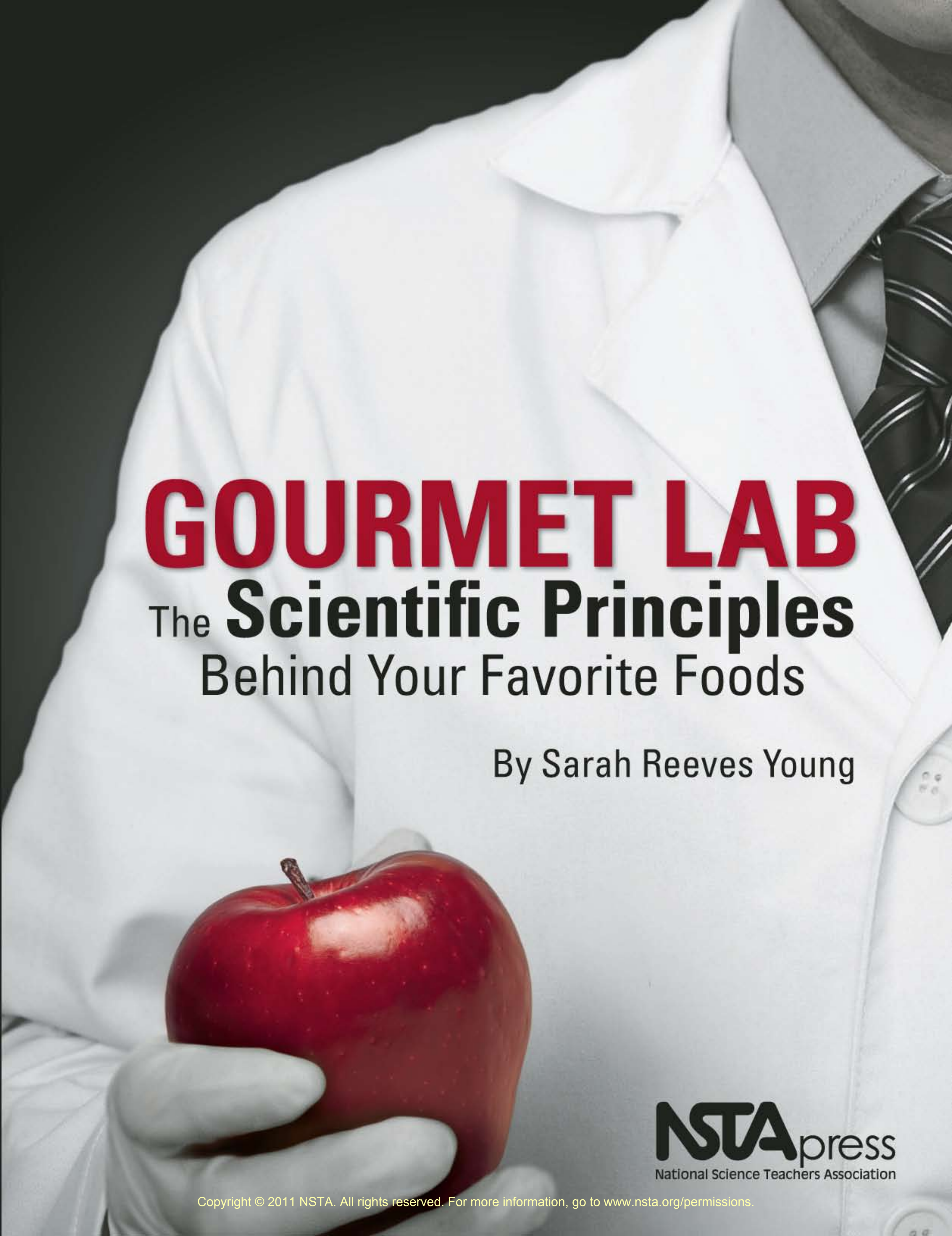

GOURMET LAB
The Scientific Principles Behind Your Favorite Foods

By Sarah Reeves Young

NSTA press
National Science Teachers Association

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INTRODUCTION

Are you hungry for science? *Gourmet Lab: The Scientific Principles Behind Your Favorite Foods* takes that phrase to a whole new level as students have the opportunity to discover science concepts and learn experimental design skills through interactions with everyday foods. This collection of hands-on experiments challenges students' take on the role of both scientist and chef, as students boil, bake, and toast their way into a better understanding of science concepts from chemistry, biology, and physics. Based on cooking edible food items such as pancakes and butterscotch, students have the opportunity to learn about physical changes, states of matter, acids and bases, biochemistry, and molecular structure. Rather than recipes, students are presented with laboratory explorations that use lab equipment such as Bunsen burners, beakers, and tongs, and work with chemicals such as sodium chloride and sucrose to experience science through cooking. This collection of lab activities brings science to life through an engaging exploration of cooking that will enhance any classroom experience.

The creation of *Gourmet Lab* stems from the general definition of *science* as "the study of the world around you." Often this connection to the real world eludes teachers and students who rely on textbooks to illustrate concepts through labs that attempt to support content with activities that are contrived and narrow in their scope. As a teacher, I found that the experiments in this book encourage students to investigate science phenomena through materials that they can connect to their daily experiences in the kitchen. This connection allows students to actively engage in the science concepts, making for an enhanced learning experience that is both meaningful and memorable.

The labs are designed for secondary science instruction, targeting students in grades 7–10. The labs can be used to illustrate individual concepts such as physical and chemical changes, or used in a series to teach a more complete picture of science concepts including molecular structure, biochemistry, and acids and bases. These topics are identified by the National Science Education Standards as integral to the education of middle school and high school students when studying chemistry, biology, physics, and more. These standards state, "The program of study in science for all students should be developmentally appropriate, interesting, and relevant to the student's lives; emphasize student understanding through inquiry; and be connected with other school subjects" (NRC 1996, p. 212). Each experiment in this book has been correlated to both content and skill standards in the National Science Education Standards, which are outlined in the table following this introduction.

Each lab is presented with both a student section and a teacher section. The student section of the lab is designed so that it can be handed out directly to students for easy implementation. Each lab begins with background information about the food and science concepts covered in the lab, and then offers a structured approach for investigating a question while building science skills. The investigations conclude with an analysis of data and with connection questions that encourage students to apply concepts from the lab to life experiences beyond the kitchen. Teachers are encouraged to remove elements of the labs such as the Data Analysis, Procedure, or Hypothesis sections to allow students the opportunity to experience the concepts through an inquiry-based model. All the elements provided allow the teacher to decide what information to use to excite students' curiosity and scaffold their investigation of each topic.

The teacher section of each experiment presents a detailed description of how to prepare for each lab, including safety highlights, a materials list that has been decoded for the grocery store, and prelab preparations for a successful experiment. This section goes on to detail demonstrations and activities to engage students, a detailed outline describing implementation of the lab, and answer keys for the students' data analysis and conclusion and connections questions. To enhance the overall learning experience, each teacher section concludes with cross-curricular suggestions for math and literacy (and technology in some cases), and suggests optional extension activities that highlight ways to make the activities engaging for middle school and high school students. The teacher sections are designed to provide teachers with a detailed approach to presenting the activity that allows you to implement it in your class the following day.

Whether you choose to implement a few of the experiments or all of them, *Gourmet Lab* is designed to improve student understanding, skills, and enthusiasm for physics, biology, and chemistry. So put on your apron, safety goggles, and chef hat and help your students start cooking up science!

REFERENCE

National Research Council (NRC). 1996. *National science education standards*. Washington, DC: National Academies Press.

NATIONAL SCIENCE EDUCATION STANDARDS: INCORPORATING *GOURMET LAB* INTO YOUR CURRICULUM

These tables are designed to help teachers identify how the experiments in this book align to the National Science Education Standards. The tables identify correlations for both middle school (grade 5–8) and high school (grade 9–12) science classrooms.

