



Rising to the Occasion: How Yeast Transforms Food

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Introduction

As a fifth-grade teacher at Miles Jones Elementary School in Richmond, Virginia, I enjoy the experience of working in a classroom in which I teach all subjects. The students I work with come from an urban environment and much of the school population consists of Black or Hispanic students. Last year, out of the school's 505 students 54% of students were Black while 40% of students were Hispanic. This provides my classroom with students that have different cultural backgrounds that lead to interesting learning and growth experiences.

As most schools in Richmond are, Miles Jones is a Title 1 school receiving financial support for the majority of students as most come from low-income households. This can bring varied elements of economic, social, and emotional strengths and weaknesses into the classroom depending on that student's background. The goal in fifth grade being end of year success in understanding of English, Math, and Science.

This planned unit aligns with the understanding that achievement in these subjects is the ultimate goal. The use of yeast in pizza dough making gives students a diverse way to investigate scientific inquiry by giving them opportunities to not only observe but also work on hands-on experiments that help make science come to life. By the end, students will have a practical understanding of how yeast works while also introducing them to the art of baking and how one of their favorite foods is created.

Rationale

At present time, the consumption of food not prepared at home is at a high rate. This can be attributed to the vast number of options of prepared foods or even groceries delivered to homes. Since the Covid-19 shutdowns, these services have become not only a convenient way to get food but for some households a lifeline as time to cook or prepare a meal may be little to none. This means students may have little to no exposure to how food is prepared or cooked or even what ingredients are present in their food and where it can be procured.

My plan for this unit is to use pizza creation as an engaging way to explore properties of matter, mixtures and solution, and property changes in matter both physical and through chemical reactions. All of these topics connect directly with the Virginia 5th grade standard 5.7 “The students will investigate and understand that matter has properties and interactions.” The goal of these units is to have students immerse themselves in authentic scientific investigation by connecting biology and chemistry to a food that not only students recognize but the majority of them enjoy. This will hopefully increase participation but also curiosity of scientific concepts and the culinary arts.

Using the picture book “Fungus is Among Us” by Joy Keller, students will be given a background of the different types of fungi and how yeast falls into that family and can be used in baking. Once background knowledge has been gained, the unit will focus on the chemical reaction of yeast and pizza dough creation. Students will design experiments to explore how variables such as water temperature, type of sugar, and the amount of sugar can affect the fermentation of the chemical reaction and the rate in which yeast reacts. Through the experiments, students will record their observations, collect quantitative data, and write evidence-based conclusions. The dough-making process also provides a great opportunity to review mixtures and solutions as students observe sugar dissolving in water and ingredients coming together to make a new substance with different properties.

When students make their conclusions, they will finally get to eat their experiments, with an optional end of unit pizza party. While the method of cooking these pizzas will be up to what the teacher and school has on hand regarding cooking elements, I will be including two possible options. One uses a toaster oven while the other uses a hot plate and a pan with instructions in the activity of temperatures and times for each. Ultimately, the hope is that students leave the unit not only with a stronger understanding of the properties of matter and reactions but also a newfound interest in cooking and how science connects with it.

Background Content

History of the Use of Yeast in Breadmaking

Yeast has been used to help with the leavening of bread for thousands of years at first incidentally and then throughout time more purposely as people started to realize what was occurring. Breadmaking has not been the only use of yeast by people throughout history as it has also been used in the making of alcoholic drinks as well. Through this background you will see the connection these beverages have with the evolution of breadmaking. But to understand how yeast has been used throughout history, we first have to answer the question: What is yeast?

What is Yeast?

Yeast is a single-celled living microorganism that falls under the fungi kingdom. Yeasts are considered eukaryotic microorganisms, meaning their cells have a nucleus containing their genetic material, not so different from human or animal cells.[1] Unlike humans and animals, however, yeasts reproduce asexually through a process called budding, a process where a new cell forms an outgrowth from the parent cell.[2] The most known species of yeast is *Saccharomyces cerevisiae*, also known as baker’s or brewer’s yeast.[3]

Yeasts feed primarily on simple sugars such as glucose and fructose and break them down to harvest energy.

This process can occur in two ways: aerobic respiration and fermentation. Aerobic respiration is the process of yeast digesting sugars when oxygen is present, allowing carbon dioxide and water to be released. Over time oxygen levels will drop and the process of fermentation begins, now releasing alcohol and more carbon dioxide as sugars are broken down.[4] This fermentation process is what people have used to make beer and wine and eventually leavened bread. In bread, as carbon dioxide is produced it gets trapped within the dough, creating air bubbles allowing the bread to rise. While this unit will be focusing on baker's/brewer's yeast, there are nearly 1,500 species of yeast.³ These species range from ones that can cause infections in people to others that can be quite beneficial, aiding in production of life-saving medicines and even biofuels.[5]

When was yeast added to bread?

