Curriculum Units by Fellows of the Yale-New Haven Teachers Institute
2020 Volume II: Chemistry of Food and Cooking

The Chemistry of Playdough

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Introduction

This five-lesson unit was designed to introduce elementary students to the basic chemistry behind making playdough as they take on the role of a chemical engineer and endeavor to develop a process (or recipe) for making playdough. In addition, it will inject a fundamental knowledge of chemistry, and students will use the basis of this knowledge to improve consistency in producing high-quality playdough that is comparable to retail brand “Play-Doh” in texture, elasticity, and pliability. Along the way, students will learn the role of each ingredient and the reasoning behind each step of the process (mixing, kneading, and applying heat). There will also be room for experimentation as students explore the role of added ingredients and/or vary the preparation and cooking processes. Students will record their measured ingredients and procedures used for each batch of playdough in a chemical engineering journal and present their best final product to the class. The unit promotes an introduction to chemistry, engineering, and using an organized method to record notes and observations. Not only that, but making playdough is a lot of fun! Fair warning – students will be excited, and some results may come out sticky and messy! The unit is designed to take five one-hour long class sessions but can be extended or shortened at the discretion of the teacher.

I personally chose to develop this unit for use in my 2nd grade STEM class and was inspired by an “Engineering is Elementary” unit titled “Improving a Playdough Process.” That unit, however, was largely based on students gathering empirical evidence through collective experimentation and recording of results as they mixed the same amount of flour, water, and salt but in a different order each time. For example, trial one: 2 parts flour, + 1 part salt, mix, add 1 part water, mix again, knead dough. Trial two: 1 part salt and 1 part water, mix, + 2 parts flour, mix, knead, and so on. They would compare their results and decide which set of steps produced the best quality playdough. After several years of teaching that unit, I can attest that neither order of the process consistently produced a high-quality result. The end results often seemed anticlimactic and the students were left with little to no understanding as to why their dough was successful or not. This unit, the Chemistry of Playdough, will greatly expand on the chemistry behind each ingredient and each step of the playdough making process.

The Next Generation Science Standards (referred to as NGSS) in chemistry are non-existent at the elementary level, yet foundational concepts of chemistry come naturally to this kind of unit. However, the NGSS also include eight practices that do connect to this unit. The applicable practices include 1) Asking Questions and

Defining Problems, 2) Developing and Using Models, 3) Planning and Carrying Out Investigations, 4) Analyzing and Interpreting Data, 5) Using Mathematics and Computational Thinking, 6) Constructing Explanations and Developing Solutions, 7) Engaging in Argument from Evidence, and 8) Obtaining, Evaluating, and Communicating Information.

This unit was written based on the knowledge I have gained in the Yale New Haven Teachers Institute 2020 Chemistry of Food and Cooking seminar under the guidance of Yale chemistry professor Elsa Yan, as well as my own research, personal experiences and observations as a teacher who has been making playdough with students for years. Much of the background information in the next section is intended to inform and prepare the teacher – to bring you up to par with what I learned as both a teacher and a scholar. I have chosen to structure it in the form of a question and answer section about each ingredient and part of the process. Why do we use flour? Why do we add salt? Water? How do other ingredients, such as cream of tartar, affect the physical attributes of the dough? How does heat play a role in improving the solutions mixed into the compound?

The basic background information, as well as the specific questions, will all be integrated into the lesson plans that are taught to students. Therefore, the subsequent section, How to Teach This Unit, will provide a well-thought out and tested sequence of instructions to help students move beyond the gathering of empirical evidence and lead them to understanding the chemistry behind their observations. As each ingredient is introduced, a scientific explanation will also be included along with relevant demonstrations.

