FOOD SCIENCE

Making and testing marshmallows

Focus questions	How does sugar type affect the chemical and physical properties of marshmallows? What role does chemistry play in how consumers prepare and consume food?
Vocabulary	Maillard reaction, refractometer, Boyle's Law

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.

You will make marshmallows using two sugars from different sources: cane sugar and sugar beet sugar. After making the marshmallows, you will test them using sensory, physical, and chemical tests.

1. Testing the Maillard reaction: When a marshmallow is toasted (not fully burned), a Maillard reaction occurs, which is a complex chemical reaction between sugars and amino acids, resulting in the desirable browned color and richer flavor. The rate of the Maillard reaction depends on the amount of moisture present and occurs at a lower temperature than caramelization.
2. Measuring sugar content and pH: 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.

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

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

Procedure

Part 1: Making marshmallows

1. Clean and sanitize your lab space before and after this procedure.
2. Lightly spray the inside of a metal baking pan with nonstick vegetable oil spray. Also label the side of the pan with the date, period or shift number, and lab team's initials.
3. Combine 17.5g cornstarch and 15g powdered sugar in a separate bowl.
4. Sprinkle 5g of the cornstarch-powdered sugar mixture all over the bottom and sides of the pan, then shake and tap the pan to make sure the powder mixture coats the inside of the pan evenly. Dump all excess powder mixture into the trash can.
5. In a metal or a glass mixing bowl, add 59.5mL of water then sprinkle 10.5g of gelatin on top of water to soak in evenly. Do not stir. Allow the gelatin to bloom (soak up all the water) while completing steps 6 and 7.
6. Add the following to a 1000mL beaker: 59.5mL of water, 170g of granulated sugar, and 60mL of corn syrup. Mix with a spatula to combine ingredients before placing on a hot plate.
7. Place the beaker on a hot plate set to medium heat and bring mixture to a boil (approximately 240oF). Once at desired temperature allow mixture to continue to boil for 1 minute, then remove from heat.
8. Carefully pour the hot sugar mixture into the gelatin mixture while wearing heat-resistant gloves.
9. Using a hand mixer, beat mixture on high for 6–8 minutes until the mixture is fluffy and forms soft peaks. Also during this mixing time, add in 2.5mL of vanilla extract and beat to combine. (Optional step: add another flavoring or food coloring if desired.)
10. Pour the marshmallow mixture into the prepared baking dish, using a greased spatula to smooth the top. Lightly dust some of the cornstarch/powdered sugar mixture (from step 3 above) over the top of the marshmallows using a sifter.
11. Allow the marshmallows to rest uncovered overnight.

12. After 24 hours, remove marshmallows from the pan. Using a greased pizza cutter or greased knife, cut marshmallows into 1 inch squares.
13. Once cut, lightly dust all sides of marshmallow with the powdered sugar mixture (from step 3 above). Store in an airtight container.

Part 2: Testing marshmallows

Maillard reaction

1. Connect the Bunsen burner to the gas jet and light burner to create flame.
2. Add a marshmallow sample to a fork or metal skewer.
3. To test the rate of browning marshmallow sample, start the stopwatch the moment the marshmallow is placed over the flame.
4. Observe the color of the flame.
5. Continue to rotate the marshmallow over the flame until an even browning has occurred around the marshmallow. Record the time it took for the Maillard reaction to take place and record the time in Data table 1.
6. Repeat steps 1–4 for a total of 3 trials for each type of marshmallow.

Brix refractometer and pH

1. Set up a water bath by heating 100mL of water in a 250mL beaker on a hot plate to 80 degrees Celsius.
2. Label a test tube with marshmallow type, then add a 1g sample of the marshmallow and 1mL of distilled water to the test tube.
3. Place the labeled test tube with marshmallow sample into the water bath to dissolve the marshmallow.
4. Once the marshmallow is completely dissolved and in a liquid state, then measure sugar content using a Brix Refractometer.
5. To use the Brix refractometer, lift the clear panel that sits on top of the blue prism of the refractometer.
6. Add two drops of the marshmallow sample to the blue prism and spread it out. Make sure there are no air bubbles in the sample and close the clear panel. Any air can be squeezed out by gently pressing down the panel and wiggle it slightly.
7. Hold the refractometer towards a bright light and look through the eyepiece. One should see a field of blue and another field of white, with a very distinct line where the two fields meet. In most analogue refractometers there is an ascending Brix scale in the middle, and a descending water content scale on the right.
8. The line will go through both scales to give both the Brix and the water content in percent in the same reading.
9. Clean the clear panel and prism using a disposable cleaning wipe or moisten lint free cloth.
10. To measure pH, add 2 drops of the marshmallow solutions from the test tube to a piece of pH paper.
11. Wait 10 seconds, then compare the color of the paper to the pH color comparator to determine pH value. Record in work order #2.
12. Repeat steps 1–9 for 3 trials of each marshmallow sample for sugar content.
13. Repeat steps 10–11 for 3 trials of each marshmallow sample for pH.

Data table 1: Marshmallow chemical evaluation

Sample type of marshmallow	Manufacture date	Date tested	pH	% Brix (sugar content)	Flame color	Maillard reaction time (s)
Sugar cane (homemade)						
Sugar beet (homemade)						
Control (manufactured)						

Note: Record the average of 3 trials for each sample.

Sensory evaluation

1. Test the marshmallow samples by tasting and smelling.
2. Complete Data table 2 by using the following terms for sensory descriptions:
   - **Aroma**
     - Floral: associated with different flowers
     - Fruity: associated with different fruits (acid, ripe, and tropical)
     - Vegetal: associated with gardens, green notes, dry leaves, and wood
     - Warm: associated with foods characterized by their sweet smell and taste
     - Chemical: not associated with food; characterized by its aggressiveness (smoked, phenolic, sulfuric, vinegary)
     - Animal: associated with animals and/or degradation (mold, urine, stable)
   - **Texture**
     - Smooth: no graininess or grittiness
     - Rough: grainy or gritty
   - **Taste**
     - Sweetness: sensation produced by products that contain sugars such as sucrose and fructose
     - Sourness: sensation produced by products that contain acids, such as citrus
     - Saltness: sensation produced by products that contain salts, such as sodium chloride
     - Bitterness: sensations produced by products such as caffeine

Data table 2: Marshmallow sensory evaluation

Sample type	Manufacture date	Date tested	Aroma	Texture	Taste
Sugar cane (homemade)					
Sugar beet (homemade)					
Control (manufactured)					

Reflection

1. Which marshmallow tasted the best?

2. Which marshmallow had the best texture?

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

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

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.			