Bread has been a staple in the human diet for hundreds of generations, but it was not until later that yeast was brought into the fold when making bread. The consumption of flatbread can be dated back to the late Stone Age in parts of the world where grains were part of the main diet.[6] It was not until the Egyptians, around 400 BCE, we found evidence of leavened breads.⁶ However, this was not the process of intentionally adding yeast like we do today. Instead, it was wild yeast in the air that would infect and feed on the sugars of a dough that was left out. As time passed, bread makers began to use leftover pieces of dough, where yeast was already present, to help raise new dough. Yeast production had become so important that even became a specialized profession in Egypt by 300 BCE.⁶

When did pizza come into the fold?

Pizza originated from Italy in the city of Naples as a working-class food that could be quickly eaten and was inexpensive. The word "pizza" is closely related to "pita" and has been referred to as such going back to the tenth century.[7] Neapolitan pizza uses a round yeast-raised crust that is stretched thin in order to make it have both a crisp and chewy texture. The crisp comes from the high temperature cooking in traditional brick ovens, and the chew comes from the gluten development when making the dough. A simple pizza at the time would have been topped with tomatoes, olive oil, garlic, and oregano.⁷

The more widely known "Pizza Margherita" was created for Italy's Queen Margherita for her visit to Naples in 1889.[8] The three toppings consist of white mozzarella cheese, red tomato sauce, and green basil giving an homage to the Italian flag. Pizza would eventually make its way to North America via Italian immigrants between the late nineteenth and early twentieth century, creating the now popular "New York Style" pizza.[9] Fast forward to present time and pizza has become one of the most popular foods eaten in the United States.

It All Starts with the Dough

While pizza making techniques can be difficult to master, the actual dough itself, that is the base of this popular food, is made with few and easily accessible ingredients. A standard pizza dough consists of flour, water, salt, sugar, and yeast with the option of including a fat such as olive oil for flavor. What can be overwhelming for some people new to pizza making is in the options of those ingredients, specifically the type of flour and yeast as there are quite a few options which will yield different results.

Choosing a Flour

In pizza making, there are three different types of flour that can be used, and all have their own place depending on what a person will be looking for in the final product. Those flours are 00 flour, bread flour, and all-purpose flour. The differences in these flours are found in their protein content. For the use of the activities

in this unit, we will be using bread flour. But to understand why, we should look at each type of flour and what sets them apart.

00 Flour is the traditional flour used when making Neapolitan style pizza. A flour of this type has a protein content that ranges from 11-12 percent.[10] This higher protein content means the flour will absorb more water than a low-protein flour, which will result in a stronger gluten network in the dough. Unfortunately, due to how fine this flour is milled, 00 flour needs a high temperature cook that would require a pizza oven for the best result.[11] Meaning this flour would not be the best option for the activity in this unit.

All-purpose flour is the most commonly known of the three flours and is a staple in most people's homes, and it can be used for a vast amount of baking products. This flour has a lower protein content ranging between 7.5-9.5 percent.¹⁰ This means it will absorb less water and make a dough that does not have as strong of a gluten network as higher protein flours. Because of the low protein content, this flour is not the best for doughs that need to rise because there will be less gluten present to capture the carbon dioxide being given from the yeast. That said this dough can be used for same day pizza dough but again will not give the best result for our application.

Bread flour, as in its name, is typically used for bread and other baked products that require leavening. This is because of the higher content of protein present, ranging from 12-13 percent.¹⁰ Similar to the 00 flour, this higher protein content leads to a higher absorption of water which creates a stronger gluten network in the dough leading to a chewier final product. More gluten means more carbon dioxide being captured from the yeast, resulting in a higher rise in the dough, making this the flour of choice for the activities in this unit.

What is Gluten?

The weight of flour consists primarily of starch, but a small percentage of proteins are also present. That percentage, as you saw in the previous section, varies depending on the type of flour. It's these proteins that are the makeup of gluten. When the proteins are in their dry state, they are inactive but when given water they can change shape and form and break bonds with one another.[12] Most of the gluten proteins consist of gliadins and the glutenins. The gliadin chains fold into themselves, creating weak bonds with other gliadin and also with glutenin proteins, while the glutenins bond with each other to create a vast tight network.[13]

On the end of these chains are sulfur-containing amino acids that can have strong sulfur bonds with the other end of glutenin chains, while the coiled middle includes weaker bonds, such as hydrogen and hydrophobic bonds. These chains link end to end to form chains that can reach a few hundred glutenins long, and the coiled segments stretch to form temporary bonds with other gluten proteins, ending in a connected network of coiled proteins known by its more common name, gluten.¹³

Is that why the dough is so stretchy?

