, A., DeSutter, O., & Wissinger, J. (2022). *Student explorations of calcium alginate bead formation by varying pH and concentration of acidic beverage juices*. Chemistry Teacher International, 4(2), 155–164. https://doi.org/10.1515/cti-2021-0027

Chen, M., Runge, T., Wang, L., Li, R., Feng, J., Shu, X.-L., & Shi, Q.-S. (2018). *Hydrogen bonding impact on chitosan plasticization*. Carbohydrate Polymers, 199, 1–8. https://doi.org/10.1016/j.carbpol.2018.07.062

Corcoran, E. R., Lydon, C., Enright, M. C., Paz Buenaflor, J., Anderson, K., & Wissinger, J. E. (2022). *Thirst for a solution: Alginate biopolymer experiments for the middle and high school classroom*. Journal of Chemical Education, 99(2), 1021–1025. https://doi.org/10.1021/acs.jchemed.1c00905

Derkach, S. R., Voron'ko, N. G., & Kuchina, Y. A. (2022). *Intermolecular interactions in the formation of polysaccharide-gelatin complexes: A spectroscopic study*. Polymers, 14(14), 2777. https://doi.org/10.3390/polym14142777

EFSA FEEDAP Panel (EFSA Panel on Additives and Products or Substances used in Animal Feed), Bampidis, V., Azimonti, G., Bastos, M. L., Christensen, H., Dusemund, B., ... & Innocenti, M. L. (2022). *Scientific opinion on the safety and efficacy of a feed additive* *consisting of sodium alginate for all animal species (ALGAIA)*. EFSA Journal, 20(3), 7164. https://doi.org/10.2903/j.efsa.2022.7164

Jiao, W., Chen, W., Mei, Y., Yun, Y., Wang, B., Zhong, Q., Chen, H., & Chen, W. (2019). *Effects of molecular weight and guluronic acid/mannuronic acid ratio on the rheological behavior and stabilizing property of sodium alginate*. Molecules (Basel, Switzerland), 24(23), 4374. https://doi.org/10.3390/molecules24234374

Lewin, W.-C., Sühring, R., Fries, E., Solomon, M., Brinkmann, M., Weltersbach, M. S., Strehlow, H. V., & Freese, M. (2024). *Soft plastic fishing lures as a potential source of chemical pollution: Chemical analyses, toxicological relevance, and anglers' perspectives*. Science of The Total Environment, 946, 173884. https://doi.org/10.1016/j.scitotenv.2024.173884

National Center for Biotechnology Information. (2025). *PubChem Compound Summary for CID 13144, Calcium Lactate*. Retrieved March 11, 2025, from https://pubchem.ncbi.nlm.nih.gov/compound/Calcium-Lactate

National Center for Biotechnology Information. (2025). *PubChem Compound Summary for CID 31304, Sodium Alginate*. PubChem. Retrieved May 3, 2025, from https://pubchem.ncbi.nlm.nih.gov/compound/Sodium-Alginate#section=Use-and-Manufacturing

Pander, J., Dobler, A. H., Hoos, P., & Geist, J. (2022). *Environmental pollution by lost fishing tackle: A systematic assessment in Lake Eixendorf*. Environments, 9(11), 144. https://doi.org/10.3390/environments9110144

Patel, J., Maji, B., Moorthy, N. S. H. N., & Maiti, S. (2020). *Xanthan gum derivatives: Review of synthesis, properties and diverse applications*. RSC Advances, 10(45), 27103–27136. https://doi.org/10.1039/d0ra04366d

Patel, J., Soni, D., Raol, G., Surati, V., Gopani, Y., & Bhavsar, N. (2019). *Agar-agar bioplastic synthesis and its characterization*. Journal of Emerging Technologies and Innovative Research, 6(3), 338. https://www.jetir.org/papers/JETIR1903D56.pdf

Song, Y., & Zheng, Q. (2008). *Improved tensile strength of glycerol-plasticized gluten bioplastic containing hydrophobic liquids*. Bioresource Technology, 99(16), 7665–7671.

https://doi.org/10.1016/j.biortech.2008.01.075

Yu, J. K., & Moon, Y. S. (2021). *Corn starch: Quality and quantity improvement for industrial uses*. Plants (Basel, Switzerland), 11(1), 92. https://doi.org/10.3390/plants11010092

Zhu, Y. B., Samsudin, H., & Yhaya, M. F. (2022). *Glycerol: Its properties, polymer synthesis, and applications in starch-based films*. European Polymer Journal, 175, 111377. https://doi.org/10.1016/j.eurpolymj.2022.111377