As explained above, my target audience is second grade, seven-year-olds. They have no knowledge of atomic structures, elements, compounds, etc. But they do love to make and play with playdough! This will be a foundational chemistry unit for them well before chemistry is formally taught in school. Yet, the process of making dough that meets certain characteristics is a very natural way to introduce chemistry-related concepts to the very young. Students will make a lot of playdough and record observations as well as rate their final product on a scale we define as a class (high quality, medium quality, low quality). High quality playdough will be stretchy but not sticky. It will be smooth to the touch and pliable enough to mold into a variety of shapes. It will bounce a little bit when dropped (a degree of elasticity) as well as can be stored in a sealed container without growing mold or becoming too hardened. After making basic salt-flour-water dough, students will learn through a mixture of demonstrations and experimentation as they test new ingredients, different types of flour, and different mixing procedures (including adding heat), to answer the question: How can I make high quality playdough that is as good as the store-bought version?

Background Information

What is Playdough (Play-Doh)?

A simple mixture of water, salt, and flour serves as the base for making a pliable modeling material that has been popular with children since the mid-1950s when a similar mixture was marketed under the brand name "Play-Doh." It was originally created as a wallpaper cleaner! This colorful, non-toxic, pliable putty continues to be a well-known toy still used in homes and schools today. According to the 2004 patent obtained by Hasbro, the current company that produces the retail version of Play-Doh, it is composed of "water, a starch-based binder, a retrogradation inhibitor, salt, lubricant, hardener, fragrance, and color. A petroleum additive gives the compound a smooth feel, and borax prevents mold from developing."[1] These additional ingredients set the retail version apart from the result that one gets just mixing proportioned amounts of flour, salt, and water. Homemade playdough rarely turns out as high quality of a modeling putty when compared to the retail brand, but it is possible. Children often enjoy the tactile experience of making shapes and models out of playdough. They like to cut it, mold it, roll it, and play with it. High quality playdough can be used in free play sensory centers, or as a tool for forming letters, numbers, shapes, or even models of animals, land formations, and building structures.

What is a Chemical Engineer?

"Chemical engineering is the branch of engineering that deals with chemical production and the manufacture of products through chemical processes. This includes designing equipment, systems, and processes for refining raw materials and for mixing, compounding, and processing chemicals to make valuable products."[2] In addition, according to the U.S. Bureau of Labor Statistics, "Chemical engineers apply the principles of chemistry, biology, physics, and math to solve problems that involve the use of fuel, drugs, food, and many other products."[3] Chemical engineers play a vital role in the growth and progress of a society and their reach and scope is vast. Some notable achievements of chemical engineering include parallel development of medicines such as vaccines, antibiotics, and dosed medications; energy resources such as the development fuels both petrol and non-fossil fuel based; the development of fertilizers to promote food production; water sanitization techniques and additives for clean, potable water; as well as the development of materials such as plastics and polymers.

As students learn the role of a chemical engineer, they will practice being chemical engineers by working on the problem of creating a high-quality playdough using a systematic process with recorded notes and observations.

What is Dough?

Dough is a thick, pliable paste made of flour derived from grains, legumes, or starchy vegetables and a small amount of water and/or other liquid. Many food products are made from dough, including breads, noodles, pasta, cookies, cakes, crackers, biscuits, pancakes, waffles, muffins, pies, tortillas, and so on. The process of making dough starts simply with a mixture of flour and water with additives such as salt, leavening agents (e.g., yeast or baking soda), sugars, oils, and fats. Depending on what you are trying to make, variations in ingredients and preparation methods will lead to different end products.

What is Flour and How is it Made?

Flour is a powder derived from finely ground cereal grains or starchy roots and vegetables (e.g., potatoes). Cereal grains are the seeds of grassy plants such as wheat, rye, rice, or corn to name a few popular varieties. When a cereal plant has reached the end of its life cycle, the leaves and stalk turn brown and seed production is complete. The seed or grain includes three parts: bran (the fiber rich outer skin), endosperm (the starch and protein rich food for the germ), and the germ (the part that will sprout and grow into a new plant).[4] These grains are harvested in large quantities and go through a milling process that includes purification (the removal of all foreign matter, husks, stems, and leaves). A variety of sifting technologies have developed over time to improve the purification process. The grains are then prepared for grinding by adjusting the moisture content of the grain to assist in separating the bran from the endosperm. Whole grains are ground using all parts of the grain, while refined flour is produced using just the endosperm. The bran and germ do have nutritional value, but the germ is especially removed to preserve the flour longer and prevent it from becoming rancid during storage and transportation due to oxidization of the polyunsaturated fats in the germ. Whole grain flours will last up to three months if stored in a cool, dry location, while refined flour can last a year. Refined flours lose most nutrients during the refining process, so refined flour is often "enriched" by having the iron and B vitamins (folic acid, riboflavin, niacin, and thiamine), and sometimes calcium and vitamin A, added back to the flour after the grinding process.[5] After the grains are ground to a fine powder through various grinding and sifting machinery, they are chemically bleached white often using bleaching or oxidizing agents such as benzoyl peroxide or chlorine gas. The bleaching process also gives the flour a finer, softer texture in addition to the whitening.

