Food Science –
Physical vs Chemical Changes:
Laboratory for Primary Level Students
Teacher Manual

WOMEN SUPPORTING
WOMEN IN THE SCIENCES

Mission Statement

This laboratory will teach chemical versus physical changes to a target audience of elementary/primary-aged students (ages ~6-12) through experiments related to food spoilage.

Contents

1. Introduction to WS2 Laboratories

1.1. Information about WS2

Women Supporting Women in the Sciences (WS2), an international organization unifying and supporting graduate and professional-level women and allies in science, technology, engineering, and mathematics (STEM), was awarded an American Physical Society (APS) Innovation Fund in 2020 to form international teams to design and distribute low-cost physics and materials science lab kits to 5000 primary and secondary school students, predominantly in eastern Africa. The lab kits are intended to utilize local resources and include topics that are especially relevant to young girls in order to spur their interest in STEM subjects. The international teams, which designed the content found in these laboratory manuals, worked with WS2 Partners in eastern Africa in order to successfully deliver and teach the science lab kits to their local communities through 2022. WS2 gratefully acknowledges the hard work of the teams in the creation of this lab kit content. For more information about WS2, please visit our website at ws2global.org.

WS2 is sponsored by the APS Innovation Fund, Northwestern University Materials Research Science and Engineering Center, and Northwestern University Multicultural Student Affairs. WS2 Partners receiving lab kits are representatives from Makerere University (Uganda), Masinde Muliro University of Science and Technology (Kenya), Mbeya University of Science and Technology (Tanzania), Mkwawa University College of Education (Tanzania), Nelson Mandela African Institution for Science and Technology (Tanzania), University of Dar es Salaam (Tanzania), University of Dodoma (Tanzania), and University of Rwanda (Rwanda). The APS, Materials World Modules, SciBridge, and Projekt Inspire have provided valuable input on WS2 lab kit design. WS2 especially thanks WS2 Partner representatives (John Bakayana, Pendo Bigambo, Daudi Mazengo, Lawrence Robert Msalilwa, Celine Omondi, Marcellin Rutegwa), Tom Coon and students of Haile-Manas Academy (Debre Birhan, Ethiopia), and Carla Johnston and students of Frank Bergman Elementary School (Manhattan, KS, USA) for piloting the lab kits with small focus groups in late 2021. WS2 also tremendously thanks the virtual lab kit design team that created the content for this lab manual.

1.2. Using this Guide

This manual is to be used by the teacher of the laboratory, and it is similar in content to the student manual but contains additional material, namely: Overview, Fundamental Physics and Materials Science Concepts Covered, Practical Skills, Background on Main Topics, Summary of Experiments, Results, Teacher Pre-Lab, Troubleshooting. These additional sections are intended to provide the teacher with the background and foundation critical for successfully implementing this laboratory kit in the classroom. It is recommended that the teachers of this laboratory go through the guide from beginning to end to familiarize themselves with the laboratory content prior to teaching the laboratory to students. Questions about the laboratory content can be directed at any time to ws2global.org@gmail.com, using the subject line "Question about Lab Kit Content".

IMPORTANT NOTES:

- This laboratory is intended for use with primary-level students (ages ~6-12), but depending on the specific students' educational background, the content may need to be modified by the teacher to be made simpler or more complex. The teacher is encouraged to also cover the laboratory content at the pace that works best for the students; some younger students may need more time and attention from the teacher and/or facilitator to go through the questions and experiments, while older students may be more independent and require less attention from the teacher and/or facilitator. Thus, the content covered, depth of coverage, and pacing are left to the teacher's and/or facilitator's discretion.
- The content in this lab manual may not fit into the specific curriculum of the school in which it is being taught. It is up to the facilitator(s) and teacher(s) whether they would like to introduce new content or skip certain sections that are not applicable to their classrooms.
- In certain areas, modifications to the supply list may need to be made depending on the availability of the supplies in the specific area in which the lab is being taught. We have attempted to list some alternatives in the supply list, but we understand this list of alternatives is not exhaustive.
- In the experiments, the students are split into groups of four. If supplies allow, students may instead be split into groups of two or three.

1.3. Key Vocabulary

- Matter: Material that has a mass and takes up space ('stuff')
- Physical change: The process by which matter remains the same, but may change shape or form
- Chemical change: The process by which matter turns into something else
- Irreversible: A change that cannot be undone
- Food spoilage: A process by which food becomes unsuitable to eat by a consumer
- Preservatives: A chemical additive used to prevent or slow food spoilage caused by chemical change

1.4. Key Questions

- What is the difference between a physical change and chemical change? Can you think of some examples?
    - Answer: A physical change is a process by which an object changes shape or form. Examples of physical changes include breaking glass, ripping clothing, or melting ice. A chemical change is when a substance turns into something else. Examples of chemical changes include baking bread, burning firewood, or digesting food.
- What are some factors that slow the rate of food spoilage?
    - Answer: Some examples include temperature, time, humidity, and sunlight. The rate of spoilage is also influenced by the type of food (what it is made of) and any preservatives that have been added.

