SEA TO STYLE

Crafting Sustainable Seaweed Biofabrics

Suhani Bansal
8th Grade
Sandpiper School
Belmont-Redwood Shores School District

SAN MATEO COUNTY OFFICE OF EDUCATION

Abstract

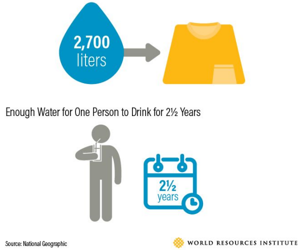
***To learn more about the textile market and harmful chemicals in everyday clothing, look at slides 31-34.**

Purpose	The purpose of the project is to make biodegradable natural fabric, to improve the textile industry. This fabric will reduce the need of existing fabrics (cotton, polyester, etc.) which are responsible for the emission of greenhouse gases (such as methane, CO_2), skin and health issues, and extreme water consumption .
Experiment	I will attempt to make fabric by mixing harmless ingredients like, seaweed (sodium alginate), glycerin, calcium chloride, and food materials like blueberry water, orange peel water, and tea.
Variables, constants	**Independent variables**: The glycerin concentration and the type of food liquid used to make the fabric **Dependent variables:** The tensile strengths of the fabrics (measured in MPa), the number of rotations it takes for the fabric to break, and whether or not the fabric is flexible when it comes to folding. **Constant:** The amount of seaweed (sodium alginate) used to make the fabric.
Hypothesis	• Strength (tensile strength) of the fabric will increase or decrease based on glycerin concentration and type of food liquid. • Flexibility (torsion and folding) of the fabric will also vary based on glycerin concentration and type of food liquid • If the fabric food liquid contains smaller amounts of calcium, then it will have less shrinkage.
Results, Analysis & Conclusion	• I was able to create 9 fabrics with different combinations and all of my hypotheses were proven correct.. • The fabric with 4g glycerin and tea food liquid was the strongest and most flexible. • The experiment concludes that it is possible to build natural biodegradable fabrics with less harmful ingredients with more research and investment.

Purpose Statement

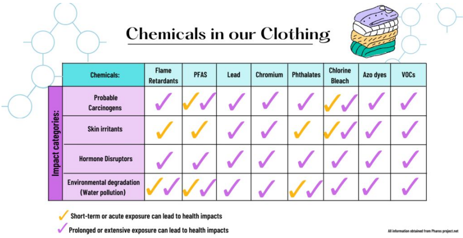
Motivation/Why - I have always been interested in textile-based art forms like sewing, embroidery, and macramé. While being involved in the textile elective in school, I learned more about the harmful effects of ingredients used in existing fabrics and wanted to do something about it.

Problem - Existing fabrics, natural (cotton, silk, wool, etc.) or synthetic (polyester, nylon, spandex, etc.), pose health challenges through harmful chemicals and environmental challenges through greenhouse gas emissions, excess water usage, and limited biodegradability.



Amount of water to make 1 cotton shirt

Total GHGs emission in 2015



Different type of chemicals present in clothing. There is a more detailed version towards the end.

Purpose - To make natural biodegradable fabric with harmless ingredients like, seaweed (sodium alginate), glycerin, and food materials like blueberry and tea, and study its characteristics..

Benefits/Outcomes - Shifting to natural biodegradable fabrics will open new ways of making environmental friendly fabrics and work towards a better planet Earth.

Hypothesis

1. **Strength (tensile strength)** of the fabric will increase or decrease based on
   - Glycerin concentration
   - Type of food liquid

2. **Flexibility (folding and torsion)** of the fabric will also vary based on
   - Glycerin concentration
   - Type of food liquid

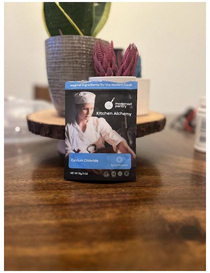
3. **If the fabric food liquid contains greater amounts of calcium, then it will shrink more.**
   - In this experiment, the orange peel fabric will shrink the most due to its greater amounts of calcium.

Experimental Materials

- **Fabric solution**
  - Seaweed (Sodium alginate)
  - Water
  - Blueberries, water, orange peels, and tea
  - Glycerin
  - **Containers/Measuring Items/Helpful tools**
    - Measuring cups and spoons
    - Food grinder/blender
    - Blending jars
    - Dehydrator
    - Paper towels
    - Immersion blender
    - Pen/marker to label the jars
    - Sifter
    - Small bowls
    - Food Scale

- **Calcium chloride solution**
  - Calcium chloride
  - Water
- **Setting the fabric:**
  - Wooden embroidery hoops
  - Canvas fabric
  - Scissors
  - Spray Bottle

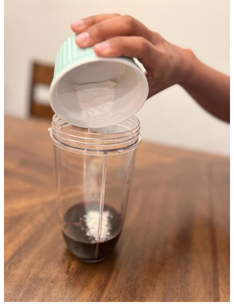
- **Testing the fabric**
  - 2 Screw Compressor Clamps
  - Newton spring scale
  - String
  - Caliper
  - Paper to take notes (optional)



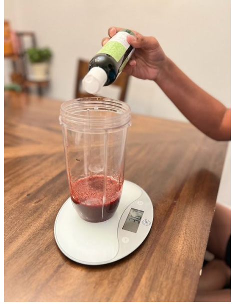
Experimental Procedure (Development of the Fabrics)

1. Boil 30g of blueberries with 200 mL of water

2. Filter the blueberry water out and measure 200mL



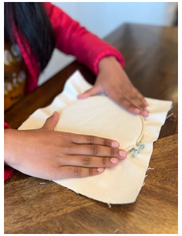
3. Add 4g of seaweed (sodium alginate)



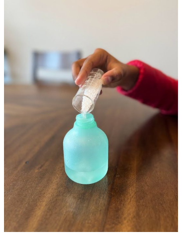
4. Add 8g of glycerin (4g and then 0g for next 2 variants).

