Gluten: Not Just an Allergen

Abstract:

Gluten has been under public scrutiny for the last couple years given the rise of gluten allergies and sensitivity, in addition to the population affected by Celiac disease, a genetic disease whose symptoms include extreme allergies to gluten. However, much of the population has no knowledge of gluten beyond the fact that it is an allergen found in bread. Making bread can be a lot of fun, and this experiment leverages that to impart knowledge through hands-on exploration. This experiment is designed to highlight the effect of gluten (and by extension, kneading), on the strength and flexibility of bread doughs.

Background:

Gluten is not one compound but a collection of several different proteins formed through the hydration of proteins found in flour. Gluten proteins generally fall under the category of gliadins (soluble in aqueous alcohols) and glutenins (insoluble in aqueous alcohols)[1]. Gliadin proteins exist as monomers, oligomers, and polymers while glutenids are always massive macro-polymers with molecular weights exceeding 2 million[2].

The main chemical properties of interest in gluten are its strong hydrogen bonding tendencies and disulfide bridges that hold the polymers together. The hydrogen bonding is a product of the amino acid glutamine, the most common amino acid in gluten[2]. This hydrogen bonding is part of what keeps the protein strands together, but also what allows it to attach to the other compounds, such as the various carbohydrates, found in the dough.

The disulphide bridges are a result of the thiol groups found in the amino acid cysteine. These bridges do the heavy lifting in holding the massive glutenid molecules together, as well as connecting different polymer strands[1]. These bonds are easily broken during redox reactions, which are common in dough throughout the entire process of preparing it[1].

The mere existence of gluten in a dough is not enough to make these polymers reach their full viscoelastic potential. Mechanical work, generally in the form of kneading, is also required. This process allows the disulfide bridges between molecules to break, and then reform after the molecules are stretched. This stretching uncoils the molecules, and the increased surface area allows for more hydrogen bonding, making the dough stronger. [2]

The involvement of yeast in this process allows for further stretching out, as the fermentation process releases CO_2 bubbles into the dough, which get trapped in the network of long proteins, further stretching it. Unfortunately, this aspect of the process takes several hours and cannot be replicated in the experiment[2].

One of the other principles this experiment puts to the test is it gives some intuition of viscoelasticity. Similar to silly putty, if you stretch it slowly, it acts like a viscous substance that will stretch quite a bit. Pulling it apart quickly makes it act more like a solid, and it will snap quickly. Similarly, pumping the balloons too fast will make them pop quicker.

Materials and Methods:

This experiment provides a novel demonstration of the elasticity that gluten provides by making balloons out of flours with varying gluten contents. Gluten content can either be varied by using different types of flours or by adding a pure gluten extract (which can be purchased in bulk at most health markets or online).

For the approach with varying flours, using plain white flour as one of the options is highly recommended, as it has by far the highest gluten content of any commonly available flour. Whole wheat and barley flours offer some gluten content, but they are far lower, and most other alternative flours have negligible gluten content.

The materials needed for this experiment are flour, gluten extract (optional), water, and a pump of some kind (ball pumps are ideal, but bike pumps function in a pinch). Each participant then mixes flour, water, and gluten. The ideal mixture is about 4 Tbsp. flour, 1 Tbsp. gluten, 2 Tbsp. water, and a pinch of salt (fig. 1). Then, on a floured countertop and with floured hands, the participants knead their dough ball to develop the gluten (fig. 2.). Allow the participants to vary the time spent kneading. When they feel that they are ready, roll out the dough with a rolling pin to an even thickness and mold it around the nozzle of the pump (fig. 3), and start pumping gently, forming a balloon.

Burst dough balloons can be recycled, as the participant can add more gluten, flour, or water and continue kneading. The goal is the produce the largest balloon possible.

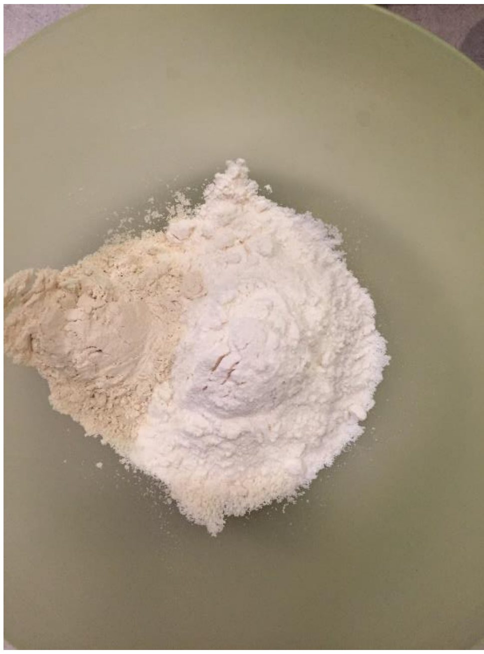
The costs for the experiment are approximately as follows (prices from Winco Foods online catalog[3]):

