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Rise and Bind: Substituting binders and flours in pancakes

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Introduction

"Does this candy bar contain any trace of tree nuts?" "Oh, I cannot eat wheat waffles because I have celiac disease." As a classroom teacher these statements and similar others have become increasingly common in our schools. Students can come to class either knowing or not knowing they suffer from a food allergy. Some schools have prevented birthday parties from being celebrated at school because of the fear of students being allergic to baked goods. At school, I bring prepackaged food to my students all the time. Due to the number of cases of students that suffer from food allergies, I have had to become knowledgeable and aware of the many food allergens and what causes those particular allergies so that my students can still enjoy snacks in class.

According to the Center for Disease Control website, "Eight foods account for 90% of serious allergic reactions in the United States: milk, eggs, fish, crustacean shellfish, wheat, soy, peanuts, and tree nuts. Food allergies are a growing food safety and public health concern that affect an estimated 4%-6% of the children in the United States. A food allergy occurs when the body has a specific and reproducible immune response to certain foods.[1]

Since food allergies are a reality for many people, it is imperative for students to understand the concepts behind substitutions. After all, food allergies often require that people change recipes by swapping potential allergens with other ingredients. This unit is designed to teach substitutions and the chemical reactions behind them. To isolate the substitution skills, we'll focus entirely on pancakes which offer endless ways to substitute ingredients.

Demographics

For the past five years I have taught students identified as being gifted and talented through a pull-out approach in elementary schools in Tulsa, Oklahoma. I have the pleasure of working with kindergarten through sixth grade twice a week for an hour. Since I teach students who are identified as gifted and talented, I am given autonomy on what I can teach; however, this unit could easily be adapted for upper elementary science

classes.

My students play a huge part in the decision making of what they are learning. At the beginning of the year, they are given an interest survey. Each year the recurring topic of interest is chemistry. My students are fascinated with chemicals and have a desire to learn more about their properties. Unfortunately, several of my students assume the only way people interact with chemicals is when there is danger involved and things are exploding.

Rationale

To respond to my students' interest in chemistry, we experimented with the Carolina Science curriculum "Chemical Tests." Although, students enjoyed the lower level experiments such as mixing cornstarch and water, I realized that so much of the science they were exposed to was from a kit or a science textbook instead of them building on their own natural curiosity or connecting to real world problems.

Like many teachers, my education background did not prepare me to teach rigorous engaging science lessons. Additionally, science has often taken a back seat at my school while the priorities have been toward math and language arts. Students need inquiry based science instruction that provides them with real life applicable situations that challenge them to be critical thinkers, by defining their own problems and coming up with innovative solutions. This type of instruction will hopefully encourage them to take advanced courses in middle and high school and expand their interests in science-related professions.

With my students' desire to learn chemistry and the onslaught of students who suffer from food allergies, I decided to really challenge myself to design a science curriculum that contains more purposeful, life applicable hands-on science lessons.

Why I Chose Pancakes

What do crepes, aebleskiver, and johnnycakes have in common? They are cultural versions of a pancake. Pancakes are a comfort food that can be eaten at breakfast, during afternoon tea, or dinner. Pancakes are considered a quick bread composed of two essential parts: dry ingredients which are typically flour, baking soda or baking powder, and wet ingredients which are usually milk, eggs, and butter. Once a person understands the basic chemical interaction of a pancake, it can be crafted using several combinations of ingredients. The possibilities are completely endless. Pancakes can be peppered with savory seafood, topped with delectable fruits and chutneys, and drizzled with syrups.

But what happens when one of those ingredients is off limits to a person due to a food allergy? Do they completely stop eating pancakes or foods that contain that allergen? No, they research wheat or egg substitutes and continue through trial and error making and enjoying their beloved pancakes.

While this unit does not primarily focus on food allergies, I want my students to be aware that, if they know the basic components of a recipe, the function of the ingredients, and how chemical reactions happen, they can substitute ingredients. This unit does not seek to bombard my students with a lot of nutritional information or to suggest one ingredient is better than others for one's health.

For this unit, my students will substitute gluten-free flours in place of wheat flour and replace the traditional binder egg with alternatives. They will be using a griddle supervised in class. It is my hope that my students will be able to transfer their acquired knowledge of the properties of making a pancake to other baked goods such as cakes, muffins and quick breads.