NATIONAL SCIENCE EDUCATION STANDARDS: INCORPORATING *GOURMET LAB* INTO YOUR CURRICULUM

The tables below are designed to help teachers identify how the experiments in this book align to the National Science Education Standards. The tables identify correlations for both middle school (grade 5–8) and high school (grade 9–12) science classrooms.

GRADE 5–8 NATIONAL SCIENCE EDUCATION STANDARDS

	Changes in Matter					Acids and Bases			Biochemistry					Molecular Structure	
NSESS Standards	Experiment 1: Butter Battle	Experiment 2: Exploding Corn	Experiment 3: “Melting” Apples	Experiment 4: Cold Milk	Experiment 5: Gummy Invertebrates	Experiment 6: Acidic Milk	Experiment 7: Berries and Bacteria	Experiment 8: American Mozzarella	Experiment 9: Ballpark Pretzels	Experiment 10: Cinnamon Rolls	Experiment 11: Growing a Pancake	Experiment 12: Under Pressure	Experiment 13: Regular or Diet Soda?	Experiment 14: Crystal Carbohydrates	Experiment 15: Strong Sugar Science
Science as Inquiry															
Abilities necessary to do scientific inquiry	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Understanding about scientific inquiry	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Physical Science															
Properties and changes of properties in matter	X	X	X	X	X	X		X	X	X	X	X	X	X	X
Motion and forces															

Transfer of energy		X	X	X	X	X	X	X						X	X
Life Science															
Structure and function in living systems							X	X	X	X	X	X	X		
Reproduction and heredity											X				
Regulation and behavior											X	X	X		
Populations and ecosystems											X		X		
Diversity and adaptations of organisms															
Earth and Space Science															
Structure of the earth system															
Earth's history															
Earth in the solar system															
Science and Technology															
Abilities of technological design											X	X		X	X
Understanding about science and technology					X					X	X	X		X	X
Science in Personal and Social Perspectives															
Personal health	X												X	X	X
Populations, resources, and environments															
Natural hazards															
Risks and benefits	X				X		X						X	X	X

	Changes in Matter					Acids and Bases			Biochemistry					Molecular Structure	
NSESS Standards	Experiment 1: Butter Battle	Experiment 2: Exploding Corn	Experiment 3: "Melting" Apples	Experiment 4: Cold Milk	Experiment 5: Gummy Invertebrates	Experiment 6: Acidic Milk	Experiment 7: Berries and Bacteria	Experiment 8: American Mozzarella	Experiment 9: Ballpark Pretzels	Experiment 10: Cinnamon Rolls	Experiment 11: Growing a Pancake	Experiment 12: Under Pressure	Experiment 13: Regular or Diet Soda?	Experiment 14: Crystal Carbohydrates	Experiment 15: Strong Sugar Science
Science and technology in society	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
History and Nature of Science															
Science as a human endeavor	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Nature of science	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
History of science		X						X							

GRADE 9–12 NATIONAL SCIENCE EDUCATION STANDARDS

	Changes in Matter					Acids and Bases			Biochemistry					Molecular Structure	
NSES Standards	Experiment 1: Butter Battle	Experiment 2: Exploding Corn	Experiment 3: "Melting" Applies	Experiment 4: Cold Milk	Experiment 5: Gummy Invertebrates	Experiment 6: Acidic Milk	Experiment 7: Berries and Bacteria	Experiment 8: American Mozzarella	Experiment 9: Ballpark Pretzels	Experiment 10: Cinnamon Rolls	Experiment 11: Growing a Pancake	Experiment 12: Under Pressure	Experiment 13: Regular or Diet Soda?	Experiment 14: Crystal Carbohydrates	Experiment 15: Strong Sugar Science
Science as Inquiry															
Abilities necessary to do scientific inquiry	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Understanding about scientific inquiry	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Physical Science															
Structure of atoms	X	X	X	X	X	X		X	X	X	X	X	X	X	X
Structure and properties of matter	X	X	X		X	X		X	X	X	X	X	X	X	X
Chemical reactions				X	X	X	X	X	X	X	X	X	X	X	X
Motions and forces															
Conservation of energy and increase in disorder	X	X		X			X							X	X

	Changes in Matter					Acids and Bases			Biochemistry					Molecular Structure	
NSES Standards	Experiment 1: Butter Battle	Experiment 2: Exploding Corn	Experiment 3: “Melting” Applies	Experiment 4: Cold Milk	Experiment 5: Gummy Invertebrates	Experiment 6: Acidic Milk	Experiment 7: Berries and Bacteria	Experiment 8: American Mozzarella	Experiment 9: Ballpark Pretzels	Experiment 10: Cinnamon Rolls	Experiment 11: Growing a Pancake	Experiment 12: Under Pressure	Experiment 13: Regular or Diet Soda?	Experiment 14: Crystal Carbohy-drates	Experiment 15: Strong Sugar Science
Interactions of energy and matter	X		X	X											
Life Science															
The cell							X	X	X	X	X	X	X		
Molecular basis of heredity															
Biological evolution															
Interdependence of organisms							X				X	X	X		
Matter, energy, and organization in living systems	X						X		X	X	X	X	X		
Behavior of organisms															
Earth and Space Science															
Energy in the earth system															
Geochemical cycles															

Origin and evolution of the earth system															
Origin and evolution of the universe															
Science and Technology															
Abilities of technological design	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Understanding about science and technology	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Science in Personal and Social Perspectives															
Personal and community health	X												X	X	X
Population growth												X			
Natural resources															
Environmental quality															
Natural and human-induced hazards															
Science and technology in local, national, and global challenges	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
History and Nature of Science															
Science as a human endeavor	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Nature of scientific knowledge	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Historical perspectives	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X

SAFETY PROTOCOL
How to Make Cooking Safe in a Laboratory

The first topic that I cover in my eighth-grade science classroom is laboratory safety. In the past, after going over rules such as "Always follow directions" and "Safety goggles are the number one fashion accessory required for lab," I always taught my students, "Food and drink are *not* allowed in the lab." When I asked them to explain why this was a rule, the students were quick to explain that food and drinks consumed in the lab may be contaminated with chemicals, and could be unsafe. It was clear, even to my eighth-grade students, that eating in a lab was not a good choice.

So I was completely taken aback when a fellow teacher shared that she was doing an "edible lab" with her class. This concept went against every lab safety poster I had ever seen in a science classroom. Eating in the laboratory was definitely not something that I would ever consider implementing with my students…or so I thought.

This teacher was nice enough to invite me to visit her class so that I could see the edible lab in action. The students were testing whether vitamin C could prevent the oxidation reaction that turned apple slices brown. Students were given food products such as tomatoes, orange juice, and lemon juice that contained different levels of vitamin C. They worked in teams to apply these solutions to the apples and measure how quickly they reached a predetermined brown color.

As I moved around the room and watched student groups, I was amazed at how engaged the students were in the experiment. Not only were students completing the experiment but they also were generating the discussion and asking questions about employing other methods for preventing oxygen from changing the color of the apples. I heard several students comment that they had asked their parents about this process, and some shared stories about how their family members approached keeping apples from turning brown. The lab engaged the students' curiosity in a context that allowed them to create personal connections.

After leaving the classroom that day, I was impressed, but still a bit skeptical. Maybe this was an honors class or there was a reward promised for good behavior, or maybe this teacher just deserved to be nominated for teacher of the year. There were many possible factors that could have created the effective learning environment. So, as a science teacher, I decided to run my own experiment. I had been approached to do a weeklong summer course for adolescent students at my school. The topic was my choice, so I decided to go with edible science. This would give me an opportunity to test the feasibility of food in the classroom with a smaller group. It would also give me an opportunity to see if edible science was really going to be as amazing in my classroom as it was in the vitamin C experiment.