1.5. Purpose

In this lab, students will learn the difference between a physical and chemical change. They will also learn about factors that slow down the rate of food spoilage. This includes the use of preservatives (lemon juice, or some form of citric acid) and/or packaging that reduces light and oxygen exposure.

1.6. Overview

Through this laboratory, elementary/primary-aged students (ages ~6-12 years) are going to be taught chemical versus physical changes through experiments relating to food spoilage.

1.7. Fundamental Physics and Materials Science Concepts Covered

This laboratory introduces the subject of Chemistry and Food Science to elementary/primary-aged students. Chemistry is the study of matter and understanding how matter can change. These labs encourage students to think critically about preparing food and preventing food from spoiling.

1.8. Practical Skills

- Students will cut food safely.
- Students will preserve food from spoilage.
- Students will connect chemistry concepts to everyday food experiences.

2. Background on Main Topics

2.1. Physical vs Chemical Changes

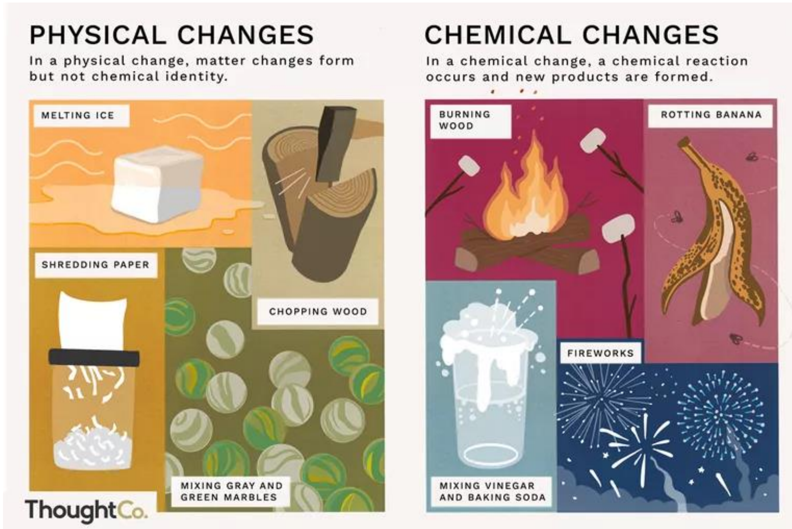


Figure 1. Examples of physical changes on left – melting ice, chopping wood, shredding paper, mixing marbles – and chemical changes on right – burning wood, rotting banana, mixing vinegar and baking soda, fireworks. Source: ThoughtCo.

A physical change occurs when matter changes form, but not chemical identity. Cutting produce (here, produce means many types of farm-produced crops like fruits and vegetables), crumbling a piece of paper, or dissolving sugar in water are examples of physical change. Chemical identity does not change; therefore, physical change is usually reversible (can return to its original form). For example, dissolved sugar in water can be reversed by evaporating the water from the solution. Once the water evaporates, sugar crystals will be left behind. Examples of physical changes are shown in Figure 1 (left). For the example of marbles in Figure 1, think about two boxes of marbles: one contains gray marbles, and one contains green marbles. Now think about mixing the two boxes together. Since the gray and green marbles can still be separated after mixing and no new types of marbles have been created, like blue marbles, this change is physical.

A chemical change occurs when a reaction forms new products. Baking a cake, leaves changing color on trees, and food digesting in your stomach are examples of chemical changes. There may be clues that a chemical reaction has taken place, such as the release of light or heat, a color change, gas production, an odor, or a sound.

Since chemical changes make new products, they are usually irreversible. Irreversible means the change cannot be undone. For example, when you burn wood, you cannot really turn the heat and gases back into a log very easily. Examples of chemical changes are shown in Figure 1 (right).

Scientists can determine if a chemical change has occurred by asking the question: Are different or new products present after the change takes place? If not, then the change is physical.

"red apple core" by roger.karlsson is licensed under CC BY 2.0

"red apple core two days" by roger.karlsson is licensed under CC BY 2.0

"Red apple core nine days" by roger.karlsson is licensed under CC BY 2.0

Figure 2. Example of a chemical change as an apple core sits out over several days. Notice how the core browns over time. Source: Roger Karlsson

When the flesh of the apple turns brown, it undergoes a chemical change. See an example of this chemical change in Figure 2. The browning of the apple is irreversible. Another example of a chemical change is rusting, which occurs when certain metals, like iron, are left outside and exposed to air and water over time. See an example of rusting chains in Figure 3. Like the browning of an apple, rusting is irreversible.