Content Background

In my non sophisticated cooking career, I have had my share of cooking catastrophes. Cakes I baked collapsed and "biscuits" I made that were originally meant to be sugar cookies. As I ponder my misfortunate disasters, I now know that I did not properly understand the function or chemical reaction of each ingredient in the recipe. Knowing what role ingredients play and understanding basic chemical reactions would have saved me my share of deplorable creations.

A pancake is called many different names in different languages all around the world. Whether one lives in North America and calls it a flapjack, spends time in France where it is known as a crepe, or Australia where it is considered a pikeleti, either way a pancake is nothing more than a quick bread. A quick bread uses leavening agents other than yeast. Quick breads can be prepared quickly. They do not require culinary skills or the time consuming labor and the climate control needed for traditional yeast breads. Pancakes are composed of flour, a liquid, and a leavening agent, that is then heated in a pan or on a griddle on a stovetop, where they are typically flipped and cooked on both sides.

One key ingredient in making quick breads, cakes, cookies, and other baked goods is the binding agent. Binders are any ingredient that can help a mixture hold its shape or remain bound together. Traditional binding agents include flour and eggs.

The most commonly used food binder is flour. Flour is created by grinding raw grains or roots into a powder and then served in diverse cuisines. Flour adds volume, texture, and taste to most recipes. As explained by Layton and Larsen, "There are three flour components used to develop structure in baked goods. They include protein; wheat and gluten-free flours which are all high in protein. Another component is starch. When starch is combined with water and heat it forms a web, much like how gluten forms a web when using wheat. Unfortunately, starch webs are much less durable than protein webs. While starch can provide some structure, it needs help from protein. The third component is lipids. All flours, no matter wheat or not, contain lipids or just plain ol' fat. In fact, that is why many high- fat flours are stored in the fridge, because the flour can become rancid when the fat oxidizes. On a positive note, lipids add flavor and help keep the flour's protein structure from overwhelming the product."[2]

The most ubiquitous flour is wheat. Wheat has long been the grain of choice for milling to turn it into flour. Wheat comes from a seed which contains an endosperm, bran and germ. First, is the endosperm. It is 83 percent of the kernels weight and contains the greatest source of proteins and carbohydrates and white flour is produced from it. Then, there is the bran, which makes up about 14½ percent of the kernel weight. Bran is included in whole wheat flour and can be bought separately. Finally, there is the germ which is about 2 ½ percent of the kernel weight. The germ is the embryo of the seed, often separated from flour in milling because the fat content limits flour's shelf-life.[3]

Wheat is classified according to hardness, color and growing season. The difference lies in the protein content, with hard wheat containing a higher level of protein than soft. Also, wheat is milled and processed in slightly varying ways to create the different flours.[4]

Feeling a little adventurous and experimental? Try adding water to wheat flour, knead the mixture into dough, then rinse the glob under water to wash away the starches and fiber, you will be left with a protein mixture called gluten.[5] Wheat flour contains different types of proteins, but there are two in particular that contribute to the complexity of wheat, gliadin and glutenin, which are stored together with starch in the endosperm. Layton and Larsen describe "gliadin as a ball with little hooks all over it."[6] This molecule makes the dough stretchy, and provides plasticity.[7] Layton and Larsen describes the glutenin molecule as a long, coiled spring[8] and provides strength and elasticity to baked goods.[9]

According to Crosby, "The network of glutenin and gliadin is formed when the long glutenin molecules cross-link with the hooks on the globular gliadin molecules. When dough is kneaded or mixed in water, the hydrated flexible proteins are stretched and aligned in the direction of kneading providing more chances to form cross-links between proteins. As kneading continues, the protein networks combine to form sheets of proteins. This step in the process can be compared to unraveling thread (proteins), and weaving the straightened thread into pieces of cloth (networks), and then pieces of cloth being stitched together to form large sheets of cloth similar to a quilt."[10]

The network that is eventually formed is gluten. Gluten, which is Latin for "glue",[11] acts as an adhesive material that can expand and stretch a certain amount without tearing and is responsible for helping trap carbon dioxide in bread dough. Gluten helps create structure and determine texture in final baked goods. Also, the gluten network gives breads and cakes a little more cohesiveness, so when you cut into that tasty lemon cupcake or zucchini bread, they don't just crumble and fall apart completely.

