

Gluten and Playdough

DESCRIPTION & OBJECTIVES:

Gluten is a component of wheat flour that can denature during dough processing and is responsible for a number of property changes during the conversion of flour dough to foods, such as baking. This activity aims to use the rheology of home-made playdough to demonstrate the role of gluten in flour dough rheology.

GRADE LEVELS:

Elementary School, Middle School, and High School

NEXT GENERATION SCIENCE STANDARDS:

Disciplinary Core Idea:

2/5-PS1.A Structure and Properties of Matter, MS/HS-PS1 Matter and Its Interactions

Performance Expectations:

2-PS1-1. Plan and conduct an investigation to describe and classify different kinds of materials by their observable properties.

2-PS1-2. Analyze data obtained from testing different materials to determine which materials have the properties that are best suited for an intended purpose.

5-PS1-1 Develop a model to describe that matter is made of particles too small to be seen.

MS-PS1-3. Gather and make sense of information to describe that synthetic materials come from natural resources and impact society.

HS-PS1-3. Plan and conduct an investigation to gather evidence to compare the structure of substances at the bulk scale to infer the strength of electrical forces between particles.

HS-PS2-6. Communicate scientific and technical information about why the molecular-level structure is important in the functioning of designed materials.

Practices: Developing / using models, Planning / carrying out investigations, Analyzing / interpreting data

Crosscutting Concepts: Cause and effect: Mechanism / explanation

OUTCOMES:

To gain a general understanding of:

- The components of wheat flour.
- How protein denature in presence of heat and salt.
- The concept of viscoelasticity.

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MATERIALS:

- All-purpose wheat flour
- Corn starch
- Food coloring
- Salt (ideally powdered salt)
- Cream of tartar
- Vegetable oil
- Measuring cup and tablespoon
- Wooden stir bar

Additional materials for high school class:

- Ruler
- Stopwatch (or timer mobile app)
- Weighty objects with a flat surface (e.g. hard cover textbook, paperboard milk carton filled with water)
- Scale (for measuring mass of weighty objects)

DIRECTIONS:

Preparation of flour/starch playdough

1. Prepare ingredient mixture in a microwavable container:
 - a. 1 cup of water
 - b. 1 tablespoon of vegetable oil
 - c. $\frac{1}{2}$ cup of salt
 - d. 1 tablespoon cream of tartar
 - e. 2 drops of food coloring (use different color depending on the type of desired playdough e.g. flour- or starch-based, or using cold water)
2. Microwave the ingredient mixture from step 1 till simmering
 - Skip this step if making cold-water playdough
3. Add 1 cup of wheat flour or starch to the mixture of other ingredients, rapidly stir with a wooden stir bar till small dough particles (~ 0.5 cm in diameter) start to form and coalesce. **CAUTION:** Mixture may be hot!
4. When the dough particles are no longer hot, knead into a large bolus of playdough. Knead repeatedly to achieve homogeneity.

Compression experiment (High School only)

5. Mold the flour playdough into a rectangular brick, with height:length:width ration roughly equals to 2:3:3. Measure all three dimensions of the playdough brick (H=height, L=length, W=width).
6. Lay the playdough brick on a hard surface. Place weighty object on top of the brick; start the timer.
7. After 60 seconds, remove the weighty object, and measure again the height of the brick (H*)

TEACHER'S NOTES

8. Calculate the strain:

$$\epsilon = \frac{H - H^*}{H}$$

9. Measure the weight of the weighty object m (in pounds), and calculate stress (in psi):

$$\sigma = \frac{m}{L \times W}$$

10. (Group activity) Plot a graph of stress (σ) vs. strain (ϵ)

HELPFUL HINTS:

- Flour needs to be added to a simmering mixture for effective denaturation of gluten.
- Canola oil can be used in replacement of vegetable oil.
- Granular salt can be used as long as it is completely dissolved in water.
- Playdough contains large quantities of salt, and should be kept out of reach by children and animals. Inadvertent ingestion of playdough may cause dehydration, which would require medical attention.
- For measurement of stress and strain values, weighty objects can be laid onto the playdough brick one at a time, for acquisition of multiple data points.
- For cold-water and starch-based playdough, lighter objects should be used for compression experiments

EXPECTED RESULTS:

- Flour playdough made with heated ingredient mixture demonstrate properties similar to commercial molding compounds (e.g. Playdoh®)
- When made with cold ingredient mixture, playdough is brittle and less viscoelastic. Starch cannot form a viscoelastic playdough.

EXPERIMENT QUESTIONS

Basic Level

Which playdough has the greatest viscoelasticity (i.e. most “stretchy”)?

Teacher's notes: “Visco-” means that the material would deform when a force is applied (e.g. by hand). “Elasticity” means that a deformation is reversible once the external force is removed. A viscoelastic material would demonstrate both viscous and elastic properties.

Medium Level

The major components of flour dough are starch and gluten. Which component is responsible for the viscoelasticity?

Teacher's notes: Gluten is a complex mixture of various proteins, and starch is a polymer of glucose. Playdough is a hydrocolloid gel, or in other words, a suspension of starch particles in a network of aqueous gluten solution.

TEACHER'S NOTES

Gluten proteins are entangled together via intramolecular forces, and these forces can be neutralized by salt and heat, enabling protein molecules to move more freely.

Cream of tartar is an acidic salt derived from wine and grape juice processing. When mixed with flour, cream of tartar lowers the pH of the mixture, thus enabling proteins to denature more easily.

Kneading causes gluten to form strands and webs, and further enhances the elasticity of the playdough.

Advanced Level

How does stress correlate with strain?

Teacher's notes: Playdough behaves as a plastic solid, which demonstrates complex rheological behavior. Under low strain levels, the material demonstrate a positive stress-strain correlation. This behavior corresponds to a tangy or gummy mouthfeel.

Playdough made with cold water or starch demonstrates fracture behavior, i.e. the material fails completely at a given stress level. This behavior corresponds to a crumbly, or crunchy, mouthfeel.

REFERENCES

1. D. N. Abang Zaidel, N. L. Chin, and Y. A. Yusof. *Journal of Applied Sciences* **2010**, 10(20) 2478
2. M Gibson and P Newsham, "Rheology", in *Food Science and the Culinary Arts*, **2018**, 89-103

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WORKSHEETS

Stress-Strain Curve