5. Use an immersion blender to mix the solution

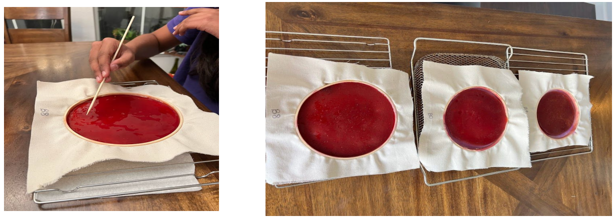
6. Refrigerate for at least 8 hours (3 liquids with 8,4 and 0g of glycerin)



7. Make the molds for the fabric



8. Develop the calcium chloride solution with 100mL water and 10g calcium chloride.

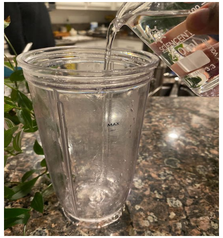


9. Spray the calcium chloride and then spread the fabric out. Pop any unnecessary bubbles. Re-spray the solution and use a paper towels to absorb excess liquid. We have three variations of fabric for the blueberry food liquid.

Experimental Procedure (Development of the Fabrics - Cont'd)


1. Dehydrate 100g of orange peels for 4 hours.

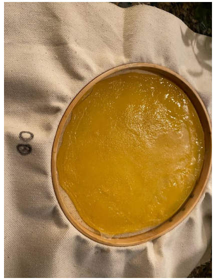

2. Grind the orange peels and sift them.



3. Pour 200 mL of water

4. Blend the sodium alginate into the water, add the glycerin (8g) and orange peel powder, and blend again.

5 .Repeat these steps for all three orange fabrics with 3 different glycerin concentrations (8g,4g, and 0g)



6. Spray the calcium chloride and then spread the fabric out. Pop any unnecessary bubbles. Re-spray the solution and use a paper towels to absorb excess liquid. We have three variations of fabric for the orange food liquid.

Experimental Procedure (Development of the Fabrics - Cont'd)

This is the development of the tea-based fabrics, which is essentially doing the same exact thing as last 2 slides, but with tea liquid. These images showcase the early development of the tea fabrics.

Experimental Procedures and Materials (Final Fabrics)

B = Blueberry - O = Orange - T = Tea - 0g, 4g, 8g = glycerin concentration

Experimental Procedures and Materials (Fabric Samples Cut From Final Fabrics)

Sample clothes cut from final fabrics

Optional read. The procedure was explained in the previous slides with pictures.

Detailed Version - Experimental Procedures (Development of the Fabrics)

Procedure

Since there are three different recipes, the glycerin concentration changes for each one. In this experiment we will use 0g, 4g and 8g of glycerin. The the three liquids that will be used are blueberry water, orange peel water, and tea. **There will be a total of 9 fabrics in this experiment.** (For each food liquid, there are three glycerin concentrations)

1. Prepare your biofabric recipes (you can make multiple fabrics at once if you have multiple wooden hoops)
    a. Fill a beaker with 200 ml of the liquid used and 4 grams of sodium alginate. Mix well using an immersion blender.
    b. Add glycerin and mix well using an immersion blender
        i. If you are using orange peel powder, use water as the liquid and add the orange peel powder with the glycerin

Ingredients	Recipe #1	Recipe #2	Recipe #3
Liquid (blueberry, orange and tea)	200 mL	200 mL	200 mL
Sodium Alginate	4 g	4 g	4 g
Glycerin	8 g	4 g	0 g

Optional read. The procedure was explained in the previous slides with pictures.

2. Procedures for making the different waters and the orange peel powder:

Blueberry water	**Black tea**	**Orange peel powder**
1. Place 100 g of blueberries and 600mL of water since three fabrics will be created) in a boiling pot. 2. Wait for the blueberries to boil. 3. Filter the blueberries out with a sifter and pour 200mL (for one fabric) into a beaker. 4. Let the liquid cool down  	1. Boil 600mL of water 2. Pour tea leaves in the water once it's boiled 3. Wait for the water to turn brown (since black tea will be used) 4. Filter the water out with a sifter and pour 200 mL of water into a beaker (for one fabric) 5. Let the liquid cool down 	1. Peel roughly 100g of oranges 2. Dehydrate the orange peels for four hours in a baking tray. 3. Check to see that the orange peels are breakable. If they are, you are ready to move onto the next step. If not, dehydrate for another hour. 4. Use food grinder to powder the orange peels. 5. Sift the orange powder and filter out big chunks (10g will be used during the experiment).   

Optional read. The procedure was explained in the previous slides with pictures.