I decided to start off in the most sterile science environment I could think of: a math classroom. Rather than worrying about the chemical contamination of my room, I was going to set up camp in a regular classroom. As part of being away from my regular lab-integrated classroom, I didn't have access to all of my science supplies, just some basic measurement tools. Each lab experiment was done with disposable items such as paper cups; Styrofoam bowls; and plastic knives, forks, and spoons. I started off with simple experiments such as comparing the melting time of chocolates in students' mouths to talk about thermal energy transfer, and creating solutions with different percentages of fruit drink mix. I was truly floored by the student response. The students were excited to come to the summer course, even though most of their parents had signed them up without asking their permission. I had parents e-mailing me to see if they could get copies of the experiments so they could see what prompted the enthusiasm from their kids as they talked about the class in the car ride home. I even had students join the class midweek based on word of mouth.

But again, the skeptic in me held off judgment. These were students whose parents felt they would be interested in a science summer course, so they had to already have some interest in the topic. What about doing this with a class of eighth-grade students who were required to be in the lab as opposed to making the personal choice to attend? But in order to test that question, I was going to have to make a big leap. I was going to have to start running the experiments in my science room.

I was terrified at the thought that I might inadvertently harm a student by exposing him or her to a chemical through an edible classroom lab experience. Although I mainly used household chemicals in my classroom, I was still concerned that cross-contamination was a huge possibility. So I erred on the side of caution. I was not willing to use *any* of the lab equipment that I had used previously in a science setting with other chemicals. Luckily, I was starting a new school year and would be receiving my requested lab replacement materials. This was a few beakers, a few thermometers, a few droppers, a couple of plastic bottles, and three new Bunsen burners. Rather than placing these items into the cabinets with the other supplies, I made space for my new "edible science" equipment. The equipment was placed in a sealed plastic storage container in a locked cabinet, so I could be sure that the equipment wasn't being used elsewhere in the lab with other chemicals.

Based on the few supplies I had, I started with a simple lab—Butter Battle—to introduce the topic of physical change. The lab didn't require heat and had very few chemicals and supplies. I was so nervous about the experience; I actually had the students complete the lab in the classroom area just to make sure we weren't exposing the food products to chemicals in the lab environment. I watched students work in pairs to create butter, and I was amazed again by their interest, engagement, and overall excitement. I had students asking for containers or cups so they could take their butter home to share with friends and family. Upon leaving class, one student who at the beginning of the year had openly told me he had never liked science said, "That was great. What are we making tomorrow?"

From that initial classroom experiment, I have slowly grown to incorporate more and more edible labs into my curriculum. With each lab, I consider safety the number one priority, and have learned many ways to make food in the lab a safe activity. With the help of books like *Inquiring Safely: A Guide for Middle School Teachers* by Terry Kwan and Juliana Texley, resources from Flinn Scientific, and cautious methods learned from working with chemicals as a high school and college student, I have been able to bring science to life for my middle school students.

GENERAL SAFETY GUIDELINES

It is recommended that all of these lab activities be carried out in a consumer science laboratory or home economics kitchen that has been designed and operated for the safe use of food products that can be eaten when health and safety protocols are followed. The following is a list of general safety guidelines that should be followed by any teacher planning to implement any of the labs in this book. Please read these guidelines before completing any of the experiments with your students.

- Use only special glassware and equipment, stored away from all sources of laboratory chemical contamination and reserved only for food experiments. (Using laboratory equipment that

has been used in other laboratory experiments is *not* recommended; even after cleaning and sterilizing, it is not guaranteed that the materials will be free from all chemical residue.)
- Wear indirectly vented chemical-splash goggles in the laboratory at all times.
- Sanitize personal protective equipment such as goggles before and after use.
- Wear proper lab attire for edible science labs, such as long pants, closed-toe shoes, and long-sleeved shirts, when working with hot liquids or chemicals that may splatter.
- Remove all jewelry and baggy clothing.
- Pull back long hair to keep out of the face before entering the lab area.
- Use nitrile-type gloves when working with acids.
- Wash your hands thoroughly at the end of all labs.
- Have 10-second access to an eyewash station and acid shower.
- Review material safety data sheets (MSDS) with students prior to using hazardous chemicals.

SAFETY GUIDELINES FOR CLEANING AND STORAGE

- If an experiment was performed in a classroom (outside the laboratory), clean all work surfaces to be sure they are free from laboratory chemicals. After cleaning work surfaces, cover all work areas with aluminum foil or a food-grade paper covering.
- Clean all glassware and apparatus to be sure they are free from laboratory chemicals, and label them FOOD ONLY.
- Store all chemicals and food-grade materials separately from other lab chemicals. This includes having a separate labeled cabinet and refrigerator for cold materials.

SAFETY GUIDELINES FOR BUNSEN BURNERS

- Model the appropriate procedures for students when using hazardous equipment such as Bunsen burners.
- Remove all flammable and combustible materials from the lab bench and surrounding work area when Bunsen burners will be used. Do *not* use a Bunsen burner in any lab when working with flammable liquids or solvents.
- Review the basic construction of a Bunsen burner and inspect the burner, attached tubing, and gas valve before use. Check for holes or cracks in the tubing and replace the tubing if necessary. (*Note*: Use only American Gas Association–approved Bunsen tubing connectors. Do not use only latex tubing.)
- Use only heat-resistant, borosilicate glassware when using a Bunsen burner. Check the glassware for scratches, nicks, or cracks before use and discard defective glassware, which may shatter without warning when heated.
- Never reach over an exposed flame.
- Never leave a lit burner unattended. Always turn off the gas at the gas source when finished using the burner.
- Do not place a hot apparatus directly on the laboratory desk or bench. Always use an insulating pad, and allow plenty of time for the apparatus to cool before touching it.
- Never look into a container that is being heated. When heating a test tube, make sure that the mouth of the tube is not pointing at anybody (including yourself).
- Use matches as a checkpoint with all student groups. Matches are specifically not handed out as a part of the materials list for any of the labs. All student groups must come and get matches from me. Before I distribute matches, I will check off that studentshave properly set up their

Bunsen burner and ring stand, they have the proper equipment and materials ready, and they are wearing the appropriate safety gear. I often ask the students to articulate who is in charge of the Bunsen burner at all times, so that they are clear on who is watching the burner, and who is available to talk to other lab groups, get additional supplies, or come to me for help.

SAFETY GUIDELINES FOR HOT PLATES

- To reduce heat stress, allow hot glassware or equipment to cool slowly before removing the object from the hot plate. Remember that hot objects remain hot for a long time, so use tongs, heat-protective gloves, or hot vessel–gripping devices as needed.
- Turn off the hot plate when not in use. The surface of the plate stays hot for quite some time and looks exactly the same as a "cold" hot plate. Place a laminated "HOT" caution sign in front of the hot plate immediately after use.
- Use only heat-resistant, borosilicate glassware and check for cracks before heating on a hot plate. Do not place thick-walled glassware such as filter flasks, or soft-glass bottles and jars, on a hot plate. The hot plate surface should be larger than the vessel being heated.
- Do not use the hot plate in the presence of flammable or combustible materials because fire or explosion may result. The device contains components that may ignite such material.
- Place boiling stones in liquids being heated to facilitate even heating and boiling. Do not evaporate all of the solvent or otherwise heat a mixture to dryness on a hot plate—the glass may crack unexpectedly when heated directly on a hot plate.
- Use a medium to medium-high setting of the hot plate to heat most liquids, including water. Do not use the high setting to heat low-boiling liquids. The hot plate surface can reach a maximum temperature of 540°C.
- Do not place metal foil or metal containers on the hot plate—the top of the hot plate can be damaged and a shock hazard may result.
- Use only Ground Fault Circuit Interruption (GFCI) protected wall receptacles for a power source.

