The Science of Sugar

SATISFY YOUR SWEET TOOTH

University of Idaho Extension

4-H Food Science Curriculum

THE Science OF Sugar

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4-H FOOD SCIENCE OF CONFECTIONS SERIES

The science of confections series contains two manuals:

***Satisfy Your Sweet Tooth: The Science of Sugar* for ages 8–18**

***Satisfy Your Sweet Tooth: The Science of Chocolate* for ages 8–18**

The manuals may be used by anyone in these age groups regardless of their prior knowledge of confections. Each manual lists the objectives for the project and each experiment includes a short lesson, followed by hands-on experiments and questions for further learning. In addition, each manual includes an achievement program to help youth identify their goals and keep track of their accomplishments.

ABBREVIATIONS

lb	pound
min	minutes
oz	ounce
tbsp	tablespoon
tsp	teaspoon

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PART I:

Project Essentials

NOTES TO PROJECT HELPER

This manual is for youth who want to learn about the science of confections. They can't do it without your help. You play a key role in helping them learn the basic information, skills, and safety practices behind the production of confections. With your help they will set goals, find resources, and evaluate their own progress as they complete this manual. **Note: Youth may use any recipe they want. If they use a recipe that does not appear herein, they need to include it with their exhibition materials.**

Your Responsibilities

- Become familiar with the material in this book.
- Assist youth in selecting and completing science experiments appropriate for their skills.
- Guide youth through thinking about why something happens or why it doesn't.
- Encourage youth to complete difficult tasks to expand their skills.
- Help youth learn about their strengths and weaknesses.
- Help youth evaluate the quality of their completed experiments. Questions at the end of each experiment help youth think through the steps in the project and how to apply their new skills and knowledge to their everyday lives.
- Set an example by following kitchen and food-safety rules.

Using Experiential Learning

Experiential learning is the process of "do, reflect, apply." It is an inquiry-based approach to learning. Rather than being provided with information, learners experience, share, process, generalize, and apply what they are learning.

Do. Experience the activity, perform, do it. This could be a group activity or experience. It involves doing, it may be unfamiliar, and it pushes the learner to a new level.

Reflect. Share reactions and observations. Learners talk about their experiences while doing the activity. They share their reactions and observations and freely discuss their feelings.

Apply. Generalize to connect the experience to real-world examples. Learners identify general trends and real-life examples of when they could use what they have learned.

Developing Life Skills

Iowa State University's Targeting Life Skills Model helps identify the life skills youth attain through the experiential learning process. The life skills targeted in this manual include the following (see right):

Head

- Planning/organizing
- Goal setting
- Critical thinking
- Problem solving
- Decision making
- Learning how to learn

Heart

- Communication

Hands

- Marketable skills
- Self-motivation

Health

- Personal safety
- Healthy lifestyle choices

MY PLANS

This manual teaches youth the scientific concepts related to confections. Youth will complete experiments in order to create chemical reactions that produce desirable confections.

Use this page to help you plan how to finish this manual.

- Select your helper and write down their contact information.
- Set goals for each year. (This manual can be used for multiple years.)
- Complete the number of experiments listed below or what is required by your state and/or county each year.
- Use any recipe you want. If you use a recipe not in the manual, include the recipe used with materials you exhibit.
- You may utilize videos from the internet to assist with learning confectionary skills.
- Complete a presentation or demonstration each year.

Project helper: _____

Contact information: _____

My Achievement Program

Complete at least one (1) Sugar Chemistry Experiment, one (1) Research and Development Experiment, and four (4) Confections Experiments each year. Ask your helper to initial each experiment after you've completed it.

My Activities		
Activities	**Date Completed**	**Helper's Initials**

WHAT DO YOU KNOW?

The following is a list of the skills you will learn in the 4-H food science manual, *Satisfy Your Sweet Tooth: The Science of Sugar*. Before you start working on the project, read through the list of skills below and rate yourself on how much you know now in the column labeled "Before." Then at the end of each project year, rate what you know after completing the activities. Use the following rating scale:

Begin each statement with the phrase, "I know," then circle 1 = not at all; 2 = a little; 3 = a lot.

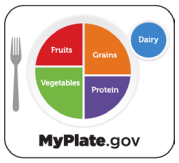
I Know . . .	**Before**			**After**		
What supersaturation means	1	2	3	1	2	3
The chemical structure of sugar	1	2	3	1	2	3
The difference between how beet and cane sugar is made	1	2	3	1	2	3
Different uses for sugar	1	2	3	1	2	3
Different types of confections	1	2	3	1	2	3
The six temperature stages of making candy	1	2	3	1	2	3
The difference between crystalline and noncrystalline candy	1	2	3	1	2	3
How to check a candy thermometer for accuracy	1	2	3	1	2	3
How to use the cold-water test	1	2	3	1	2	3
What Maillard browning is	1	2	3	1	2	3
The steps to replicate a confection	1	2	3	1	2	3
How to conduct a sensory test	1	2	3	1	2	3

MyPlate

We use it every day—a dinner plate! MyPlate is a visual reminder of how to fill our plate with healthful foods to build and maintain healthy bodies and minds. What you eat and drink matters (United States Department of Agriculture n.d.). Try the following:

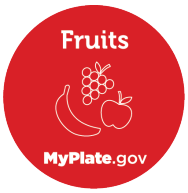
- Focus on variety, amount, and nutrition
- Choose foods and beverages with less saturated fats, sodium, and added sugars
- Start with small changes to build healthier eating styles
- Support healthy eating for everyone

Ready to get started? These images will remind you which steps to take for a healthy body.

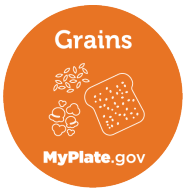


Find your healthy eating style and maintain it for a lifetime. Focus on variety, amount, and nutrition. Need quick meals? Try ready-made fresh vegetables. Remind yourself that your healthy eating style over time is what matters most.

Make half your plate fruits and vegetables. Try a variety of vegetables from all six subgroups: dark-green, starchy, red, and orange, beans and peas, and other vegetables. Raw, cooked, fresh, frozen, canned or dried/dehydrated are all good choices.

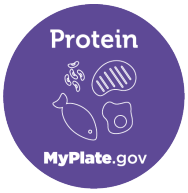


Make half your plate fruits and vegetables. Focus on whole fruits instead of juices. Fruit is the original fast food. Keep a bowl of fruit on your kitchen table or countertop. Try adding fruit to any meal.



Make half your grains whole grains. Look for the words ”100% whole grain” or ”100% whole wheat” on the food label. Try brown rice, whole grain bread, pasta, and tortillas for added fiber.

Try to drink or eat more low-fat/fat-free milk or yogurt. Use dairy products on baked potatoes, as a sandwich spread, or in a smoothie. Need **lactose**-free options? Try fortified soy, almond, oatmeal, or rice beverages.



Vary your protein routine. Try nuts, seeds, nut butters, beans, and peas occasionally instead of just eating meat, poultry, and seafood. Add protein to breakfast or snack time.

Make small changes: Cut out one sugary beverage per day, use a lower-salt food, or add a protein food to breakfast. Each healthy choice becomes a step toward a healthier you!

Which Food Group Does Candy and Chocolate Fit In?

Chocolate is a functional food, which means it contains an active antioxidant flavanol substance called **catechin**. This antioxidant reduces the destruction of healthy cells. The fat and sugar in chocolate adds calories to our diet, so eat it occasionally (USDA MyPlate n.d.).

Candy is sweet and contains a large amount of sugar, corn syrup, and/or fat. This makes its taste very desirable. Sugar is a simple carbohydrate which is rapidly digested to provide quick energy and a burst of flavor. Sugar contributes to the formation of dental caries (tooth decay) or cavities and can add extra calories to our diet. Candy should be an occasional food choice to enjoy for celebrations.

Food Group Review

Protein foods. Plant and animal sources of protein-rich foods provide our body with the nutrients needed to grow and maintain muscles and hair and to repair wounds. Select from meat, fish, poultry, seafood, beans, nuts, seeds, and nut butter.

Dairy products. Calcium is the main mineral needed for healthy bones and teeth. Dairy products are a rich source of calcium and are fortified with vitamin D. Enjoy low-fat milk, yogurt, and cheese as part of every meal. If you need a dairy alternative, choose lactose-free choices or a nonmilk option fortified with calcium and vitamin D.

Grains. Choosing whole grains means our body receives all parts of the edible plant. Look for brown rice, oats, rye, and wheat as a first ingredient in breads and cereals. Rich in carbohydrates, this food group provides energy for our body to work, play and grow. Fiber helps our digestion to work properly.

Vegetables. We all have our favorites, so try a new vegetable each week. Choose a variety of colors to benefit from the plant nutrients in the dark green of spinach and green beans, the red of tomatoes, the orange of winter squash and carrots, and the white of turnips and potatoes, to name a few. Beans and dry peas are also vegetables.

Fruit. Fruit choices include fresh, canned, frozen, or dried. You decide whether to eat them whole, cut up, or pureed. Any fruit is a good choice. They may be a deep yellow color and provide vitamin A, such as apricots and mangos, or citrus fruits rich in vitamin C, like oranges, lemons, limes, and strawberries.

Meal-Planning Activity

What's for dinner? It's a popular question that sometimes helps us decide what to cook. Now that you know which foods are in each food group, plan your meals to include at least one choice from each food group at every meal. Want to make it fun? Include a food that crunches when we bite into it and one with a new color we haven't tried before (for example, celery with hummus dressing or purple cauliflower with low-fat dressing). You can do this as a group activity.

Map out your meals. Plan to eat foods you like and new ones to try. Include beverages and snacks.

	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
Breakfast							
Lunch							
Dinner							

Find balance. Plan to have the recommended number and size of servings in a twenty-four-hour day. If you miss a vegetable at lunch, have two for dinner. Visit myplate.gov to find the calorie-intake level that is best for you.

Vary protein foods. We all like variety, so choose different types of protein throughout the week. Challenge yourself to have a different choice each day, ie. Sunday/fish, Monday/chicken, etc.

Make a grocery list. Once your meals are planned, help the adult who does the shopping at your home to make a grocery list. Start by checking your own food supply at home, including the pantry, refrigerator, and freezer.

Love your leftovers. To prevent food wastage, enjoy any extra food as a "plan over" meal. This saves you time and money.

KITCHEN AND FOOD-SAFETY BASICS

Kitchens are safe. It's the people who work in kitchens who can make them dangerous. Prevent that by using equipment and utensils properly and by handling sharp items, hot foods, and liquids carefully. When working in a kitchen, be aware of safety hazards and take precautions to keep injuries or accidents from happening by creating and maintaining a safe working environment.

Kitchen Safety

Many common accidents happen in the kitchen, such as burns, cuts, and falls. While cooking should be fun, you need to follow a few basic rules:

- Don't be in a hurry. Accidents happen when you're rushing.
- Always clean up spills. Serious injuries can occur when someone falls on a wet floor.
- Never leave food unattended on the stove. Many fires develop while the cook is not paying attention to what is cooking.
- Don't use a towel in place of a hot pad. Always use pot holders for both hands.
- Turn handles to the side and away from the edge of the stove.
- When cutting food, always cut away from you. Learn how to handle a knife properly.
- Never put a sharp knife or utensil in a sink of soapy water. Someone might put their hand in the sink and get cut.
- Don't leave a metal spoon in a pot that is boiling.
- When opening the lid on a steaming pan, always lift away from you. Steam can burn just as easily as boiling liquid can.
- Don't use electrical appliances around the sink or water.
- Avoid loose clothing and flowing hair. If you have long hair, tie it back.

Food Safety

- Wipe up spills when they happen.
- Wash your hands with soap under warm water for at least twenty seconds. Dry hands on a disposable paper towel or a towel designated just for hands.
- Use clean towels and dishcloths.
- Never put a spoon in your mouth and then back in the food.
- Keep all preparation and cooking surfaces clean.
- Thoroughly clean all dishes, equipment, and utensils with hot, soapy water after use.
- Check each experiment recipe for the preferred best storage options.

Hot Syrup Safety

Since hot syrup is the base for making confections, safety precautions are necessary:

- Stay ALERT! Avoid multitasking while making or working with hot syrups.
- Place a clean, moist cloth nearby so you can wipe up spills.
- Never taste confections until they have completely cooled.
- Cook all confections in a heavy, smooth, deep, and clean pan.
- Use long-handled wooden spoons — NEVER METAL!
- Use a heavy oven mitt and stand back when adding ingredients to boiling sugar.
- Always have an adult present when making confections.

FOOD-SCIENCE LAB ESSENTIALS

Below is a list of equipment you may need to complete this curriculum.