Flours with low protein contents will generate less gluten and flours with high protein content will create more. Wheat is the most common source of gluten and creates the highest percentage of it. Different strains of wheat have different concentrations of glutenin and gliadin proteins, based on the growing climate, so varying the source of wheat will vary the amount of protein in its flour.[12]

There is an array of wheat flours on the market that serves different purposes. The most commonly used and readily accessible flour is all-purpose wheat. All-purpose is made from the endosperm of the wheat grain.[13] Because it is a blend of hard and soft wheat, this is the go-to flour for pie crusts, pancakes, certain cookies, as well as breading for fried meats. All-purpose flour has 8 to 11 percent gluten.[14]

Another type of wheat flour is bread flour. This is made entirely from hard wheat. High gluten content helps bread rise because the gluten traps and holds air bubbles as the dough is mixed and kneaded.[15] But wait, not to be out done, durum flour has the highest protein content, and thus can produce the most gluten.

For the bakers and cake aficionados, cake flour is made entirely of from soft wheat and contains the lowest protein content which is 5 to 8 percent. The low protein content guarantees a tender texture; as when making baked goods with a high ratio of sugar to flour, this flour will be better to hold its rise and will be less liable to collapse.[16]

Flour that healthy foodies prefer is whole wheat flour. It is brown in color, and is derived from the complete

whole kernel (the bran and germ). Because of the presence of bran it reduces gluten production. When used in bread baking, it gives a nutty flavor and a denser texture when compared to all-purpose flour.[17]

Finally there is self-rising flour. The name says it all. This variety is premixed flour with baking powder, a chemical leavening agent, and salt. The added ingredients are evenly distributed throughout the flour which aids a consistent rise in baked goods.

Wheat flour substitutes

Most people think of flour in terms of "wheat" flour; however, flour can be ground from a variety of nuts and seeds. Some types of alternative flours available in grocery stores are: almond, buckwheat, oat, and rice. Making pancakes, cookies, cakes, and other pastries can be achieved without wheat flour, but require an understanding about the different proportions, measuring, and mixing of the alternate ingredients being used. The following flours do not contain gluten, yet can still provide structure for baked goods. Although these flours contain proteins, they don't form good networks to trap bubbles.

To build structure for pancakes that do not contain wheat, one should use a mixture of flours with high and low levels of protein. According to Layton and Larsen "most gluten-free flour blends use a ratio of about 70 percent high-protein flours to 30 percent lower-protein or high-starch flours. This ratio makes a flour blend that acts pretty much like all-purpose wheat flour in pancakes as well as other baked goods."[18] A good mix of different flours helps compensate for the lack of gluten. Another tip to ensure structure in gluten-free pancakes is to add additional eggs to the pancake batter. Egg proteins help provide structure, but the amount of liquid used will need to be reduced by 2 tablespoons.[19]

A common wheat flour substitute is almond flour. Almond flour is usually made with almonds that have been blanched, meaning without skin and then finely ground to a light, floury texture. Since almond flour lacks gluten, compared to a pancake recipe that calls for wheat, more eggs will need to be added to provide structure to the baked good. On the other hand, almond flour contains more moisture, so baked goods won't dry out as fast.

Amaranth is an ancient grain. Amaranth contains more protein than any other gluten-free grain and more protein than wheat flour.[20] Amaranth has intense, nutty flavor it is most commonly combined in a recipe in a proportion of 1 part to 3 parts of other flours. If wheat is being substituted, 1 cup amaranth can replace 1 cup of wheat flour.

Besides almond and amaranth flours, oat flour is made from ground whole oats. This flour does not contain gluten and tends to make baked goods moister than wheat flour. Oat flour adds a rich, nutty flavor and denser texture. In baked foods that need to rise, oat flour must be combined with other flours.

Two in particular are xanthan and guar gum. Xanthan gum is a sugar-like compound made by mixing aged (fermented) sugars with a certain kind of bacteria. Guar gum is derived from the ground endosperm of guar beans. The husks of the seeds of the guar bean are removed, the seeds are milled, and an off-white powder is then produced. In gluten-free baking, guar gum is **used much like xanthan gum**. It provides **binding, elasticity**, and **structure** for baked goods that do not contain gluten.

Another binding agent is eggs. Eggs have a number of roles in baked goods, but their starring role is as a binder. The protein in the eggs gives structure to the batter so it's neither stiff nor crumbly. Eggs can also act as a leavener when they are beaten with butter and sugar.[21]

There are several common binding substitutes people can use in a pancake instead of eggs. Half of a mashed banana works great to replace eggs as it has the binding qualities. It's best suited for cookies and pancakes as it complements the flavors.

Besides a binding agent, pancakes contain a leavening agent that causes the bread to rise. When using baking soda, which is an alkaline, the pancake must have an acidic ingredient that will react with the baking soda to form carbon dioxide.