SAFETY GUIDELINES FOR STUDENT ALLERGIES

- Many students have food allergies that often are not shared with teachers but exist in their school files. As part of my class, I specifically ask parents to document any food allergies on the lab safety acknowledgment form I ask students and parents to sign at the beginning of the year. This helps me know if there are materials or lab activities I need to avoid, so I can plan my approach effectively.
- Allergies exist in many forms, from peanuts to fruit, dairy, and wheat. Take every student allergy seriously, and know the steps and procedures to follow in the event that a student is exposed to a product he or she is allergic to. In some cases, this means having access to epinephrine injection devices. Know where these injectors are kept so that you don't find yourself searching the school for them when they are needed most.

Aside from the suggestions offered here, please note that many schools and districts have their own rules and guidelines for laboratory safety. Many times this includes rules about having food in the classroom. Check with your school administration to ensure that giving out edible products in the class-room is allowed. Also, most teachers as employees are required to be working in laboratories under the Occupational Safety & Health Administration (OSHA) laboratory standards and best professional practices. (See the NSTA position statement *Safety and School Science Instruction* for more information.)

If you feel that you cannot meet all the expectations outlined here for the safe implementation of edible laboratory activities, then you should not use these activities in your classroom with the purpose of having students taste or consume the edible materials. The experiments can be implemented without students consuming the products with modifications to the questions and presentation.

The most important rule of all is to be safe. Your students will not love science if they get hurt learning about it. Always be cautious, and when in doubt, seek out additional resources to clarify questions before taking on a new lab. Suggested resources include the following:

- OSHA's Laboratory Standard or Hazard Communication Standard outlines safety expectations for a laboratory environment.
- Local and state health codes require specific environments, free from hazardous microorganisms and hazardous chemicals for food preparation.
- Books on best practices, such as *Investigating Safely* and *Inquiring Safely* published by NSTA, have content that addresses food safety in the science classroom.

Gourmet Lab Reminders

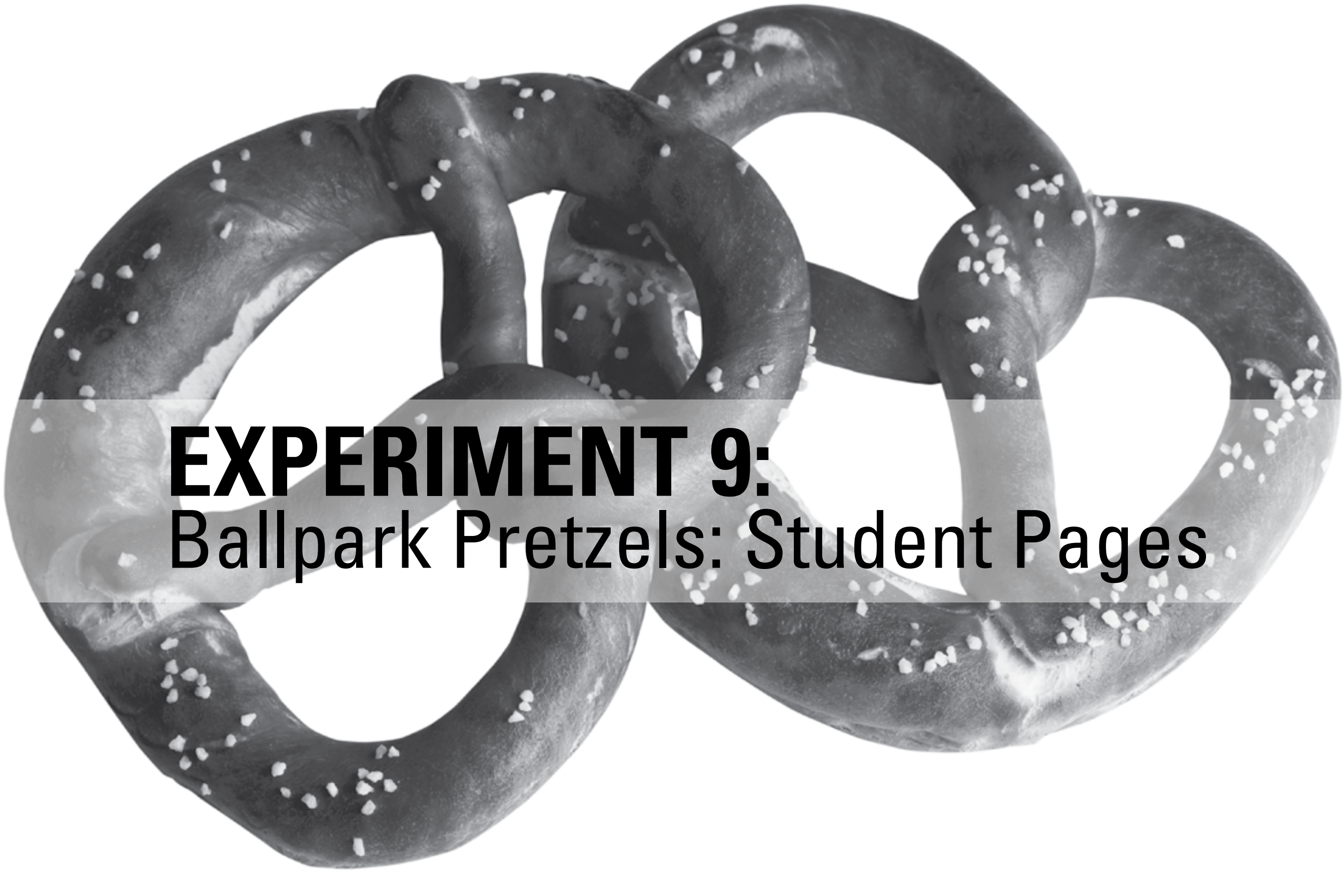
Following is a list of general reminders for teachers implementing any of the experiments in this book.

All science lab supplies need to be used exclusively for *Gourmet Lab* experiments. Cleaning and sterilization of other supplies does not guarantee that all chemical residues have been removed from previous experiments.

Gourmet Lab materials, such as beakers and glass rods, need to be cleaned and sterilized before being used to create food that will be consumed by the students. Please see the Safety Protocol section at the beginning of the book for specific instructions about safely cleaning your lab equipment.

Label each of the ingredients with their chemical name and appropriate hazard warning. You can place the ingredients in separate lab containers such as beakers and flasks and then have students try to identify the common name through observation such as taste, smell, or appearance, or you can place the labels directly on the store-bought containers so students can compare the chemical names with the ingredients listed on the package.

Remind students to practice the ABC policy—Always Be Cleaning— at the outset of the lab.



EXPERIMENT 9:
Ballpark Pretzels: Student Pages

USING MICROSCOPES TO OBSERVE YEAST FERMENTATION OF SUGAR

BACKGROUND

"Take me out to the ball game; take me out with the crowd." The pastime of baseball is not just known for the athletes and rivalries, but for the food as well. From peanuts and crackerjacks to cotton candy and pretzels, baseball games are just one example of an event where the food helps to create the memorable experience.

For this experiment, we are going to focus on the ballpark pretzel. Soft ballpark pretzels are made from simple bread dough, which has all sorts of chemistry and biology taking place within its moldable form. Dough is formed from flour and water, which locks together to form massive molecules known as gluten. The gluten is formed from two proteins: glutenin and gliadin. The gluten arrangement can be incredibly dense, creating hard products like pasta. That wouldn't make for a very soft pretzel, though, so recipes use two techniques that change the arrangement of the gluten in the dough.

The first process is incorporating yeast into the mixture. Yeast is a unicellular fungus (see Figure 9.1) that thrives on sugar to multiply. The yeast is used in pretzels to create air bubbles of carbon dioxide in the dough. These air bubbles allow the dough to double in size and become softer and lighter when baked. The second process is called kneading, where the dough is pushed, pulled, and pounded repeatedly to cause the gluten chains to line up and form new chains that are linear as opposed to globular.