3. **After the fabric solutions are created,** refrigerate the fabric solution overnight or for at least 8 hours to get rid of the bubbles
    a. Make sure to label the jars to avoid the confusion (E.g: B8 [Blueberry with 8 g], O0 [Orange with 0 g])
4. **Make the fabric molds:**
    a. Cut small squares out of the canvas fabric for each fabric that you are making (no smaller than 26 x 26 in).
    b. Split the embroidery hoops in two, and if you are unable to detach them, you can use a screwdriver to unscrew them
    c. Place the canvas fabric square on the circular part of the hoop
    d. Place the other part over the canvas and screw it.
    e. Gradually pull the fabric out and make sure it is as tight as possible.
    f. It should look like an embroidery hoop
    g. Make sure to label the canvas the same way you labeled the jars.
    h. Repeat these steps for the rest of the fabrics.
5. **Prepare the calcium chloride solution (this can be prepared once for all of the fabrics that you make)**
    a. Pour 100 mL of water into a spray bottle
    b. Pour 10 grams of calcium chloride into the water
    c. Shake the solution for 10-15 seconds
    d. Wait for a few minutes for calcium chloride to dissolve
6. After taking the fabric solution out, make sure it is liquid. If the solution is solid, it is likely that the food concentration was too high.
7. Take out any extra foam/bubbles if necessary. Most of the foam should be dissolved.

Optional read. The procedure was explained in the previous slides with pictures.

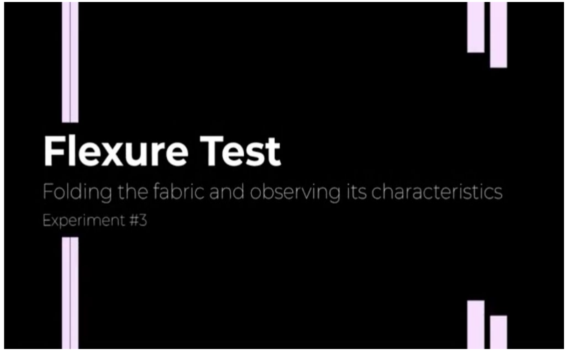
8. **Make the fabric**
    a. Gently pour the the fabric solution into the mold and use a spoon to stick the solution to the edges
    b. Make sure to not move the spoon too rigorously, since it might create extra bubbles
    c. If there are any bubbles, you can try to use the spoon to pop them, or you can scoop them out
    d. Spray the calcium chloride solution all over the layer, once you are satisfied with the bubbles.
    e. Right after the solution is sprayed, it is likely that the sides will detach and shrink, which is completely normal. It will shrink more with the orange fabric.
    f. After waiting for at least 15 seconds, use a paper towel to absorb the solution completely. If the solution sticks, re-spray it.
        i. This is the most difficult part of the experiment.
        ii. If you feel like there is too much calcium chloride, make sure to absorb it with paper towel
9. Repeat these steps for the rest of the fabrics.
10. It may take 5-7 days for the fabric to form.
    a. If the fabric grows fungus, it is likely that there was too much calcium chloride. Scooping the fungus out or ignoring that section while experimenting is the best way to work around that problem.
11. Gently peel the fabric off of its mold.
    a. If it is difficult to do so, unscrew the mold and then peel it off.
12. Now, you have your final fabrics after doing this experiment for all 9 samples.

Experimental Procedures (Testing Stage)

1. **Tensile Strength test** (measuring strength of fabric when pulling it apart).
2. **Torsion test** (number of rotations needed for the fabric to break)
3. **Flexure test** (folding to see if it broke, if it comes back to its original shape, and if it leaves a fold line after it is folded.

Link to video - Tensile Strength Test

Link to video - Torsion Test



Link to video- Flexure Test

Optional read if you have seen the videos on Slide 15.

Detailed Version - Experimental Procedures (Testing Stage)

Tensile Strength Test (measuring strength of fabric when pulling it apart)

1. Cut a small piece of fabric (roughly 0.5 X 4 cm)
2. Using a caliper, measure its thickness and width in meters
3. Measure the cross-sectional area by multiplying the two dimensions.
4. Attach the sample on to one of the screw clamps. Once it is firmly attached, align the fabric and attach it to the second screw clamp.
5. Take a piece of string and pull it through the screw clamp and tie a half-hitch knot to secure it in place. On the other end of the string, tie a regular knot
6. Hook the Newton spring scale on that end and firmly hold the first screw clamp
7. While holding the first screw clamp, slowly pull the fabric apart, with the spring scale. Keep track of the measurements (the fabric might suddenly break). If the fabric detached, try again
8. Divide the force (N) by the cross-sectional area (m^2) to get the tensile strength in pascals
9. Repeat these steps for the rest of the fabrics
10. Calculate the average tensile strength for every section (eg. the average tensile strength for 4 grams is ______)

Optional read if you have seen the videos on Slide 15.

Torsion Test (measuring strength of fabric when pulling it apart)

1. As seen in the previous steps, attach another 0.5cm X 4cm fabric to the two screw clamps
2. Hold one of the clamps still and rotate the other one until the fabric completely breaks
3. Keep track of the number of rotations
4. Find the average number of rotations as well

Flexure Test (folding the fabric and testing out different factors)

1. Cut a small piece of fabric (roughly 0.5 X 4 cm)
2. Fold the fabric in half
3. Check to see if the fabric breaks / springs back to its original state / or leaves a fold line
4. Repeat these steps for all of the fabrics
5. Record the results on the data table

Create the following bar graphs to analyze the experimental results.