Figure 3. Example of a chemical change as metal chains rust over time. The chains on the left have rusted. The chains on the right have not because they have a special coating that prevents them from rusting. Source: photostock-israel/getty images

If an apple browns significantly, the apple is likely spoiled. Spoiled food can look, feel, taste, and smell unpleasant. It can also make you sick if you eat it. Various factors such as light, oxygen, heat, humidity, temperature, bacteria, and fungi can spoil food making it unsuitable for consumption. Food is more likely to spoil when exposed to one or more of these factors over time.

2.2. Sources

Helmenstine, Anne Marie, Ph.D. Examples of Physical Changes and Chemical Changes. ThoughtCo, Apr. 1, 2021, thoughtco.com/physical-and-chemical-changes-examples-608338.

Helmenstine, Anne Marie, Ph.D. How Rust and Corrosion Work. ThoughtCo, Feb. 16, 2021, thoughtco.com/how-rust-works-608461.

Helmenstine, Anne Marie, Ph.D. Why Do Apple Slices Turn Brown? ThoughtCo, Aug. 25, 2020, thoughtco.com/why-cut-apples-turn-brown-604292.

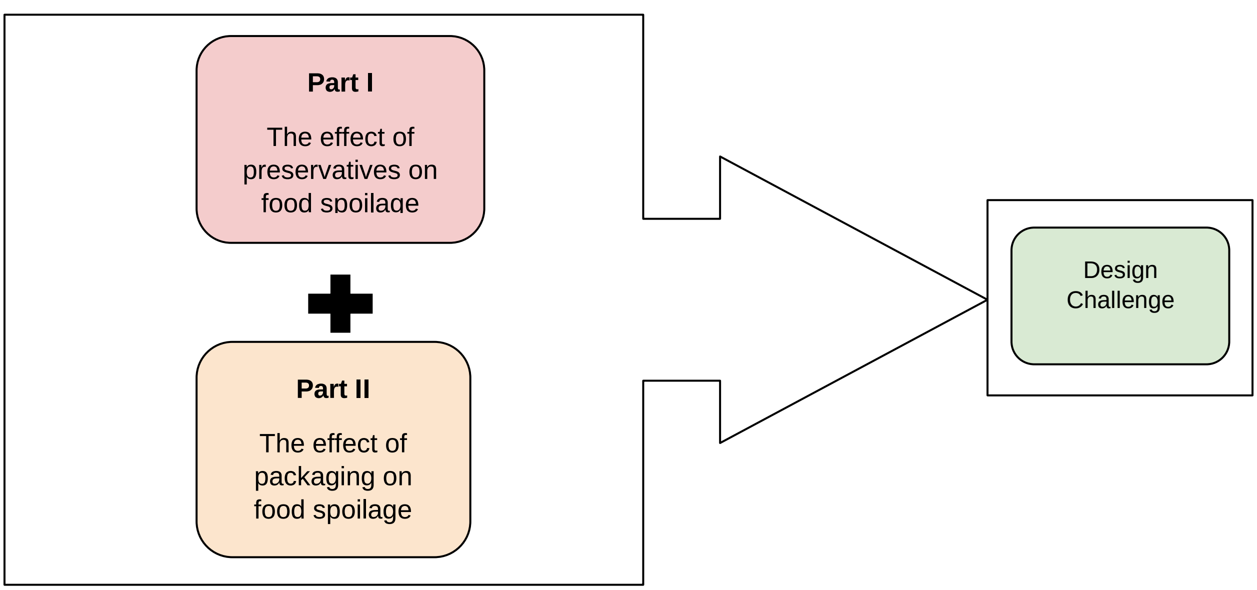
Ashish. (Feb 1, 2021). Why Do Apples Turn Brown? How To Keep Apples From Turning Brown?. Science ABC, Feb 1, 2021, https://www.scienceabc.com/eyeopeners/why-do-apples-turn-brown-and-how-can-you-prevent-it.html.

For more advanced information on apples browning, visit the following website:

McLandsborough, L. (2007, July 30). Why do apple slices turn brown after being cut? Scientific American. Retrieved May 10, 2021. https://www.scientificamerican.com/article/experts-why-cut-apples-turn-brown/.