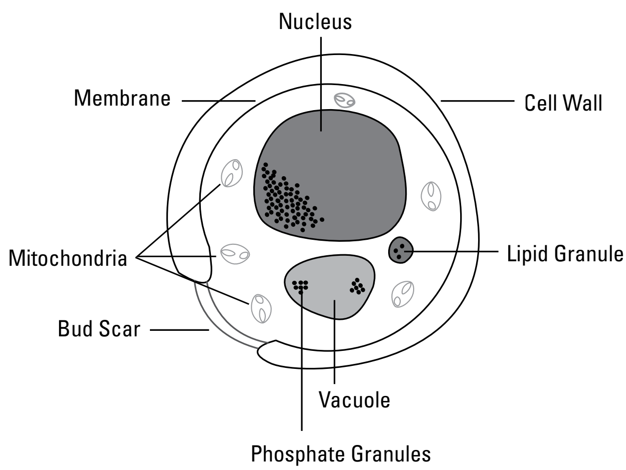


Figure 9.1: Diagram of a yeast cell and components of a yeast organism.

Finally, the pretzel is boiled in sodium bicarbonate and water. Boiling the pretzel dough before baking causes the surface starch to gelatinize into a thin, slimy coating that produces a glossy brown crust when baked. This is the final step before the pretzel is baked and paired with salt, cinnamon sugar, or mustard to be consumed by the masses.

HYPOTHESIS

We will be using yeast and sucrose when making pretzels for this experiment. Does the amount of sucrose impact the yeast's speed of fermentation? Or, is there a constant rate at which the yeast is able to synthesize sugar? We will be using a microscope to measure this process by counting the number of gas bubbles yeast makes when exposed to different levels of sugar.

Predict how you think the rate will change or stay the same as we increase the amount of sugar. Use an "If…Then…Because" statement and explain your answer using the background information provided in the previous section.

MATERIALS NEEDED PER GROUP

Materials Used Prior to Fermentation of Sugars

- One-half package of active dry *Saccharomyces cerevisiae* (baking yeast)
- 30 ml of warm dihydrogen monoxide, H_2O (water)
- 120 ml of warm dihydrogen monoxide, H_2O (water)
- 2.5 ml of sucrose, $C_{12}H_{22}O_{11}$ (sugar)
- 5 ml of sodium chloride, NaCl (table salt)
- 475–550 ml of all-purpose powdered grains (flour)
- Two pieces of filter paper
- One sheet of aluminum foil
- Lipids as needed (shortening)
- Graduated cylinder
- Balance
- Beaker, 100 ml
- Beaker, 200 ml
- Glass stir rod
- One antibacterial wipe
- Indirectly vented chemical-splash goggles
- Aprons

Materials Used After the Fermentation of Sugars

- Large beaker (over 400 ml)
- 400 ml of dihydrogen monoxide, H_2O (water for boiling)
- Bunsen burner
- Ring stand
- Tongs
- Indirectly vented chemical-splash goggles
- 10 ml of sodium hydrogen carbonate, $NaHCO_3$ (baking soda)
- Two pieces of filter paper
- Aprons

Materials for Microscope Analysis

- Active *Saccharomyces cerevisiae* solution with eyedropper (yeast solution)
- Microscope slide
- Microscope cover slip
- Microscope
- Bottles of 5% sucrose solution, 15% sucrose solution, and 30% sucrose solution
- Timer or clock

PROCEDURE FOR PRETZELS BEFORE FERMENTATION OF SUGARS

1. Read through the entire procedure before beginning.
2. Put on your safety goggles and apron, and gather all your materials at your lab station. If you notice any of the materials are dirty or discolored, notify your teacher.
3. Use an antibacterial wipe to wipe down your lab table thoroughly. You will be using this surface to create your dough, so it needs to be spotless. Cover your work area with a piece of waxed paper.
4. Once you are finished wiping down the table, thoroughly wash your hands with soap and water.
5. Begin by taking half a package of *Saccharomyces cerevisiae* and dissolving the granules in 30 ml of warm water. Mix with a glass stir rod.
6. Using a dry graduated cylinder, measure out 2.5 ml of sucrose and place on a piece of filter paper labeled “sucrose.”
7. Using the same dry graduated cylinder, measure out 5 ml of sodium chloride and place on a piece of filter paper labeled “sodium chloride.”
8. Measure 120 ml of warm water in a 200 ml glass beaker.
9. Add 2.5 ml of sucrose from the filter paper to the beaker with warm water. Stir to dissolve with a glass stir rod.
10. Add the *Saccharomyces cerevisiae* solution to the 200 ml beaker with the sucrose solution along with the 5 ml of sodium chloride. Stir well.
11. Using a large beaker, measure out 475 ml of all-purpose powdered grains.
12. Add the powdered grains onto the waxed paper on the lab table and create a small mountain.
13. Poke a hole in the center of your powdered grains mountain so that it looks like a volcano.
14. Pour a small amount (about 30 ml) of the sucrose *Saccharomyces cerevisiae* solution into the center of the volcano.
15. Use your hands to push the liquid and dry powdered grains together to start to mix the two together. If liquid runs out of the mountain, use the dry powdered grains to scoop it back in.

16. Repeat this process until all the liquid is incorporated into the dough. If the dough is too soft, add additional powdered grains. If the dough is too stiff, add additional water 5 ml at a time.
17. Once all the powdered grains and liquid are incorporated, use your hands (which have been washed thoroughly) to knead the dough on your lab table. Knead for 10 minutes or until your dough is stiff and elastic.
18. Grease a piece of aluminum foil with lipids. Place the dough on the foil and turn it until coated with the lipids. Cover the dough with a damp paper towel and let the dough rise on the counter until it has doubled in size. This will take about 30 minutes, during which time you are going to make microscope observations. Make sure you label the foil with your name.
19. Clean your lab area before you move to the microscope observations.

PROCEDURE FOR MICROSCOPE OBSERVATIONS

1. Read through the entire procedure before beginning.
2. Gather your lab materials at your station. Carry the microscopes with two hands, one hand at the arm and one hand on the base.
3. You will be making a wet mount slide or a microscope slide that has a liquid for viewing. Begin by taking your microscope slide. Use a flat glass slide to prepare a wet mount. The slide should be clean and free of dust or other fine particles.
4. Keeping the slide flat, place two drops of the *Saccharomyces cerevisiae* solution on the center of the slide using the plastic dropper.
5. Take a coverslip and place the edge of the coverslip on the edge of your liquid on the slide. Slowly lower the coverslip into place. If you do this too quickly, you will have large air bubbles that will make your observations difficult, so be careful.
6. Place the coverslip on top of the slide, making sure the edges of the coverslip match up with the edges of the slide. Do not press down on the coverslip.
7. Grasp the slide/coverslip combination by the outer edges. You should keep the slide as horizontal and as steady as possible. Place it on the viewing tray of your microscope.

8. Start with the lowest degree of magnification on your microscope. Use the coarse adjustment to bring the slide into view, and then the fine adjustment to fine-tune your image. Once you have achieved a clear view, increase the magnification to get a better look at the *Saccharomyces cerevisiae* cells.
9. Make an observation about the *Saccharomyces cerevisiae* and record it in your Microscope Observation Data Table. Your observation can be descriptive with words, or a diagram, or a combination of both.
10. Count the number of bubbles visible in your slide. These should be clearly defined and appear different from the *Saccharomyces cerevisiae* size. Record the number of bubbles in your data table.
11. Note the time and wait for two minutes. Do not move the slide during this time.
12. At the conclusion of two minutes, count the total number of bubbles again and record this in your data table. You can then solve for the number of bubbles created during two minutes.
13. Throw away the coverslip in the trash.
14. Wash off the *Saccharomyces cerevisiae* and dry your slide with a paper towel.
15. Repeat steps 4–14 using two drops of *Saccharomyces cerevisiae* and three drops of 5% sucrose solution from the dropper bottle.
16. Repeat steps 4–14 using two drops of *Saccharomyces cerevisiae* and three drops of 15% sucrose solution from the dropper bottle.
17. Repeat steps 4–14 using two drops of *Saccharomyces cerevisiae* and three drops of 30% sucrose solution from the dropper bottle.
18. Clean your lab area and wait for your teacher to ask you to retrieve your dough.

