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Sweet Science: How Sugar Molecules Are Manipulated in Candy Making

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This unit seeks to combine a topic which will appeal to my third grade students while also providing them with the opportunity to learn some basic science. While my students overwhelmingly enjoy science the actual amount of scientific knowledge they have is limited. In the last couple of years fifth grade students and higher have been taking a science test as part of the Connecticut Mastery Test. Presumably the testing in science will eventually be extended down to third and fourth graders. While we do three science kits a year on Rocks, Plants and Unknown Powders most of the children see science as isolated experiments or demonstrations. Little emphasis has been placed on students mastering some basic scientific principle. The hands on process has been stressed without much regard for the actual building of a content of knowledge. One of my main objectives is to have students come away with some fundamental ideas they can build on. In this case, the core ideas will be the effect of heat on sugar solutions.

Introduction to the Unit

In the beginning of the unit, students will take stock of what they know about sugar. Usually we employ a graphic organizer called a KWL (what I know; what I want to know; and what I learned) chart. Here the teacher would solicit from students what they know. This would include whatever perceptions they have whether correct or incorrect. Then the class would suggest questions they have about sugar. The questions suggested here would likely include scientific questions about sugar; practical questions about where and how sugar is grown and could also extend to the nutritional value of sugar.

Doing this process with my students elicited some basic knowledge that one would expect: that sugar is something sweet; has a pleasant taste and is added to other foods. They were aware of the fact that there was white and brown sugar and that it grew as a plant. It was mentioned that sugar was in candy and it caused cavities. An argument almost ensued as one student said that sugar was "bad" because people got fat eating foods with a lot of sugar. Another student countered that sugar wasn't bad and that it wasn't sugar that caused a problem. We tabled the discussion for our research.

When we turned to what they wanted to know the questions ran the gamut from how sugar got its name to how it was made. Students wanted to know what "ingredients were in sugar." They also wanted to know about

where it came from and what was it that made sugar sweet. Still others questioned how salt was like sugar and why it was white.

Their questions offered a suggestion as to how this unit could proceed. I would suggest that each question would be given to a student or pair of students so they could do some preliminary research. Children would do research about sugar to answer and verify what they think they know and want to know. If they find information that contradicts what they offered the KWL chart would be corrected. As they begin to build background knowledge the unit would then start considering the science of sugar. The last column on the chart of what I learned can be filled in as the unit progresses or if preferred after the unit is completed. I think that given this topic and the breath of information that I would like students to build the information on charts that would be hanging in class so they could readily see the growth of information and have it for easy reference.

Background Information

It will be necessary for students to be provided or to find some background into the history of sugar and other sweeteners. There is an extraordinary breadth of information about what seems to be a simple subject - sugar. I suggest that this part of the unit can either begin or be taught alongside the science portion. Check out the bibliography at the end of this unit for suggested references. I recommend chapter 13 of McGee's book and especially Sugar by Jacqueline Dineen.

It has been said that the first taste of sweetness after mother's milk is honey. Honey has been consumed by humans for centuries. It can only be imagined how early humans first discovered and tasted the sweet substance that the bees were storing in their hives. The bible is full of references to honey and there are hieroglyphics of bee keeping and honey as far back as the Egyptians. [1]

While most plants form sugar through the process of photosynthesis, people have found only two of these plants are practical enough to raise for sugar. These include sugar cane and sugar beets. Sugar cane is like tall grass that can grow to over ten to fifteen feet tall. Historically speaking the sugar cane was found by the Persian emperor Darius in India in the fourth century. Darius referred to it "as the reed which gives honey without the help of bees."Later the use of sugar cane found its way to the Middle East and the countries around the Mediterranean. [2]

In Europe they continued to use honey to sweeten their food until the eleventh century. At that time the soldiers returning from the wars in the Middle East brought home sugar. Its taste was used the mask the bitterness of some of the drugs given to patients. These "confections" (from the Latin conficere, to "put together, or "to prepare") were made by ancient druggist. It was very expensive. During the next few centuries sugar remained a high price commodity that was carried by caravans overland to Europe. [3]