3. Summary of Experiments

In this food science laboratory, students will investigate which type of preservative and packaging keeps produce from spoiling. By the end of the laboratory, students should be able to differentiate between physical and chemical change, understand some factors that affect food spoilage, and design a method that allows produce to be preserved. The laboratory is split into two experimental parts: Part I investigates the effect of preservatives on food spoilage and Part II investigates the effect of packaging on food spoilage. Students can extend their knowledge with a design challenge. A schematic describing the laboratory and experiments is shown below.



3.1. Supplies List

- Tools: knife, paper, pen or pencil
- Produce: Potato, banana, or plantain (additions and/or alternatives: apples, pears, lettuce)
- Preservatives: Lemon juice, table salt (additions and/or alternatives: lemon, orange, orange juice, lime, lime juice, vinegar, raw honey)
- Packaging: Aluminum foil, paper (additions and/or alternatives: newspaper, paper bags, wastepaper, cloth, wax paper, metal container, foil wrappings from candy)
    - The key is to find two types of packaging: one that is mostly impermeable to air and non-absorbent, like a metal can or foil, and one that is permeable to air and absorbent, like paper or cloth. You are encouraged to recycle waste materials when possible

3.2. Safety Information

Before the students begin the laboratory, please take into consideration the following safety concerns:

- Demonstrate to the students how to safely hold a knife and cut produce to avoid injuries. You may also pre-cut the produce to avoid any safety concerns.
- Lemon and lime juice (or citrus juice) are acidic and may sting open cuts and wounds as well as if they get into students' eyes.
- While tasting food is part of the food preparation process, please do not taste the food in this lab because the spoiled food may cause the taster to get sick.

3.3. Results

- See Appendix C for pictures of results for Part I and Appendix D for pictures of results for Part II.
- See Appendix E for additional pictures of set-up and results of other fruits for Parts I and II.
- Google Photo Album link for more pictures: https://photos.app.goo.gl/UQ2JcKNiaE1fkB9e7

3.4. Teacher Pre-Lab

To avoid injuries, teachers should show students how to hold a knife in order to cut produce. Teachers may also pre-cut some of the produce that are difficult for students to cut, such as potatoes.

Teachers may print the following to save time from making data tables.

- Copies of Appendix A (Part I) for every group
- Copies of Appendix B (Part II) for every group

4. Experiments

4.1. Part I. Effect of Preservatives on Food Spoilage

4.1.1. *Pre-Experiment Questions*

1. How is a physical change different from a chemical change?
    a. Answer: In a physical change, the matter remains the same while in a chemical change, the matter changes into something else.
2. What are some examples of physical and chemical changes while preparing a meal?
    a. Answer:
        i. Physical change examples: cutting, shredding, melting, freezing, boiling, dissolving additives (e.g., sugar, salt, food coloring)
        ii. Chemical change examples: baking, grilling, burning, charring
    b. Extension question to ask: Are different materials present after the change takes place? If not, then the change is physical, not chemical. Since chemical changes make new material, they are usually irreversible.

3. What happens when you leave produce, such as potatoes and bananas, out for a week?
    a. Answer: It spoils. It is no longer nutritious nor edible.
    b. Extension question: How does the old produce look?
        i. Answer: It usually changes color, turning brown or black. There may be mold on it. Potatoes can grow sprouts.
    c. Extension question: How does the old produce feel?
        i. Answer: It will likely be softer to touch, soggy, and/or slimy.
    d. Extension question: How does the old produce smell?
        i. Answer: It may smell rotten, rancid, and/or pungent.
    e. Extension question: How might the old produce taste?
        i. Answer: It will taste different – probably rotten, rancid, and/or pungent. It might also make you sick.
4. What are preservatives? What are some examples of preservatives?
    a. Answer: A preservative is a chemical that is added to prevent food from decay. Some examples of preservatives are salt, nitrites, and citric juice. Other examples of preservatives may be acceptable.
5. Which preservative do you think will keep your food from spoiling: no preservative, lemon juice, or salt? Or will they all keep the freshness the same? Why do you think this?
    a. Answer: Various answers are acceptable. The teacher can also make a chart of students' predictions and reasonings.
    b. Instead of asking a question, the student can use a sentence starter: "I think the food with … (nothing, lemon juice, salt) will keep the food from spoiling because ..."

4.1.2. *Assignment of Tasks (2-4 students per group)*

Student 1: One student will be responsible for cutting the food. This student will slice three pieces of food (potato and banana) to be the same size as one another. Put the slices of potato and banana on the paper in rows. This student can also make a table on paper, such as the picture shown in Figure 4.