The gluten present in dough has both an elasticity (glutenin) and plasticity (gliadin) to it.¹³ This causes dough to change shapes with given pressure and allow it to resist and come back to its original shape when there is no longer pressure. These properties are what enables dough to expand when carbon dioxide is created from the yeast but not get too thin and break during the rising process. The gliadins, because they are compressed, let parts of the glutenins slide past each other without creating bonds which gives gluten in plasticity, while the elasticity comes from the kinked and coiled structure of the chained gluten proteins.¹³

When a dough is kneaded, it unfolds and realigns the proteins, but there are still loops present along their

chain links. Once the dough is stretched, the loops and kinks are straightened out, but once the pressure of stretching is discontinued, the molecules revert to how they were.[14] This is why in the activity in this unit it is important to let the dough rest before attempting to stretch it.

Why does the dough need to rest?

If you have even attempted to make anything with dough, you may have noticed how difficult it can be to stretch or create a desired shape right after kneading. This is because of the elastic characteristics of wheat flour doughs, but luckily if dough is given time to rest, that elasticity will relax over time. But how does this happen?

It comes back to the protein molecules; in a well kneaded dough, the protein molecules have been aligned and created many weak bonds. With so many bonds, proteins hold firm and resist being stretched creating a firm dough.¹⁴ This is why in pizza making bakers bring the dough together into a taut dough ball before resting. This physical tension of the ball shape slowly breaks some of the bonds because they are weak, allowing the structure to relax into a much more malleable dough.

Can We Control How Strong Gluten is?

Gluten strength can absolutely be controlled because not all baked goods benefit from a strong gluten network. While a strongly bonded elastic gluten is great for yeast-leavened baked goods, it would lead to undesirable toughness in other forms such as cakes and cookies, where a more tender product would be desired.¹⁴ There are quite a few ingredients and techniques bakers use to control the bonded strength of gluten, one of which was covered earlier in this unit when discussing the different types of flour. Some others include:

- Oxidizing substances (aging and improving substances) can increase the end-to-end linking of the glutenin, making the dough's gluten network stronger.¹⁴
- The amount of water in the dough can influence how concentrated the gluten proteins are and how much they can bond to one another.¹⁴ Less water leads to a crumbly texture while more gives the dough a softer moister feel.
- Kneading (the process of pressing and folding dough into itself) can also affect the elastic network for the gluten proteins as the more dough is kneaded the stronger the network.^[15]
- The presence of salt can strengthen gluten greatly; this is because the positively charged sodium and the negatively charged chloride ions cluster the charged glutenin proteins. Preventing those charged parts from repelling each other lets the proteins come closer together to form a stronger bond.¹⁵
- Sugar at a concentration of 10% or more of the flour weight can limit gluten development caused by its dilution of the proteins in the flour.¹⁵
- Fats can weaken gluten as well because it will bond to the hydrophobic (water fearing) amino acids along the protein chains preventing them from bonding to each other.¹⁵
- Last, acidity can weaken a gluten network by increasing the amount of positive charged amino acids running along the protein chains and increasing the repulsive forces between the chains.¹⁵

Why Does Yeast Work in Pizza Dough?

It all comes down to gas bubbles; this is what gives leavened doughs their light texture. Bread products such as pizza can be aerated to the point where as much as 80% of their volume is empty space.¹⁵ These bubbles weaken the gluten network and starch and divide dough into millions of thin delicate sheets where gas can be

captured.

It's a bit of a misnomer that yeast or other chemical leaveners are creating gas bubbles while dough is rising. These ingredients don't create new bubbles. Instead, the carbon dioxide released from them is captured and enlarges the tiny bubbles that already were there. These bubbles were created when the dough was kneaded and air was introduced. The more bubbles produced when the dough was prepared, the more tender the final product.[16]

The Chemical Reaction of Yeast in Dough

As overviewed earlier in the history of yeast section, people have been using yeast to leaven bread for thousands of years. People have used its production of carbon dioxide to add gas to help dough rise, but now we should dive deeper into the science that causes this to happen. The source of the yeast producing gas comes in its metabolism of sugar. When yeast metabolizes sugar for energy, it produces carbon dioxide gas and alcohol as by-products. This is considered a chemical reaction because the sugars are broken down into entirely new substances.

The chemical equation of this process that takes place in the yeast is: $C_6H_{12}O_6 \rightarrow 2C_2H_5OH + 2CO_2$ (1 molecule of glucose yields 2 molecules of alcohol plus 2 molecules of carbon dioxide).¹⁶ During the dough making process, both carbon dioxide and alcohol are trapped within the dough and only released by the heat of the baking process.¹⁶ In an unsweetened dough the yeast will feed on the glucose, fructose, and maltose which enzymes in flour naturally produce from the broken-down starch.¹⁶ A small amount of sugar added (like what will be added in one of the activates) will increase the yeast's reaction. Only a small amount will be added as if too much sugar is added it will decrease yeast activity as salt does.