- Tensile strength vs. glycerin concentration, # of twists vs. glycerin concentration, Tensile strength vs. type of fabric, and # of twists vs. type of fabric

Experimental Results

Tensile Strength Test

(Measuring strength of fabric when pulling it apart, measured in MPa, Megapascals)

	Tensile strength (MPa)			
Trial	**With 8g glycerin**	**With 4g glycerin**	**With 0g glycerin**	**Average**
Blueberry liquid	3.37	6.49	2.49	**4.12**
Orange peel liquid	0.35	2.79	0.39	**1.17**
Tea liquid	1.86	2.76	3.91	**2.84**
Average	**1.86**	**4.01**	**2.26**	

*Tensile strength formula in Megapascals (Maximum force applied/cross-sectional area) * 10^{-6}

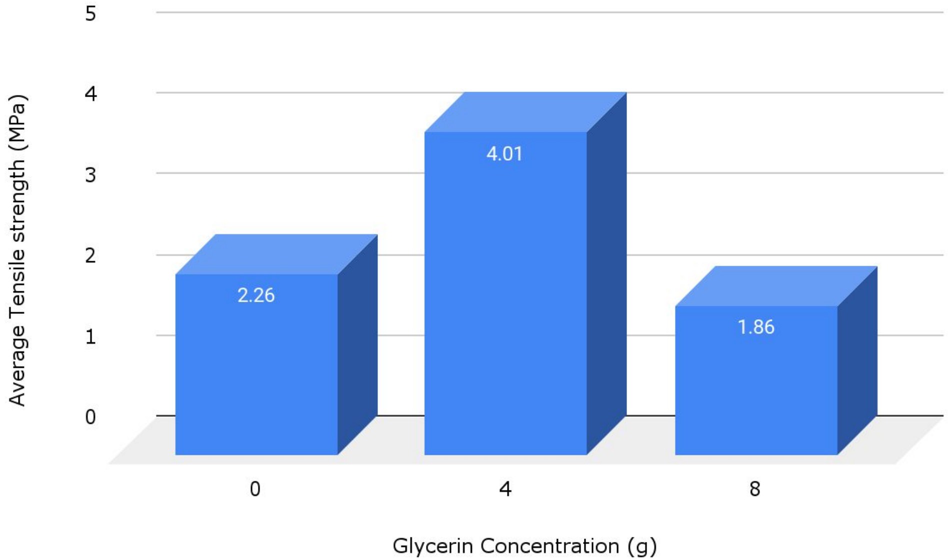
Green = greatest tensile strength in the category, Red = least tensile strength in the category

Experimental Result Analysis

Tensile Strength* (MPa) vs. Glycerin Concentration (g)

<u>Hypothesis #1 was proven correct</u>

The fabric with 4g Glycerin concentration is the strongest across all other glycerin concentrations.



WHY

- The 0g glycerin fabric does not have enough moisture and the 8g glycerin has too much moisture, which makes them easier to break when pulled apart.
- The 4g glycerin has a balanced amount of moisture, making it the strongest.

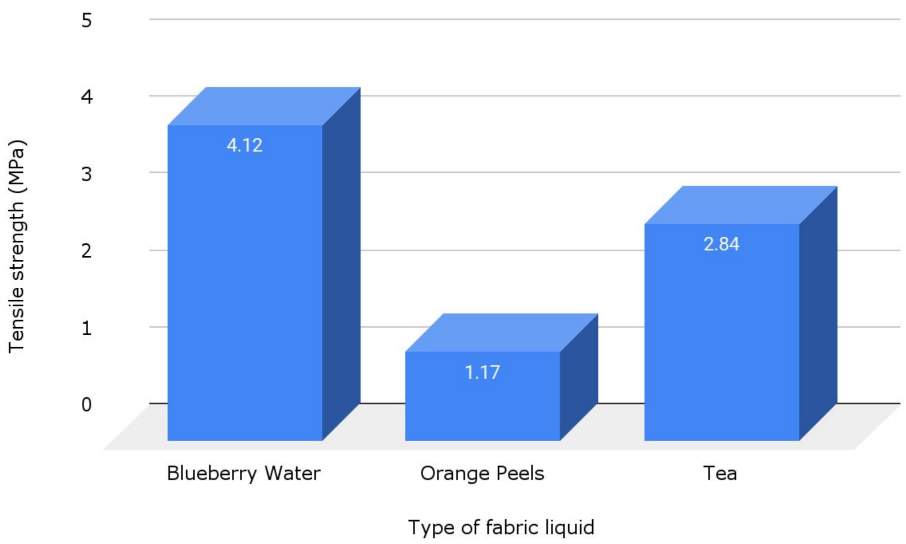
*Tensile Strength is measuring strength of fabric when pulling it apart to understand its durability.

Experimental Result Analysis

Tensile Strength* (MPa) vs. Type of fabric liquid

<u>Hypothesis #1 was proven correct</u>

The fabrics with blueberry liquid are the strongest across all the different liquid concentrations



WHY

- It is evident that fabric made out of blueberry is the strongest potentially because of its binding properties.
- The fabric made out of orange peels performed the lowest due to its grainy texture, making it easier to break.

*Tensile Strength is Measuring strength of fabric when pulling it apart to understand its durability.