Each type of flour, depending on the source of the grain and how it is processed, has different nutritional values as well as cooking or baking characteristics.

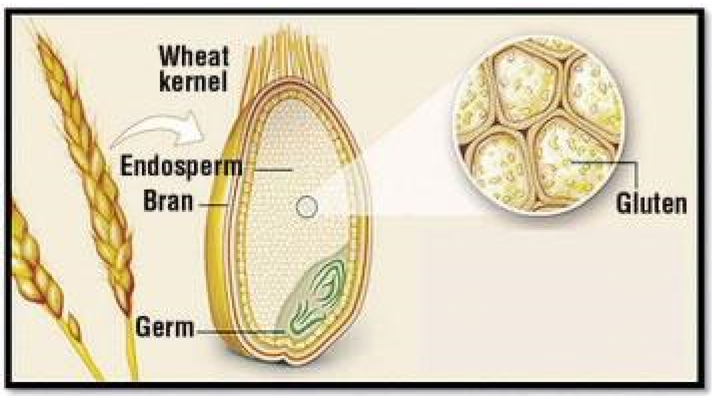


Figure 1 The internal composition of a grain of wheat.

What are the Differences between Various Types of Flour?

There are hundreds of varieties of flour, and wheat flour is one of the most prevalent. Protein content varies depending on the type of flour. High-protein wheat varieties (10 to 14 percent protein) are classified as "hard wheat", while low-protein wheat varieties (5 to 10 percent protein) are classified as "soft wheat." Higher protein correlates to more gluten in wheat flours. Some of the most common will be listed here, although this list is not comprehensive.

All Purpose Flour: Made from a blend of high gluten hard wheat and low gluten soft wheat. Wheat gluten levels can vary due to the season the wheat was grown, or by using different varieties of wheat. This flour is made only using the endosperm of the grain. All-purpose flour is refined and often enriched by having the stripped nutritional values added back at the end of the refining process. The protein content is 10% to 12%.

Wheat Flour: Made from the whole grain of wheat and has a higher nutritional and fiber content, but shorter shelf life. Often produces heavier breads. The protein content is like all-purpose flour at 10% to 12%.

Self-Rising Flour: This is all-purpose flour, but has salt and a leavening agent, such as baking soda added during the manufacturing process. Used as a convenience for baking without yeast, but not recommended for playdough due to the added ingredients.

Cake Flour: Made from soft wheat which has a higher starch but lower gluten levels. This produces a lighter, crumbly texture. The protein content is usually 5% to 8%.