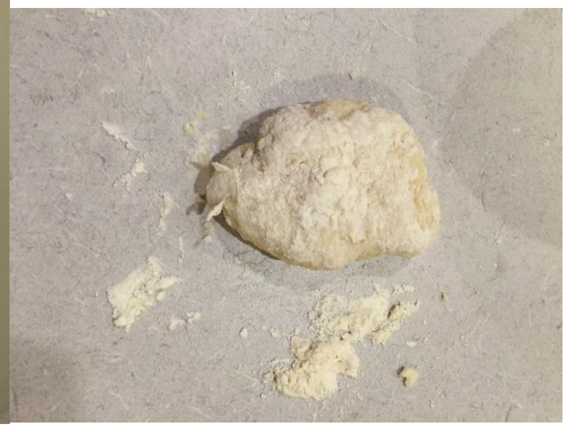
●White Flour: $0.40 /lb

●Vital Wheat Gluten: $2.70/lb

●Salt: $0.68/lb

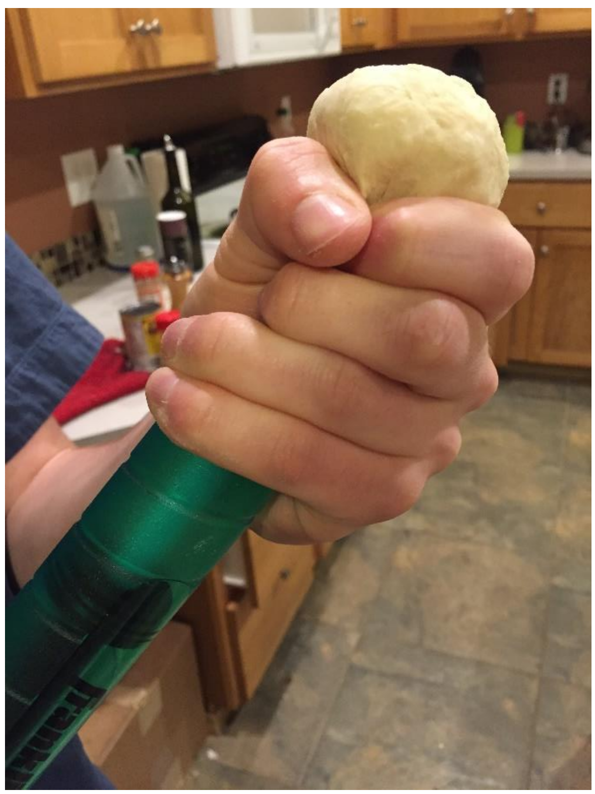
Additionally, a ball pump can be purchased for approximately $10 at any supermarket or sports supply store, and a rolling pin for about 5$ (any cylindrical object will do in a pinch). One experiment will use approximately $.03 of flour, $.04 of gluten, and less than $.01 of salt. This means this experiment will cost about $2.50 per 30 kids, with the additional one-time investment in a pump and rolling pin.





(Fig 1: Unmixed flour and gluten)

(Fig 2: mixed dough with flour on surface for kneading)



(Fig 3: Dough sealed on the pump)

Results and Discussion:

The ideal results of this experiment should be that higher gluten content and more kneading should correlate to larger balloons. This correlation is the basic idea that is supposed to be communicated through the experiment. While this whole experiment can appear somewhat banal, the novelty of making balloons out of such strange materials as well as the aspect of competition have made this experiment plenty engaging for everyone who has tried it.

The one aspect of this experiment that could still use some refining is the non-white flour with essential wheat gluten mixture. These flours did not perform very well even with lots of gluten added. One hypothesis is that the grains tested are simply too bulky for the gluten to hold together very well. Still, only two low-gluten flours (barley and buckwheat) have been tested, so further testing is needed on less coarse grains before any definite conclusion can be reached.

The only real chemistry or rheology that should be explained to an elementary school audience (the real target audience for these experiments) is that gluten forms long, stretchy strands that you unwind as you knead the dough. The idea is not for the students to understand the chemical capabilities of these polymers, and more for them to experience the “magic” of interesting physical phenomena to support a desire to continue to learn about chemistry and physics.

Conclusion:

Overall, this experiment is a fun hands-on way for children (or adults) to gain some intuition into the purpose and function of gluten in bread doughs. For an older audience, this demonstration also displays the rheological capabilities of different polymers, as these doughs have significant viscoelastic properties. While the target audience, elementary school students, is unlikely to understand any of the chemistry, it will still provide a hands-on experience to help understand why bread dough works the way it does.

Works Cited

1: Weiser, Herbert. "Chemistry of Gluten Proteins." Food Microbiology 24.2 (2007): 115`-19. ScienceDirect. Web. 11 May 2016.

2: Reuben, Bryan, and Tom Coultate. "On the Rise." On the Rise. Royal Society of Chemistry, n.d. Web. 11 May 2016.

3: Bulk Items. Winco Foods, n.d. Web. 15 May 2016. <http://wincofoods.com/departments/bulk-foods/items/>