Experimental Results

Torsion Test

(Number of rotations needed for the fabric to break)

	Torsion (Number of rotations)			
Trial	**With 8g glycerin**	**With 4g glycerin**	**With 0g glycerin**	**Average**
Blueberry liquid	10.5	8	5.5	**8**
Orange peel liquid	6	4	4.5	**4.8**
Tea liquid	8	5	5	**6**
Average	**8.25**	**5.67**	**5**	

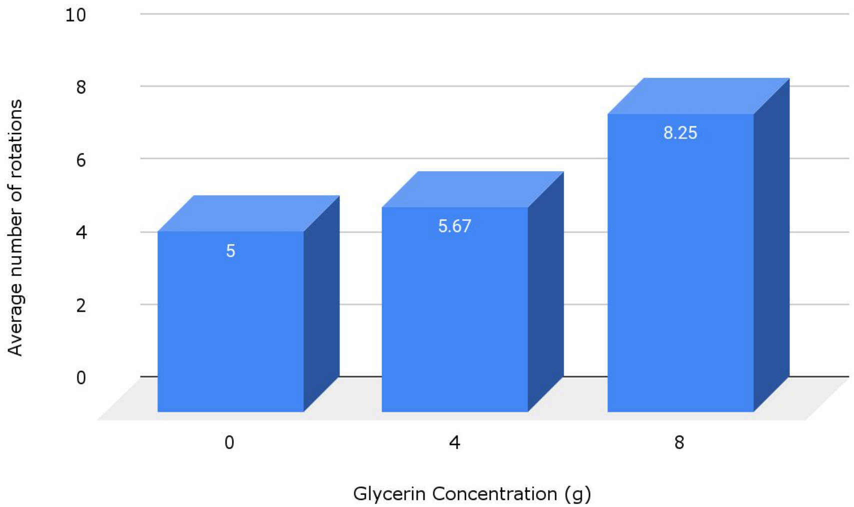
Green = greatest number of twists, Red = least number of twists

Experimental Result Analysis

Torsions* vs. Glycerin Concentration (g)

<u>Hypothesis #2 was proven correct</u>

The fabric with 8g glycerin tolerated twisting the most among all other glycerin concentrations.



WHY

- It is evident that the fabrics with 8g glycerin tolerated twisting the most compared to the other ones due to the glycerin being the "plasticizer" of the fabric.
- Similarly 4g tolerated twisting more than 0g

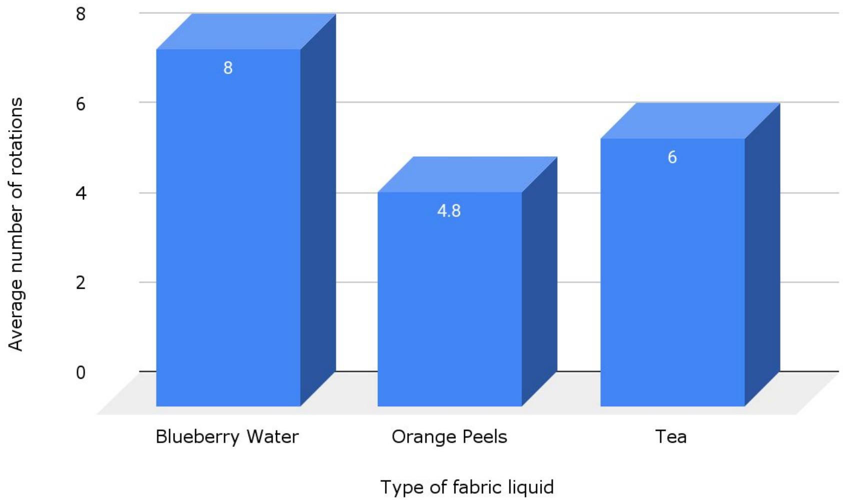
*Torsions= Number of rotations needed for the fabric to break

Experimental Result Analysis

Tortions* vs. Type of fabric liquid type

Hypothesis #2 was proven correct

The fabrics with blueberry liquid tolerated twisting the most as compared to other liquid types



WHY

- It is evident that fabric made out of blueberry performed the best and is the easiest to twist because of its binding.
- The fabric made out of orange peel water was the toughest to twist, compared to the other types of fabric due to its rigid properties.

*Torsions= Number of rotations needed for the fabric to break

Green = desirable, Red = less desirable

Experimental Results & Analysis

Hypothesis #2 was proven correct

Flexure Test

1. All the fabrics, regardless of the type of liquid used or the glycerin concentration
   a. Did not break when folded
   b. Displayed a fold line
2. It is not completely conclusive, however, the fabric with 4g glycerin concentration was the most flexible in the test.

Trial	Did the sample break after folding?			Does the fabric spring back to its original shape after folding?			Is there a fold line after folding?		
	8g Glycerin	4g Glycerin	0g Glycerin	8g Glycerin	4g Glycerin	0g Glycerin	8g Glycerin	4g Glycerin	0g Glycerin
Blueberry Liquid	No	No	No	Yes	Yes	No	Yes	Yes	Yes
Orange Peel Liquid	No	No	No	No	Yes	No	Yes	Yes	Yes
Tea Liquid	No	No	No	No	Yes	No	Yes	Yes	Yes

Experimental Result Analysis

<u>Hypothesis #3 was proven correct</u>

The fabric with orange peel powder liquid shrunk 55% more than the blueberry and tea liquid.

Orange fabric vs. Blueberry fabric

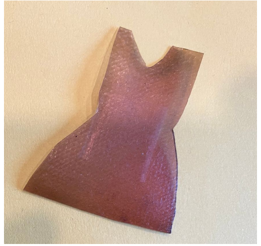
WHY

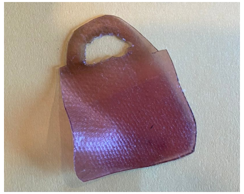
- Orange peels contain calcium, glycerin + sodium alginate creates calcium alginate, making it a thick gelatinous mixture.
  - More calcium would make the mixture thicker, causing it to shrink.
- Diameter of the orange peel fabric was 2.5 inches, and the diameter of the tea and blueberry fabrics were 5.5 inches.