The chemical reaction in yeast can also be aided by temperature. The cells grow and produce gas the best at about 95 degrees Fahrenheit or 35 degrees Celsius.¹⁶ Not only is the yeast producing gas to help the dough rise but also several other chemicals that affect the dough's consistency through strengthening the gluten network but also the taste of the baked good. But there is not only one form of yeast for baking and choosing the correct one (like flour) is important for having the best result in the final product.

Choosing a Yeast

When choosing a yeast for baking, there are three common forms: compressed yeast, active dry yeast, and instant dry yeast. Each of these forms is a different genetic strain of *Saccharomyces cerevisiae* just with different traits.¹⁶ Let's explore each to help understand which will be the best for the application of pizza dough making.

- Compressed yeast is a moist block of fresh and alive yeast cells and produces the most leavening gas of the three forms.¹⁶ Unfortunately, because it is fresh that also means it is perishable and must be kept refrigerated and even then, has a very short shelf life of one or two weeks. Which makes it not a great option for the use of this unit's activity.
- Instant dry yeast is dried quickly and in the form of small porous rods that can take in water faster than active dry yeast. This means this yeast does not need to be presoaked before mixing with other ingredients and produces carbon dioxide vigorously.¹⁶ While this sounds great, this quick rise can cause structural concerns which can lead to stretching issues once the rise is over.
- Leaving active dry yeast as the best option for pizza making. This form of yeast is dried into granules with a protective coating of yeast debris that allows the yeast to stay dormant and can be stored for

months at room temperature.¹⁶ When ready to be used the yeast is soaked in warm water before mixing the dough to bring it out of its dormant state. Because it ferments slower than the other two forms, it makes the dough much easier to handle and helps fill in gas bubbles more uniformly.

Pizza Dough: Mixture or Solution?

To answer this question, we must first establish what a mixture is compared to a solution. A mixture is a combination of two or more substances that come together while keeping their own physical properties.^[17] Mixtures can fall under two categories: heterogenous or homogenous. In a heterogeneous mixture, the product is not uniform throughout, and sometimes the substances making the mixture can be recognized by the eye.¹⁷ Examples of this can include salad, cereal and milk, and chocolate chip cookies. This is compared to a homogenous mixture which is uniform and has no differences in makeup throughout.¹⁷ Examples of this include coffee, steel, and air.

Homogenous mixtures can actually be further classified as solutions. Solutions are made of particles the size of a small molecule.¹⁷ The example of air would fall under the definition of a solution because of its small gas molecules. Pizza dough would fall under the categorization of a heterogenous mixture. This is because the ingredients of flour, yeast, salt, and water are not dissolved at a molecular level and keep their individual physical properties.

What are the important things to look for when making pizza dough?

Making a pizza dough can look intimidating on the surface. You walk into your favorite pizza parlor, and you see the worker in the back with flour everywhere and throwing dough into the air with no effort. Making it seem that this is something that the average person cannot do at home or in a classroom. It is actually much easier than you might think and following some important techniques and strategies making pizza can be one of the easier and fun things someone could do, and it all comes down to the science and math of it.

Measuring and Leveling Ingredients

Make no mistake, baking is an exact science and estimating how much of an ingredient you add or using improper tools for techniques can result in an inferior final product. Measuring ingredients properly is very important as baking is not as forgiving as cooking can be; even the slightest miscalculation can turn a soft dough into one that is as hard as a rock. But using a technique called “spoon and level” can be a tool for success.^[18]

Flour is one of the most important ingredients in pizza dough and is often the most common to be improperly measured. A measuring cup is the tool of choice when measuring flour, and while your first instinct would be to scoop the flour right out of the bag into the cup, this is the mistake that most people make. Because this packs the flour down into the cup and could end up giving you much more flour than you need. Instead, using a spoon, scoop the flour into the measuring cup until you reach the desired amount. Do not pack or tap the measuring cup as this will cause the flour to settle and give you an inaccurate measurement.¹⁸ Once the measuring cup is full, using the flat back of the spoon, level off the top of the measuring cup to remove any excess flour and to give the most accurate measurement.

The Need to Knead

Once the ingredients are measured and mixed, kneading is the next crucial step in the development of the dough. Kneading is the process of physically manipulating the dough by stretching, folding, and compressing

the dough many times.[19] These actions strengthen the gluten network by unfolding the proteins in the flour and encouraging them to form weak bonds between their neighbors. The glutenin molecules also form strong end-to-end bonds with each other, creating the gluten chains.¹⁹

As kneading progresses, the dough will gradually get harder to manipulate and will take on a smoother look. But be careful not to over knead the dough as those bonds will begin to break down, and the dough will become sticky and no longer elastic, though this is usually only a problem when not kneading by hand.¹⁹ Kneading also adds air to the dough as it will trap pockets of air. The air gets trapped and squeezed as you continue to knead forming small and more numerous pockets, the perfect place for the carbon dioxide from the yeast to settle. The more pockets the finer the texture in the final product.¹⁹

Some recipes call for little to no kneading, which usually results in fewer and larger air pockets which can create a coarser texture.¹⁹ This lack of kneading also means less gluten development when fermentation starts. But as dough rises, the gluten network will continue to develop, so even doughs that are not kneaded too much can eventually rise and give a tender texture.¹⁹ This is why some pizza dough recipes advertise no-knead methods, but since our activity will be more hands-on, students will need to know how to knead for this unit.