In 1493 when Christopher Columbus made his second voyage to the West Indies, he planted some sugar cane seedlings that he had brought with him. The sugar cane thrived in the warm climate and soon sugar found its way back to Spain. Sugar cane is a highly perishable crop. Once it is cut, it must be crushed and the syrup removed the same day. Because there were not enough laborers to do all the work the slave trade developed. In Africa, warring tribes sometimes enslaved their defeated enemies. European slave traders stole or bought

these slaves and transported them to the Caribbean where those who survived were sold to plantation owners. [4]

Figure 1: Sugar Plantation on the island of Reunion in the late 1800's [5]

Even after the sugar trade began to flourish in the Caribbean, it was still very expensive and was sold by the ounce not the pound. During the seventeenth century there was more sugar flowing into Europe and candy makers appeared to sell candy to the prosperous middle class. One of the first sugar candies was marzipan which is a paste made with finely chopped almonds. Candy making spread and the different cultures and countries developed a variety of candy. The American colonies found the use of maple sugar and maple syrup. Hard candies first appeared in England on a large scale in the nineteenth century; while the United States made the manufacturing of candy a leading industry in the twentieth century. [6]

One of the most significant developments in the sugar industry came about with the discovery by a Prussian chemist Andreas Marggraf that the juice of the white beet which was a common European vegetable could be an alternative to sugar cane. Sugar beets as they are now called have a leafy green top where the sugar is produced and roots underground where the sugar is stored. Sugar beets have a two year life cycle. Farmers usually pick them after the first year when their roots are full of sugar. Sugar beets are usually rotated with another crop such as wheat or corn. They are fast growing so that beets planted in the spring are harvested in the fall. Sugar beets are not as perishable as sugar cane and they can be grown in more moderate climates. [7]

In the United States most of the sugar beets are grown in California, Colorado, and Utah. Sugar cane is grown in Florida, Hawaii, Louisiana, and Texas. At present about 30% of the world's sugar comes from beet sugar. [8]

Sugar: a Natural Food

Many things are naturally sweet such as fruit and the sap of some kinds of trees and the juice of some plants. Through the process of photosynthesis sunlight acts on the chlorophyll, the green substance in the leaves causing carbon dioxide to chemically combine with water to form sucrose. Sucrose is what we know as regular table sugar. Sucrose can be chemically broken down into two other sugars - glucose and fructose. In plants, the two sugars are taken from the leaves and stored in other parts of the plant. Fruit is sweet because fructose is stored in the fleshy part of the fruit. [9]

Figure 2: Brown Sugar Crystals [10]

Bees carry the nectar of flowers which contain fructose and put it into the cells of the honeycomb. As the water evaporates the nectar thickens into honey. The juice from the sugar cane and the sap from certain trees such as the sugar maple are boiled to evaporate the water and produce thicker sweeter syrup. Sugar cane juice is boiled leaving behind molasses. Light molasses has high sugar content and as it sits it becomes darker, more concentrated and less sweet. [11]

What is sugar?

Sugar or sucrose is a carbohydrate and naturally comes from sugarcane and sugar beets. Sugar is a compound which means it is a substance formed when two or more elements are chemically joined. The molecular structure of sugar is composed of 12 atoms of carbon, 22 atoms of hydrogen, and 11 atoms of oxygen. [12]

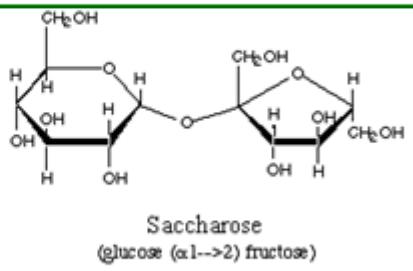
Sugar	Structure
Saccharose (glucose + fructose)	 Saccharose (glucose (α1-->2) fructose)