Equipment	Use
Dry measuring cups	Used to measure dry and solid ingredients. They usually come in a nesting set of 1 cup, ¾ cup, ½ cup, ⅓ cup, and ¼ cup.
Liquid measuring cups	Clear measuring cups used to measure liquid. Recommend a two-cup unit or more. Glass is best, especially when working with hot liquid that needs to be measured.
Measuring spoons	Used to measure dry and liquid ingredients. They usually come in a nesting set of 1 tbsp, ½ tbsp, 1 tsp, ½ tsp, and ¼ tsp. When you measure liquid ingredients, measure carefully to avoid spills.
Candy thermometer	Used to measure the temperature and therefore the state of the cooked sugar solution.
Saucepans	Heavy-bottomed pans in small, medium, and large sizes. Use those that have a smooth, heavy bottom with straight sides so that you can more reliably clip the candy thermometer onto its sides.
Mixing bowl set	Made of plastic, glass, or metal. A three-piece nested set is recommended.
Bench scraper	Used to work candy on cookie sheets and stone slabs.
High Heat–Resistant spatula	Used for mixing high-temperature ingredients.
Wooden spoons	Wooden spoons are best because they do not get hot. But choose those long enough to keep your hands safe from any hot steam and that will keep the spoon from falling down into the ingredients.
High Heat–Resistant pastry brush	Used for brushing sugar crystals from the side of pan while cooking.
Stand mixer	Equipment that properly aerates certain types of candies.
Digital scale	Used to weigh ingredients.
Stone slab	Used to work candy with a bench scraper.
Timer	To time candy preparation and development.
Oven mitts	Used to protect hands when working with hot foods and pans. Silicone is best.
Gummy molds	Make sure molds are heat resistant, durable, and made for candy.
Lollipop molds	Due to various sizes of lollipop or candy molds, the number of molds needed per recipe varies.
Food-grade plastic gloves	Used for molding foods that require you to use your hands.

Common Lab Ingredients

(italicized words are also defined in the glossary at the end of manual)

Butter. One of the most frequently used fats in confectionary. It is added directly or through dairy products containing butterfat.

Dairy products. Cow milk–based food stuffs that provide moisture, *amino acids*, and *lactose* for *Maillard browning*. They contribute to a confection's fat content and act as an ***emulsifier***.

Gelatin. A protein mixture that comes from animal collagen. It provides the gel consistency that is necessary for some confections.

Glucose syrup (corn syrup). A thick, sticky, and sugary solution made with cornstarch and that is used in many confection recipes.

Honey. Made up mainly of fructose and glucose, its flavor and color are influenced by the types of flowers from which bees collected the nectar.

Maple sugar and maple syrup. A sweet liquid substance, mainly sucrose, made by concentrating the sap from a sugar maple or black maple tree. The highest grade of maple syrup is the lightest in color and flavor and the lowest grade is the darkest. Darker syrup has a less subtle and more robust flavor, which is better for making confections.

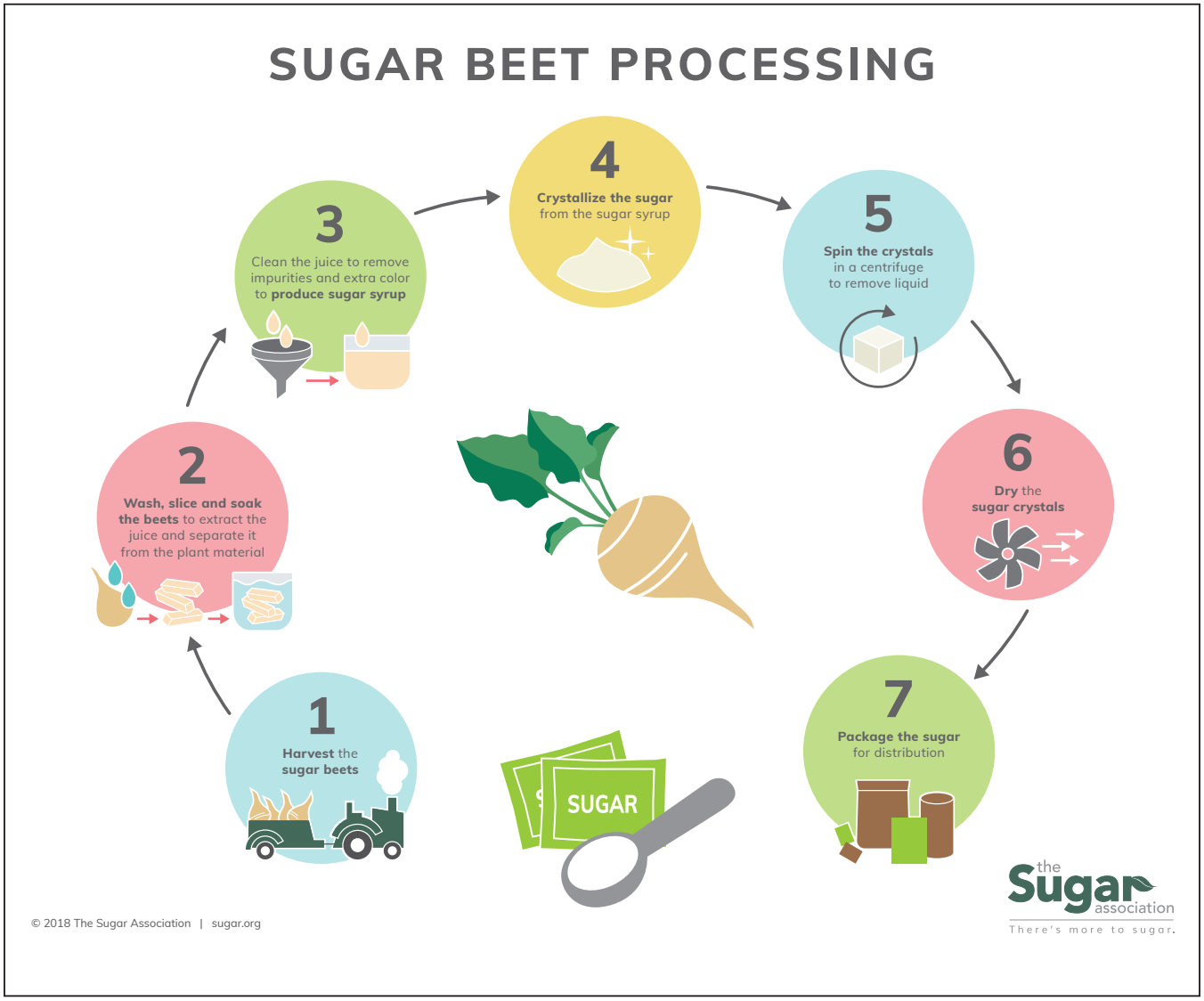
Molasses. A thick, brown by-product of the sugar-refining process that is used for its distinctive flavor. Molasses used for human consumption comes from sugar cane.

Processed dairy products. Food stuffs such as sweetened condensed milk and evaporated milk. Sweetened condensed milk is more resistant to curdling during cooking and this stability, along with milk's low-moisture content, makes it ideal for some caramel formulas. Evaporated milk has a substantial portion of water removed, which makes it suitable for caramel production.

Sugar (sucrose). A *disaccharide* is made up of one molecule of *fructose* and one molecule of glucose. Sucrose is one of the purest food substances available. Its defining feature is its tendency to crystallize at high temperatures. Understanding this and knowing how to control it are two of the most important concepts in confection making.

HOW SUGAR IS MADE

Sugar is made from two products: sugar beets and sugar cane. The processing involved for each differs markedly (see illustrations), but the end result is the same — a wonderfully sweet product.



Courtesy of Sugar Association, Inc. www.sugar.org.

Courtesy of Sugar Association, Inc. www.sugar.org.

TYPES OF SUGAR

White Sugar	
"Regular" or white granulated sugar	• What you typically find in your sugar bowl. • The most common sugar ingredient listed in recipes. • "Regular" sugar granules are fine-grained because small crystals are ideal for bulk handling and not susceptible to caking.
Confectioners' or powdered sugar	• Granulated sugar ground to a smooth powder and sifted. • Commercially available powdered sugar is mixed with a small amount of cornstarch (3%) to prevent caking. • Often used in icing, confections, and whipping cream. • You can make it at home: using a blender, combine 1 cup white sugar and 1 tbsp of cornstarch to get 1 cup of powdered sugar.
Superfine sugar	• Also known as caster or bar sugar, this sugar has the smallest crystal size of white granulated sugars. • Generally used to make delicate or smooth desserts, such as mousse or puddings. • Because the crystals are so fine, they dissolve easily, even in cold drinks.
Sanding sugar	• Has large or fine crystals; both types reflect light and give the product a sparkling appearance. • Used mainly in baking and confectionery to sprinkle on top of baked foods (often in fun colors!)
Coarse sugar	• Has a larger crystal size than that of regular sugar. • The result of crystallizing molasses-rich sugar syrups that are high in sucrose. • The large crystal size makes it highly resistant to color change or **inversion** (the natural breakdown of sucrose to **fructose** and glucose) at cooking and baking temperatures, important characteristics for use in making fondants and confections.
Fruit sugar	• Smaller and more uniform in crystal size than that of regular sugar. • Used in dry mixes, such as gelatin and pudding desserts or powdered drinks. • The uniformity of crystal size prevents the settling of the sugar crystals to the bottom of the box, an important quality in dry mixes.
Baker's special sugar	• Offers a crystal size finer than that of fruit sugar. • As its name suggests, it was developed especially for the baking industry. • Used for sugaring donuts and cookies and used in some cake recipes to create a fine crumb texture.

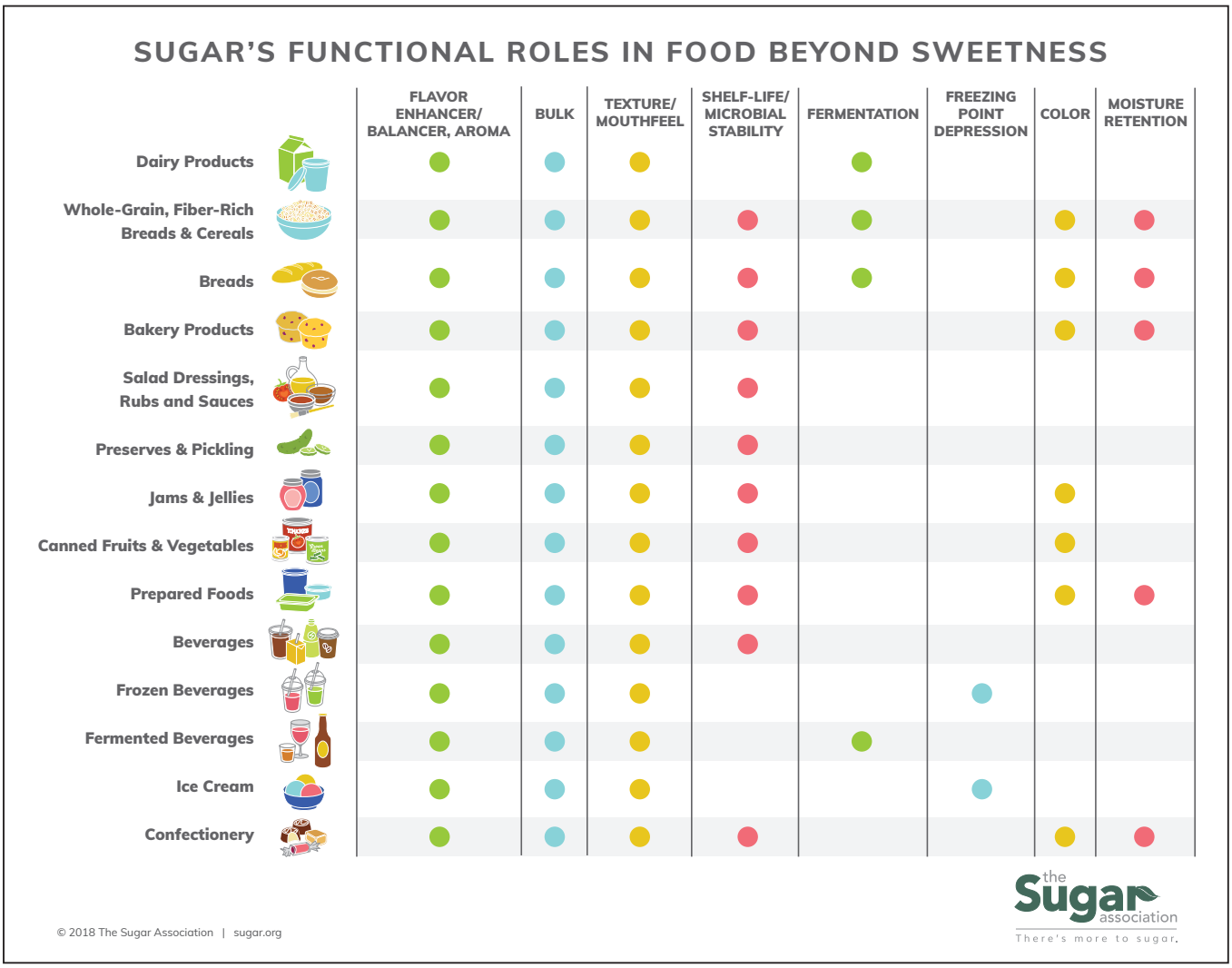
Brown Sugar	
Light and dark brown sugar	• Made by mixing white sugar with various amounts of **molasses**. • Light brown sugar is often used in sauces and most baked goods. • Dark brown sugar has a deeper color and stronger molasses flavor than light brown sugar. The rich, full flavor makes it ideal for gingerbread, baked beans, barbecue, and other full-flavored foods. • Brown sugar tends to clump because it contains more moisture than white sugar, allowing baked foods to retain moisture and stay chewy.
Demerara sugar	• A light-brown-colored sugar with large golden crystals that are slightly sticky from the adhering molasses. • Can be made by dehydrating cane syrup after its extraction from sugarcane. • Popular in England, it is often used in tea, coffee, or on top of hot cereals.
Turbinado sugar	• A partially processed sugar whose surface molasses has been washed off. • Has a blond color, mild brown-sugar flavor, and larger crystals than brown sugars used in baking. • Turbinado is the sugar in your packet of “raw sugar,” but it is not unprocessed as the name may suggest.
Muscovado sugar	• An unrefined cane sugar in which the molasses has not been removed. Also known as Barbados sugar. • Very dark brown in color with a particularly strong molasses flavor. • The crystals are slightly coarser and stickier than regular brown sugar, giving this sugar a sandy texture.
Free-flowing brown sugar	• Also known as granulated brown sugar, this powder-like brown sugar is less moist than regular brown sugar. • Since it is less moist, it does not clump and is free flowing, like white sugar. • To get the brown sugar taste in a free-flowing product, the sugar undergoes a special process, making it a very low-moisture sugar. • Easy to measure and sprinkle; great as a topping on cereals and oatmeal.