PROCEDURE FOR PRETZELS AFTER THE FERMENTATION OF SUGARS

1. Read through the entire procedure before beginning.
2. Put on your safety goggles and apron and gather all your materials at your lab station. If you notice any of the materials are dirty or discolored, notify your teacher.
3. Use an antibacterial wipe to wipe down your lab table thoroughly. You will be using this surface to create your dough, so it needs to be spotless.
4. Once you are finished wiping down the table, thoroughly wash your hands with soap and water.
5. Break the dough into four equal pieces.
6. Using your lab table, roll each piece into a long stick about 25 cm long and twist this into a pretzel or knot shape.
7. Set up a Bunsen burner and ring stand with wire mesh on the iron ring. Make sure your Bunsen burner gas intake tube is securely connected to the gas nozzle and that the ring is set about 3 in. above the barrel of the burner (see Figure 9.2). Light the Bunsen burner to create a flame that is no more than 3 in. high. (It should not be touching the wire mesh.)

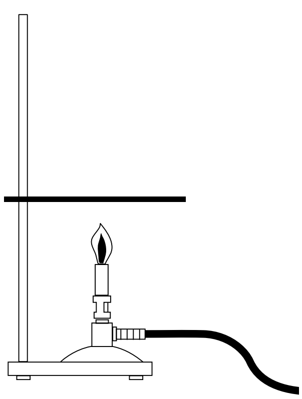


Figure 9.2: Bunsen burner and ring stand.

8. Measure 10 ml of sodium hydrogen carbonate and combine with 250 ml of water in a large 400 ml beaker.
9. Using the tongs, place the beaker on the ring stand. Bring the beaker to a boil.

10. Use the tongs to drop in one pretzel at a time and wait for them to float (about one minute). Remove the pretzel with tongs and place it on your aluminum foil with the lipids. *Safety note*: Be careful not to cause the boiling water to splash; it can cause serious skin burns.
11. Once all the pretzels have been boiled, place them in the toaster oven and bake them at 232°C (450°F) for 12 minutes or until they are golden brown.
12. Clean your lab area while you are waiting for your pretzels to be baked.

DATA AND OBSERVATIONS

Microscope Observation Data Table

	Observations (description or graphic is acceptable)	Number of bubbles in initial slide	Number of bubbles after two minutes	Total number of bubbles created
Saccharomyces cerevisiae with no sucrose				
Saccharomyces cerevisiae with 5% sucrose solution				
Saccharomyces cerevisiae with 15% sucrose solution				
Saccharomyces cerevisiae with 30% sucrose solution				

DATA ANALYSIS

For each of the following questions, be sure to explain using detail and complete sentences. If the question requires you to complete calculations, show all of your work.

1. Create a bar graph that shows the number of bubbles created by the yeast when combined with different amounts of sucrose. Remember to include all elements of a scientific graph (title, labeled axes, units, legend, etc.).

2. What was the rate of bubbles being created for each of the *Saccharomyces cerevisiae* slides? Show your work in the table below.

	Number of bubbles created	Time for bubble creation (seconds)	Rate of bubbles created per second
Saccharomyces cerevisiae with no sucrose			
Saccharomyces cerevisiae with 5% sucrose			
Saccharomyces cerevisiae with 15% sucrose			
Saccharomyces cerevisiae with 30% sucrose			

CONCLUSION AND CONNECTIONS

1. Was your initial hypothesis correct? Restate your hypothesis and identify whether you were correct or incorrect, using data to support your answer.

2. Why is it necessary for the dough to be kneaded? What process does this accomplish? What would you expect dough to look like if it had not been kneaded?

3. Why does the dough need time to rise? What process is occurring during this period? What would you expect dough to be like if it had not been given time to rise?

4. If you wanted to speed up the rising time for the pretzels, how would you alter the procedure?

EXPERIMENT 9:
Ballpark Pretzels: Teacher Pages

USING MICROSCOPES TO OBSERVE YEAST FERMENTATION OF SUGAR

This experiment provides a hands-on lab experience for students to begin their investigation into yeast and the fermentation of sugars. The experiment allows students to view the yeast under the microscope, gaining skills in using the microscope and creating wet mounts. In connection with these observations, students also get to experience a practical application of yeast fermentation to create soft pretzels. The visual and hands-on experiences creating yeast and watching it rise provide an excellent context for understanding the process of fermentation that is viewed under the microscope, and create a memorable, edible lab.

STANDARDS ADDRESSED

National Science Education Standards: Grades 5–8

Content Standard A: Science as Inquiry
- Abilities necessary to do scientific inquiry
- Understanding about scientific inquiry

Content Standard B: Physical Science
- Properties and changes of properties in matter

Content Standard C: Life Science
- Structure and function in living systems

Content Standard F: Science in Personal and Social Perspectives
- Science and technology in society

Content Standard G: History and Nature of Science
- Science as a human endeavor
- Nature of science

National Science Education Standards: Grades 9–12

Content Standard A: Science as Inquiry
- Abilities necessary to do scientific inquiry
- Understanding about scientific inquiry

Content Standard B: Physical Science
- Structure of atoms
- Structure and properties of matter
- Chemical reactions

Content Standard C: Life Science
- The cell
- Matter, energy, and organization in living systems

Content Standard E: Science and Technology
- Abilities of technological design
- Understanding about science and technology

Content Standard F: Science in Personal and Social Perspectives
- Science and technology in local, national, and global challenges

Content Standard G: History and Nature of Science
- Science as a human endeavor
- Nature of scientific knowledge
- Historical perspectives

VOCABULARY

Yeast: Any of various unicellular fungi of the genus *Saccharomyces*, especially *S. cerevisiae*, reproducing by budding and from ascospores and capable of fermenting carbohydrates (*The American Heritage Dictionary of the English Language* 2000).

Gluten: The mixture of proteins, including gliadins and glutelins, found in wheat grains, which are not soluble in water and which give wheat dough its elastic texture (*The American Heritage Dictionary of the English Language* 2000).

Wet mount slide: A microscope slide that contains a liquid material for viewing and uses a coverslip.

MATERIALS NEEDED, DECODED FOR THE GROCERY STORE

One-half package of active dry *Saccharomyces cerevisiae* (baking yeast)

- Yeast can be purchased in the section of your grocery store with the baking powder and flour. Yeast is usually sold in packages for less than $1. One package will work for two lab groups, so base your purchase on the number of lab groups that will be conducting this experiment.
- Make sure that the yeast has not expired. If you purchase yeast and want to use it later in the year, store it in a cool, dry area.

2.5 ml of sucrose, $C_{12}H_{22}O_{11}$ (sugar)

- Sugar is sold in as small as 5 lb. bags, and increases from there. A 5 lb. bag will give you enough sugar for more than 100 lab groups for this experiment.

5 ml of sodium chloride, NaCl (table salt)

- Each group uses salt in the creation of its dough, so a single salt container will be more than enough for 20 lab groups. The salt also can be used later for adding additional flavor to the finished pretzel.

475–550 ml of all-purpose powdered grains (flour)

- You will want a shopping cart for this material. The students need quite a bit of flour for this lab, but it actually isn't as much as you might think. I purchased one 25 lb. bag of flour (around $20) and have been using it for three years. A 5 lb. bag of flour will give you enough for at least four groups. I think the larger bags are worth the cost (and the weight).

Lipids as needed (shortening)

- One can of shortening is all you need for years of this lab. Students need a small amount to grease their aluminum foil so the dough does not stick while rising or cooking. You could purchase a nonstick cooking spray as well, but the shortening option is cheaper and lasts longer.