Figure 3: Table sugar is made up of glucose and fructose [13]

Sugar and Water

The simplest candy is a mixture of water and sugar. In most cooked candy, sugar is mixed with water or other ingredients that contain water. The important concern in candy making is what happens to the sugar as it cools. Each grain of sugar is a tiny crystal. As the temperature grows the amount of water decreases. This directly affects the size of the crystals that will form. Candy makers speak of the size of the crystal as "the grain." Because the sugar syrup can become unpredictable many candies contain corn syrup which is the same as sugar but doesn't crystallize. It helps prevent the sugar from recrystallizing. [14]

Heating a Sugar Solution

When the sugar solution is heated, the water boils away and the sugar concentration increases along with the temperature. As Harold McGee points out it seems somewhat contradictory that in candy making sugar is first mixed with water and then heated to in order to boil the water away. This is important because it allows the sugar to be heated at high temperatures without burning. [15] Before there were candy thermometers candymakers had their own visual way of figuring out if the sugar syrup had reached the correct temperature. These different stages that occur when heating the solution are based on how the solution behaves when some of the mixture is put into cold water. The following is taken from Science of Candy and Baking 911.com. (http://www.baking911.com/candy/chart.htm).If you look at the web site: Science of Candy (http://wwwexploratorium.edu/cooking/candy/sugar-stages.html) there are photos and video that show each stage of the heating of a sugar solution.

Thread Stage: 230 º F-235 º F; sugar concentration is 80%

A lot of water still remains in this syrup. You might use the syrup to cover ice cream

Soft-Ball Stage: 235 º F- 240º F; sugar concentration is 85%

Sugar syrup will form a soft, flexible ball. If you remove the ball it will flatten in your hand like a pancake. Fudge, pralines, fondants are cooked at this stage.

Firm-Ball Stage: 245 º F- 250 º F; sugar concentration is 87%

Sugar forms a firm ball that won't flatten when taken out of water, but remains malleable and will flatten when squeezed. Caramels are cooked in this stage.

Hard-Ball Stage: 250º F-265 º F; sugar concentration is 92%

Sugar forms thick threads as it drips from a spoon. Sugar concentration is high which means there is less moisture. The mixture forms a hard ball when dropped into cold water. The ball will not flatten when taken out of the water. The ball will stay hard but you can change its shape by squashing it. Nougats, marshmallows, gummies, divinity, and rock candy are cooked in this stage.

Soft-Crack Stage: 270 º F-290 º F; sugar concentration is 95%

At this stage bubbles on top become smaller, thicker, and closer together. Moisture content is low. Dropped into cold water this syrup solidifies into threads that are flexible not brittle. They will bend slightly before breaking. Saltwater taffy and butterscotch are cooked to this stage.

Hard-Cracked Stage: 300 º F-310 º F; sugar concentration is 99%

This is the highest temperature that is usually seen in candy recipes. There is almost no water left in the syrup. Dropped into cold water the syrup will form hard, brittle threads that break when bent. To avoid burns, the syrup should cool in the cold water a few moments before touching it. Toffee, nut brittles, and lollipops are all cooked to this stage.

If the syrup is heated to a higher stage you will be on the way to creating carmelized sugar (the brown liquid stage) - which is added to many desserts.

Clear-Liquid Stage 320 º F; sugar concentration is 100%

Water has all boiled away at this stage. The remaining sugar is liquid and a light amber color

Brown-Liquid stage 338 º F; sugar concentration is 100%

The liquefied sugar turns brown due to carmelization. The sugar is beginning to break down and form more complex compounds that give the syrup a richer flavor. This is used for dessert decorations and also to candy coat nuts.

Burnt-Sugar Stage; sugar concentration is 100%

Above 350º F the sugar begins to burn and has a bitter, burnt taste.

Unit Activities

Each child would be given a spiral notebook and/or folder to write notes and do observations. As the children begin answering their questions about the background of sugar I would display the major findings on charts around the classroom. Students would report about what they had learned and world begin with some solid knowledge of where sugar comes from and how it is produced.