PART II:

The Science of Sugar

THE PURPOSE OF SUGAR

Sugar is more than a food sweetener. It plays many vital roles in food technology:



Courtesy of Sugar Association, Inc. www.sugar.org.

SUGAR CHEMISTRY EXPERIMENTS

Complete all experiments with the help of an adult.

Essential Terms

atoms. The building blocks of matter, made up of electrons, neutrons, and protons.

concentration. The amount of one substance in a solution relative to the amount of other substances.

disaccharide. A two-sugar molecule (for example, sucrose).

molecules. Particles composed of atoms and chemical bonds.

monosaccharide. One sugar molecule (for example, fructose or glucose).

saturated solution. A mixture that has reached the maximum amount of solute. As you dissolve sugar (solute) in a glass of hot water (solvent), a moment will come when the solvent can no longer dissolve any more sugar.

solute. The substance to be dissolved. For example, sugar is the solute when you are dissolving sugar in water.

solution. A group of molecules that are mixed and evenly distributed in a system.

solvent. A substance that dissolves into other substances. Water is the solvent when you are dissolving sugar in water.

supersaturated solution. A mixture that has more solute (sugar) dissolved in it than is possible under normal circumstances. For example, you can add more sugar to a glass of hot water that has reached its saturation point so that when the solution cools down to its original temperature, it is considered supersaturated.

unsaturated solution. A mixture that has not reached the maximum amount of solute (sugar) or that can still dissolve more solute.

Experiment 1: Atoms and Molecules

Objective:

Using a molecule kit, youth will learn how sugar is made from the elements of carbon, oxygen, and hydrogen.

Sugar is a **disaccharide** made up of one molecule of glucose and one molecule of fructose (both monosaccharides). There are over one trillion molecules of sucrose in one teaspoon of sugar.

Sugar is made of atoms of carbon (four bonds), oxygen (two bonds) and hydrogen (one bond) arranged in a specific way.

To build a molecule kit, use dough, marshmallows, or candy to represent the atoms of carbon, hydrogen, and oxygen that you need. Use toothpicks, pipe cleaners, or straws to represent the bonds between the atoms.

Purchase molecule kits if you prefer.

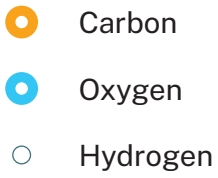
Instructions:

Create a molecule of glucose ($C_6H_{12}O_6$) and a molecule of fructose ($C_6H_{12}O_6$).

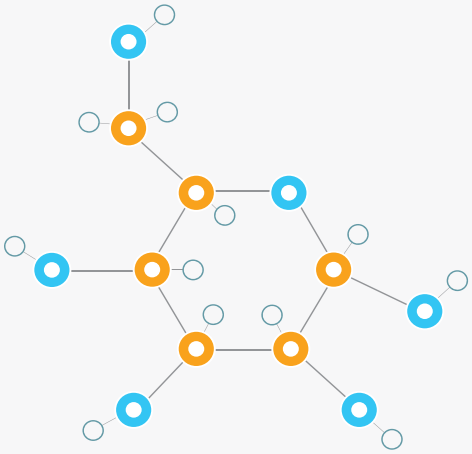
Note that both molecules have the same number of carbon, hydrogen, and oxygen atoms but are arranged in a different configuration.

Sucrose ($C_{12}H_{22}O_{11}$) is a combination of one molecule of glucose with one molecule of fructose. Notice that sucrose has two less hydrogen atoms and one less oxygen atom, because the by-product of combining fructose and glucose is water (H_2O).

Take your glucose molecule and your fructose molecule and combine them to make sucrose and water.

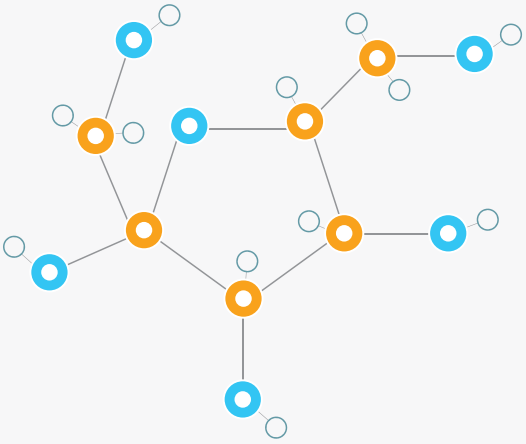


GLUCOSE



Glucose is the body's preferred form of energy and is found in animal blood and plant sap. Glucose is a six-ring monosaccharide.

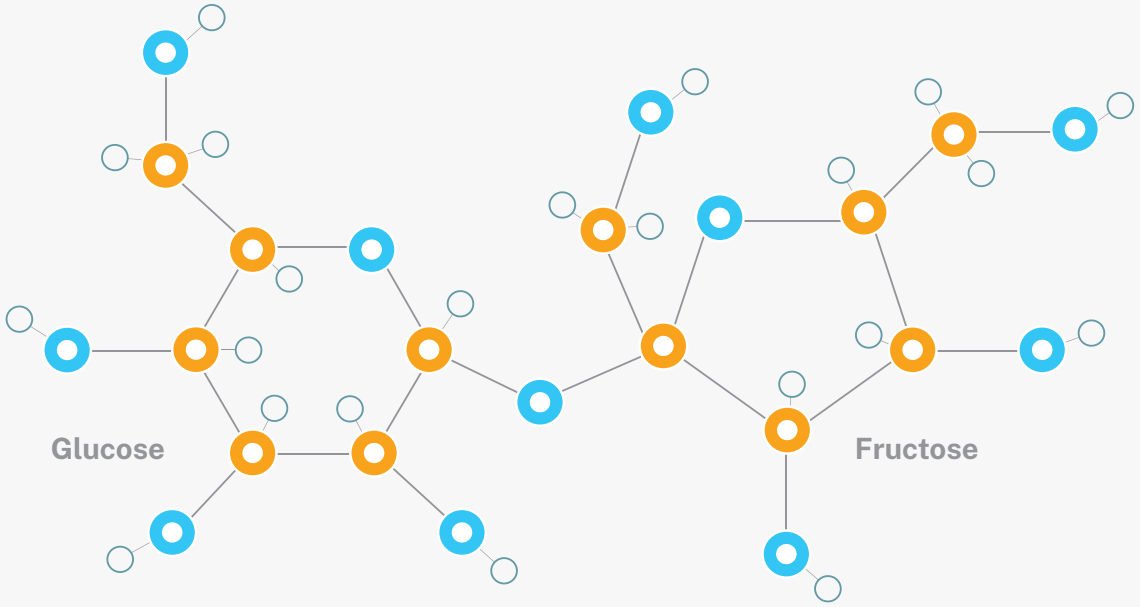
FRUCTOSE



Fructose is abundant in nature, occurs in many fruits and vegetables, and is a component of honey. Fructose is a five-ring monosaccharide.

Carbon Oxygen Hydrogen

SUCROSE



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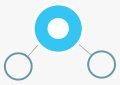
WATER



What is a molecule made up of?

What atoms did you use to create a water molecule?

What atoms did you use to create a fructose molecule?

What atoms did you use to create a glucose molecule?

How is a fructose molecule different than a glucose molecule?

How are the fructose molecule and glucose molecule the same?

How is a sucrose molecule formed?

Experiment 2: Creating a Rainbow of Sugar

Objective:

Youth will start to learn about the relationship between solute and solvent and their relationship to weight.

The following experiment offers a colorful lesson in food science, one that reveals the density differences of a sugar-water rainbow via a colorful stack.

Density = mass/volume

In liquid, density is directly related to concentration. **Concentration** is the relationship between the amount (mass) of solute (sugar) and the volume of solvent (water).

To create a sugar rainbow, you will need the following supplies:

- Transparent cups (Five: One for each color plus one to pour your rainbow into. The cups must hold at least 1½ cups [12 oz] of liquid)
- Sugar
- Water
- Pan to heat water (the water can be heated in a microwave, using a microwave-safe measuring glass)
- Food coloring (four different colors)
- Liquid measuring cup and measuring spoons
- Dropper works best, a spoon works as well

Directions:

1. Label each cup (1, 2, 3, 4).
   In cup #1: measure 2 tbsp of sugar
   In cup #2: measure 4 tbsp of sugar
   In cup #3: measure 6 tbsp of sugar
   In cup #4: measure 8 tbsp of sugar
2. Heat the water.
   Measure 3 oz (⅓ cup) of hot water into each cup. Stir to dissolve the sugar. Add a different food coloring to each cup.
3. After the solutions have cooled, use a dropper or spoon carefully along the side of the cup to add the contents of cup #3 to cup #4. Observe what happens.
4. Use a dropper or spoon carefully along the side of the cup to add the contents of cup #2 to cup #4. Observe what happens.
5. Use a dropper or spoon carefully along the side of the cup to add the contents of cup #1 to cup #4. Observe what happens.

Estimate how many molecules of sugar are in four tablespoons (cup #2).

Estimate how many molecules of sugar are in six tablespoons (cup #3).

What colors of the rainbow do you see?

Describe why the layers are the way they are.

What would happen if you added just water to the mixture?

Experiment 3: How Much Sugar Can You Dissolve?

Objective:

Youth will learn how boiling water added to sugar causes a reaction that adds more space between molecules. The reaction allows for more sugar to be dissolved into the water to create a supersaturated solution.

Water molecules move faster when heated, which causes the boiling action. As water temperature increases, water molecules move faster, creating more space between them. After you add sugar to heated water, more and more sugar molecules move into this space and dissolve. This created a supersaturated solution.

Materials needed:

Liquid measuring cup

Water

2 clear glass containers

Measuring spoons

Sugar

Spoon for stirring

Pan for heating water

Directions: Part I

1. Measure ½ cup of room-temperature water using a glass container.
2. Measure 1 tsp of sugar and add it to the glass of water and stir until dissolved.
3. Continue to add sugar, one teaspoon at a time, stirring between additions, until the sugar no longer dissolves.

How many teaspoons of sugar were you able to dissolve in ½ cup of room-temperature water?

Directions: Part II

1. Heat the water.
2. Measure ½ cup of hot water using a glass container.
3. Measure 1 tsp of sugar and add it to the glass of water and stir until dissolved.
4. Continue to add sugar, one teaspoon at a time, stirring between additions, until the sugar no longer dissolves.

How many teaspoons of sugar were you able to dissolve in ½ cup of hot water?

Explain the difference between the number of teaspoons of sugar in the room-temperature and hot water that dissolved.