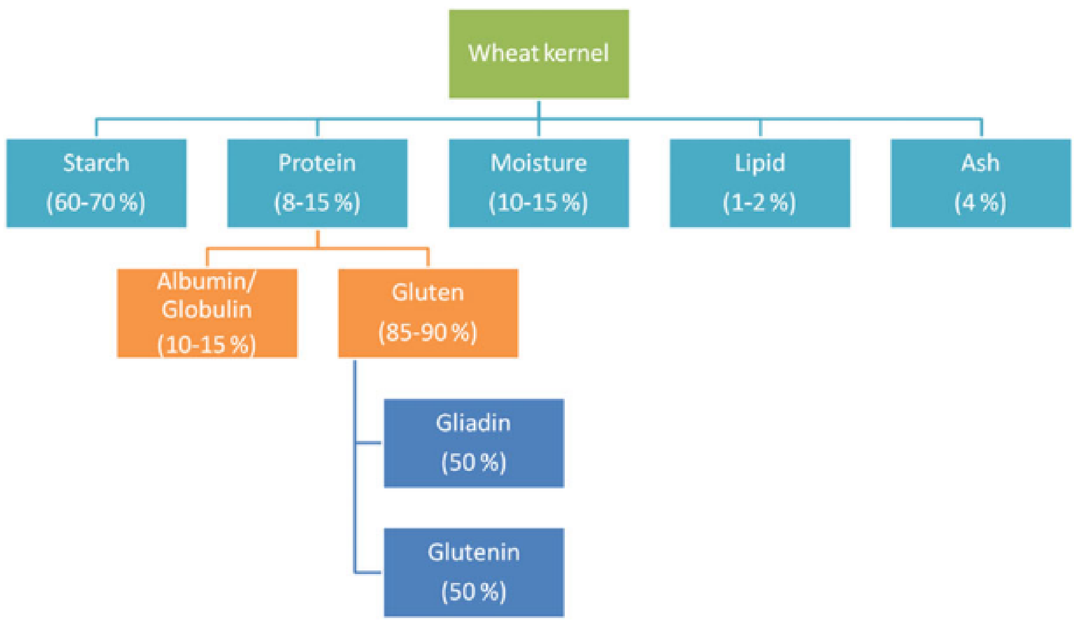
Bread Flour: Opposite of cake flour. Has a higher gluten level, but less starch and is made from hard wheat. The extra gluten helps trap carbon dioxide gas as the bread bakes, producing a tougher and chewier texture. The protein content is usually 12% to 14%.

Semolina Flour: Made from a coarsely ground, high gluten durum wheat variety and is used for making pasta.

Gluten Free Flours: Gluten free flours contain little to no wheat and are produced from other plants. Almonds, coconuts, peanuts, potatoes, rye, soy, oat, rice, and corn are a few examples of sources of gluten free flours. Gluten free flours may also be a blend of several non-wheat sources. Protein content for gluten free flours can vary depending on the source, with some varieties having as much protein as bread flour without the gluten.[6]

What are the Molecular Components of Flour?

"The wheat kernel contains 8%–15% of protein, of which 10%–15% is albumin/globulin and 85%–90% is gluten. Gluten is a complex mixture of hundreds of related but distinct proteins, mainly gliadin and glutenin. Different wheat varieties vary in protein content and in the composition and distribution of gluten proteins."[7]



Approximate breakdown of wheat components.

Figure 2 The composition of a grain of wheat broken down into starch, protein, moisture, and other components.

As you can see in Figure 2, most of the wheat grain is starch, protein (in the form of gluten), and moisture. The percentages vary depending on the variety and growing conditions of the harvested wheat.

What is Gluten?

Gluten is protein found in flour. It contributes to the elastic nature of flour dough in cooking. For example, making Asian noodles or bread calls for flour with high gluten content for the chewiness, while making cake calls for flour with low gluten content for fluffiness. Kneading can help gluten molecules align and stretch out in the dough such that a molecular network can form and improve elasticity of dough. Wheat-based flour, as you can see in Figures 1 and 2, contains two dominant proteins – Gliadin and Glutenin. When these two proteins encounter water, they bond together and change shape. This creates an elastic network called gluten. This gluten network can trap gases in the baking process. The more the gluten, the higher the protein content and the heavier the bread. In dough, starch molecules and gas bubbles, usually aided by a leavening agent like yeast or baking soda, causes the dough to rise.[8] In this unit, students will explore the gluten content of flour and see how it changes the texture and elasticity of playdough.

What is Starch?

The four classifications of carbohydrates are monosaccharides, disaccharides, oligosaccharides, and polysaccharides. Monosaccharides are simple, single monomer sugars that include glucose, fructose, and galactose. Disaccharides are a pair of monomers linked together by a covalent bond known as a glyosidic linkage and include lactose, sucrose, and maltose. Oligosaccharides contain 3 to 10 linked monomers, and polysaccharides contain more than 10 linked monomers. Starch is a polysaccharide, a polymer with a long molecular structure, and therefore can act as a binder to keep molecules together.[9]

Almost all types of green plants produce starch that serves as a storage for energy. Fruits, seeds, and tubers also store starch in preparation for the next growing season. When extracted, starch looks like a fine, white, semi-crystalline powder. It is also one of the major components in flour. Polysaccharides have a lot of hydroxyl (-OH) groups that can form hydrogen bonds with water, and therefore it can hold on to water molecules, keeping playdough moist.