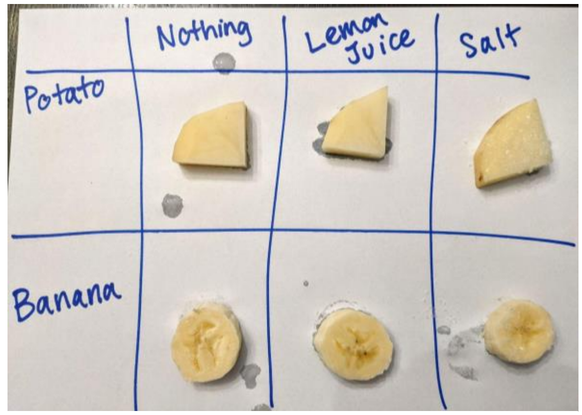


Figure 4. Example of cut produce with different preservatives added. The table helps to organize the produce and preservatives.

Student 2: One student will be responsible for adding the preservatives to the produce. This student will do nothing to the first slice of food in each row. This student will then squeeze a few drops of lemon juice on the second slice in each row so that the whole surface of the piece has lemon juice on it. Lastly, this student will sprinkle salt on the third slice in each row so that the whole surface has a thin layer of salt on it. See the picture in Figure 4 for the general set-up.

Student 3: One student will be the starting observer. On a separate piece of paper, make the table in Appendix A big enough to fill out the whole sheet. Draw a picture of the food and write down observations about how it looks, feels, and smells. Record the date and time of observations.

Student 4: The fourth student will be the final observer. At the end of the school day (or the next school day), look very closely at your pieces of produce. On a separate piece of paper, make the chart in Appendix A big enough to fill out. Record the date and time of observations. Draw a picture of the food and write down observations about how it looks, feels, and smells. Note the changes you see happening (if any).

See Appendix C for pictures of results.

4.1.3. *Post-Experiment Questions*

1. During this investigation, what step is an example of a physical change? What step is an example of a chemical change?

    a. Answer: Step 1, where the student is cutting the food, is an example of a physical change because the food remains as the same substance. Step 3 to 4 is an example of a chemical change because the food is starting to spoil and is no longer safe to eat.
2. Which preservative led to the least spoiled produce: no preservatives, lemon juice, or salt? Or did they all keep the freshness the same? How do you know?
    a. Answer: Lemon juice seems to preserve the produce the longest because the banana and potato did not brown as much. Next time you are at a store or restaurant, check out the bags of apple slices you can get. If you look at the ingredients list, those apples have citric acid (found in lemon juice) added to them! Packing apple slices for lunch? Add a few drops of lemon juice to the apples to prevent them from spoiling.
    b. Instead of asking a question, the student can use a sentence starter: "I noticed the food with… (nothing/ lemon juice/ salt) kept the food from spoiling because I observed that …"
3. Which preservative led to the most spoiled produce: no preservatives, lemon juice, or salt? Or did they all keep the freshness the same? How do you know?
    a. Answer: Surprisingly the salt spoiled the produce the most. It sucked a lot of water out of the potato and banana and turned the produce a black/brown color.
4. What are some other preservatives that may affect the spoilage of produce?
    a. Answer: Sugar, raw honey, vinegar, other citric juices
5. What are some additional consequences of using a preservative?
    a. Answer: It changes the taste and flavor of the food when eaten. It may affect people with different dietary needs. It requires additional materials that may be costly, uncommon, or limited.

4.2. Part II. Effect of Packaging on Food Spoilage

4.2.1. *Pre-Experiment Questions*

1. How do you store your produce?

    a. Answer: Various answers are acceptable. Encourage students to share and listen to one another.
2. What food storage do you think will keep your food the freshest: no storage, aluminum foil, or paper bag? Or will they all keep the freshness the same? Why do you think this is?
    a. Answer: Various answers are acceptable. The teacher can also make a chart of students' predictions and reasonings.
    b. Instead of asking a question, the teacher can use a sentence starter: "I think the food wrapped with… (nothing/ aluminum foil/ paper) will keep the food from spoiling because ..."

4.2.2. Assignment of Tasks (2-4 students per group)

Student 1: One student will be responsible for cutting the food. This student will slice three pieces of food (potato and banana) to be the same size as one another. Put the slices of potato and banana on the paper in rows.

Student 2: One student will be the starting observer. On a separate piece of paper, make the chart in Appendix B big enough to fill out the whole sheet. Write the date and time of observations. Draw a picture of the food and write down observations about how it looks, feels, and smells. Record the date and time of observations. (This is a slightly different procedure compared to Part I because the student must observe before the food is packaged.)

Student 3: One student will be responsible for wrapping the produce. This student will do nothing to the first slice of food in each row. This student will then wrap the second slice of produce tightly with aluminum foil. Lastly, this student will wrap the third slice of produce with paper. See the picture in Figure 5 for the general set-up.