Prep Time: 10 min

Cook Time: 15 min

Resting Time: 5 days or more

Total Time: 5 days, 25 min

Materials needed:

Lollipop sticks or bamboo skewers

2 plates

Large heavy pot

Wooden spoon or spatula

Pint mason jars

Clothespins

Fork

Ingredients:

1 cup of water

3 cups of granulated sugar

1–2 drops of food coloring

1–2 tsp flavoring (optional)

Sugar Sticks:

1 cup of water to dip candy sticks into

2 tbsp granulated sugar on a plate

Experiment 4: Making Rock Candy

Objective:

Youth will use a supersaturated solution to make rock candy, something that is pleasing to eat.

Rock candy is considered a crystalline candy. It is an example of how large crystals form due to no agitation: a supersaturated solution that is boiled and then poured into a vessel into which strings or candy sticks seeded with granulated sugar are suspended. The vessel is then covered and left to sit undisturbed for 1–3 weeks. During this time the hope is that large sugar crystals will form on the suspended sugar. Once the crystals have stopped growing, remove the strings or sticks, rinse the candy in cool water, and air dry it.

Rock Candy

Directions:

1. Begin by dipping the sticks in water and then rolling them in sugar. A plate works well to hold the sugar. Only dip it where you want the sugar crystals to grow. Set the sticks aside on a plate and allow them to dry. These are the seed crystals that the other crystals will grow on.
2. Add a large pot to the stovetop and set it to medium heat. Pour in 1 cup of water and bring it to a simmer. Then add in the sugar a cup at a time, stirring to dissolve. Bring the mixture to a boil.
3. Remove the pot from the heat.
4. Allow the sugar solution to cool for twenty minutes.
5. In the meantime, run the tap water until it gets really hot. Let the water run over a mason jar to heat it up until it is really warm so that they do not break when the hot sugar solution is added to them. Make sure to use a pint mason jar. The sugar solution should fill two to three jars, depending on how much solution you add to the jars.
6. Pour the hot sugar solution into the mason jars. If you want to develop different colors/ flavors, now is the time to add them (optional).

7. Attach a clothespin to a sugar stick and set it in the solution. If necessary, use a metal ring on top of the mason jar so the clothespin can sit on it. Try and keep the stick in the very middle of the glass and at least 1.5 inches from the bottom. If it is too close to the bottom, the crystals might fill up the bottom.
8. Let the crystals form for one to three weeks. Use a fork and gently break away any thin layer of sugar that has formed on the surface of the solution. Then pull out the rock candy and place it in another clean jar to dry for four hours. That's it — enjoy!

What did you learn about making rock candy?

What challenges did you have making rock candy?

What would you do differently next time?

HISTORY OF CONFECTIONS

Candy making began when healers used natural sweeteners such as honey or maple syrup to sweeten medicines. Later, some of the first true candies were made by rolling fruits and nuts in honey or something similar to create a nougat.

Most early candy makers or confectioners made candy by using their senses. They relied on the look, smell, and touch of their confections to determine if they were done. By the 1800s and 1900s, confectioners added other techniques, as candy production developed into a major industry. The procedures led to the production of many of the modern candies we enjoy today. In fact, the current top ten candies have been around for about one hundred years.

Some of the newer ways that confectioners test and produce sweet confections include technological advances, like equipment upgrades. But it also involves pure science, like improvements in understanding molecules and microbial growth. Indeed, better understanding about what happens to ingredients during the candy making process underscores how much candy making is a scientific process. Combining the technical knowledge of science with time-honored culinary skills has enabled confectioners to develop new and unique formulas.

TYPES OF CONFECTIONS

Confections are classified by syrup thickness or the extent to which the sugar is caramelized. The density of the syrup determines the general types of confections. Three of the main classifications of confections include the following:

- **Crystalline or creamy** confections contain small sugar crystals that provide a smooth, creamy texture (fondant, fudge, penuche, divinity, pralines, marshmallows, and rock candy).
- **Noncrystalline or amorphous** solutions harden or set without forming crystals (caramels, butterscotch, lollipops, brittles, toffee, taffy, and hard candy).
- **Jellies and gummies** are a supersaturated solution that is bound to a stable gel (gummy bears, jelly beans, pectin jellies, and gumdrops).

CANDY THERMOMETERS AND ELEVATION ADJUSTMENT

Note: Carry out the following procedure before making confections each day.

Candy thermometers are used to measure the temperature and thus the state of the cooked sugar solution with which you are working. Consequently, it is very important to know how to use a candy thermometer.

According to FoodSmart Colorado (a resource of food-related information by Colorado State University Extension), “at sea level, the boiling point of liquids is 212°F, but for every 500 feet above sea level, the boiling point decreases 1°F due to less resistance on surface molecules. . . . The lower the boiling point, the quicker evaporation occurs, so at higher elevations, this faster loss of water can result in a sugar mixture either becoming too hard or too grainy.” This is why it is important to adjust for altitude when making confections. For each one thousand feet above sea level, reduce the finish temperature by 2°F. Ultimately, “the adjustment allows the [confectioner] to control the degree of evaporation necessary to achieve the proper sugar concentration for the desired end product” (Kendall 2020).

For example, if your thermometer reads 204°F when water is boiling and the recipe says to cook to 230°F, subtract 8°F and cook to 222°F.

Two ways to check the temperature of your confections to determine if they are ready are the candy thermometer test and the cold-water test. But it's best to use both.

Candy thermometers typically measure from 100°F to 400°F. There are many models and types, but they usually have a clip that allows you to attach the thermometer to the side of your pan. If you can't find a model that works for you, use a digital instant-read thermometer. But please note that using one while making confections requires you to put your hand over hot steam. Consequently, do not opt for using these thermometer types when youth are involved.

Boiling-Water Test

Altitude adjustment requires confectioners to perform a boiling-water test on a candy thermometer. To do this, submerge the candy thermometer into a pan of boiling water and note the temperature five minutes after the water comes to a boil. This method not only allows for altitude adjustment but also reveals any inaccuracies in the thermometer.

Boiling-Water Test Results

Boiling point at sea level		**212°F**
Temperature of thermometer 5 minutes after boiling	-	
What is the degree of adjustment to make to recipes?	=	

See **Confections-Stages Guide** chart for more information.

Helpful Hint: If the thermometer steams up, use a paper towel and very carefully wipe off the steam.

Example: If a recipe calls for a solution cooked to 270°F, what temperature do you need to cook the solution to based on your boiling-water test results?

Cold-Water Tests

Cold-water tests are another way to check the doneness of your syrup solution. Start by dropping a small amount of the hot syrup solution into a bowl of cold water. Then quickly remove the syrup from the water and examine its firmness, which indicates the syrup's temperature.

Use a candy thermometer to gauge where you are at but double check its accuracy with the cold-water test to make sure that your sugar solution is at the stage you want it to be.

Confections-Stages Guide

Syrup Boiling Point	Confection	Cold-Water Test
212°F	Water	Boils at 212°F at sea level
Thread Stage 215°F–235°F/108°C–118°C Sugar concentration: 80%	Syrup, fruit liqueur, and some icings	Thread: At this temperature, there is still a lot of water left in the syrup. Liquid sugar may be pulled into brittle threads between the fingers. Or take a small amount of the syrup onto a spoon and drop it from about 2 inches above the pot. Let it drip into the pan. If it spins a long thread, like a spider web, it's done.
	Jelly, candy, and some icings	Pearl: 220°F–222°F. The thread formed by pulling the liquid sugar may be stretched. When a cool metal spoon is dipped into the syrup and then raised, the syrup runs off in drops which merge to form a sheet.
	Delicate sugar candy and syrup	Blow or soufflé: 230°F–235°F. Boiling sugar creates bubbles resembling snowflakes. The syrup spins a 2-inch thread when dropped from a spoon.
Soft-Ball Stage 235°F–240°F/118°C–120°C Sugar concentration: 85%	Fudge, fondant, pralines, peppermint creams, classic buttercreams	Soft-ball: A small amount of syrup dropped into chilled water forms a soft, flexible ball, but flattens like a pancakes after a few moments in your hand.
Firm-Ball Stage 245°F–250°F/123°C–125°C Sugar concentration: 87%	Caramel candies	Firm-Ball: Forms a firm ball that won't flatten when removed from water but remains malleable and flattens when squeezed.
Hard-Ball Stage 250°F–265°F/125°C–133°C Sugar concentration: 92%	Nougat, marshmallows, gummies, divinity, and rock candy	Hard-Ball: Syrup forms thick, "ropy" threads as it drips from the spoon. The sugar concentration is rather high now, meaning less moisture in the sugar syrup. Syrup dropped into cold water may be formed into a hard ball that holds its shape on removal. Although hard, the ball's shape can still be changed by squishing it.
Soft-Crack Stage 270°F–290°F/135°C–145°C Sugar concentration: 95%	Taffy	Soft-Crack: As the syrup reaches soft-crack stage, the bubbles on top become smaller, thicker, and closer together. Moisture content is low. Syrup dropped into cold water separates into hard but pliable threads. They bend slightly before breaking.
Hard-Crack Stage 300°F–310°F/150°C–155°C Sugar concentration: 99%	Butterscotch, brittles	Hard-Crack: The highest temperature you are likely to see specified in a candy recipe. At these temperatures, almost no water remains in the syrup. Syrup dropped into cold water separates into hard, brittle threads that break when bent.
Hard-Crack Stage 320°F–335°F/160°C–168°C Sugar concentration: 99%	Hard candies, toffee	Hard-Crack: The highest temperature you are likely to see specified in a candy recipe. At these temperatures, almost no water remains in the syrup. Syrup dropped into cold water separates into hard, brittle threads that break when bent.

CONFECTIONS EXPERIMENT: CRYSTALLINE CONFECTIONS

Crystalline confections are made by creating a supersaturated solution and then promoting crystallization of the solution with varying degrees of **agitation**. Crystalline candies need to have a sufficient amount of water removed from the sugar mixture to ensure that the solution will be supersaturated upon cooling and will therefore crystallize.

Word Glossary

aeration. The introduction of air into a material.

agitation. The action of briskly stirring or disturbing something.

albumen. The mixture of the proteins found in egg whites.

inclusion. An added ingredient that remains discrete in a finished product.

Lab Note: When preparing your experiments, use the following terms:

- **full rolling boil.** A vigorous, bubbling boil that does not stop when stirred.
- **stirring.** Using a spoon, spatula, or another utensil to mix ingredients together, without vigorous motion, until they are uniformly blended.

Creamy Confections

Fondant and fudge are two creamy confections. The two critical steps to carry out when making either include the following:

1. Let the cooked mixture cool (120°F/50°C) and be undisturbed before agitation.
2. Agitate the cooled mixture constantly until it is well crystallized.

Fondant

- Fondant consists of small sugar crystals surrounded by a saturated sugar solution. It is a thick, creamy white sugar mixture that can be dipped in chocolate or put into the center of chocolate molds. Its smoothness is determined by the size of the sugar crystals. Using vigorous (active) agitation produces small sugar crystals. When cooking fondant avoid stirring the mixture after it comes to a boil because it might cause premature crystallization. After preparing and then pouring the sugar solution onto a working area, agitate it until the syrup changes from a thick, sticky, and elastic substance to an opaque (white), short-textured, and somewhat hard mass. Store fondant in an airtight container overnight before use. This allows it to ripen, making it easier to handle.

Experiment 1: Fondant

Objective:

Youth will learn how agitation can change the consistency and color of a supersaturated solution.

Basic Cream Fondant

Prep Time: 5 min

Cook Time: 25 min

Cooling Time: 30 min

Mixing Time: 30 min

Total Time: 1 hr 30 min

Materials needed:

medium saucepan

measuring cups and spoons

thermometer

pan of ice water

marble slab or flat hard surface (baking sheet pan)

bench scraper, wooden spoon, or spatula

zipper-top plastic bags

Ingredients:

4 cups sugar

1½ cup cream, half and half or milk

2 tbsp light corn syrup

2 tbsp butter

dash of salt

candy flavoring

Directions

1. Combine sugar, cream, syrup, 1 tbsp butter, and salt in the saucepan.
2. Boil until mixture reaches the soft-ball stage (230°F/110°C).
3. Drop the rest of the butter into the hot syrup. Do not stir. Place a tight cover over the pan.
4. Cool as rapidly as possible by setting the pan in the ice water.
5. Let cool thoroughly until the mixture is cool to the touch.
6. Pour onto a marble slab or on a flat hard surface that you can scrape on. Use a bench scraper, wooden spoon, or spatula to knead the mixture.
7. The mixture will be shiny and stiff. As you mix, the mixture becomes thin and loses its gloss. Keep kneading until the mixture is firm.
8. Add flavor and color, then place mixture in a zipper-top plastic bag until ready to use.

Source: From a submission based on an out-of-print Idaho church cookbook, circa 1960s.