Pizza Dough Making Being Difficult Might Be a Stretch

The stretching of pizza dough is the culmination of all the work that has been put into the dough and is usually the most intimidating step for first-time pizza makers but with the right techniques even a child can do it. The first key step is to let the dough get to room temperature if it has been cold fermenting in the fridge. When the dough is cold, the gluten proteins have become tight, which makes stretching the pizza very difficult and will result in it just snapping back to its original shape.[20] Letting the dough come up to room temperature for at least thirty minutes before stretching can ease these proteins and make for much easier stretching.

The next step is to give the work surface you will be stretching the dough on some flour or oil to avoid the dough from sticking. Flour works but too much and the dough can become tough. An oil, such as olive oil, is the better option as it not only keeps the dough from sticking to your work surface but also gets it ready for the cooking surface as well and encourages a golden crispy crust.²⁰

Now that the dough is up to temperature and the work surface is ready, it is time to work the dough with some easy techniques. The first being to press the pizza dough before stretching it by flattening it into a disc. Using the palm of your hands and your fingers press the dough from the center making sure to widen the dough into a large circle about six inches across, the dough should be pliable and should not shrink back when pressed.²⁰ If there is a little bit of shrinking back that is fine but if the dough snaps back or if you make a mistake do not worry. An easy fix of resting the dough for about fifteen minutes should make it pliable again.

Once your circle is made, it is now time to stretch the dough with your stretching partner, gravity. While you may be tempted to toss the dough up in the air to do like they do in the restaurants, which can be impressive, by keeping the dough close using your hands to pull and letting gravity do the rest can result in just as good of stretch. When ready, pick up the dough and hold it with both hands on one edge and let the dough hang down. As you do this, gravity will be doing some of the work as you gently rotate the dough in one direction like turning a steering wheel.²⁰ While doing this slowly pull the dough from hand to hand as the dough hangs down.

Continue doing this until the dough has been stretched to the desired diameter, for our activity about eleven

to twelve inches. While stretching you may have noticed some thin spots or holes, don't worry, they are easy to fix before the cooking process. Simply pinch these areas together by pressing around them to cover those spots. The dough circle may shrink back a little; this is common and the reason while most recipes call for over stretching the dough.²⁰ Following these steps and techniques should result in a pizza parlor quality pizza dough.

Teaching Strategies

Inquiry based learning: During this unit, students will be allowed to discover scientific concepts by asking questions and conducting investigations. They will be exploring how different variables, such as temperature, the amount of sugar, or rising time can affect yeast activity and dough development. Students will make predictions, observe and complete experiments, and record their results to determine the conditions to make the best dough. This strategy encourages critical thinking and helps students review the scientific method while learning about the role of yeast in pizza dough making.

Hands-On Learning: This unit engages students by letting them actively participate in pizza dough making while exploring the science behind each of its ingredients. As the students measure, mix, knead, and observe dough as it rests, they learn that yeast is a living organism that feeds on sugar to produce carbon dioxide gas, causing the dough to rise. Students can also explore how flour contains gluten, giving it structure, through bonds. By observing these physical and chemical changes, students will develop a deeper understanding of scientific concepts through real-world experiences.

Cooperative Learning: Students will be encouraged to work together in small groups to complete the pizza making process and investigate the science involved. Each student can take on a role such as measuring ingredients, mixing the dough, or recording observations. As they collaborate, students can discuss their findings and help each other understand how yeast fermentation and a gluten network can contribute to a successful pizza dough. This strategy will also help strengthen communication, teamwork, and problem-solving skills while helping build their scientific knowledge using a shared learning experience.

Classroom Activities

Activity One: Meet Yeast-The Fun Fungus

Introduction

To introduce this unit on the chemical reactions of fermentation in yeast, students will first need to develop an understanding that yeast is a living member of the fungi kingdom, while also relating its role in the rising of pizza dough and breads. This first activity is designed to help students familiarize themselves with an indicator of a chemical reaction, $2 \text{H}_2\text{O}_2 \rightarrow 2 \text{H}_2\text{O} + \text{O}_2$ the production of a Oxygen, to establish a foundation for a later investigation into fermentation when they make their own pizza dough. Through a read aloud of the book *"Fungus is Among Us!"* by Joy Keller, classroom discussion, and a demonstration of Elephant Toothpaste

(demonstrations of this experiment can be found if you search “Elephant Toothpaste Experiment” on YouTube), students should connect the visible production of oxygen gas to the chemical reaction of carbon dioxide being released during fermentation in a later activity.

