Lab: Solubility Plays a Role: Making Seitan from Flour

FOR THE TEACHER

Summary
This lab offers insight into a practical aspect of solubility and demystifies a common ingredient, wheat flour. In this lab students will read about the composition and observe some properties of whole wheat flour by preparing seitan, a vegetarian meat substitute made from the glutenin and gliadin proteins in flour. Gluten, formed from the interaction of the aforementioned proteins, has a unique property of elasticity.

Grade Level
High School

NGSS Alignment
This lab will help prepare your students to meet the performance expectations in the following standards:

- HS-PS2-6: Communicate scientific and technical information about why the molecular-level structure is important in the functioning of designed materials.
- Scientific and Engineering Practices:
  - Analyzing and Interpreting Data
  - Engaging in Argument from Evidence

Objectives
By the end of this lab, students should be able to
- Identify water soluble and water insoluble components of flour.
- Summarize the processing of wheat flour into seitan.

Chemistry Topics
This lab supports students’ understanding of
- Molecular Structure
- Physical Properties
- Solubility
- Intermolecular Forces

Time
Teacher Preparation: 30 minutes to run through lab; 10 minutes to set out materials, plus a trip to the supermarket
Lesson: 45 minutes

Materials
- Supermarket items:
  - Wheat berries (small sample, see photo)
  - Whole wheat flour (5 lb bag is enough for about 16 lab groups)
  - Cheese cloth (cut into approx. 20 x 20 cm pieces; 1 per lab group; not essential, but useful for troubleshooting)
- Lab materials:
  - Paper towels or newspaper to cover work surface
  - Bowls or beakers for mixing and washing dough (1 per lab group)
- Wooden spoons (1 per lab group)
- Several ½ cup measuring cups (groups can share)
- Several 1 cup measuring cups (groups can share)
- 1 L beaker
- Hot plate

**Safety**

- Always wear safety goggles when handling chemicals in the lab.
- Students should wash their hands thoroughly before leaving the lab.
- When students complete the lab, instruct them how to clean up their materials and dispose of any chemicals.
- Food in the lab should be considered a chemical not for consumption.
- Students with celiac disease or a gluten allergy should wear gloves or be excused from the lab activity.

**Teacher Notes**

- Be sure to read the Background section of the Student Handout in advance. Below are brief annotations of some suggested resources.
  - Oregon Agriculture Website: This site is easy-to-read and compares and contrasts types of wheat and flour. There is a useful glossary at the end.
  - How Products are made: This website focuses on the processing of flour from wheat and addresses the history of flour.
  - Eating Rules: This resource is helpful because the photographs show what to expect during the seitan-making activity.
  - There is a great basic visual of the gliadin and glutenin structures on this blog that could be helpful for student reference in the background section of the activity.

- Talking points for Prelab Questions:
  - These questions are meant to get students talking about food and to expose any misconceptions. For example, processed foods are often thought of as “bad” without having evidence to back up that claim. A processed food is usually defined as a food that has been altered, by cleaning, milling, cooking, packaging, etc., from its natural state. A good resource is *What is a Processed Food?*, from FoodInsight.org. Flour is a processed form of wheat. Seitan is further processed from flour.

- Helpful Hints for Student Instructions:
  - Step 2: You may want to demonstrate proper kneading technique, either with dough or a piece of clay. Students should have a well-formed dough before they proceed with the washing step (Step 5), otherwise the dough will “fall apart” in the bowl of water and decrease their yield of gluten. If this occurs, have them knead the dough a bit longer and use cheesecloth to surround the dough during the washing stage.
  - Step 3: You may want to show students how to do the following elasticity test with a piece of clay: “stretch out the dough without ripping it and release it.”
  - Step 7: At the start of the lab fill a 1 L beaker about ¾ of the way with tap water and heat on a hot plate to boiling. Reduce heat level so water continues to simmer. Add the gluten pieces as students finish and simmer for about 15 minutes. Allow to cool, then let students have the seitan to finish their observations. (To save time, you can pre-cook some seitan so they do not have to wait to complete their observations.)

- Teacher Answer Key with expected results included for download.
Extension Idea:
- The teacher, in a food safe environment, may prepare seitan for the students to consume. Pre-made and often flavored seitan is available in many supermarkets and simply needs to be heated. All taste testing should be done in the cafeteria or a family and consumer science room.
- Research gluten-free flours and additives like xanthan gum and how they serve to mimic the unique properties of gluten.
- Investigate the differences between whole wheat flour and white flour.

FOR THE STUDENT
Lesson

Making Seitan from Flour

Prelab Questions
Without using outside resources, discuss the following questions with your lab group.

1. What do you know about “processed” foods? Name some foods that are processed.
2. What is the difference between wheat and flour?
3. Do you know what seitan is? If so, what do you know about it?