Basic Water Fondant

Prep: 5 min

Cooking: 25 min

Cooling: 45 min

Mixing: 30 min

Total: 1 hr 45 min

Ingredients:

4 cups sugar

1⅓ cups water

¼ cup light corn syrup

4 tbsp butter

Dash of salt

Candy flavoring

Directions:

1. Mix all ingredients together.
2. Place over med/low heat until dissolved.
3. Bring to a boil and cover for five minutes. Uncover and boil to soft-ball stage (232°F/111°C).
4. Pour onto a marble slab or other flat, hard surface that you can scrape on (could be jelly roll pan).
5. Use a bench scraper, wooden spoon, or spatula to knead the mixture. The mixture will be shiny and stiff. As you knead, the mixture becomes thin and loses its gloss. Keep kneading until the mixture is firm and white.
6. Working with your hands, add flavoring, coloring, and place fondant in a tightly covered bowl until you are ready to dip it.

Source: From a submission based on an out-of-print Idaho church cookbook, circa 1960s.

Directions:

Prepare both types of fondant. Fill out the questions that follow to determine your findings.

What did you learn about making fondant?

Which fondant did you prefer making and why?

How do you think you will use fondant in the future?

Fudge

Fudge is fondant with the addition of milk, fat, and flavoring. The smoothness of fudge is determined by the size of the sugar crystals. Using vigorous (active) agitation causes lots of small sugar crystals to form, which results in a smooth texture. When cooking fudge, constantly stir it in order to prevent burning. If adding salt, add it after cooking but while the product is still hot enough to dissolve the salt. Agitate the fudge until the syrup turns creamy and slightly opaque; however, overagitating it causes crystallization, making it impossible to spread. Once poured into a pan, fudge sets up in less than an hour, but let it sit overnight so that it can properly crystallize. Wrap the fudge to prevent its hardening over time.

Experiment 2: Fudge

Objective:

Youth will learn how the addition of milk, fat, and flavoring alters a crystalline confection.

Peanut Butter Fudge

Directions:

1. Line a 9 x 9–inch square pan with parchment paper and spray pan with cooking spray.
2. Add butter to microwave-safe bowl. Cook for about one minute or until softened.
3. Add the evaporated milk and sugar and stir together with the butter. Cook for three minutes, stirring well.
4. Continue cooking at thirty-second to one-minute intervals, checking the temperature when you pull it out of the microwave, stirring well each time. Cook until the thermometer reaches 234°F/112°C (this could take 5–10 minutes, depending on your microwave wattage).
5. Once the sugar mixture reaches, 234°F, add marshmallow crème. Stir until smooth.
6. Add the vanilla and peanut butter. Stir until well blended.
7. Pour into prepared 9 x 9–inch pan.
8. Cool for at least three hours or refrigerate until set.
9. Store in airtight container.

*Developed using a 1000-watt microwave. You may need to adjust the times if your microwave has a different wattage.

Adapted from "Old Fashioned Fudge with Peanut Butter," Back to My Southern Roots, https://www.backtomysouthernroots.com/old-fashioned-fudge-recipe-with-peanut-butter/#mv-creation-32-jtr.

Prep: 5 min **Cook:** 14 min

Cool: 3 hrs **Total:** 3 hrs, 19 min

Yield: 24 pieces

Materials needed:

9" x 9" square pan

Parchment paper

Cooking spray

Microwave-safe large glass bowl

Measuring cups and spoons

Wooden spoon

Thermometer

Oven mitts

Microwave (1000 watts)*

Airtight container

Ingredients:

¾ cup butter

5 oz evaporated milk

3 cups sugar

7 oz jar marshmallow crème

1 tsp vanilla

1 cup creamy or chunky peanut butter

Chocolate Marshmallow Fudge

Materials needed:

9” x 9” square pan

Parchment paper

Cooking spray

Medium saucepan

Measuring cups and spoons

Wooden spoon

Airtight container

Ingredients:

1½ cups granulated sugar

⅔ cup evaporated milk

2 tbsp butter

¼ tsp salt

2 cups miniature marshmallows

1½ cups (9 oz) semisweet chocolate chips

1 tsp vanilla extract

½ cup chopped pecans or walnuts (optional)

Directions:

1. Prepare a 9 x 9–inch pan by lining it with parchment paper and spraying with cooking spray.
2. In the saucepan, combine sugar, evaporated milk, butter, and salt. Heat over medium heat to a full rolling boil, stirring constantly. Boil for 4–5 minutes while stirring.
3. Remove from heat. Stir in marshmallows, semisweet chocolate chips, vanilla, and nuts (optional).
4. Stir vigorously until the marshmallows are melted and everything incorporates.
5. Pour into the prepared 9” x 9” pan. Refrigerate for at least two hours.
6. Remove from pan and cut into pieces.
7. Store in an airtight container.

Adapted from “Famous Milk Chocolate Fudge,” Verybestbaking.com (Nestlé Toll House), https://www.verybestbaking.com/toll-house/recipes/famous-milk-chocolate-fudge/.

Directions:

Prepare two types of fudge. Fill out the questions below to determine your findings.

What recipes did you use?

What did you learn about making fudge?

Which fudge recipe did you prefer making and why?

Which fudge recipe did you like sampling more and why?

CONFECTIONS EXPERIMENT: AERATED CONFECTIONS

The most popular aerated confections are divinity, nougat, and marshmallows. **Aeration** is achieved after using a mechanical device (usually a mixer) to whip cooked sugars and an ingredient that acts as an aerator (commonly, gelatin or albumen). Scientifically put, these confections successfully form when gas bubbles incorporate into a mixture and then get trapped there, creating a light, sweet-tasting food product.

Albumen Confections

Albumen is a mixture of the proteins found in egg whites. Their creation is a three-part process: First, confectioners whip egg whites to a soft-peak consistency and stream a prepared hot syrup into them to stabilize and pasteurize the foamy mixture. Second, they continue to aerate the foam by whipping it until the mixture cools. Third, they mix in any **inclusions** (like nuts), if desired. Two basic types include divinity and nougat.

Prep: 5 min

Cook: 40 min + standing

Yield: 1½ lb (60 pieces)

Materials needed:

3 sheet pans or cooling racks

Parchment paper

Stand mixer

Large, heavy saucepan

Measuring cups and spoons

Wooden spoon

Thermometer

Cookie scoop or two spoons

Airtight container

Ingredients:

2 large egg whites

3 cups sugar

⅔ cup water

½ cup light corn syrup

Pinch of salt

1 tsp vanilla extract

1 cup chopped pecans (optional)

Divinity

Directions:

1. Line sheet pans with wax or parchment paper.
2. Place egg whites in the bowl of a stand mixer; let sit for thirty minutes.
3. Add sugar, water, and corn syrup to the saucepan. Heat over medium heat until boiling, stirring constantly to dissolve sugar. Once boiling, stop stirring and continue to cook until thermometer reads 250°F/121°C (hard-ball stage).
4. As the syrup cooks, add a pinch of salt to the egg whites. Whip egg whites on medium speed until stiff peaks form.
5. Remove the sugar solution from the heat at hard-ball stage.
6. Slowly pour the sugar solution into the egg whites while the mixer whips at high speed.
7. Add vanilla and continue whipping until the mixture holds its shape and becomes slightly dull (5–10 minutes). Try not to overmix because your mixture can get stiff and crumbly. If adding nuts, fold them in.
8. Working quickly, drop spoonfuls of the mixture onto the prepared sheet pans.
9. Allow the divinity to dry and harden. This can take from two hours to overnight. Store in an airtight container.

Adapted from "Divinity Candy," Taste of Home, https://www.tasteofhome.com/recipes/grandma-s-divinity/.

Prep: 10 min

Cook: 10 min

Cool: 1 hr

Total: 1 hr, 20 min

Yield: 4–6 servings

Materials needed:

4" x 6" pan

Parchment paper

Cooking spray

Mixer

Small saucepan

Measuring cups and spoons

Wooden spoon

Thermometer

Small, flat weight

Wax paper

Airtight container

Ingredients:

1 egg white

2 cups powdered sugar

1 tsp light corn syrup

2 tbsp honey

2 tbsp water

2 oz sliced, peeled almonds, toasted (optional)

Nougat

Directions:

1. Line the 4 x 6–inch baking pan with parchment paper and spray it with cooking spray.
2. With the mixer, whisk egg white until stiff peaks form.
3. In the saucepan, combine sugar, light corn syrup, honey, and water.
4. Heat slowly over low heat until the mixture reaches 275°F/135°C (soft-crack stage).
5. Remove from the heat.
6. Whisk egg white with a mixer while drizzling syrup into it. Continue to whisk until mixture is glossy and begins to stiffen.
7. Stir in almonds, if using.
8. Spread mixture in prepared pan, pressing it down well.
9. Cover with another sheet of parchment paper and place a small weight on top.
10. Allow the nougat to sit until cold. Remove it from the pan and cut it into squares.
11. Wrap the squares in wax paper and store them in an airtight container.

Adapted from "Nougat," Food Network, https://www.foodnetwork.com/recipes/nougat-recipe-1969120.

Gelatin Confections

Gelatin is a water-soluble protein made from collagen. It is not as light as albumen and aerates as well as stabilizes confections by forming a gel when it sets. When making aerated gelatin, cool the cooked sugar until its temperature falls to approximately 212°F/100°C. Once cooled, add the gelatin to the sugar mixture and whip them together. Gelatin is very sensitive to heat and can be damaged by excessive heat. A basic recipe includes the following:

Homemade Marshmallows

Prep: 35 min **Cook:** 10 min

Inactive: 4 hr **Total**: 4 hr, 45 min

Yield: approximately 9 dozen

Materials needed:

Mixer bowl

Measuring cups and spoons

Small and medium-heavy saucepans

Wooden spoon

Thermometer

Mixer (with whisk attachment)

2 small bowls

9” x 13” pan

Parchment paper

Nonstick cooking spray

Spatula

Cutting board

Knife, pizza wheel, or scissors (with adult supervision)

Airtight container

Ingredients:

3 packages of unflavored gelatin

1 cup ice-cold water, divided

1½ cups granulated sugar

1 cup light corn syrup

¼ tsp salt

1 tsp vanilla extract (or flavor you choose)

¼ cup powdered sugar

¼ cup cornstarch

Directions:

1. Place the gelatin and ½ cup of water into the bowl of a stand mixer. Let stand.
2. In a small saucepan, combine the remaining ½ cup of water, granulated sugar, corn syrup, and salt. Cook over medium-high heat, covered, for 3–4 minutes.
3. Uncover the pan and cook the sugar syrup until it reaches 240°F/115°C. Remove from heat.
4. With the whisk attachment installed, turn on the stand mixer to low speed. Slowly pour the sugar syrup down the side of the bowl into the gelatin mixture. Once you have added all of the syrup, increase the speed to high. Continue to whip until the mixture becomes very thick and is lukewarm (approximately 12–15 minutes). Add the vanilla during the last minute of whipping.
5. In the meantime, combine the powdered sugar and cornstarch in a small bowl. Line a 9” x 13” pan with parchment paper and spray with nonstick cooking spray. Add the powdered sugar/cornstarch mixture to the pan and swish it around until the bottom and sides are coated. Tap out any extra powdered sugar/cornstarch mixture into a bowl for later use.

6. Pour the whipped gelatin mixture into the prepared pan. Use a lightly oiled spatula to spread out the mixture evenly. Dust the top of the mixture with some of collected the powdered sugar/cornstarch mixture to lightly cover.
7. Allow the marshmallows to sit uncovered for at least four hours and up to overnight.
8. Dust the cutting tool with the leftover powdered sugar/cornstarch mixture. Turn the marshmallows out onto a cutting board and cut into 1-inch squares. Once cut, dust all sides of each marshmallow with the remaining powdered sugar/cornstarch mixture.
9. Store in an airtight container for up to three weeks.

Adapted from "Homemade Marshmallows," Food Network, https://www.foodnetwork.com/recipes/alton-brown/homemade-marshmallows-recipe-1953933.

Experiment 3: Aerated Confections

Objective:

Youth will learn how to aerate a confection that uses either albumen or gelatin.

Prepare two types of aerated confections. Fill out the questions below to determine your findings.

What confections did you make?

What did you learn about making aerated confections?

Which product did you prefer making and why?

Which product did you like sampling better and why?

NONCRYSTALLINE CONFECTIONS

In noncrystalline confections, sugar exists in an uncrystallized form. The goal when making these confections is not to crystallize the sugar. Noncrystalline confections rely on glucose syrup to prevent recrystallization of the sugar (sucrose). When these confections are made, the sugar dissolves into the liquid and then is cooked until the desired amount of water has been removed. The more water that is removed the harder, more solid, the confection.

Essential Terms

cold flow. The tendency of a center to ooze and change shape at room temperature.

gelatin. A protein mixture derived from animal collagen.

Maillard reaction. A chemical reaction between amino acids and **reducing sugars** that gives food its distinctive flavor.

reducing sugars. Lactose, dextrose, fructose, and some sugars found in **glucose sugar**. These are sugars that react with amino acids in a Maillard reaction.

Basic Hard Candy

Basic hard candy is one of the oldest forms of confections. Virtually all the water is removed during the cooking process, which leaves a glassy, supersaturated, noncrystalline solution. Confectioners cook the syrup as quickly as possible to the highest temperature possible in order to remove as much water without browning the solution. They pour the solution either into molds or onto an oiled surface to be worked. When they work it, they fold it repeatedly with a bench scraper so that it cools evenly before pulling it by hand to aerate it and help it to develop an opaque consistency. They use the pulled sugar to make candy canes, ribbon candy, candy sticks, and other individual candies.

When coloring hard candy, add gel color during the cooking process if the entire batch will be one color. Otherwise, add it after pouring the cooked syrup onto a working surface. Add flavoring only after completing the cooking process and in a highly concentrated form. Extracts, oils, and manufactured flavors are best for hard candies.

Confections you can make using a basic hard candy recipe include suckers, glass candy, and hard candy squares.

Hard Candy

Prep: 5 min **Cook:** 25 min

Additional: 15 min **Total:** 45 min

Yield: 36 servings

Materials needed:

Baking sheet

Medium-heavy saucepan

Measuring cups and spoons

Thermometer

Wooden spoon

Candy molds (optional)

Airtight container

Ingredients:

3¾ cups granulated sugar

1½ cups light corn syrup

1 cup water

1–3 tsp flavoring

½ tsp food coloring (optional)

¼ cup powdered sugar for dusting

Directions:

1. Grease a baking sheet.
2. Stir together the sugar, corn syrup, and water in the saucepan.
3. Cook the mixture, stirring over medium heat until the sugar dissolves; then bring to a boil.
4. Without stirring, heat to 300°F–310°F (149°C–154°C) or until a small amount of syrup dropped into cold water forms hard, brittle threads.
5. Remove pan from the heat and allow the bubbling in the mixture to slow down; then stir in the flavoring and food coloring (if desired).
6. Pour the mixture onto the baking sheet and dust the top with powdered sugar or pour into candy molds.
7. Let the mixture cool. Break the product into pieces. Store in an airtight container.

Adapted from "Hard Candy," Allrecipes, https://www.allrecipes.com/recipe/35842/hard-candy/.

Prep: 75 min

Cook: 15 min

Total: 90 min

Yield: 12–18 canes

Candy Canes

Materials needed:

3 jellyroll sheets/baking sheets or a marble slab

Medium-heavy saucepan

Measuring cups and spoons

Thermometer

Wooden spoon

Pastry brush

Bench scraper or spatula

Heat-safe gloves or cotton gloves with food-safe gloves over the top

Kitchen shears

Saran wrap or cellophane

Ingredients:

Approximately 2 tbsp butter

3 cups granulated sugar

1 cup light corn syrup

¼ cup water

1½ tsp peppermint flavoring or your favorite flavor

Red food gel coloring (white optional)

Directions:

1. Butter two jellyroll sheets and the baking sheet and set aside. Preheat oven to 150°F–170°F/65°C–76°C.
2. In the saucepan, carefully combine the sugar, corn syrup, and water. Over medium-high heat, bring the solution to a boil. Stir continuously while the sugar dissolves. Try not to get sugar on the sides of the pan. Brush down the sides of the pan with a pastry brush to prevent sugar crystals from forming.
3. Once the solution begins to boil, continue to cook it **without stirring** until the solution reaches 265°F/129°C (the end of the hard-ball and beginning of the soft-crack stages).
4. Remove the pan from the heat. Let the bubbles stop, then add the flavoring and mix them together. Different flavorings vary in strengths; you may want to adjust the flavoring, especially peppermint, for future batches.
5. Pour half of the mixture onto one prepared jellyroll sheet. Place it in the preheated oven to keep warm.
6. Add a few drops of food coloring to the remaining sugar solution. Mix together.
7. Pour the other half of the sugar solution onto the remaining sheet. Allow it to sit briefly, until it just starts to form a skin.

8. Butter a bench scraper and use it to begin spreading the candy out and pushing it back together, working it across the board and allowing it to cool.
9. As soon as the candy is cool enough to handle, but still quite hot, put on your heat-safe gloves. Take the candy in both hands and pull your hands in opposite directions, stretching the candy into a long rope.
10. Bring the ends of the strands together and twist the candy into a rope, then pull it out into a long strand.
11. Continue to twist and pull it until it has a satin-like finish, has an opaque red color, and is becoming difficult to pull.
12. Once the candy is still pliable, but barely warm, pull it into a strand about 2 inches thick and place it on the remaining buttered sheet. Put this sheet back into the oven and **turn off the heat.** The pulled candy will remain pliable in the warm oven while you work the second portion.
13. Remove the baking sheet that contains the other half of the sugar syrup. Add white food coloring if you wish, but the candy will naturally turn white after being pulled. If you add the white coloring, knead it into the candy.
14. Repeat steps 7–11.
15. By the end, the candy should be a pearly white color. Form it into a log 2 inches in diameter, just like the red candy.
16. Remove the colored candy from the oven. Cut a 2-inch segment from the white and the colored log and put the rest of the candy back in the oven to stay warm.
17. Place them next to each other and press them together so they are one log.
18. Begin to twist the candies together, pulling and twisting gradually to form the familiar candy stripes.
19. Once the twisted candy is the thickness you want, use oiled kitchen shears to cut them into smaller lengths.
20. Immediately form the hook at the top of the cane and place it on a baking sheet to firm up at room temperature.
21. Repeat the twisting with the remaining candy.
22. If the candy gets too hard to pull, place it in the warm oven for a few minutes to soften, but don't let it sit too long and melt. They should be as hard as regular candy canes at room temperature, but, just like regular candy canes, they will get sticky if left out for long periods of time.
23. Wrap them in cling wrap or cellophane once they are set to preserve their shelf life.

Adapted from "Homemade Candy Canes," The Spruce Eats, https://www.thespruceeats.com/candy-canes-recipe-521012.

Experiment 4: Hard Candy

Objective:

Youth will use a supersaturated solution to make a noncrystalline confection as well as learn how to aerate a noncrystalline confection.

Prepare two types of hard-candy confections. Fill out the questions below to determine your findings.

What confections did you make?

What did you learn about making hard-candy confections?

Which product did you prefer making and why?

Which product did you like sampling better and why?

Taffy

Taffy is a chewy candy that is pulled in order to aerate it. The cooking technique is similar to those needed to make soft caramels and the pulling technique is similar to those for aerated hard candy (candy canes). Taffy must be wrapped immediately because of **cold flow**; otherwise, the pieces lose their shape. Unlike aerating hard candy, taffy must be cooled to nearly room temperature before it is firm enough to be pulled. Taffies of different colors may be twisted, rolled, or formed together to create unique striped and patterned candies.

The process of pulling taffy adds air to the taffy mixture, which in recent years has been made of corn syrup and sugar. The process of adding air to the taffy keeps it soft. Aerating the taffy also makes it lighter and chewier.

Prep: 5 min **Cook:** 25–35 min

Additional: 45 min

Total: 85–95 min

Yield: 100 servings

Materials needed:

Large, heavy saucepan

Measuring cups and spoons

Thermometer

Marble slab or baking sheet (buttered)

Wooden spoon

Food-safe plastic gloves

Bench scraper

Kitchen shears

Wax paper

Airtight container

Ingredients:

6 cups white sugar

3 cups vinegar

Coloring (1–3 drops), optional

Butter

In years past, taffy was also made from molasses, a mixture that was then boiled, cooled, and finally pulled or made into squares. The process also enabled it to be twisted into various rope-like shapes, including braids.

Vinegar Taffy

Directions:

1. In the saucepan and over medium heat, combine the sugar and vinegar. Stir the mixture until it begins to boil.
2. Continue cooking it on medium-high heat, without stirring, until the mixture reaches 295°F–300°F/146°C–148°C.
3. Remove the mixture from the heat and add food coloring (optional). Stir briefly. Cool it on a buttered marble slab or in a buttered pan until it can be handled.
4. Begin working the sugar solution with a bench scraper by folding the solution into itself. As soon as the candy is cool enough to handle, but still quite hot, put on your food-safe gloves.
5. Add butter to your gloved hands and start pulling the taffy by stretching it out into a rope, folding it over, and repeating until the taffy is white, porous, and too stiff to pull.
6. Cut the taffy into 1-inch pieces with buttered kitchen shears. Wrap each taffy piece in waxed paper and store in an airtight container.

Recipe courtesy of Emily Althera Severe Hardy.

Prep: 15 min

Cook: 25 min

Additional: 30 min

Total: 70 min

Yield: about 35 pieces

Materials needed:

Medium heavy saucepan

Measuring cups and spoons

Sifter

Whisk

Thermometer

Marble slab or **heat-proof** dish

Food-safe plastic gloves

Kitchen shears

Wax paper

Airtight container

Ingredients:

1 cup sugar

1 tbsp cornstarch

1 tbsp unsalted butter

⅔ cup light corn syrup

1 tsp salt

½ cup water

1 tsp vanilla extract or ½ tsp flavoring of choice

2 drops of food coloring

Saltwater Taffy

Directions:

1. Add the sugar to the saucepan.
2. Sift the cornstarch. Whisk cornstarch into sugar until well combined.
3. Add the butter, corn syrup, salt, water, vanilla, and/or flavoring.
4. Heat over medium heat, whisking to combine until the mixture reaches 250°F/120°C.
5. Add the food coloring and stir to combine.
6. Pour the candy onto the marble slab or into a greased heat-proof dish and cool until you are able to handle it, 5–10 minutes.
7. As soon as the candy is cool enough to handle, but still quite hot, put on your food-safe gloves.
8. Add butter to your gloved hands. Start pulling the taffy by stretching it out into a rope, folding the candy over, and repeating. The taffy will turn from being translucent to opaque.
9. Cut into 1-inch pieces with buttered kitchen shears. Wrap each taffy piece in wax paper and store in an airtight container.

Adapted from "Saltwater Taffy, Tasty, https://tasty.co/recipe/saltwater-taffy.

Experiment 5: Taffy

Objective:

Youth will learn how to aerate taffy through the pulling process.

Directions:

Prepare two types of taffy. Fill out the following questions to determine your findings.

What were the main differences between making vinegar and saltwater taffy?

What did you learn about making taffy confections?

Which product did you prefer making and why?

Which product did you like sampling better and why?

Maillard Reaction Confections

A Maillard reaction is a chemical reaction between the **amino acids** (proteins) and reducing sugar that give a food its distinctive flavor(s). Depending on the type of food, browning may occur. In confections, the proteins generally come from dairy products. The more dairy products in the solution, the more browning. Time and temperature also play a role: longer cooking times cause more browning.

Brittles

Brittles are similar to hard candy because they consist of sugar and glucose syrup and are boiled to a high temperature. They contain either nuts or seeds and possibly butter for flavor and richness. Another important ingredient, baking soda, produces a carbon dioxide gas that forms bubbles during the cooking process, giving brittles their unique look and texture.

Two key steps in making brittles:

1. Stir constantly after adding the nuts or seeds to prevent scorching.
2. Cook to the desired temperature to develop sufficient caramel color and flavor. Do not overcook the solution since this will cause the brittle to develop a bitter taste.

Peanut Brittle

Prep: 10 min

Cook: 15 min

Additional: 30 min

Total: 55 min

Yield: 16 servings

Materials needed:

Baking sheet

Cooking spray (optional)

Medium heavy saucepan

Measuring cups and spoons

Wooden spoon

Thermometer

Knife or spoon

Ingredients:

1 cup granulated sugar

½ cup light corn syrup

¼ tsp salt

¼ cup water

1 cup peanuts

2 tbsp butter, softened (plus extra for greasing sheet)

1 tsp baking soda

Directions:

1. Prepare a baking sheet with cooking spray or butter. Set aside.
2. In saucepan, add sugar, corn syrup, salt, and water. Bring to a boil over medium heat until the sugar dissolves.
3. Stir in peanuts.
4. Continue cooking, stirring frequently to prevent burning until the mixture reaches 300°F/150°C (hard-crack stage).
5. Remove mixture from the heat and immediately stir in the butter and baking soda.
6. Carefully pour the hot mixture onto the prepared sheet. Use a knife or spoon to spread the mixture out evenly.
7. Cool completely. Break cooled brittle into random-sized pieces. Store the pieces in an airtight container.

Adapted from "Mom's Best Peanut Brittle," Allrecipes, https://www.allrecipes.com/recipe/15987/moms-best-peanut-brittle/.

Toffees and Caramels

Toffee is a hard caramel confection made with dairy products; caramel is a chewy confection that has a sweet, nutty, buttery, or bitter flavor. Both get their flavor from Maillard browning. Toffee cooks at a higher temperature. It thus contains less water in the end, which gives it a darker color and harder texture. Caramels cook at a lower temperature and thus contain more water, which gives them a lighter color and softer texture. However, both confectionary mixtures are sensitive during the cooking process. They can foam up, so lowering the temperature is necessary to prevent their boiling over. Also, because the dairy products in them might scorch, stir either mixture continuously.

The following two recipes provide the specifics about how to make either confection:

Almond Toffee

Prep: 10 min

Cook: 30 min–1 hr

Additional: 12 hr

Total: 13 hr, 40 min

Yield: about 2 lb

Materials needed:

Jelly roll pan or baking sheet

Large saucepan

Measuring cups

Thermometer

Wooden spoon

Offset spatula or butter knife

Airtight container

Ingredients:

1 lb butter (plus some for greasing the baking sheet)

2 cups sugar

¼ cup light corn syrup

6 milk chocolate bars (no nuts)

1 cup sliced almonds

Directions:

1. Grease a jelly roll pan with butter and set it aside.
2. In the saucepan, add butter, sugar, and corn syrup.
3. Heat over medium heat to boiling.
4. Turn heat to low and cook while stirring to 280°F/137°C (soft-crack stage).
5. Remove from the heat and pour onto jelly roll pan.
6. Allow to cool for 5 minutes.
7. Place chocolate bars on top of toffee; let melt.
8. Spread the chocolate with spatula so that all the toffee is covered.
9. Sprinkle the toffee with sliced almonds.
10. Let it sit overnight until the toffee solidifies. Break into pieces. Store in an airtight container.

Recipe courtesy of Karen Scharnhorst Wittman.

Easy Caramels

Prep: 5 min

Cook: 1 hr

Total: 1 hr, 5 min

Yield: 128 one-inch caramels

Materials needed:

Medium-to-large heavy saucepan

Measuring cups and spoons

Wooden spoon

Thermometer

9” x 13” baking dish, buttered

Knife

Wax paper

Airtight container

Ingredients:

2 cups granulated sugar

½ cup light corn syrup

1½ cups heavy cream

1 cup butter

Pinch of salt

1 tsp vanilla

½ cup chopped nuts (optional)

Melted chocolate (if dipping)

Directions:

1. In saucepan, mix together sugar, syrup, cream, butter, and salt.
2. Stir until it begins to boil.
3. Cook the mixture slowly and keep it boiling until you reach 240°F–245°F/115°C–118°C (soft-ball to firm-ball stage).
4. Add vanilla and nuts (if using). Pour mixture into a buttered baking dish and cool.
5. Cut in squares. Wrap each square in wax paper or dip each in chocolate and roll in more chopped nuts.
6. Store in an airtight container.

Note: For a thicker caramel, use an 8” x 8” pan (yields about 64 one-inch caramels).

Recipe courtesy of the Lucy Anderson family.

Experiment 6: Maillard Browning

Objective:

Youth will learn how Maillard reactions can give certain confections distinctive colors and flavoring.

Directions:

Prepare two types of Maillard reaction confections. Fill out the following questions to determine your findings.

What confections did you make?

What did you learn about making Maillard reaction confections?

Which product did you prefer making and why?

Which product did you like sampling better and why?

Jellies and Gummies

When making gummy products, gelatin is the binding agent of choice. Gelatin makes the product chewy but elastic and allows it to melt in your mouth (which releases the flavor). When working with gelatin, do not expose it to extreme heat for a prolonged period of time — this causes the gelatin to degrade. If using an acid (citric acid) for a sour-tasting gummy, add it as close as possible to the time you put the solution into the molds.

The following two recipes are two examples of jelly and gummy confections:

Gumdrops

Prep: 10 min **Cook:** 25 min

Set Time: 12 hr **Total:** 12 hr, 35 min

Materials needed:

2 qt saucepan

Measuring cups and spoons

Microwave

Whisk

Thermometer

Wooden spoon

Silicone pan

Ingredients:

2 packets of unflavored gelatin

¼ cup cold water

¼ cup boiling water

1 cup light corn syrup

¾ cup granulated sugar

3 tbsp cornstarch

¼–½ tsp flavoring of choice

Gel food coloring

Optional: ¼ tsp citric acid (for sour-tasting gumdrops)

Extra sugar (for rolling gumdrops in)

Directions:

1. In the saucepan, add two packets of gelatin and ¼ cup cold water. Set aside and let sit 5 minutes.
2. In a microwave, heat ¼ cup water to boiling.
3. Add boiling water to the gelatin. Mix well with a whisk.
4. Add corn syrup, sugar, and cornstarch to the gelatin. Mix well with a whisk.
5. Cook to boiling over medium-high heat. Reduce heat to medium-low and cook to 240°F/115°C (soft-ball stage). Stir continuously.
6. Remove mixture from the heat. Add flavoring, coloring, and citric acid (if using). Mix well.
7. Pour into a greased or silicone pan.
8. Let sit for twelve hours. Remove from pan. Cut into 1-inch squares. Roll in sugar.
9. Let sit for twenty-four hours.

Prep: 10 min **Cook:** 25 min

Set Time: 24 hr **Total:** 24 hr, 35 min

Gummy Bears

Materials needed:

Bowl

Small heavy (2–3 qt) saucepan

Measuring cups and spoons

Wooden spoon

Thermometer

Spouted container (for example, a liquid measuring cup)

Gummy Bear molds*

Wax paper

Ingredients:

2 packages of unflavored gelatin

¼ cup water

⅓ cup sugar

⅓ fruit juice (juice pouches work great)

If you use lemon, use half lemon juice and half water

¼ cup corn syrup

½ tsp citric acid (not needed, but helps the flavor)

*You have three options for the molds:

- Silicone molds, sprayed with oil.
- Any pan sprayed with oil. About 1–2 loaf pans make a good-sized gummy for this recipe. Cut the gummies into the desired shapes after they have set (right after removing them from the pan — do not wait — otherwise, they'll completely firm up).
- A cornstarch mold. Pour ½- to 1-inch thick of cornstarch into a sheet pan and create desired shapes in the cornstarch by making indentions. After the gummies have set up, toss them in the cornstarch, then put them into a colander and shake them for a little while to get as much of the cornstarch off as possible. Next, spray them with oil and toss to absorb any excess cornstarch. The excess cornstarch can be reused for another batch of gummies.

Directions:

1. Bloom the gelatin: sprinkle it over the ¼ cup of water, stir to dissolve, then let it sit.
2. Prepare your molds.
3. Mix sugar, fruit juice, corn syrup, and citric acid (if using) in the saucepan.
4. Cook in saucepan over medium heat, stirring until the sugar has dissolved.
5. Continue cooking, stirring periodically to prevent sticking, until the syrup reaches the firm-ball stage (250°F/121°C). Adjust the boiling temperature for elevation: decrease the temperature by about 1°F for every 500 feet in elevation.
6. Remove from the heat. Cool to about 225°F/107°C. Add bloomed gelatin and stir until the gelation completely dissolves.
7. Pour the mixture into a spouted container (such as a liquid measuring cup) and remove the foam from the top of the mixture (to create clear-looking gummies).
8. Pour mixture into prepared molds.
9. Let it set in the molds until firm (20–60 minutes, depending on the syrup's concentration).
10. Remove the gummies from the molds and place on wax paper. If you eat them now (which is fine), they will have more a fruit-snack texture. If you let them sit for 24–72 hours, the "gummy" texture will develop. The transformation works best if you intermittently rotate the gummies, exposing a different side to the air so they dry out evenly.

Experiment 7: Gummies

Objective:

Youth will learn how to use gelatin to make gummy confections.

Directions:

Prepare two types of gummy confections. Fill out the following questions to determine your findings.

What were the major differences in the two gummy products?

What did you learn about making gummy confections?

Which product did you prefer making and why?

Which product did you like sampling better and why?

RESEARCH AND DEVELOPMENT EXPERIMENTS

Food science is a multidisciplinary field involving chemistry, biochemistry, nutrition, microbiology, and engineering to solve real problems associated with food. Research and development allows food scientists to design and execute experiments and analyze and interpret data to make sound recommendations on food products and processes.

Experiment 1: Copy a Product on the Shelf

Objective:

Youth will examine a commercial candy and determine its individual components; they will find a recipe for each part of the commercial candy and copy them; and they will experiment with duplicating the commercial product in a kitchen.

Directions:

Imagine that you are starting your own candy shop. You know that your customers love several commercially bought candies, such as gummy bears, Starbursts, and Tootsie Rolls. So, you want to re-create a popular confection for your customers. How would you go about this?

Step 1: Examine the confection you want to copy. What ingredients are used? Are there any other components present such as nuts, caramel, marshmallow, etc.?

Step 2: Look for a recipe either in this manual, in a candy cookbook, or on the internet. List the ingredients needed below.

Component/Ingredient	Quantity

Step 3: Prepare your recipe.

Step 4: Compare your creation to the original. Ask questions, such as

- How is it different?
- Do I like the differences?
- What changes do I need to make?

Step 5: Make the necessary changes and repeat steps 3–5 until you are happy with your copycat.

Step 6: Reflect on your experience by answering the following questions.

What candy did you replicate?

What challenges did you have with replicating this candy?

What will you do differently next time?

Experiment 2: Sensory Testing

Objective:

Youth will conceptualize a confection product they want to create from name to recipe.

Part of research and development is sensory testing. Sensory testing includes having others taste the product you have created.

Types of tests:

- Paired Comparison test
- Preference test
- Hedonic test
- Descriptive test

Paired Comparison Test: A paired comparison test is used to compare two items to see if consumers think they are the same or different. In this test, two samples are given to participants. About half of the participants receive the same item in each sample, while others receive different ones. The participants are asked if the items are the same or different. They have a 50% chance of randomly selecting the correct choice. If less than 50% of participants identify the correct choice, the items are not statistically different. If more than 50% of participants identify the correct choice, the items are statistically different.

The paired comparison is often used when a company is trying to match two items and they want to see if consumers can tell the difference. They might do this if they are changing the supplier for the flavoring used and they want to see if consumers can taste the difference between the old and the new flavoring.

Preference Test: With a preference test, participants are given between two and six different items (too many different items become difficult to rank). They are then asked to rank each item, from favorite to least favorite.

This type of test indicates which items consumers like compared to others. Usually, similar items are compared to each other (for example, you can compare different brands of hot chocolate). This test is useful for when you want to identify consumer preferences.

Hedonic Test: A hedonic test is like a preference test, except it provides more information. In a preference test you don't know how much more someone likes different items from each other. Perhaps the difference is between first and second place is very small, but the one in third place is disliked a lot more.

With a hedonic test, participants taste each item one at a time (do not use more than six items, which can skew the results — items sampled later may not be enjoyed as much simply because they are given last). Participants then rank how much they like each item, using a scale. This is typically a five-point hedonic scale (although either more or fewer points can be used):

1. dislike extremely
2. dislike slightly
3. neither like nor dislike
4. like slightly
5. like extremely

The points for each item are added up (or can be averaged). The item with the highest points is the most-liked item, while the one with the least is the least-liked item. You then know how much more consumers like one item compared to another. Both this test and the preference test can be used for items that are like each other or that are very different from each other.

Descriptive Test: The final type of test is a descriptive test. This test is used when you want to find out what people do or do not like about a product. With this test, a group of people try a product, describe it, and report what they do or do not like about it. This type of test can involve more than one product's evaluation.

General Testing Requirements

Typically, you want to conduct "blind" product tests. This means that the participants do not know which item they are testing. Sometimes this means that literally need to blindfold participants. If you're testing differences in taste, smell, and/or texture only, using one is a good idea. If a product's brand is visible to participants, blindfolding is a must. For example, it would be difficult for participants to test M&M candies fairly versus other candy-coated chocolates due to the fact that the letter "M" appears on each piece of candy. In this case and others like it, blindfold participants to strengthen the integrity of your study.

But often you won't need to use blindfolds. You can just remove any identifying marks from the products — for example, take all the test items out of their distinctive packaging and serve them on the same type of plate. If you choose that "blind" set up, keep track of which product is which by coding each plate with a unique number or letter.

Another helpful strategy is to mix up the order that items are presented to participants. Sometimes participants prefer the first item the most or are tired by the time they get to the last item. In order to avoid "order preference" from creating bias, place the items in a different order for each participant.

To help level the testing field further, provide plain water and a nonsalted saltine cracker so participants can rinse out their mouth in-between tasting each item. That helps to keep participants from tasting any carryover flavors as they sample each item. Also, participants should not be starving nor full when they start tasting, because hunger affects how food tastes.

Sensory Test

Create a sensory test to analyze one of the products that you made and gather at least five people to test your product.