Final Analysis

Final analysis:

- If I were to choose one fabric out of all, I would choose the fabric made with **blueberry liquid and 4g glycerin** because
  - It was the strongest
  - It would wear and tear less
  - It was the most flexible fabric





Conclusions

*Review slides 35 and 36 for FAQs on this project

1. **Going into this experiment some of the major question were**
   a. Is it possible to create sustainable fabrics using seaweed, food, and less harmful chemicals?
   b. What type of fabric works the best?
   c. How does the type of fabric liquid and the glycerin concentration affect the results for the tensile, torsion, and folding test?
2. **I was able to explore answers to these questions and proved that**
   a. Yes, it is possible to create a sustainable fabric using natural ingredients (seaweed, glycerin and food liquid)
   b. I also was able to prove that glycerin has great impact on strength and flexibility of the fabrics so amount of glycerin needs to be balanced in making the fabric.
   c. I also proved all our hypothesis, the strength and flexibility of fabric will vary based on glycerin concentration and type of food liquid.
3. **Key Learnings**
   a. Patience and perseverance are key to success - my initial attempts to build the fabrics failed since they were too wet, developed fungus, etc.. But overall, I was able to create 9 different fabrics.
   b. Learning how to use scientific instruments such as newton meter, caliper, screw clamps, etc. for tensile strength test/torsion test/ flexure test,
   c. Analyzing data and coming out with simple and practically applicable recommendations
   d. Learning more about the properties of fabric, learning more about the effects of glycerin and food concentration in fabric.
4. **Improvements and future opportunities**
   a. Changing seaweed concentration and study impact on fabric strength and flexibility
   b. Exploring how to increase the fabric strength to match industry standards
   c. Exploring how to reduce the time it takes for the fabric to develop
   d. Exploring other ingredients that can be used to make the fabric even better

Acknowledgements

- My dad, for motivating me to continue this project during its tough times. Thank you for not getting bored of me presenting the slideshow and constantly giving me feedback throughout the process.
- My mom, for helping me take pictures and videos to showcase the experiment and reviewing the project summary.
- Ms. Gow, my science teacher, for helping finalize my STEM Fair project and giving me useful feedback on the slides.

Bibliography and Sources

- *Torsion Test*. (n.d.). https://www.instron.com/en/resources/test-types/torsion-test
- ADMET Testing Systems. (2010, April 22). *Polyurethane Foam Tensile Strength Test - ASTM D3574 Test e* [Video]. YouTube. https://www.youtube.com/watch?v=clLEhdbQ6Uq
- *Textile Market Size, Share & Trends Analysis Report by raw material (Wool, chemical, silk), by product (Natural Fibers, polyester), by application, by region, and segment Forecasts, 2024 - 2030*. (2023, May 29). https://www.grandviewresearch.com/industry-analysis/textile-market
- Drew, D. (n.d.). The apparel industry's environmental impact in 6 graphics. World Resources Institute. https://www.wri.org/insights/apparel-industrys-environmental-impact-6-graphics
- Kiron, M. I. (2022, February 15). Types of mechanical properties of textile fibers and materials. Textile Learner. https://textilelearner.net/mechanical-properties-of-textile-fibers/
- Vartan, S. (2018). Fashion Forward: How three revolutionary fabrics are greening the industry. JSTOR Daily. https://daily.jstor.org/fashion-forward-three-revolutionary-fabrics-greening-industry/
- United Nations Environment Programme. (n.d.). Putting the brakes on fast fashion. UNEP. https://www.unep.org/news-and-stories/story/putting-brakes-fast-fashion
- Buddies, S., & Buddies, S. (2023, June 22). *Make Sustainable Fabrics from Seaweed | Science Project*. Science Buddies. https://www.sciencebuddies.org/science-fair-projects/project-ideas/GreenChem_p006/green-chemistry/alginate-seaweed-biofabrics
- https://greenamerica.org/toxic-textiles-scorecard
- Wilson, J. (2022, November 5). Toxic textiles: The chemicals in our clothing. Earth Day., https://www.earthday.org/toxic-textiles-the-chemicals-in-our-clothing/
- Adamiak, K., & Sionkowska, A. (2023, June 8). State of innovation in alginate-based materials. MDPI https://www.mdpi.com/1660-3397/21/6/353

Failed Versions

This fabric failed due to the uneven layer of calcium chloride that was sprayed on top.

This fabric failed due to the excess amount of calcium chloride solution.

This fabric turned into jelly instead of a thick liquid mixture due to the high amounts of food concentration.

These fabrics developed fungi due to the excess calcium chloride solution and shrunk due to the removal of the mold at an earlier stage.

Major US Apparel Brands + Textile Chemical Protection

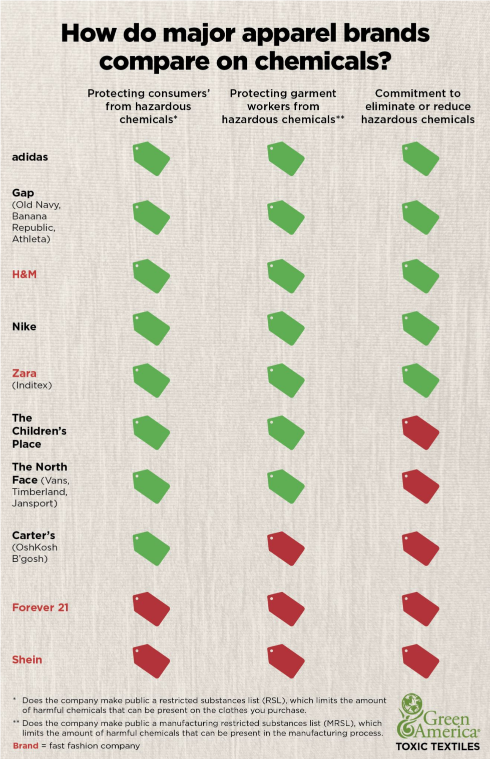


Image source: https://greenamerica.org/toxic-textiles-scorecard

Image source: https://www.earthday.org/toxic-textiles-the-chemicals-in-our-clothing/

Chemicals Used In the Textile Industry

Chemicals in our Clothing

Impact categories: \ Chemicals:	Flame Retardants	PFAS	Lead	Chromium	Phthalates	Chlorine Bleach	Azo dyes	VOCs
Probable Carcinogens	✓	✔ ✓	✓	✓	✓	✔ ✓	✓	✓
Skin irritants	✔	✔	✓	✓	✔	✔ ✓	✓	✓
Hormone Disruptors	✓	✓	✓	✓	✓	✓	✓	✓
Environmental degradation (Water pollution)	✔ ✓	✔ ✓	✓	✓	✔ ✓	✓	✓	✓

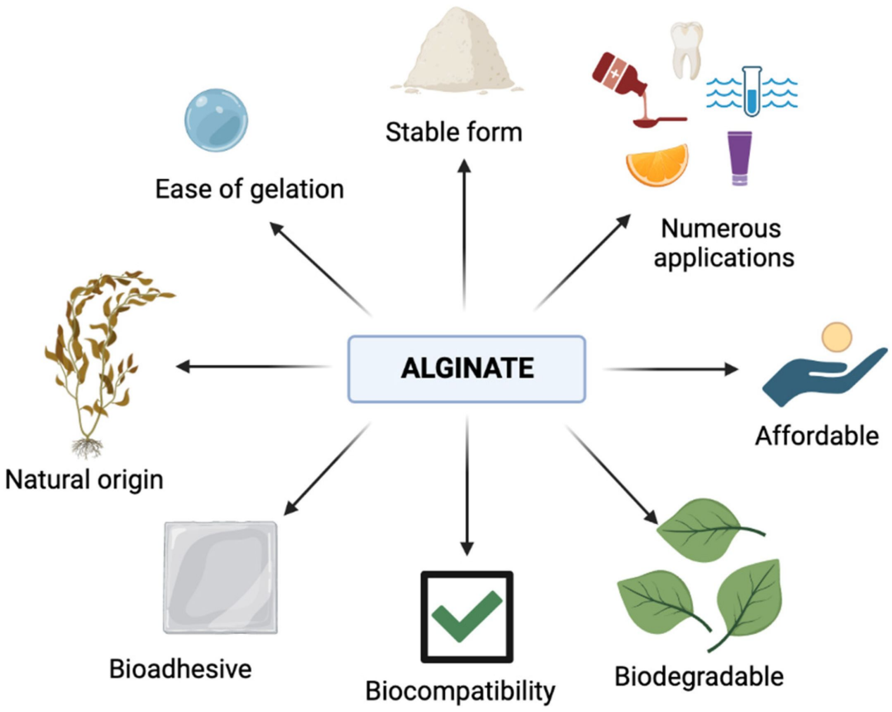
✔ Short-term or acute exposure can lead to health impacts