Materials

“Fungus is Among Us” book, at least 16-ounce plastic bottle, a tray or large container (to help contain mess), ½ cup hydrogen peroxide, 1 tablespoon liquid dish soap, food coloring (optional but help with visual), 1 tablespoon active dry yeast, 3 tablespoons warm water (to activate yeast), small cup, funnel, safety goggles, safety gloves, student science journals.

Procedure

1. Read *“Fungus is Among us”* and discuss the characteristics of fungi with class. The teacher should ask students what they already know about yeast and where they have seen it in their everyday life to spark conversation.
2. Explain to students they will be observing a demonstration that will show a chemical reaction through gas being created.
3. Before the demonstration, have students write the following hypothesis prompt in their science journals: “If yeast is added to hydrogen peroxide and dish soap, then _____ because _____.” The blanks will vary from student to student but something about gas or bubbles being created because of a chemical reaction or ingredients combining is the base of what should be written by students who understand.
4. Put on safety equipment, and if students are close during demonstration have them put on safety equipment as well.
5. Mix the yeast and warm water in a small cup and allow to sit for two to three minutes to activate. Be sure to show students what it looks like after mixing and after time waiting so they can see the difference.
6. While waiting, place the plastic bottle on the tray or in a container.
7. Pour the hydrogen peroxide in the plastic bottle.
8. Add the dish soap and food coloring (if you choose to use it) and gently swirl the bottle to combine.
9. Quickly pour the yeast mixtures into the bottle and step back to observe the reaction or heated foam being created.
10. Once the demonstration is finished, have students record their observations in their science journals, making sure they write what they saw before, during, and after the reaction. While also writing if their hypothesis was correct or not and why.

Conclusion Explanation

Once time has been given for students to record their observations, some describe what they saw during the demonstration. Use prompting questions such as: What changes did you see? What caused the foam to rise? Do you think what you saw today is similar to how yeast makes pizza dough or bread rise? Students should recognize that gas was produced which caused the foam to rapidly expand and rise out of the bottle. This shows a chemical reaction occurred.

Explain to students while they did see gas being produced today this was oxygen gas not carbon dioxide which is created during fermentation in bread making. In Elephant Toothpaste oxygen is trapped in the soap bubbles and causes the foam to expand, which in fermentation yeast produces carbon dioxide as it breaks down sugar for energy. Although the gases are different and the reactions occur in different ways, both this

demonstration and fermentation show the formation of a gas as evidence of a chemical change.

Activity Two: Revealing the Gluten Network

Introduction

As shown to students in the previous activity, yeast plays an important role in pizza dough and bread by producing carbon dioxide during fermentation. This gas is responsible for filling the dough's air pockets allowing it to rise. But without those air pockets the gas produced from the yeast would quickly escape and the dough would not rise. But the yeast does not create these pockets; there is something else present building this structure in the dough.

The structure that's responsible for trapping the carbon dioxide is called the gluten network. As stated in the content section, gluten is made from proteins found in wheat flour that become connected when water is mixed in and the dough has been kneaded. This network creates an elastic structure that can stretch and expand as yeast is producing carbon dioxide.

In this activity, students will get a chance to measure ingredients and make dough, but instead of cooking it, they will be washing away the starches leaving behind only the gluten itself. By removing the starch, students will be able to observe the protein network that normally surrounds and traps carbon dioxide during fermentation. This will help students understand how this stretchy structure is able to trap, expand, and hold its shape during the dough rise.

Materials (Groups of 2-4)

2 cups bread flour, $\frac{3}{4}$ cup of water, mixing bowl, spoon or spatula (strong enough to mix dough), measuring cups, strainer or mesh colander, another bowl for rinsing dough, water for rinsing, knife (teacher use only), microwave safe plate, and a microwave.

Procedure

1. Have students measure and combine the flour (scope and level method from content) and $\frac{3}{4}$ cup of water in a bowl and mix until a dough forms.
2. Once the dough comes together, have students knead the dough for about 5-10 minutes until it becomes smooth and stretchy (the teacher can demonstrate this to students before splitting them into groups) While kneading students should observe how the feel of the dough is changing as it is
3. As students record their observations of the texture in their science journal, they should allow the dough to rest for about 5 minutes.
4. Using the other bowl with water, students should place their dough in and begin gently squeezing and stretching the dough to rinse out all the starch in the flour.
5. Continue rinsing and replacing the water until the cloudy appearance caused by the starch starts to disappear.
6. What students will have remaining is the gluten network itself formed from the proteins that were contained in the flour. Students should record in their journals its texture and appearance while gently stretching it.
7. When observations have been recorded, students can ask the teacher to collect their dough to be microwaved. Microwave the dough on a microwave-safe plate, adding 1 tablespoon of water at the bottom of the plate to generate steam, for 3 minutes on high power. Letting it rest for 1 minute after for

it to stabilize, it should look puffed up from the steam expanding the pockets of air inside the gluten network. If it needs more expansion after resting continue to microwave in 1-minute bursts until fully puffed. Remember to let it rest again once satisfied with how the dough puffed up.