Step 1: Determine what you want to test (a candy that you created or different brands of candy, etc.).

Step 2: Determine the type of test you want to use (difference test, preference test, hedonic scale, or descriptive).

Step 3: Determine how you want to blind your test. Are you going to remove labels? Blindfold participants? Identify the products using numbers?

Step 4: Gather participants. The more people you can get, the better results you will have.

Step 5: Perform sensory test, as planned.

Step 6: Calculate and record the results.

Sensory Test Questions

What confections did you test?

What sensory test did you use?

Which challenges did you have with sensory testing?

What will you do differently next time? Why?

Experiment 3: Exploring Food Regulations

Objective:

Youth will be able to use four types of tests to set up a sensory-tasting experience.

Today, in the United States, almost all food we buy from the store is safe to eat. This wasn't always the case. In the 1800s, lead used to be a common ingredient used to color candies. Without proper labeling and enforced food regulations, consumers did not know what ingredients were in the candies they purchased and ate. Stores using lead to color candies unintentionally caused many illnesses and even deaths from poisoning, especially in young children.

Catastrophes like these caused national outcry, which led to the creation of what is now known as the Food and Drug Administration (FDA) and the first food safety–related law — the Code of Federal Regulations Title 21 (CFR 21). Over the years, CFR 21 has had several amendments added to it, which have helped to improve food safety. Several of these regulations are confection-related. Find the full CFR 21 online. Parts 70, 73, 74, 101, 104, and 110 are particularly applicable to confections, including information about what ingredients can or cannot be added to candies and colors and flavorings that are allowed.

Natural versus artificial flavors (CFR 21, part 101.22): The regulations regarding added flavors have made food quality safer in general. But figuring out to what degree or whether it comes from an natural or artificial source can be very confusing. For instance, "100% naturally flavored" indicates that a food product's flavoring comes only from the original ingredient that has the name of the flavor. Hence, all the flavor in a strawberry food product labeled as 100% naturally flavored comes from actual strawberries. If any of the flavor comes from another source (even if it is something that people would consider "natural," such as a different fruit), the label will indicate that by stating the food product is naturally **and** artificially flavored. If none of the flavor comes from the original source, it will be labeled "artificially flavored."

Food coloring: Since colors have caused so many health problems, the colors that are and are not allowed in foods are strictly regulated. You cannot simply add something for color and sell it for public consumption, even if you think it won't cause any harm, unless it is on the approved colors list. There are two types of colors for use: typically called artificial and natural. The former needs to be certified before it is okay to use it; the other is exempt. The following table lists the colors allowed for use in making confections.

Food-Coloring Regulation Types

Colorant	Notes	Type
FD&C Blue No. 1	Artificial color, requires continued safety testing	Certification
FD&C Blue No. 2	Artificial color, requires continued safety testing	Certification
FD&C Green No. 3	Artificial color, requires continued safety testing	Certification
FD&C Red No. 3	Artificial color, requires continued safety testing	Certification
FD&C Red No. 40	Artificial color, requires continued safety testing	Certification

Colorant	Notes	Type
FD&C Yellow No. 5	Artificial color, requires continued safety testing	Certification
FD&C Yellow No. 6	Artificial color, requires continued safety testing	Certification
Annatto Extract	Safe for all general food uses	Certification exempt
Beet Powder	Safe for all general food uses	Certification exempt
Calcium Carbonate	For soft and hard candies, inks on candies, but **not chocolate**	Certification exempt
Caramel	Safe for all general food uses	Certification exempt
Carmine	Safe for all general food uses	Certification exempt
Carotene	Safe for all general food uses	Certification exempt
Carrot Oil	Safe for all general food uses	Certification exempt
Fruit Juice	Safe for all general food uses	Certification exempt
Grape Color Extract	Safe for all general food uses	Certification exempt
Paprika	Safe for all general food uses	Certification exempt
Pearlescent Pigments	No more than 1.25%, by weight, of the total food weight	Certification exempt
Riboflavin	Safe for all general food uses	Certification exempt
Saffron	Safe for all general food uses	Certification exempt
Spirulina	Safe for all general food uses	Certification exempt
Synthetic Iron Oxide	For soft and hard candies, mints, and chewing gums	Certification exempt
Titanium Dioxide	No more than 1%, by weight, of the total food weight	Certification exempt
Tomato Lycopene	Safe for all general food uses	Certification exempt
Turmeric	Safe for all general food uses	Certification exempt
Vegetable Juice	Safe for all general food uses	Certification exempt

FD&C, Food, Drug, and Cosmetic (Act).

Experiment 4: Exploring Food Regulations

Objective:

Youth will select candy products at a store, read their labels, and determine how to name the products based on the CFR.

Directions:

Go to a store and look at the **ingredient declarations** (list of ingredients on food labels) for different types of confections. Determine what is used for the flavor — that is, if the confection can be labeled as "naturally flavored," "artificially and naturally flavored," or "artificially flavored." Identify what is used for their colorings. Do they contain certified colors or certified exempt colors? Record your responses in the following table; then elaborate by answering the questions that follow.

Confection Name	Flavor	Flavoring Used	Naturally Versus Artificially Flavored	Color Used

What confections did you examine?

What challenges did you have determining the flavors and colors used?

What will you differently next time? Why?

Experiment 5: Labeling Confections

Objective:

Youth will select a candy they made and create a label for it.

If you want to create confections to sell, you need to follow all the rules and regulations based on where you live. Most states have "cottage food laws" that apply only if you sell a small amount of food prepared in your home directly to a consumer or if you sell less than a certain dollar amount of products.

Cottage laws vary by state; follow the ones governing the state in which you will be selling your product. Compliance usually requires the use of an inspected, commercial kitchen, regular food inspections (conducted by FDA inspectors), as well as displaying written procedures that ensure food safety.

Learn about cottage food laws and food laws in general in your state by Googling "cottage food laws" for your state. Sites that end in .gov or .edu typically contain trustworthy information.

Directions:

Choose one of the confections that you created and make a label for it. Include these items on your label:

- Name of confection
- Ingredients, list in order of most to least
- Allergens present
- Nutritional facts (use an online tool to calculate; try searching the web for a recipe nutrition calculator)
- Serving size
- Expiration date/storage

Remember to follow all naming rules found in the CFR.

Use your creativity to create and display a label.

GOING FURTHER

Starting Your Own Confections Company

Do you have a family favorite recipe that has been passed down through the generations? Do you enjoy making confections and then giving them to friends and neighbors? Do they tell you that you should make and sell this stuff? Do you have a dream to start your own confections company?

If you answered yes to either of the last two, there are a few different paths you can take in order to make confections for a living. If you want to create new flavors of candy bars, or new chocolate/candy concoctions, consider working in a candy manufacturer's research and development division. There you ensure good quality and safety of the confections the factory produces (includes taste testing). Another option is to work for a large candy company such as Storck, Haribo, the Hershey Company, or Mars. Or open your own confections shop in your hometown.

Although there are numerous ways to begin making confections a career, two traditional paths to breaking into the confections industry include getting a degree in food science or the culinary arts. Several universities offer food science degrees (as a bachelor's, master's, or doctorate) and/or culinary degrees (often as a formal bachelor's degree). Or you can receive training through a trade school. A degree in food science teaches you about food laws and regulations, how to ensure food safety and quality, the science behind how food works, and how to create new products. If you take the food-science path, after graduation you will probably start out working in food manufacturing. You can then work with ensuring food quality (including any type of confections), managing the manufacturing of foods, or researching and developing new products. A culinary arts degree teaches you how to cook and plate foods. If you take this path, after graduation you will probably start out working in restaurants. From there, try branching out by making confections in restaurants or bakeries or start selling them yourself at farmers markets or even start your own catering business.

Dream Big, start small!

❖ If you need more space, add additional pages.

Ways to learn more about making confections as a career:

- Learn about your local cottage food laws, develop a business plan, and sell the confections that you make.
- Find a local company that makes confections, ask to interview the manager/confections maker, and see if you can tour their facilities.
- Find any food-manufacturing company in your area, ask to interview someone from their research and development team or talk to their quality assurance manager to learn more about food science.
- If you have a university in your area, see if they offer a food science program. Talk with a food science advisor and tour their facilities.

Career Development Questions

What did you do to learn more about a confections careers?

What did you learn about a future career in confections?

What challenges did you have in learning about a confections careers?

Activities to Get You Started on Your Confections Career:

Research the Market

- What are the current trends in confections making?
- Who are your customers?
- What confections are being sold in your area? What is the most popular-selling item?
- Is there a local market to sell your confections?
- How many items do you plant to make and sell?
- Tour different confections companies.
- Ask lots of questions.

Record your findings here:

Identify Your History/Story and Create a Company Name

- Tell your story. How did you develop/discover the confection that you plan to sell? Why do you want to sell it? Identifying these aspects will help your business stand out from your competitors.
- Come up with a name. Make it catchy and easy to recognize. It can have something to do with your story.
- Make it legal. Get your business license and seller's license. Get certified in food safety.
- Learn about the cottage food law in your state.

Record your findings here:

Determine/Identify Your Building Space

- Will you be located in a brick and mortar building?
- A home kitchen?
- Or will you rent a commercial kitchen?

No matter what operating space you choose, please look into local, state, and federal guidelines. Have all the necessary inspections done to keep you and your customers safe and your business legal. If you intend to be an online business only, make sure you know the rules.

Record your thoughts or plans here:

Establish Proper Funding

- Create a business plan.
- Talk to banks or financial institutions about the steps to securing a loan.
- Are you going to have partners?
- Are you funding your business yourself?
- Consult with a financial advisor or certified public accountant.
    - » How many employees will you need?
    - » What is the cost of benefits?

Before consulting any financial institution, put your ducks in a row, so to speak. Develop a very clear-cut business plan, including start-up expenses, building plans, vendor costs for all your supplies, a marketing plan, hiring employees, tax responsibilities, equipment needs, etc.

Record your thoughts or plans here:

Selling and Marketing

- Are you going to sell retail or wholesale?
- Are you going to sell through a website and/or social media?
- Will you be selling at events, such as weddings, fairs, farmers markets, sporting events, roadside stands, etc.
- Create designs for product packaging and storefront (building or website).
- Prep product samples. Providing samples makes a big difference and can help you penetrate local markets.
- Network. Sometimes friends and who you know ("word of mouth") make the best marketing officers.

Record your thoughts or plans here:

Develop and Protect Your Recipes

- Are your recipes a family secret?
- Have you invented a new confection?
- Do you have new technique?

You might want to talk to a lawyer who specializes in trademarks and copyrights to help you keep those recipes yours.

Record your thoughts or plans here (but not your secret recipes):

GLOSSARY

aeration. The introduction of air into a material.

agitation. The action of briskly stirring or disturbing something.

albumen. The mixture of the proteins found in egg whites.

amino acids. Molecules that combine to form proteins.

atoms. The building blocks of matter; made up of electrons, neutrons, and protons.

cold flow. The tendency of a center to ooze and change shape at room temperature.

concentration. The amount of one substance in a solution relative to the amount of other substances.

disaccharide. A two-sugar molecule (for example, sucrose).

emulsifier. In foods, any number of chemical additives that encourage the suspension of one liquid in another.

fructose. A type of sugar known as a monosaccharide.

gelatin. A protein mixture derived from animal collagen.

glucose sugar. The main type of sugar in the blood and the major source of energy for the body's cells.

heat-proof or glass container. A container that can withstand heat without melting, warping, or burning.

inclusion. An added ingredient that remains discrete in a finished product.

lactose. A sugar present in milk.

Maillard reaction. The chemical reactions between amino acids and reducing sugars that give food its distinctive flavor.

molecules. Made from atoms that are connected by chemical bonds.

monosaccharide. One sugar molecule (for example, fructose or glucose).

reducing sugars. Sugars that are used to react with amino acids in a Maillard reaction (lactose, dextrose, fructose, and some sugars found in glucose sugar).

saturated solution. A solution in which the maximum amount of solute has been dissolved in the solvent. For example, as you dissolve sugar (solute) in a glass of hot water (solvent), there comes a point when no more sugar will dissolve.

solute. The substance to be dissolved. For example, sugar is the solute when it is dissolving in water.

solution. A group of molecules that are mixed and evenly distributed in a system.

solvent. A substance that is able to dissolve other substances. A solvent is the substance doing the dissolving. For example, water is the solvent in sugar water.

supersaturated solution. A solution that has more solute (e.g., sugar) dissolved than is possible under normal circumstances. A glass of hot water that is saturated can dissolve more sugar. But when it cools to its original temperature, it is considered supersaturated.

unsaturated solution. A solution that has not reached the maximum amount of solute (sugar). You can easily dissolve a tablespoon of sugar in a glass of water. Since you can still dissolve more solute if the water is heated, it is unsaturated.

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