

# Making and testing marshmallows

<b>Focus questions</b>	How does sugar type affect the chemical and physical properties of marshmallows? What role does chemistry play in how consumers prepare and consume food?
<b>Learning target</b>	Students will compare the effects of different sources of sugar on the chemical, physical, and sensory outcomes of homemade and store-bought marshmallows
<b>Vocabulary</b>	Maillard reaction, refractometer, Boyle's Law

## HS-PS1-3 Matter and Its Interactions HS-ETS1-1 Engineering Design

<b>Performance expectation</b> HS-PS1-3 HS-ETS1-1	<b>Classroom connection:</b> Students will conduct an investigation to test the difference in chemistry, taste, and texture of marshmallows using sugars from different sources (sugar beet sugar and cane sugar).
---	--

## Science and engineering practices

<b>Planning and carrying out investigations</b> <b>Defining and Delimiting an Engineering Problem</b> <b>Optimizing the Design Solution</b>	<b>Classroom connection:</b> Students will be given a protocol to complete the investigation. <b>Classroom connection:</b> Once completed, students will be given the opportunity to create their own protocol using other sugar sources.
---	--

## Disciplinary core ideas

<b>PS1.A: Structure and Properties of Matter</b>	<b>Classroom connection:</b> The activity applies the ideal gas law to link temperature and volume while making a marshmallow from liquid ingredients.
<b>PS2.B: Types of Interactions</b>	<b>Classroom connection:</b> Students will determine the difference between differently-sourced sugars and their impact on structure and flavor.

## Cross-cutting concepts

<b>Patterns</b>	<b>Classroom connection:</b> Students will look for patterns between different sugar sources and amounts of ingredients used.
<b>Stability and Change</b>	<b>Classroom connection:</b> Students will connect the use of gelatin as a protein source to the structure of the marshmallow.

## Background

During this activity, students will make and test marshmallows using sugars from two sources to see the differences that result. The testing will consist of inducing the Maillard reaction and using tools to test the sugar content and pH. A demonstration of Boyle's Law can be performed to show the relationship between pressure and volume as an extension.

The marshmallow market in the United States has a value of \$342 million and is projected to grow to \$535 million by 2028 according to Fortune Business Insights™ (2021). This growth can be attributed to an increased demand for premium and artisanal confectionery products. Up-and-coming brands are dedicating their businesses to large scale production of “premium” marshmallows. These premium marshmallows include a wide range of unique flavors to draw both adventurous and health-conscious consumers.

Even in something as seemingly simple as marshmallows, there is a lot of chemistry and science involved. The primary ingredient in marshmallows is sugar. The main sugar source is granulated sugar (sucrose) and corn syrup (glucose). The glucose prevents recrystallization of sugar. Gelatin (protein) is also an ingredient in marshmallows that halts recrystallization and creates a smooth texture.

When heated, the sugars undergo caramelization, where they break down and form new compounds, resulting in a brown color and sweet flavor. The Maillard reaction occurs when sugars and amino acids from the gelatin react, creating complex flavor compounds and contributing to the toasty, browned color. The air pockets within the marshmallow expand as it heats, causing it to puff up and soften. Read more about the chemistry of marshmallows: [cen.acs.org/food/food-science/s-marshmallows-ingredients-work-together/99/web/2021/04](https://cen.acs.org/food/food-science/s-marshmallows-ingredients-work-together/99/web/2021/04)

A Brix refractometer is a portable, precision optical instrument that measures the sugar content of a solution by measuring how light bends through it. A marshmallow's primary chemical property includes a high sugar content, stabilized by gelatin protein, which creates a foamy structure due to trapped air. Another chemical property of marshmallows includes a slightly acidic pH level typically ranging between 5 and 6.

Boyle's Law states that pressure is inversely proportional to volume. Mini marshmallows in a small syringe can demonstrate this process. Watch: [tiktok.com/@mrs.b.tv/video/6979270683553451269](https://www.tiktok.com/@mrs.b.tv/video/6979270683553451269) to see the demonstration.

## Prior knowledge

Students should be able to measure and mix ingredients in a mixing bowl and use hot plates safely. Students will be operating a hand mixer during this activity, so they should have some basic understanding in using a hand mixer properly.

## Suggested timing

1 class period to make marshmallows; 1 class period for testing

## Materials

### Part 1

- 170g granulated sugar of each type (cane and sugar beet)
- 119mL of water
- 60mL or 73.5g of corn syrup
- Nonstick vegetable oil spray
- Optional: parchment paper (to line bottom of pan)
- Cornstarch/powdered sugar mixture (17.5g of cornstarch mixed with 15g of powdered sugar)
- Paper bowl
- 10.5g unflavored gelatin for each type
- 2.5mL of vanilla extract
- 2 1000mL beaker per group
- Hand mixer
- Metal mixing bowl
- Spatula
- Candy thermometer
- Sifter

## Part 2

- Syringe
- Mini marshmallows
- Marshmallow samples
- Store-bought marshmallows (control)
- Safety goggles
- Metal fork or skewer with handle
- Stop watch/timer
- Bunsen burner or alcohol burner
- % Brix refractometer
- 250mL beaker
- Disposable pipette
- Cleaning wipes
- Hot plate or water bath
- Test tubes
- Distilled water
- Thermometer