Background

Wheat flour is made from the edible seeds of the wheat plant, called wheat berries. Flour is made by grinding wheat berries into a powder. Flour is a mixture containing mostly starch (i.e. polysaccharides) and the proteins, glutenin and gliadin. The interaction of water with glutenin and gliadin allows for formation of the protein mixture gluten. Gluten has unique elastic properties giving bread its distinctive texture and is the reason that gluten-free imitations of bread products are often subpar.

In this activity, gluten in flour will first be “developed,” then isolated. Gluten is the main ingredient in the vegetarian meat-replacement known as seitan. The texture of seitan is chewy or meat-like and the flavor is easily manipulated by adding herbs, spices, and sauces.

To develop the gluten, water must be added to flour to allow free movement of the glutenin and gliadin proteins, followed by the process of kneading. Kneading causes glutenin and gliadin to interact and realign to form disulfide covalent bonds, intermolecular forces of attraction, and ionic bonds. These interactions serve to crosslink glutenin and gliadin. The chemical formulas and structures of these proteins are varied and complex, so will not be shown, but you teacher may show you a simplified drawing. To picture developed gluten, think of what happens to cooked, cold spaghetti noodles—they stick together and form a tangled mass. Once the gluten is developed in the dough, it can be isolated by rinsing the dough in water. Due to the low content of hydrophilic amino acids (i.e. lysine, arginine, glutamic acid, and aspartic acid), gluten is largely insoluble in water and so will remain in the dough; however, the starches are water-soluble and will dissolve into the water. The remaining gluten can then be simmered to make edible seitan.
Objective
To determine what properties allow for seitan to be made from wheat flour.

Materials
- Whole wheat flour (about 1 cup)
- Paper towels or newspaper to cover work surface
- Bowl mixing and washing dough
- Wooden spoon
- Measuring cups

Safety
- Always wear safety goggles when handling chemicals in the lab.
- Wash your hands thoroughly before leaving the lab.
- Follow the teacher’s instructions for cleanup of materials and disposal of chemicals.
- Food in the lab should be considered a chemical not for consumption.
- Students with celiac disease or a gluten allergy should wear gloves or be excused from the lab activity.

Procedure

Observations: Wheat Berries and Flour

- The teacher will pass around a sample of wheat berries.
- The teacher will pass around a sample of whole wheat flour.
- Record observations in the appropriate table.

Making Seitan

1. Obtain a mixing bowl and wooden spoon.
2. Measure 1 cup of whole wheat flour into the mixing bowl. Add ½ cup of cool tap water to the bowl. Mix until the dough clumps together. Then knead the dough (fold it over on itself) for about 3 minutes using your hands.
3. Perform elasticity test: stretch the dough without ripping it, then release. Observe what happens. Record these and other general observations in the observation table.
4. Set the dough on a paper towel and clean out the bowl for use in the next part.
5. Fill the bowl with cool tap water. Place the dough in the bowl and knead it in the water. Continue “washing” the dough until the water is clear, changing the water as necessary. Small, brown pieces may dislodge from the dough. This is the bran (outer seed coating) in the flour. Getting rid of it will produce a better seitan.
6. At this point, the gluten from the dough should be isolated. Remove the mass of gluten from the water. Blot dry with a paper towel. Perform the elasticity test again. Record observations.
7. Bring your piece of gluten to the teacher. The teacher will simmer (gently boil) the gluten pieces in water for 15 minutes to make the meat substitute, seitan. Once cool, perform the elasticity test again and record observations.
8. Wash all equipment well and throw away the seitan.
**Observation Tables**

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<tr>
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<th>Wheat Berries</th>
<th>Flour</th>
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<td><strong>Observations</strong></td>
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<tr>
<th></th>
<th>Dough after kneading</th>
<th>Gluten after washing</th>
<th>Seitan after simmering</th>
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<td><strong>Observations</strong></td>
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<td>after stretching</td>
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<td><strong>General</strong></td>
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<td>observations</td>
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**Analysis**

1. Elasticity describes the ability of dough to retract to its initial position after being stretched. Which sample demonstrated the greatest elasticity: dough, gluten, or seitan?
2. What evidence from the activity supports the following statement: Some components of dough are water-soluble?
3. Look up the chemical structure of starch. What features of its structure allow for starch to be soluble in water?
4. Why is it essential to knead the dough before washing it?
5. Bread doughs contain an essential ingredient that our dough lacked, a leavening agent, usually in the form of yeast. Leavening agents serve to produce gas. Predict how gluten and gas may interact to produce bread.
6. Compare the texture of the seitan to that of meats you have eaten—DO NOT eat the seitan prepared in lab! Do you think seitan is a good meat replacement based on texture? Why or why not?

**Conclusion**

In your own words, using three or four sentences, summarize how seitan is prepared. In your summary, be sure to use and underline the following terms: seitan, soluble, flour, starch, gluten, elasticity.