Aluminum foil

- Each lab group will need a sheet of aluminum foil to use for its dough when it is rising, as well as for cooking. I have students use the same sheet to save money. Rolls are sold in varying lengths, but a 75-yard roll will work for 100 lab groups.

Antibacterial wipe

- Each lab group will need to wipe down its work area thoroughly before placing the flour and dough on the counter. I give each group one wipe, so a typical tube will last for about 60 lab groups, depending on the number of sheets.

10 ml of sodium hydrogen carbonate, $NaHCO_3$ (baking soda)

- The baking soda goes into the water that pretzels are boiled in to create the hard outer shell. A single box of baking soda will work for about 25 lab groups. I recommend placing the baking soda in a large beaker with a metal scoop for the students to measure the necessary volume. In the box the powder is difficult to pour and often ends up spilling, even when a funnel is used.

Dish soap

- This is necessary for cleanup. I ask students to use an amount about the size of a quarter for each glass container, and I have one bottle available for every four lab groups to share.

SAFETY HIGHLIGHTS

- The Bunsen burners and ring stands present a potential for students to burn themselves if used incorrectly. Please make sure students have had Bunsen burner safety training before allowing them to participate in this lab. As a teacher, you also need to be prepared with burn treatment options, such as running the burned area under cold water, if a student gets hurt.
- If a glass stir rod breaks, you should dispose of the entire mixture in the beaker. Even if the break is minor, you may have shards of glass in the mixture that are not visible.
- Because students will be handling the food during the dough-making process, it is important that their work area is sterilized with antibacterial wipes and then covered with a food-safe material such as waxed paper before placing food on the counter. If there is concern about the cleanliness and sanitation of the table or counter space, students need to create their dough in a sterilized bowl.

Note that these safety highlights are in addition to the safety information detailed in the Safety Protocol section at the beginning of this book. Please refer to that section for additional information about safety when implementing this or any lab in this book.

PREPARATION

1. You will need to make an active yeast solution for the students to use in the microscope observation period that occurs while the yeast is rising. Take half a package of the dry yeast and mix it with 30 ml of warm water. Add the label "Caution: Active Organism Environment" and include a small plastic eyedropper. (I typically use disposable droppers when working with yeast so I don't need to worry about cleaning and sterilizing them.)
2. You also need to prepare sucrose dropper bottles for the microscope observation. I think it is best to have these prepared for students because of the time limit factor, but you can ask your students to make these solutions if you would like them to have experience making solutions of different concentrations. Making the solutions ahead of time also eliminates the amount of materials necessary for this step.
   (a) Measure 100 ml of warm water in a glass beaker. Measure 5 ml of sugar and pour it into the warm water. Stir until all the sugar is suspended. Then pour the solution evenly among three plastic dropper bottles, labeling each dropper bottle "5% Sucrose Solution."
   (b) Repeat step a for a 15% sugar solution by mixing in 15 ml of sugar and labeling the bottles "15% Sucrose Solution."
   (c) Repeat step a for a 30% sugar solution by mixing 30 ml of sugar and labeling the bottles "30% Sucrose Solution."
   (d) This will give you nine dropper bottles. If you have more student groups than nine, you can easily double the values to make more dropper bottles of each concentration.

PROCEDURE

I recommend having students work in teams of three or four for this experiment. The final product creates four small pretzels, which is plenty to share among a large group. There is also a significant amount of labor involved with the preparation of the dough, which can be shared equally by a large group. The large group size also cuts down on the total number of lab groups per class and the overall cost of supplies.

This lab requires sticking to a tight schedule if you are going to fit the entire process into a 90-minute period. If you have 45-minute classes, you can always have one group begin the dough-making process and complete microscope observations, and have the second class finish the pretzels and complete microscope observations while waiting for the pretzels to bake.

When I have completed this lab with large student groups (40 or more students), I have taken the entire class through the lab step-by-step rather than have all students attempt the procedure on their own. Although this makes the lab more directed, it alleviates the continuous calls for teacher attention from lab groups around the room. It also allows you to direct the times when cleaning is appropriate.

1. Begin by placing the students in lab groups and asking them to read the Background section. You can introduce the activity by asking them what their favorite foods are at sporting events to provide context and connections for each of the students.
2. Once students have read the Background section and moved to writing their hypothesis, I like to show them products that contain yeast, such as canned biscuits, crescent rolls, and sliced bread. I allow students to pass these around to help them see that sugar (sucrose) is a component in all of these breads. This also can initiate a discussion about the different densities and consistencies of each of these products.
3. This lab is broken down into three parts: pretzels before fermentation, microscope observations, and pretzels after fermentation. I instruct students to handle each part as a separate lab. This controls the materials that are out, the use of space, and the safety concerns at each moment in the classroom. I have also completed the lab when all the materials were out at one time, but found it was a bit chaotic and overwhelming. I recommend placing *only* the materials needed for the pretzels before fermentation out at the outset of the lab. The other two sets of materials can be kept in large boxes or containers that are not set out but will be exchanged when the students are ready to move on.
4. The students will be creating their dough on the flat tabletop or countertop. Students can complete these steps on a piece of waxed paper or in a large mixing bowl if you have concerns about the sanitation of your tabletops. I have asked students to bring in plastic or metal mixing bowls in the past.
5. The mountains of dough are messy. Preparing students for the messiness will prevent some screams that might occur when liquid leaks out of the dough. Although there are four students in each lab group, only two need to

be involved in the hands-on incorporation of the liquid. Another student can pour liquid in the mountain, while the fourth can be cleaning out used glassware. Remind them of the importance of adding small amounts of liquid at a time so it doesn't leak off the table. *Safety note*: Immediately wipe up any liquids spilled on the floor to prevent a slip/fall hazard.

6. When the dough is finished and students are covering it with a damp paper towel, make sure the towels are not constricting the dough from rising. It is often helpful to walk around and pull the paper towels off the dough and place them back about 15 minutes into the rising process.
7. When you reach the microscope observations, it is important to show your students how to correctly carry the microscopes with two hands—one on the base and one on the arm—if they are moving them from a cabinet or central supply area to their work area.
8. Depending on their experience with microscopes, it may be helpful to demonstrate a wet mount for the entire class before sending the students off to make their own observations.
9. If you are running short on time, you can prepare the slides and microscopes to allow students to view in a rotation. Do not leave the lights of the microscope on, as this can overheat and kill the yeast.
10. For the pretzel twisting technique, take the two ends of the dough rope and twist them together. Then fold the twisted end back over and attach to the center of the loop of dough. I encourage students to create whatever shape they want, keeping in mind if all the dough is packed together in a ball, they will have raw dough in their final product.
11. When the pretzels are placed in the water with the baking soda, the water will fizz up and potentially spill over the edge of the beaker. This is important to know so you can keep an eye on students' Bunsen burner flames. If a flame goes out, students need to immediately turn off the gas valve so gas does not leak into the room.
12. The most difficult part of this lab is removing the boiled pretzels from the beaker of water. I have the students use two pairs of tongs. Some pretzels may fall apart, but students can put them back together before they bake.
13. There are two options for baking the pretzels: First, you can ask the staff in your cafeteria to help you with the baking process. Most schools have rules about students not being in the school kitchen, so check with your administrative staff. The second option is to use toaster ovens. I have had several donated so that I am up to four toaster ovens, which works well for cooking