## Teacher preparation

### Part 1: Making marshmallows

1. Copy student documents for each group.
2. Prepare materials for each group to use.
3. Consumable materials for 6 lab groups:
  - Pure cane granulated sugar: 1,020 grams (approx 4 lb bag)
  - Sugar beet granulated sugar: 1,020 grams (approx 4 lb bag)
  - Unflavored gelatin: 126g (1 box of 32 envelopes)
  - Cornstarch: 1 lb box
  - Powdered sugar: 1 lb box
  - Corn syrup: 720ml (2 - 1 pt bottles)
  - Vanilla extract: 30mL (4oz bottle)
  - Vegetable oil spray: 2 cans
  - Disposable metal baking pans: 6 (small pie/cake or bread pans work)
  - Candy flavorings (optional)
  - Food dyes (optional)
4. Instruct or remind students on the proper technique of using a hand mixer. This quick video could be used to instruct students: [youtu.be/b4ezir4DRPQ](https://youtu.be/b4ezir4DRPQ). For younger students this “paper plate hack” could be used to cut down on splatter: [youtu.be/HhQMt02IIJs](https://youtu.be/HhQMt02IIJs)
5. Ask students when they last ate a marshmallow. Discuss the ingredients in marshmallows. Discuss what other products might have those same ingredients. Highlight information from the background above.
6. Determine if any of the students are vegetarian or vegan. If so, an alternative to gelatin from animal sources will need to be substituted.
7. Have students complete the procedure below to make marshmallows from cane and sugar beet sugar.
8. After completing the activity, explain the chemistry to students so they can connect what they observed.

### Part 2: Chemical and sensory evaluations

1. Optional: Watch this video: [tiktok.com/@mrs.b.tv/video/6979270683553451269](https://tiktok.com/@mrs.b.tv/video/6979270683553451269)  
Show the demonstration applying Boyle’s Law to the action of the marshmallow.
2. Students use samples of the marshmallows they made to test for chemical and sensory properties.
3. Prepare lab stations with materials for each set of students.
4. Have students complete the chemical and sensory tests on their marshmallows and a store-bought control.
5. Ask students to complete the reflection questions on the student document.

# Student handout

## Reflection

1. Which marshmallow tasted the best?

Student answers will vary.

2. Which marshmallow had the best texture?

Student answers will vary.

3. How might you change the recipe to create a marshmallow with a different taste or texture?

Student answers will vary.

4. Optional: Explain how Boyle's Law can be demonstrated using a marshmallow.

Possible answer: Boyle's Law states that pressure is inversely proportional to volume. When a marshmallow is in a small syringe with the air removed and the opening plugged, pulling the plunger up reduces the pressure and increases the volume of the marshmallow. Releasing the opening increases the pressure and the marshmallow returns to its original volume.

## Differentiation

Other ways to connect with students with various needs:

- **Local community:** Visit a food processing facility in your community; this could be done through a virtual field trip with a leader from the company or from a processing facility that is not in your community.
- **Students with special needs (language/reading/auditory/visual):** Students who have restrictions on movement may be paired with others who can do the mixing for them. Other students with reading or writing limitations may be paired with a student who can read the recipe to them. If students are vegan or vegetarian, they should have an alternative or be excused from the taste and texture portions of the testing.
- **Extra support:**
  - Students may watch this video: The Science of marshmallows: [youtu.be/a2cJmNIEb6k](https://youtu.be/a2cJmNIEb6k)
  - Boyle's Law demo: [tiktok.com/@mrs.b.tv/video/6979270683553451269](https://tiktok.com/@mrs.b.tv/video/6979270683553451269)
- **Extensions:**
  - Investigate the history of marshmallows to determine where they originated and how they got their name.
  - Challenge students to make a better-tasting marshmallow or one with a different consistency. Students may try different combinations of liquid sweeteners (i.e. molasses, agave, or honey) as a substitute for corn syrup to see the effects on the taste and consistency of the marshmallow.
  - Create a recipe for vegan marshmallows using soy protein and carrageenan.
  - Create gummy treats by altering the amount of gelatin and corn syrup.

## Assessments

### Rubric for assessment

Skill	Developing	Satisfactory	Exemplary
Student followed the protocol for making and testing marshmallows.	Student did not follow the protocol for making marshmallows or did not test marshmallows or did not suggest a different variable to use to make them.	Student followed the protocol for making and testing marshmallows and suggested a different variable to use to make them.	Student followed the protocol for making and testing marshmallows and suggested a different variable to use to make them and can explain the impact of gelatin on the structure or different sugars on the taste/texture.

### Rubric for self-assessment

Skill	Yes	No	Unsure
I conducted an investigation by comparing homemade marshmallows from two different sugar sources to each other and store bought marshmallows.			
I can explain how marshmallows are made from liquid ingredients yet still have a semi solid state.			
Optional: I can explain Boyle's Law using a marshmallow.			