Why Add Water to Flour to Make Dough?

Water is responsible for hydrating the starch, as well as hydrating the proteins to trigger the natural chemical processes in forming gluten. It is an essential ingredient in making dough, as without water these natural processes would not occur. In making playdough, one must carefully control the ratio of flour to water. Too much water will produce runny dough that will not hold its shape nor form gluten properly, while too little water will produce a sticky paste. Hydration levels are important in baking, and even the room humidity can influence dough quality even when consistently using the same proportioned measurements. For our playdough, humidity should not play a huge factor in the dough quality.

A baker's rule of thumb for dough hydration is around 65%. This means that the weight (more on using weight rather than volume later) of the water should be around 65% of the weight of the flour and other ingredients. For example, I used 200 grams of flour and 100 grams of salt, and 65% of that is 195 grams of water (I rounded up to 200 grams of water for the playdough in this unit). Some experimentation might be necessary here, as the type of flour and even the quality of water (hard or soft, any added minerals or chemicals) can affect dough hydration. Since we are not working with yeast or other leavening agents, it is okay to add a little more water or a little more flour to make minor adjustments. Making dough is a tactile experience (part of why children love it) and eventually you will be able to tell when the dough is ready because it will feel just right – not too sticky, not too dry, not too wet.

What is the Role of Salt in Dough?

Salt in the dough helps strengthen the gluten bond by affecting the electrostatic interactions. The gluten proteins naturally repel one another, but the chloride ions in salt help them overcome that repulsion and stick together. This results in a dough that is less sticky or tacky. Salt also plays a beneficial role in preventing or reducing the growth of mold, therefore acting as a preservative.[10]

How Does Heat Affect the Formation of Dough?

Heating, or cooking, the dough will help the physical and chemical processes be faster and more complete. Starch becomes soluble in water when heated. When the granules swell and burst, the semi-crystalline structure is lost and the smaller amylose molecules start leaching out of the granule, forming a network that holds water and increasing the mixture's viscosity. This causes the starch to gelatinize. Heating provides the additional energy to make insoluble grains of starch soluble in water. There are plenty of “no cook” playdough recipes to be found online, some use heated water. Others rely on a lot more mixing and kneading. In my experience, I have found the “no cook” playdough recipes to be less reliable when making (often too runny or too firm) as well as produce an inferior playdough (too grainy or does not last as long).

Why Do We Knead the Dough?

Kneading the dough is a process that involves massaging, stretching, and folding the dough to create a strong gluten matrix. When the dough ingredients are first mixed, the proteins are mangled and knotted in no particular order. But as the dough is kneaded, the proteins line up to form long chains of gluten molecules, creating a matrix within the dough itself. The process of kneading helps combine the ingredients as well as improve the gluten matrix.

Why Do We Add Cream of Tartar?

Cream of Tartar (it is a white powder, not a cream) is an acidic compound that grapes produce as they ferment. It is often used in baking as a leavening agent when combined with baking soda to produce carbon dioxide bubbles. In fact, baking powder is a mixture of baking soda and cream of tartar. It is slightly acidic, and because of this, it affects the gluten structure of the playdough to make it more elastic. Tartaric acid acts as an emulsifier, so it helps prevent any added oil from separating. It also prevents the salt from crystalizing, resulting in a smoother, softer playdough. I have found this to be an essential ingredient to make long-lasting, brand quality playdough. If cream of tartar is unavailable (usually found in grocery store spice section), baking powder or 2 teaspoons of lemon juice might be a fair substitute.

Why Do We Add Oil to the Dough?