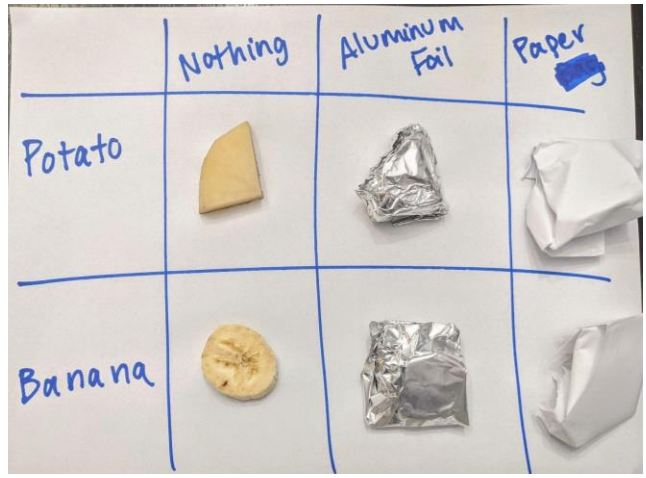


Figure 5. Example of cut produce with different packaging. The table helps to organize the produce and packaging.

Student 4: The fourth student will be the final observer. At the end of the school day (or the next school day), look very closely at your pieces of produce. On a separate piece of paper, make the chart in Appendix B big enough to fill out the whole sheet. Draw a picture of the produce and write down your observations about how it looks, feels, and smells. Note the changes you see happening (if any). Record the date and time of observations.

See Appendix D for pictures of results.

4.2.3. Post-Experiment Questions

1. Which packaging preserved the food the best: no packaging, aluminum foil, or paper?
    a. Answer: Aluminum foil
    b. Extension question: How do you know?
        i. Answer: The food wrapped in aluminum foil had the least number of brown and black spots. It also seemed as if the foil helped retain the moisture within the produce, whereas the paper absorbed some moisture and dried out the produce more.
        ii. Instead of asking a question, the teacher can use a sentence starter: "I noticed the food wrapped in … (nothing, aluminum foil, paper) kept the food from spoiling because I observed that ..."

2. Which packaging did not really preserve the food: no packaging, aluminum foil, or paper?
    a. Answer: No packaging
    b. Extension question: How do you know?
        i. Answer: It had many brown spots and was the softest to touch.
3. What are other packaging methods that may preserve produce longer?
    a. Answer: Plastic bags, plastic wraps, plastic containers, metal containers, thermos, newspaper, etc. Various answers are acceptable.
4. We've tested preservatives (Part I) and packaging (Part II) for their effects on food spoilage. What are some other ways you can keep food fresh longer?
    a. Answer: Colder temperature - refrigerators and freezers. Other answers may be acceptable.

5. Design Challenge

This challenge may require additional food/materials: sliced apples or sliced avocados or more bananas.

The Challenge: You are packing (sliced apples/ sliced avocados /a banana) for lunch tomorrow. Design a method that will keep the food (sliced apples/ sliced avocados/ a banana) as fresh as possible (or to be ready) for lunch.

Extra Challenge: Can you keep the food fresh for 2 days? How about 3 days?

5.1. Pre-Design Questions

1. What results from both experiments will you use to design your method?

    Answer: The results from Experiment I show that lemon juice preserved the food the longest. The results from Experiment II show that aluminum foil packaging preserved food the best.
2. What other information do you need to know in order to design your container/environment?

    Answer: All answers are personal and will vary. Some examples include: What is the current state of the food? How many hours until lunch? How long does this food need to be preserved for? What materials can I use? What materials are we provided?

3. What other variables may you want to test during the design process? A variable is something you change during the test.

   <u>Answer:</u> Colder temperature, amount of light, amount of oxygen. Various answers are acceptable.

<u>Extension Question:</u> What are the risks of testing new variables during the design process?

> <u>Answer:</u> The food may spoil even faster. Also, testing many variables at once can be confusing because you may not truly know which variable affected food spoilage. Consider testing the effect of food spoilage with lemon juice and aluminum foil. What if the lemon juice influences the aluminum foil (or vice versa) and this affects the food spoilage? This is why testing one idea or variable at a time is a good idea. Other answers are acceptable.

<u>Extension Question:</u> What are the benefits of testing new variables during the design process?

> <u>Answer:</u> The food may be preserved longer. Even if the food is not preserved well, you can share your results with others. Others can learn from your mistakes and results. This sharing of findings and results saves some time, effort, and materials. This is the process of science and teamwork. Other answers are acceptable.

<u>Extension Question:</u> Do you think the benefits outweigh the risks? Are you willing to test new variables with your design?