✓ Prolonged or extensive exposure can lead to health impacts

All information obtained from Pharos project.net

Image source: https://www.mdpi.com/1660-3397/21/6/353

Alginate As a Useful Biopolymer



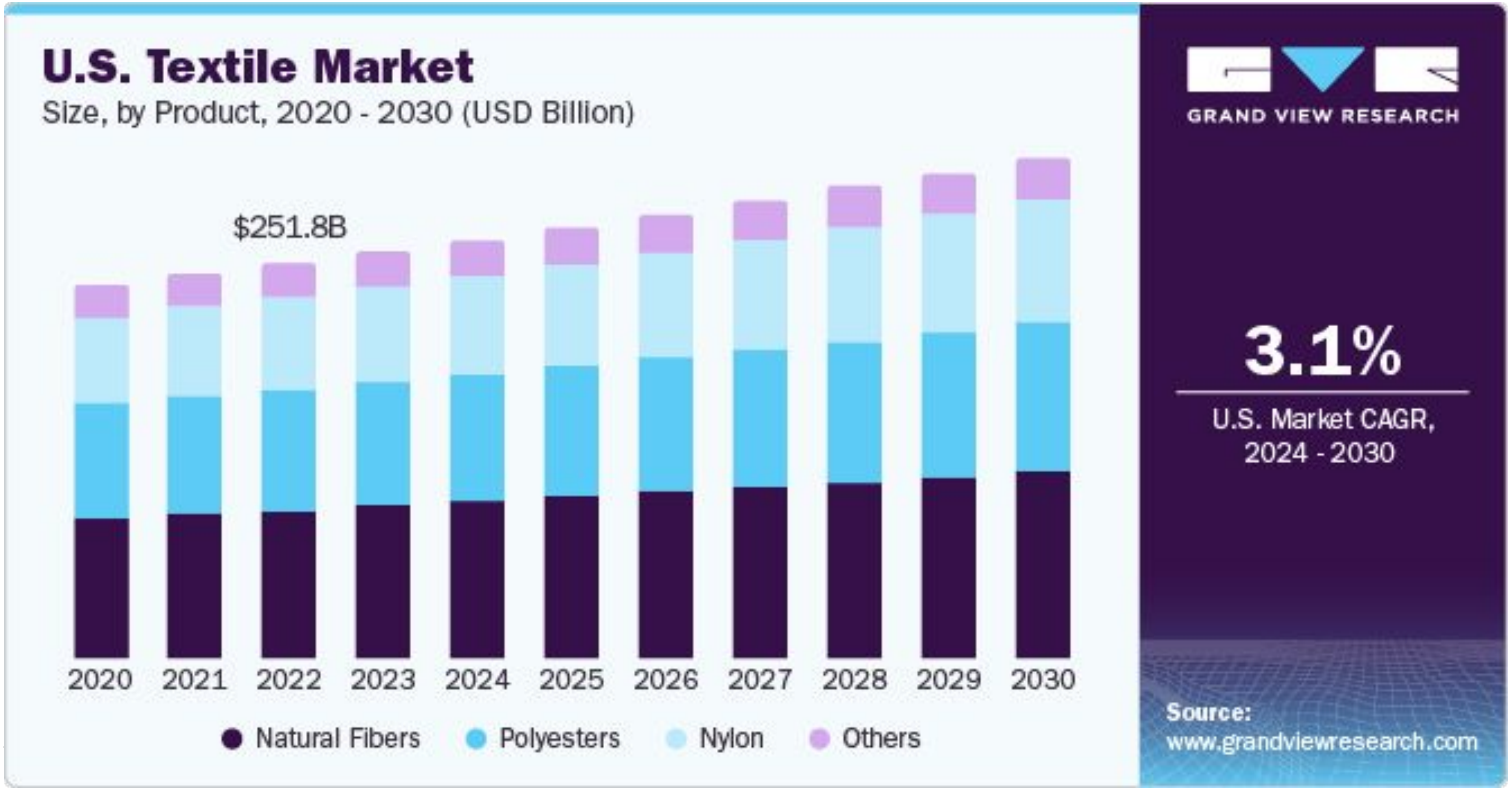
Alginate is a polymer typically obtained from brown seaweed.

Positive characteristics of alginate:

- Biocompatible
- Has low toxicity
- Low cost
- Gelatinous properties
- Biodegradable
- Natural

Textile Market Size

Image source: https://www.grandviewresearch.com/industry-analysis/textile-market



FAQs

1. **What is sodium alginate?**
   a. A chemical compound made of algae (a type of seaweed) that can be used as a biopolymer to create more sustainable fabrics, and is generally used as a thickening agent in food and is used in various other industries including the medical industry.
2. **How is sodium alginate fabric better than the fabrics out there?**
   a. Sodium alginate is recognized as a chemical that is not as toxic as the other chemicals used, which is why it is a better source. Slide 33 explains the reasons why sodium alginate is a great alternative.
3. **Is anyone else is making fabric commercially with Seaweed?**
   a. Some companies have launched seaweed fabric, including Kelsun (a seaweed manufacturing company), Algaeing (an eco-friendly fiber-selling company), Oliver and Charles (a sustainable fabric online store), and Frank and Oak (another sustainable fabric development company). However, no major retailer has attempted to create seaweed fabrics.
4. **How much water does it take to make the fabrics in this experiment?**
   a. After calculating the diameter of the fabric and realizing that it takes 200 mL of water to make it, an average cotton shirt is roughly 2.5 meters, which makes the water usage roughly 3.5 liters. To be on the safer side, it can be exerted to 6-10 liters
5. **What other natural materials (other than seaweed) can be used in fabric development**
   a. Hemp, cork, and bamboo are some examples of other natural materials

FAQs (Cont'd)

6. **What is the difference between these biofabrics and natural fabrics?**
    a. Bio Fabrics are usually derived from biological substances like bacteria, yeast, or algae, while natural fabrics are made from natural materials such as plants (cotton, linen) and animals (wool, silk).
    b. Bio Fabrics have properties such as biodegradability and can be designed to be eco-friendly. Natural fabrics cannot be altered as much, and have the same properties as their natural counterparts.
    c. Bio Fabrics are still in the early stages of development, while natural fabrics have been around for thousands of years.
7. **How do you compare biofabrics in terms of strength and flexibility in terms of strength against cotton and polyester?**
    a. Strength:
        i. Bio Fabrics can be engineered to have various different strengths. In this experiment, the Bio Fabrics that were created had a fairly low amount of tensile strength compared to industry fabrics like cotton or polyester. Synthetic fibers are known for their strength, which is why fibers like polyester and nylon would perform better in tensile strength tests.
    b. Flexibility:
        i. Bio Fabrics can be engineered to have various different types of flexibility. In this experiment, the Bio Fabrics that were created had a fairly low amount of flexibility compared to industry fabrics. Cotton fabrics, for example, are known for their flexibility. While polyester fabrics are known to be more rigid.
8. **Why are biofabrics not as popular?**
    a. Cost, scale and production capacity and consumer awareness and acceptance

Thank you!