Adding a small amount of oil to the dough reduces elasticity of the gluten by restricting longer molecule development, but it also improves the moisture-retaining properties of the playdough. I find adding a small amount of oil produces better overall playdough that is less sticky, yet still more elastic than playdough made without cream of tartar. Any oil will do, but I prefer a scented lavender oil as this gives the playdough a nice fragrance.

Measurement Tips

While it is common to measure dry and liquid ingredients by volume, such as cups or liters, I have found that it is far more accurate to base measurements on weight. I use an inexpensive postal scale that can display weight in grams. Having students use measuring cups is a good practice, but there can be a great deal of discrepancy between any two or more student-measured cups of flour, usually due to air pockets and how well students packed down the flour. Measuring by weight eliminates this problem and is far more accurate.

What is My Favorite Playdough Recipe?

If you search the internet for playdough recipes, you might find hundreds of variations – many claiming to be the best. My favorite recipe does involve cooking the playdough, even though that may seem daunting to do with a class of first graders. With a simple hot plate, saucepan, and appropriate precautions and safety discussion, this should be a low-risk activity that will also greatly excite and interest your students.

My favorite recipe:200 g flour (about 2 cups)100 g salt (about 1 cup)200 g water (about 1 cup, add food coloring to water)10 g Cream of Tartar (about 2 teaspoons)10 g Lavender Oil (about 2 tablespoons)

Simply mix all ingredients together over medium heat. Stir constantly, insuring dough does not burn on bottom of pan. After five to seven minutes of stirring what seems to be a soup, the dough will rapidly begin to coalesce. Eventually you will have a ball of dough stuck to the spoon. Keep stirring until almost all the dough has separated from the pan and let cool for a few minutes. While it is still warm and soft, knead the dough to help form a strong gluten matrix and nice, stretchy playdough.

Teaching Strategies

This unit relies on demonstrations, student-led experimentation, and careful recording of results. While the goal for students is to make the perfect playdough, the science goals for this unit are heavily steeped in the NGSS Practices. The applicable practices include 1) Asking Questions and Defining Problems, 2) Developing and Using Models, 3) Planning and Carrying Out Investigations, 4) Analyzing and Interpreting Data, 5) Using Mathematics and Computational Thinking, 6) Constructing Explanations and Developing Solutions, 7) Engaging in Argument from Evidence, and 8) Obtaining, Evaluating, and Communicating Information. There are no chemistry standards for 2nd grade.

The unit is divided into five one-hour long sessions. The first three sessions will include teacher/student discourse about the topic along with a demonstration. At the end of each demonstration, students will repeat the demonstration by making the same thing. The final two sessions will allow for greater, student-led experimentation. In the end, students will evaluate their final products, discuss their results with other classmates, and come up with a class consensus for the best process for making playdough. Students will be encouraged to record each process and evaluate the playdough according to a class established rubric.

My Experimentation Results

I conducted several experiments to research this unit. These experiments can be repeated in a class setting.

Figure 3 This is the 40g gluten mass I extracted from 200g of all-purpose flour and 50g of water.

Gluten extraction demonstration: For this experiment, I wanted to see if I could extract the gluten from flour by rinsing away all the starch. I started with 200 g of flour and 50 g of water – enough to make a ball of dough. After kneading the dough, I rinsed it under cold water for about ten minutes, making sure to massage out as much starch (cloudy white in water) as I could. The result was a 40 g mass of gluten. It resembled semi-dried glue. It was stretchy and elastic yet would tear if pulled too far apart. Torn pieces were reabsorbed into the mass of gluten with a little bit of kneading. The first experiment was with all-purpose flour, and it produced the 40 g gluten mass. The second trial was with gluten-free coconut flour, and it did not produce any gluten. All the flour just rinsed away. This would be a good demonstration to record on video and share with the class.

Figure 4 Playdough produced by gluten-free coconut flour, pastry flour, bread flour, and all-purpose flour.