8. Remove the cooked gluten, giving a moment for it to cool before the teacher uses the knife to cut it in half so the air pockets inside can be seen.
9. Return these pieces to the group of students so they can record their final observations and what has changed after cooking. (eating is not recommended)
10. Once students have recorded final observations, have them return to the whole group for discussion of their findings.

Conclusion Explanation

Begin discussion with prompting questions, such as: How did the dough feel before and after washing it? Were you surprised by what it looked like after cooking? Why? How would you describe the gluten network after seeing it cooked? Why is the gluten network so important to pizza dough making? After discussion, explain to students that the flour they used contains several components but mainly starch and proteins. When water is added and the dough is mixed the proteins in the flour connect and form gluten. The gluten creates the stretchy network throughout the dough.

During a normal dough rise using yeast, the yeast will consume sugar and release carbon dioxide gas. This gas is trapped within the dough thanks to the gluten network's ability to stretch and hold the gas in place. Without the gluten, the gas would escape and the dough would not rise. The gluten students observed after rinsing the dough is the same structure that will exist in pizza dough that they will be making in the next activity.

Activity Three: Yeast's Sweet Treat, The Role of Sugar in Fermentation

Introduction

Throughout this unit's activities, students have explored the theory of how yeast contributes to the chemistry of pizza dough creation. Students have learned that yeast is a fungus that uses sugar as a food source during fermentation to break down to produce carbon dioxide, which gets trapped within the network of gluten causing the dough to rise. Now is the time for students to see this process in action. In this activity, the students will apply their understanding of all these concepts by creating their own pizza dough.

They will investigate if different quantities of sugar affect the rate in which the dough will rise. Each group of students will prepare dough using the same ingredients and procedures with the independent variable being the quantity of sugar added, although the sugar will be the same, white sugar. As the dough rises, students will mark their containers as time passes to measure later the rate in which the dough has risen. By measuring, student groups can later compare the data to other groups to see if the quantity of sugar makes a difference in the chemical reaction of fermentation. After completing the investigation, the students will be given a chance to shape and top their dough for cooking by the teacher to see the full process from start to finish.

Materials (for each group of 2-5)

1 ½ cups bread flour, ½ cup warm water, ½ teaspoon active dry yeast, Varied amounts of white sugar depending on groups (0 teaspoon as the control, ½ teaspoon, 1 teaspoon, 1 ½ teaspoons, increasing ½

teaspoons for each additional group), $\frac{1}{2}$ teaspoon salt, 1 teaspoon olive oil, mixing bowls, measuring cups/spoons, spoon or spatula (strong enough to mix dough), quart sized deli containers, black marker, timer, student science journal, pizza cutter or knife, pizza sauce, and mozzarella cheese (for toppings). Cooking elements can be a toaster oven or pan with hot plate depending on the classroom, cooking instructions using either will be included.

Procedure

1. Each group will receive the same amount of flour, water, yeast, and salt (as listed in materials). The only difference between groups will be the quantity of white sugar added to the dough as the independent variable.
2. Students mix the yeast and warm water (about 105°F) in a small cup and allow it to sit for 3 to 5 minutes to activate, similar to the first activity.
3. While yeast is activating students should measure other ingredients (using scoop and level method from the content section) and combine them in a bowl.
4. Once the yeast is activated add water mixture to the bowl and mix together until dough begins to form.
5. Students should have extra flour to add to their work table so they can take the dough out of the ball and begin to knead it so it will not stick. Students should knead the dough (taking turns if they choose) until the dough ball becomes smooth, about 10 minutes. Kneading method to share if needed in the content
6. Once kneaded, have students add olive oil to the deli container so the dough will not stick and then add the dough to the container with the lid on.
7. Use a marker to mark the starting height of the dough and also write how much sugar was used in the group.
8. Students should write their hypothesis on how much sugar they think will work the best or if they will all be the same, except the control.
9. Have students check dough and mark their deli container every 30 minutes for 2 hours in total. There should be 5 marks by the end.
10. Have students measure and record how much the dough has risen at each 30-minute time mark after they have recorded the starting height.
11. At the 2-hour time mark, have students place their containers next to each other so each group can observe differences, if any, on how much the pizza dough has risen.
12. After students have collected data and completed their observations of how much sugar was the most effective and why sugar is so important to the fermentation process, it is now time to make their pizzas.
13. Students should put more flour (to stop dough from sticking) on their table and remove their dough from the deli container onto the table. They should notice how the texture has changed and the dough should be much softer than when they put it in. This is from the gluten relaxing as discussed in the content section.
14. Have students gently stretch their dough into a small circle pizza shape (stretching technique to show students is discussed in the content section). Students should see the dough can be stretched easily and not break because of the elasticity from the gluten network.
15. Have students add a small amount of pizza sauce and cheese to their pizzas and raise their hands when ready to be cooked by the teacher.
16. The teacher will cook the pizza for that group using whichever cooking method allowed in the classroom but two have been included below for convenience.

Toaster Over Option

1. Preheat the toaster oven to 425 degrees Fahrenheit.
2. Place the prepared pizza on a lined baking tray (parchment paper is best).
3. Cook the pizza for 8-12 minutes keeping close observation of the pizza at the 8-minute mark and the dough's thickness and toaster oven settings will vary cooking time.
4. Remove the pizza when the crust is cooked through and the cheese is melted. Allow pizza to cool before cutting and giving back to the student group for eating.

Hot Plate and Pan Method

(Note for this method pizzas should be pan cooked before students can top them)

1. Preheat a nonstick pan on a hot plate over medium heat. Add 1-2 tablespoons of cooking oil when preheated.
2. Place the stretched pizza dough inside the oiled pan. Cook for 4-5 minutes or until the crust is browned. Flip dough over and have students top the browed portion while the other side is browning.
3. Once toppings are added, place a lid on the pan and cook for another 10 minutes checking the bottom of the pizza after 5 minutes to make sure it's not burning. If burning, quickly turn the hot plate down. The lid will help trap steam which will help melt the cheese on top.
4. Once the crust is browned and cheese melted remove pizza from pan and let cool before cutting and serving the students.

Conclusion Explanation

While students are eating their pizza, have them come back together in a whole group for discussion of what they observed and recorded. Give them question prompts such as: How much sugar appeared to help the yeast produce the most carbon dioxide? Was your hypothesis correct? What happened to the one with no sugar added? Reveal to the students that the activity today connected all the processes explored throughout this unit.

The first being that yeast uses sugar during fermentation and produces carbon dioxide. That the carbon dioxide becomes trapped within the gluten network of the dough. The gluten allows the dough to stretch and hold the gas without letting it escape causing the dough to rise. Finally, the heat from the cooking of the dough changes the dough into its final pizza crust form as the browning is another chemical reaction. The pizza made in this activity is a result of chemical and physical changes as well as mixtures all coming together into the pizza they ate.

Endnotes

[1] Money, *The Rise of Yeast*, 13

[2] Money, 130

[3] Money, 15

- [4] Money, 10
- [5] Money, 1
- [6] McGee, *On Food and Cooking*, 517
- [7] Civitello, *Cuisine and Culture*, 266
- [8] Civitello, 267
- [9] Civitello, 264
- [10] McGee, 530
- [11] Pradhan, "Bread Flour vs. All-Purpose Flour vs. 00 Flour."
- [12] McGee, 521
- [13] McGee, 522
- [14] McGee, 523
- [15] McGee, 525
- [16] McGee, 526
- [17] LibreTexts, "9.1: Mixtures and Solutions."
- [18] McKenney, "How to Properly Measure Baking Ingredients."
- [19] McGee, 537-538
- [20] Splawn, "How to Stretch Pizza Dough."

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Civitello, Linda. 2008. *Cuisine and Culture: A History of Food and People*. Hoboken, N.J.: John Wiley, ©, [I.E. A comprehensive exploration of how food has reflected history, culture, and economic throughout humanity.

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Appendix on Implementing District Standards

VA Science 5.1 The student will demonstrate an understanding of scientific and engineering practices.

This standard focuses on scientific investigation through experiments and observations. Throughout each activity of this unit students will be asked to make hypotheses, record findings, and draw conclusions from their observations or hands-on activities in their science journals which connect directly with this standard. A review of independent and dependent variables will be present in activity three as students investigate how different types of sugar (the independent variable) affect the rate of yeast fermentation (the dependent variable). Through this investigation, students will collect and analyze data to determine how changes in the independent variable influence the chemical reaction, and if their hypothesis made at the beginning was confirmed. In this activity students will also be measuring using elapsed time and collecting data from other groups which align with this standard as well.

VA Science 5.7 The student will investigate and understand that matter has properties and interactions.

This is the standard that is the main focus of this unit as students will investigate the properties and interactions of matter through a series of hands-on scientific investigations involving yeast, fermentation, gluten development, and mixtures. During activities two and three, students will review the concept of mixtures as they combine individual ingredients to make pizza dough, identifying how substances can be physically combined before undergoing chemical change. Students will also be exploring the physical properties of gluten by isolating and examining the gluten network in dough. These activities allow students to compare physical and chemical changes, analyze how matter interacts under different conditions, and use evidence to construct their scientific conclusions.

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