Acids and bases have distinctive properties. Many of the foods we eat such as grapes, cottage cheese, eggs, beef, and sweeteners like honey and corn syrup contain acids. Acids give foods a tart or sour taste. Bases, known as alkaline, are characterized by their bitter taste and slippery feel. Some foods that contain alkaline are kale, avocado, and tofu. Commonly used bases are baking soda and alkaline water.

Baking soda is an alkaline leavening agent made of sodium bicarbonate that reacts immediately when dissolved in a liquid and combined with an acid, breaking down into sodium, water and carbon dioxide.[22] The chemical equation of sodium bicarbonate ($NaHCO_3$) is:

$NaHCO_3 \xrightarrow{water} Na^+ + HCO_3^- \xrightarrow{acid} Na^+ + H_2O + CO_2$

In most quick bread recipes, the baking soda is mixed with the other dry ingredients before any liquid ingredients are added. In order for baking soda to work properly as a leavening agent, it must be used in recipes that contain acidic ingredients, such as molasses, buttermilk, or chocolate. The chemical reaction produces carbon dioxide gas, which cause the batter or dough to rise.[23]

Another chemical leavening agent, baking powder, is a mixture of baking soda, cream of tartar, an acidic ingredient, and a starch, such as cornstarch, which prevents clumping of the powder. It is most often used in quick bread recipes that contain no acidic ingredients. It reacts immediately when added to liquids. "Baking powder is often referred to as: "double acting baking powder," because it causes two separate rising actions to occur in the dough or batter. The first reaction occurs when the baking powder is mixed with liquid ingredients causing carbon dioxide gas to be produced, which causes the batter or dough to rise. The second reaction occurs when heat is applied during the baking process, which causes further expansion."[24]

When baking, up to 1 teaspoon of baking powder or ¼ teaspoon baking soda is sufficient to leaven 1 cup of flour in any given recipe. When using baking powder as a substitute for baking soda, four times the amount of baking powder as baking soda will be needed as called for in the recipe. For example, ½ teaspoon baking soda = 2 teaspoons of baking powder. [25]

So far we have covered flour, eggs, and leaveners. Another essential ingredient in traditional pancakes is - buttermilk. True buttermilk is the liquid whey left after cream has been churned to create butter. The methods for making buttermilk have changed over the years. In the past, buttermilk was fermented by naturally occurring bacteria as unpasteurized butter cream sat for a length of time before churning. "This process is called "ripening." In modern times, as all milk and cream are pasteurized, a process that kills the naturally occurring bacteria, buttermilk is made by reintroducing *Lactobacillus acidophilus,* the probiotic bacteria that gives buttermilk its sour taste."[26]

Buttermilk is acidic and the slightly acidic batter helps keep baked goods moist and tender by breaking down long, tough strands of gluten. Buttermilk contributes to the leavening of pancakes. In conjunction with baking

soda, buttermilk produces carbon dioxide gas.

Before baking powder was invented, baking soda ruled a home cook's kitchen, and it needed an acidic ingredient to help it activate and balance its flavor. Buttermilk was just the essential ingredient to do just that.[27]

While baking soda works well with buttermilk, if a recipe calls for baking powder, take care in substituting buttermilk for regular milk as it upsets the balance of alkali to acid. Buttermilk has more acid than regular milk, which will speed up the release of carbon dioxide and impede the leavening process.[28]

Teaching Objectives

This month long unit will be taught in the second semester after the students have a basic understanding of science content and processes. This unit will be divided into two parts. Part one will include the history of pancakes and will include activities pertaining to pH scale, leavening, and binding agents. Part two will be the culminating activity. Students will use the information they learned from part one and develop a pancake recipe that substitutes traditional flours and binders.

Engineering Design Process

This strategy will guide the entire unit. Students will be asked to define the problem, identify possible constraints, brainstorm multiple solutions to the problem, select a solution, create and test their solution, come up with ways to improve their solution, and communicate their results.

Cooperative Learning

During this unit, students will participate in cooperative learning through flexible grouping. Students will view themselves as scientists and will understand a large part of solving problems is working with others. Flexible grouping either through whole group, small group, or with a partner will allow students to work with and learn from their peers in a way they feel comfortable contributing as a learner.

Anchor charts

Anchor charts will be used throughout the unit to recognize the learning goal, record my students thinking, visually see vocabulary words, and to highlight important parts of the lesson.

Science Notebook

Students will keep science entries containing important vocabulary words, their inquiries, predictions, observations, and findings throughout the unit.