Types of flour: In this experiment, I created a basic playdough using 200 g flour, 100 g salt, 200 g water. The three ingredients were mixed under medium heat in a saucepan. When the soupy dough congealed, and formed a solid mass of playdough, I let it cool for 5 minutes and then kneaded the dough for 5 minutes. The only difference was the type of flour I used. Batch 1 used all-purpose flour, batch 2 used bread flour (highest gluten potential), batch 3 used pastry flour (lowest gluten potential), and batch 4 used gluten-free coconut flour. The first three batches turned out remarkably similar, with no noticeable differences. The 4th batch, gluten-free, did not produce a playdough. I could see the coconut flour absorbed the water, but it was fluffy yet still dry to the touch. My recommendation based on these results is to just use the cheapest all-purpose flour. The differences in gluten levels did not seem to matter too much unless it was gluten-free. Unfortunately, without the added ingredients of cream of tartar or oil, these batches of playdough became very sticky after two days of sitting out.

Added oil: Following the same recipe for playdough as above, I also added 10 g (about 2 tablespoons) of vegetable oil (although any oil, especially scented lavender oil, will work). The result was a softer, smoother texture. After two days of sitting out, this batch was still pliable and not sticky like the other batches.

Added cream of tartar: I also created a batch with an added 10 g of cream of tartar. The result was a smoother playdough that was much more elastic and only slightly sticky to the touch. After two days of sitting out, this batch was still pliable and not sticky like the batches without oil.

Added oil and cream of tartar: Finally, I created a batch following the same steps, but this time added 10 g of oil and 10 g of cream of tartar. While the result was like the batch with just cream of tartar, it was slightly less sticky to the touch and a bit less elastic. After two days of sitting out, this batch was still pliable and not sticky like the other batches. This was my preferred version.

Figure 5 All samples prepared for two days of storage, both inside and outside of a plastic bag.

Classroom Activities

Each session is timed for approximately one hour. Although I have written these sessions while trying to maximize student involvement, I have found that it is also feasible for the teacher to do the demonstration one day (or have it prerecorded) and have students make the playdough the next day. By planning each session to be about one hour, I anticipate you can adapt it to your schedule.

Session 1: Begin by introducing the role of a chemical engineer. There are several YouTube videos available on the subject that are student friendly. Then take out and show them a fresh can of Play-Doh. Discuss how chemical engineers wanted to create a fun type of clay for kids to play with that was soft, stretchy, and strong enough to mold into shapes. They also wanted it to be easy to extrude, or squeeze through, molding machines that could make shapes, grow Play-Doh hair in plastic figures, mold pretend food, etc.... Showing an old Play-doh commercial would be appropriate here.

After about 15 minutes of the above introduction, demonstrate making a batch of playdough from flour, water, and salt. Use my favorite recipe, mentioned earlier in the unit, but do not add the cream of tartar or oil yet. Those will be saved for future experiments. You will also be modeling how to weigh your ingredients on the scale. Stress making careful measurements. After the demonstration, which should take 15 minutes, have students work in small groups or pairs to make a batch just like you demonstrated. If you prepare materials in advance, it should take them 30 minutes to make their own batch. Record the ingredients used (including measurements) on chart paper for batch 1. I recommend making these student batches the same color. It will be easier to compare them to other batches and students will get a chance to choose their own color later in the unit. Label and save each student product in a plastic bag.

Session 2: Compare saved playdough to store bought Play-Doh. Discuss that materials have properties that we can use to describe them. Play-Doh is soft, stretchy, cool to the touch, smells nice, can be sticky, dry, or brittle when dried out. Set a goal to make the perfect playdough. Develop a rubric together based on important characteristics such as texture, elasticity, stickiness, etc.... It should look something like this:

Batch #	Sticky	Stretchy	Soft	Able to make shapes	Overall rating
1	Very Sticky A Little Sticky Not Sticky	Very Stretchy A Little Stretchy Not Stretchy	Very Soft A Little Soft Not Soft	Yes No	
2					
3					
4					
5					

Demonstrate a second batch, using a different color, but this one includes added oil. During the demonstration, discuss the definition of molecules and how the oil shortens the molecule chain, making the dough a little less stretchy, but also helps retain moisture and slows the drying out process. As before, have students replicate your example. Save the final product in labeled plastic bags. Update the chart paper for batch 2, and add scores based on the rubric for the first two batches made.

Session 3: In this session, discuss how scientists feel it is important to track their progress and record results.

Now that students have made two batches of play dough, we need to record the step in our own notebook. Refer to the chart paper you have recorded notes on in class. Students can create their own note format, or you can create a copy for them. It should look something like this:

Batch #	Amount of flour	Amount of salt	Amount of water	Amount of oil	Amount of Cream of Tartar	Notes
1	200 g	100 g	200 g	0	0	
2	200 g	100 g	200 g	10 g	0	
3	200 g	100 g	200 g	10 g	10 g	
4						
5						

Once the notebooks are updates, continue with your 3rd batch – this time adding Cream of Tartar. Explain that Cream of Tartar is slightly acidic, and because of this, it affects the gluten structure of the dough to make it more elastic. Tartaric acid acts as an emulsifier, so it helps prevent any added oil from separating. It also prevents the salt from crystalizing, resulting in a smoother, softer playdough.

As before, have students make batch 3 with added oil and Cream of Tartar and record their ingredients used and rate the final product according to the class rubric.

Sessions 4 and 5: The last two sessions are for students to make 2 or more additional batches of playdough but allow them to modify one ingredient at a time. For example, they may elect to use 50 g of salt instead of 100 g, but all other ingredients remain the same. My advice is to have students work in pairs and decide on the modified ingredient as a class. Then have each pair of students follow the same recipe. This is a good time to emphasize the scientific methodology of having only one variable in an experiment and repeating the experiment several times. Be open to different ideas (within reason). Maybe students will want to try a different type of flour or oil instead of modifying the amount of an ingredient. Whatever they decide, the ingredients and rating should be included in their notebooks.

During these sessions, it may be interesting to model the gluten extraction as detailed in the beginning of the teaching strategies section of this unit. It does take about 15 minutes, so doing a live demonstration may not be appropriate if students are eager to work. I recommend introducing the idea live, then have a recording of the process to show, followed by a chance to see the extracted gluten ball in person. It will keep for a few days but trust me – if you leave it out too long (more than a few days without refrigeration) it will rot and smell horrible!

Students at this age will learn the role of a chemical engineer and how to conduct and record experiments by doing the activities. To teach chemistry concepts, I recommend integrating discussions about mixtures and solutions, atoms, and molecules in addition to the chemistry of gluten and starch that is related to dough. Much of the content provided in the background information can be taught to students through discourse as they are discussing how to make playdough.

I initially taught this lesson to 2nd grade students, and once we had perfected a recipe for playdough, I had a small group take on the challenge of providing playdough to the play-based learning centers in our kindergarten classes. My group of students took orders from the kindergarten students and were thrilled to deliver the playdough they made to the kindergarten classes. I also gave my students a copy of the recipe to take home, and many excitedly reported making their own batches of playdough at home.

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Appendix on Implementing District Standards

As mentioned in the introduction to this unit, there are no chemistry standards for 2nd grade. In fact, chemistry standards do not come along until 6th grade. However, this unit was designed for introducing chemistry to younger students and is aligned with the NGSS Science and Engineering Practices. There are eight practices, and this unit aligns with six of them. Two of the eight practices, Analyzing and Interpreting Data and Using Mathematics and Computational Thinking do not necessarily apply to this unit. The applicable practices include:

1) Asking Questions and Defining Problems. This unit is guided by the question “How can we make the best playdough?” and from there, many more questions will arrive. The problem students are asked to define is built into the main question.

2) Developing and Using Models. Students will be creating a process for making playdough. This process, while in cooking is a recipe, is what students are developing.

3) Planning and Carrying Out Investigations. Students test different ingredients and, under careful teacher guidance, form an investigation to determine the results of each added or modified ingredient.

4) Constructing Explanations and Developing Solutions. Students gather empirical evidence based on their experimentation to determine the best process for making playdough.

5) Engaging in Argument from Evidence. Students can argue the effectiveness of each ingredient based on evidence they collect from individual experiments and comparing their results to those of other students.

6) Obtaining, Evaluating, and Communicating Information. After determining the best process for making playdough, I have students share their findings with younger classes and make playdough for them. It is an exciting way to communicate results.

Endnotes

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