> <u>Answer:</u> Answers are personal and will vary.

5.2. Post-Design Questions

Answers are personal and will vary. There are no wrong answers. Teachers can encourage classmates to share their answers and to listen to others.

1. Explain your method to keep produce fresh.
2. How do you feel about the results of your design?
3. Which method had the most success? What characteristics made it have the most success?

4. How would you change your method for next time after viewing yours and your classmates' results?
5. What was challenging about completing the design challenge? How did you work through those moments of confusion or frustration?
6. What did you enjoy most about completing this design challenge?
7. What advice would you give a group about completing this design challenge?

6. Appendices

6.1. Appendix A – Table for Part I

The Effect of Preservatives on Different Produce

Date: ______ Time: ______		Preservatives		
		nothing	**lemon juice**	**salt**
Food	**potato**	Drawing: How does it look? How does it feel? (gentle!) How does it smell?	Drawing: How does it look? How does it feel? (gentle!) How does it smell?	Drawing: How does it look? How does it feel? (gentle!) How does it smell?
	banana	Drawing: How does it look? How does it feel? (gentle!) How does it smell?	Drawing: How does it look? How does it feel? (gentle!) How does it smell?	Drawing: How does it look? How does it feel? (gentle!) How does it smell?

6.2. Appendix B – Table for Part II

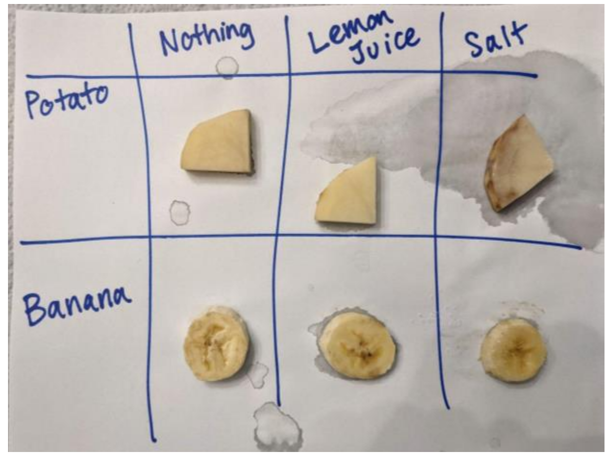
The Effect of Packaging on Different Produce

Date: _____ Time: _____		Packaging		
		nothing	**Aluminum foil**	**paper**
Food	**potato**	Drawing: How does it look? How does it feel? (gentle!) How does it smell?	Drawing: How does it look? How does it feel? (gentle!) How does it smell?	Drawing: How does it look? How does it feel? (gentle!) How does it smell?
	banana	Drawing: How does it look? How does it feel? (gentle!) How does it smell?	Drawing: How does it look? How does it feel? (gentle!) How does it smell?	Drawing: How does it look? How does it feel? (gentle!) How does it smell?

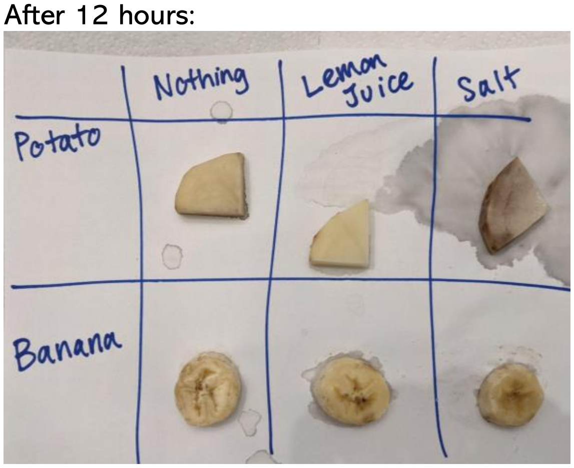
6.3. Appendix C – Results of Part I

Starting/Set-Up:

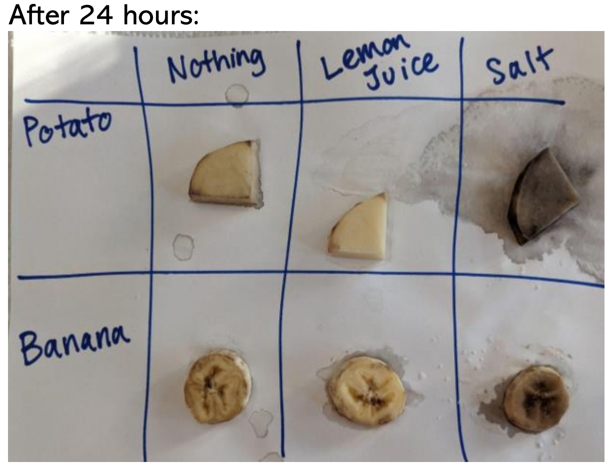
After 3 hours:



After 12 hours:

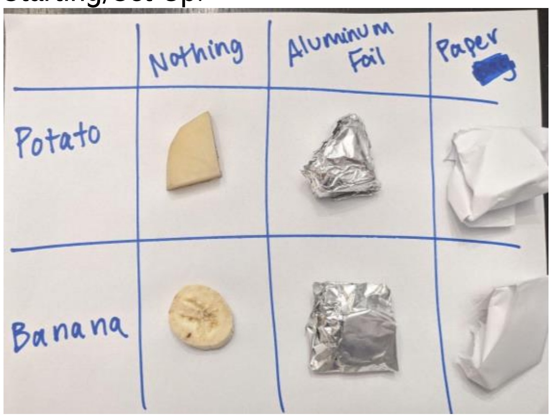


After 24 hours:



6.4. Appendix D – Results of Part II

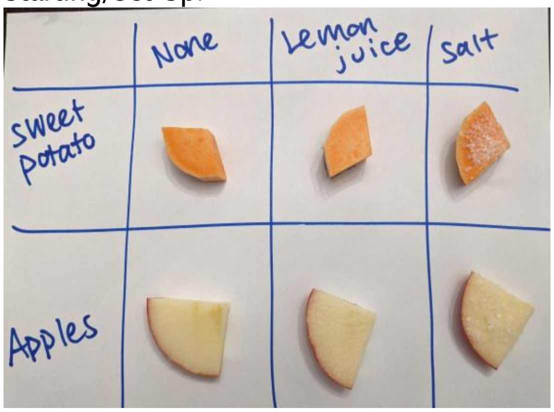
Starting/Set-Up:



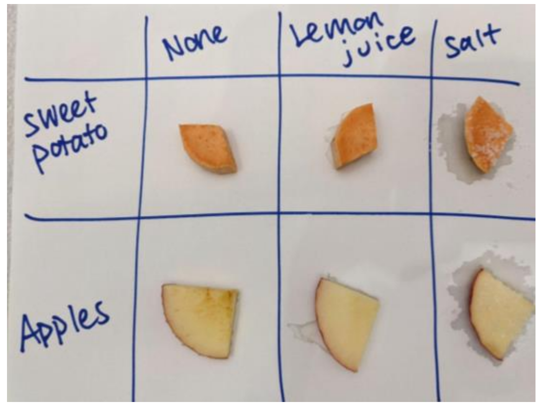
After 24 hours:

6.5. Appendix E – Results of Part I and Part II with Other Produce

Starting/Set-Up:



After 3 hours:



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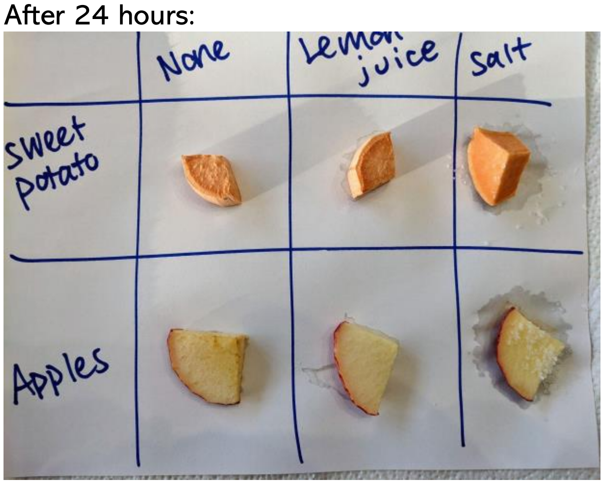
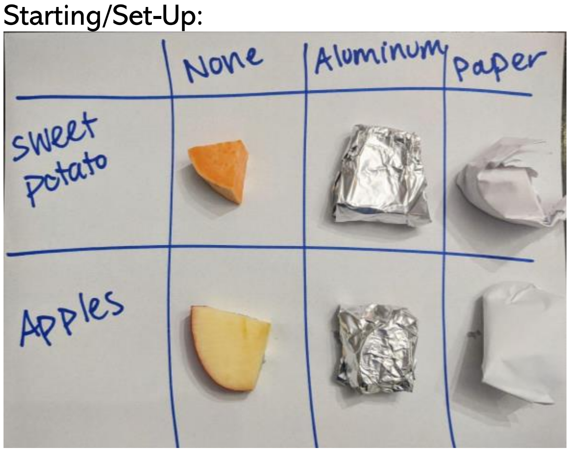


Starting/Set-Up:



After 24 hours: