Seaweed-based Edible Liquid Capsules: Green Innovations for Single-Use Plastics

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Department of Chemistry

AACT Summer Symposium
Inventing Green through Education
August 4, 2020
11:45am-12:05pm CDT
Background/Acknowledgements

- **Emma Corcoran** (Wissinger group)
  - Honors senior thesis project
  - Expanded scope of exploration
  - Developed curriculum materials for middle school and high school classroom

- **Mollie Enright** (Beyond Benign/UToldeo)
  - Initiated Collaboration
  - Activity based on Ooho! Product
  - Bring awareness to plastics problems and innovative solutions

- **Cassie Knutson** (White Bear Lake HS, MN/Beyond Benign)
  - High School classroom implementation/consultant
  - Teacher Workshop
  - Beyond Benign
Curriculum Development Research

- **Plastics** – Relatable topic that engages students

- **Polymers** – Unique properties offering mechanical and physical testing
  - NGSS *engineering*
- **Design** project friendly (guided-inquiry)
  - NGSS *design, evaluate, refine*
- **Green Chemistry Principles**
  - Key to invention of new environmentally benign material!
  - NGSS *reduces impacts of human activities on environment*
Sodium Alginate + Calcium X→ Cross-linked Gels

- Sodium Alginate – natural polysaccharide extracted from brown seaweed/algae

- Used in food, textile printing, pharmaceuticals, dentistry
- With calcium counter ions forms hydrogels
  - Biodegradable absorbent
  - Wound dressings
Past Use in Experiments

- Published classroom experiments ($\text{CaCl}_2$)

- Apply to new Ooho innovation of replacing water bottles
- Use food grade calcium lactate
NotPLA (Skipping Rock Labs)

• Addressing the Plastic Water Bottle problem (and other single use plastics)
  – London Marathon (saved 200,000 bottles)

• Edible Water Pods
  – Sport
  – Cocktails – juices, waters, alcoholic cocktails
  – Sachets (saucers, salad dressings, condiments)
  – Take-away items
  – Liner for cardboard take out

https://www.notpla.com/
Edible Water Capsules: A Thirst for a Solution

Student Handout

Name: ____________________________  Date: ____________________

Part 1: Synthesizing Calcium Alginate Hydrogels

Purpose: To create edible, water-filled capsules from calcium lactate and sodium alginate.

Background:

• Single Use Plastics – 95% packaging lost to economy after single use
• Water Bottles - 1 million bottles purchased/minute
• What is a polymer?
• Linear vs. cross-linking polymers
• What is calcium alginate?
• Green Chemistry
  • Renewable versus non-renewable resource
  • Biodegradable

Experiment Design (MS):

• Groups Activities to learn concepts
  • Spaghetti/marshmallow bridges
  • Ball of string
• Water capsules
  • Prepare
  • Evaluate
  • Explore
Activities

• What is a renewable resource?
• What is a non-renewable resource?
  – Students sort a list.

• Spaghetti noodles and marshmallow bridges between desks (timed competition)
  – Team 1 – 20 spaghetti + 40 marshmallows but no resupply (non-renewable)
  – Team 2 – 5 spaghetti + 10 marshmallows but can replenish (renewable)

<table>
<thead>
<tr>
<th>Renewable resources</th>
<th>Non-renewable resources</th>
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<tbody>
<tr>
<td>- Biomass</td>
<td>- Coal</td>
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<tr>
<td>- Wind power</td>
<td>- Oil</td>
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<tr>
<td>- Biofuel</td>
<td>- Nuclear power</td>
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<td>- Water</td>
<td>- Minerals from rocks</td>
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<td>- Solar power</td>
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<td>- Geothermal</td>
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<td>- Plants</td>
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<td>- Animals</td>
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<table>
<thead>
<tr>
<th>Renewable resources</th>
<th>Pros</th>
<th>Cons</th>
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<tbody>
<tr>
<td>- Biomass</td>
<td>• Does not run out</td>
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<tr>
<td>- Wind power</td>
<td>• Can be used over and over again</td>
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<tr>
<td>- Solar power</td>
<td>• Smaller amounts of material at the beginning, not always renewable right away (waiting for crops to grow)</td>
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<td>- Geothermal</td>
<td>• Can get a large amount of the material very quickly</td>
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<tr>
<td>- Plants</td>
<td>• Eventually runs out and cannot be replaced quickly enough</td>
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<td>- Animals</td>
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**Procedure(s)**

[https://www.youtube.com/watch?v=r-dm1fEY6UU](https://www.youtube.com/watch?v=r-dm1fEY6UU)

**Kitchen Equipment** *(blender, bowls)*

1. Mass 1 gram of sodium alginate.
2. Place the sodium alginate into the blender with 250 mL of tap water.
3. Blend the sodium alginate with the water for 20 seconds. Pour the solution into one of the beakers. Label the beaker “sodium alginate”.
   1. Optional: Add 3-4 drops of food coloring to the mixture.
4. Measure 250 mL of tap water into another beaker. Label this beaker “calcium lactate”.
5. Mass 1 gram of calcium lactate and add it to the calcium lactate beaker. Stir the calcium lactate solution with a glass stir rod until dissolved.

**Laboratory Equipment** *(hot plate/stirrer, beakers)*

6. Fill a measuring spoon with the sodium alginate mixture, then set it into the calcium lactate mixture following the steps below:

   7. Repeat this process so that there are 4-5 capsules in the calcium lactate bath.
   8. Let the capsules sit 15-20 minutes, then take them out and set them in a weigh boat or paper to observe.

Corcoran, E.; Wissinger, J. E. *Earth-Friendly Plastics. Celebrating Chemistry, Chemists Celebrate Earth Week, 2020*, p. 8
Variables Affecting Capsule Quality and Shape

- **Food Coloring** → no structural effects
- **Time in alginate bath** → thickness of gel
  - > 90 minutes thickening
  - Overnight gave solid gel
- **Freeze sodium alginate in ice cube trays** → somewhat more uniform capsules
- **Decrease or varied quality with:**
  - Reverse order of addition
  - Heating of sodium alginate
  - Calcium chloride inferior to lactate for capsules
  - Addition gum Arabic or starch
  - Concentrations
High School Version

Driving Question: Can edible capsules be engineered to become adequate replacements for single-use plastic water bottles?

Objectives: Students will...

- Create edible, water-filled, capsules from sodium alginate and calcium lactate.
- Compare the properties of capsules made with calcium ions and those made with other group II cations.
- Design and carry out experiments to study different ways to potentially improve the capsules.

Key terms: Polymer, monomer, linear polymer, cross-linked polymer, hydrogel, green chemistry.
Extensions

- Develop physical test of capsule wall strength
- What are weakness of these hydrogels?
  - Scale up
- Journal article discussions
  

  Binding and Leakage of Barium in Alginate Microbeads

  Yrr A. Mørch,^1 Meirigeng Qi,^3 Per Ole M. Gundersen,^4 Kjetil Formo,^1,3 Igor Lacik,^5 Gudmund Skják-Bræk,^1
  Jose Oberholzer,^3 and Berit L. Strand^1,2,*

- Effect of pH on capsule formation – NEW

Dr. Jeffrey Buenaflor, postdoc
12 Principles of Green Chemistry for Innovation

1. Reduce Waste
2. Atom Economy
3. Less Hazardous Chemical Synthesis
4. Designing Safer Chemicals
5. Safer Solvents and Auxiliaries
6. Design for Energy Efficiency
7. Use of Renewable Feedstocks
8. Reduce Derivatives
9. Catalysis
10. Design for Degradation
11. Real-Time Pollution Prevention
12. Safer Chemistry for Accident Prevention
12 Principles of Green Chemistry for Innovation

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12. Safer Chemistry for Accident Prevention
Conclusion

- Curriculum sharing new innovations to solve the single-use plastic problem
- Lessons – these problems are challenging
- They could be part of the solution and be inventors!
- Materials meet NGSS (6 middle school & high school)
- Versatile from outreach demo to sophisticated HS
- Engaging and fun for students
- Safe, inexpensive, green & sustainable for instructors
Thank you for listening!

Questions?

jwiss@umn.edu
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