Classroom Activities

Part One

I will read Pancakes, Pancakes by Eric Carle to build anticipated interest in learning about pancakes. We will have guided discussion about what the ingredients were that the mother in the story used to make her son a pancake. I will use an anchor chart to write down the students' responses. This chart will be our reference each time we discuss an ingredient.

After I have read the story, we will have a discussion about food allergies. I will ask if they know someone who cannot eat certain foods due to having a food allergy. Then we will return back to the anchor chart and discuss what may be possible allergens. I will ask my students what is the main ingredient in a pancake. After they have successfully stated flour, we will discuss the properties of flour, in particular wheat flour. They will learn that wheat contains gluten which is a protein that provides pancake dough the structure it needs. As a class, we will discuss that some people are not able to consume wheat because it causes them to have an allergic reaction.

Wheat flour substitution activity

The next time I see my students, we will review from the anchor chart the ingredients in a traditional pancake. As a whole group, we will discuss possible wheat flour substitutes. I will display almond, coconut, oat, and wheat flours. Students will create a Venn diagram to compare and contrast the physical properties of each flour using their five senses to analyze the different flours.

Binding activity

After we have discussed wheat substitutions, I will demonstrate the importance of eggs as a binder in pancakes. I will ask the class what they believe the role of an egg is in pancakes. I will make a pancake that contains wheat flour, milk, and baking soda. Students will observe the eggless pancake and discover that the egg is what helps bind the other ingredients. To further explain the idea of a binding agent, I will ask them what can they use to bind two pieces of paper together. Student responses may include tape, mayonnaise, or glue. A teacher never knows the vivid imagination of their students. After discussing the characteristics of a binder, students will work in groups of four to brainstorm what foods can be added to a pancake in place of an egg to serve as a binder. The idea behind this activity is to get my students to understand that in baking, cooks go through trial and error to determine what works in recipes.

Leavening agent activity

Before students make their own pancakes substituting different flour and binders, students need to understand what makes a pancake rise. I will demonstrate a concept they are already familiar with which is the chemical reaction between baking soda and vinegar. I will explain to them that the vinegar is an acid, a chemical that can be described as being sour or tangy. I will further explain that baking soda is a base, a chemical that is bitter in taste. I will ask the students what they think the vinegar and baking soda produces when they are combined. We will discuss that the bubbles they see being formed are carbon dioxide. After that, I will set up an experiment where students will predict which unknown chemicals combined with known acids will produce bubbles (carbon dioxide).

Students will be asked to predict what two ingredients they think cause the chemical reaction. Without me telling my students what each powder is, students will be given cups containing baking powder and baking soda along with other miscellaneous white powders. Using a work mat and a spoon, students will place each of the powders on individual circles on the work mat. Students will be asked to apply acids such as yogurt, buttermilk, lemon juice, and vinegar to each circle and observe if a chemical reaction takes place. Based off their prediction of what they know is in a pancake, they will realize that baking soda or baking powder along with an acid like buttermilk causes a chemical reaction in pancakes.

Objective: To determine what two ingredients cause a chemical reaction in pancakes.

Materials:

Work mat worksheets with three circles for the reactions and spoons

Containers of unknown chemicals marked with colored dots that contain baking soda, baking powder, corn starch, and talcum powder

acids: buttermilk, lemon juice, and vinegar

Procedures:

1. Predict what unknown chemicals will produce a reaction when combined with the acids.

2. Place baking powder on each circle on the work mat.

3. Add buttermilk on the first circle. Observe what happens.

4. Write down in notebook what you observed.

5. Repeat the first four steps for the other acids.

Work Mat example of red dot which is baking soda

Part Two

After students have completed part one activities, students will work with a partner using the engineering design model to create a pancake that contains a substitute for wheat flour and eggs.

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Appendix

Next Generation Science Standards

Engineering Design

Asking Questions and Defining Problems

Asking questions and defining problems in 3–5 builds on grades K–2 experiences and progresses to specifying qualitative relationships.

Define a simple design problem that can be solved through the development of an object, tool, process, or system and includes several criteria for success and constraints on materials, time, or cost. (3-5-ETS1-1)

Planning and Carrying Out Investigations

Planning and carrying out investigations to answer questions or test solutions to problems in 3–5 builds on K–2 experiences and progresses to include investigations that control variables and provide evidence to support explanations or design solutions.

Plan and conduct an investigation collaboratively to produce data to serve as the basis for evidence, using fair tests in which variables are controlled and the number of trials considered. (3-5-ETS1-3)