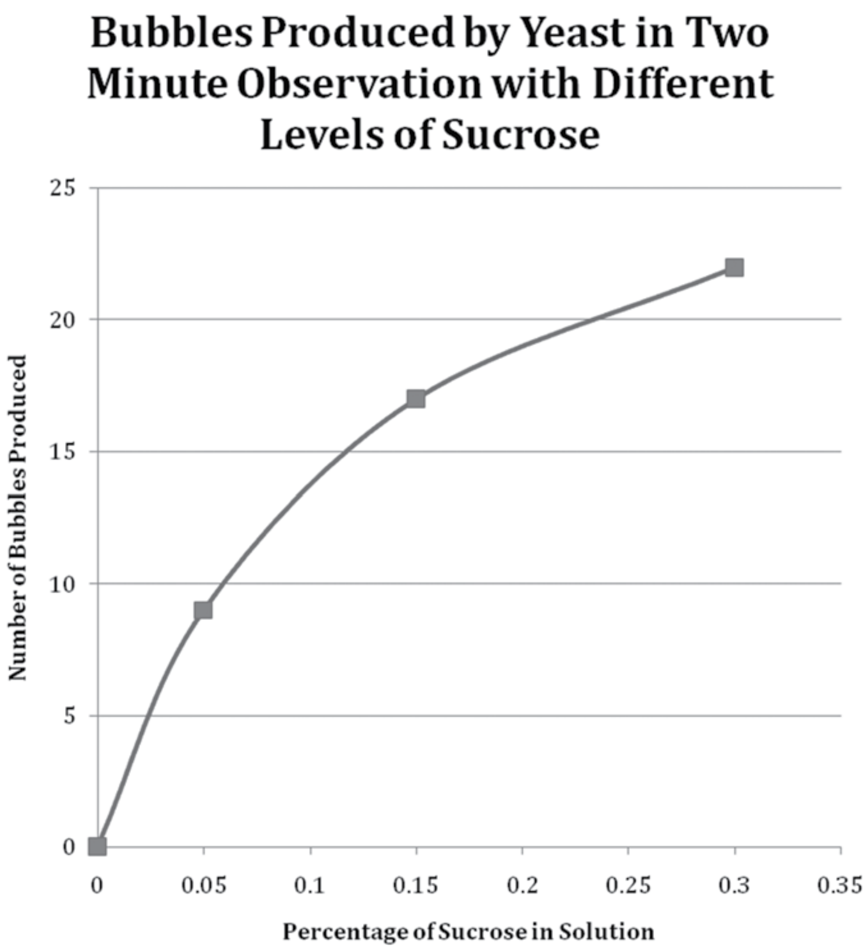
pretzels in rotation for up to 35 students. You can get inexpensive toaster ovens for around $25. These ovens have made other labs possible as well without bothering the kitchen staff.

14. I handle the baking of pretzels, and require that all the students in a single group have all their pretzels on a single piece of aluminum foil that can fit in the toaster oven. This cuts down on baking time, allowing you to bake four pretzels at once. I also do not hand out a single pretzel until the entire lab is clean.
15. Students can add salt, cinnamon sugar, or other condiments to their pretzels after they are baked. If these condiments are placed on the pretzels before the baking, they often burn, so it is better to add them after baking is complete.
16. Once the pretzels have cooled, tear the aluminum foil sheet into four pieces and allow each student to take his or her pretzel while working on their data analysis.

DATA ANALYSIS ANSWER KEY

All the data analysis for this lab is math based. If students are struggling with the questions, I recommend using a sample data set and going through the calculations as a class on the board. Then students can use the same skills and apply them directly to their data.

1. ***Create a bar graph that shows the number of bubbles created by the yeast when combined with different amounts of sucrose. Remember to include all elements of a scientific graph (title, labeled axes, units, legend, etc.).***



2. ***What was the rate of bubbles being created for each of the*** Saccharomyces cerevisiae ***slides? Show your work in the table below.***

   Each student will have slightly different numbers, but those numbers should show the trend that more bubbles are created as the sucrose content increases. To find the rate of bubbles created, students need to take the total number of bubbles created and divide that number by 120 seconds. (Watch that they do not use two minutes because that is not the unit format in the table.) Here is a sample showing student data and calculations:

	Number of bubbles created	Time for bubble creation (seconds)	Rate of bubbles created per second
Saccharomyces cerevisiae with no sucrose	0	120 seconds	0 bubbles/second
Saccharomyces cerevisiae with 5% sucrose	9	120 seconds	0.075 bubbles/second
Saccharomyces cerevisiae with 15% sucrose	17	120 seconds	0.142 bubbles/second
Saccharomyces cerevisiae with 30% sucrose	22	120 seconds	0.183 bubbles/second

CONCLUSION AND CONNECTIONS ANSWER KEY

This section of the lab offers a great opportunity to engage the entire class in discussion to clarify the main ideas of the lab and allow the students to make their own connections between science and cooking. I ask that students answer the Data Analysis questions and attempt to answer the Conclusion and Connections questions, with the understanding that we will spend time the next day discussing the Conclusions and Connections section.

1. ***Was your initial hypothesis correct? Restate your hypothesis and identify whether you were correct or incorrect, using data to support your answer.***

   Students will have different initial answers based on their specific hypotheses, but everyone should identify that the trend in the graph shows that the rate of bubble creation increases as the sucrose content increases. This is demonstrated by the rise in the graph.

2. ***Why is it necessary for the dough to be kneaded? What process does this accomplish? What would you expect dough to look like if it had not been kneaded?***

   The dough is kneaded to realign the gluten chains to make the dough smooth and more elastic. If the dough had not been kneaded, it would have turned

out lumpy with an inconsistent texture because of globular gluten concentrations being different throughout the dough.

3. ***Why does the dough need time to rise? What process is occurring during this period? What would you expect dough to be like if it had not been given time to rise?***

   The dough needs a chance to rise to give the yeast organisms an opportunity to ferment the sugars in the dough and produce the air bubbles that make the bread light and fluffy. Dough that was not given time to rise would be dense with no air bubbles because the yeast would not have time to produce the gas.

4. ***If you wanted to speed up the rising time for the pretzels, how would you alter the procedure?***

   There are two common answers for this question. One approach would be to increase the amount of sugar. Based on the student data, higher sucrose content produces more bubbles, and therefore should cause the yeast to rise faster. The other answer would be to increase the amount of yeast. By increasing the amount of yeast, there are more microorganisms completing the fermentation reaction, and therefore the yeast should rise faster. A third approach would be to heat the temperature of the rise environment to promote the fermentation process. Any of these answers, or a combination of the three, is acceptable.

CROSS-CURRICULAR NOTE: MATH

This experiment provides an excellent opportunity to work with the math teacher on skills such as rates and percentages. Students can also look at the graph to see whether the trend fits linear growth or exponential growth.

CROSS-CURRICULAR NOTE: LITERACY

There is a real-world connection between this lab and sporting venues. Students can research how much money is generated from the sales of pretzels at a nearby ballpark or stadium. How do pretzel sales compare to the sales of potato chips? Ask students to write a persuasive argument for why pretzels are a better choice for a snack when compared to chips. They should use data from their research to support their argument.

OPTIONAL EXTENSIONS

Middle School

1. Students can determine the effect of temperature on glucose fermentation. They can test temperatures such as 4°C, room temperature, 26°C, 32°C, 36°C, 41°C, and 49°C.
2. Students can compare fermentation of different sugars by baker's yeast (*Saccharomyces cerevisiae*) and brewer's yeast (*Sacc. pastorianus*, or *S. bayanus*). Optional sugars include glucose, fructose, sucrose, maltose, lactose, galactose, and starch.
3. Ask students to break down the lab procedure for creating pretzels and identify where chemical changes are taking place and where physical changes are taking place to study the difference between the two processes.

High School

1. You could modify this lab to incorporate more inquiry by having students create a procedure for measuring the relationship between sugar concentration and yeast fermentation.
2. Have students look at the actual process of fermentation as anaerobic respiration. Students can compare and contrast this model to the aerobic respiration of the Krebs cycle, glycolysis, and electron transport chain.
3. Students can look at the cellular structure of yeast. Ask, "How does the yeast cell compare with the human cell? What organelles are similar, and which are different?" This line of questioning can lead into a discussion about early life on Earth and evolution.

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Zea mays everta. *See* Popcorn