Whether through sites on the web or pictures from textbooks, I would show students what sugar cane and beet look like. We would also plot where sugar cane and beet are grown in the United States and around the world.

One of the first activities I would have would be to allow students to observe the different kinds of sugar (white, powdered, raw, brown, fructose, maple syrup, molasses, and honey). There could be a few microscopes or magnifying glasses set up so students could see the individual sugar crystals.

I chose this beginning recipe because it is simple and easy. It also begins with the idea that candy is an old

food item that extends back centuries.

Recipe: Honey Balls

This recipe is based on Egyptian candies that were basically mixed honey with seeds and fruits. [16]

1/3 cup of milk powder

1/3 cup honey

1/3 cup peanut butter, either chunky of smooth

1/4 teaspoon vanilla

1/3 cup of one of these extra ingredients: wheat germ, sesame seeds, crushed dry cereal, chopped raisins, dates, or other dried fruit

1. Put the dry milk powder, honey, peanut butter, and vanilla in the mixing bowl.
2. Mix well to form a smooth paste. Be sure to stir until the grains of powdered milk disappear.
3. Add one of the extra ingredients or divide and add 2 tablespoons of one of the suggested extra ingredients, or leave them plain.
4. Cover and refrigerate. This makes about 30; with added ingredients about 30 balls.

I have also included at the end of this unit Lesson #1 - "Comparing Sweeteners" which basically entails making the same cookies 3 times with white sugar, brown sugar, and honey. Students get to compare the cookies to see that although the sweetness level used in each batch is the same, there is a discernable difference in the taste of each cookie.

Another observation would be done to see the difference between the sugar and salt crystals. It is not surprising that in assessing their knowledge the students connected sugar and salt.

A mixture is when two or more substances are mixed together. Each substance has its own properties which do not change. Because candy making usually includes the addition of water and/or ingredients that contain water this relationship is important to cover at the beginning of the unit. The sucrose molecule falls apart in hot liquids. When sugar is poured into water it goes into solution.

Experiment: What happens when you mix sugar and water?

Materials: 2 measuring cups one that will hold at least 2 cups of liquid, water and sugar

Place 1 cup of water in the larger cup and 1cup of sugar in the other cup

Pour the water into the cup with the sugar and stir.

What did you notice? First, all of the sugar did not dissolve into the water. Also if you check the cup measurement you do not have two cups. What happened? We have made a solution which means we have mixed ingredients and those ingredients may undergo a physical change. Some of the molecules of sugar have filled into the space between the water molecules. However, there was not enough space for all of the sugar to fit in and so the solution is now saturated.

Try the experiment again, but this time have three cups one filled with water at room temperature; one refrigerated and a cup of boiling water. Have students add sugar a tablespoonful of sugar to each cup and observe. They should see that the amount of sugar that dissolves depends on the temperature of the water. The higher the temperature the more thoroughly the sugar is dissolved. Place the cups to the side and allow them to cool. What happens? Students should see the solution reverse and the sugar separate back to the bottom of the cups as they cool.

Recipe: Marshmallows

One of the problems with any science/cooking activity is getting students to be part of the process, not only so they will learn more but in order to cut down on potential behavior problems. It is a good idea to give students; particular jobs. With candymaking the temperatures necessary for the sugar solutions is usually quite high and the teacher needs to be the primary cook. However, there are ways to include students. In the case of the marshmallow recipe, since the mixture needs to be constantly stirred for about 15 minutes I would recommend choosing 3 assistant cooks who would do the stirring with your supervision.

Another student could control a timer and break the stirring into 3 - 5minute intervals so each student helper would get an equal time at stirring the mixture. There would also be one child who would be in charge of measuring out and adding the vanilla during the last minute of cooking. Another student could grease and flour the baking pan. When the marshmallow loaf is taken out of the pan (you need to do this) cut it into inch strips and let some students help cut the marshmallows and dip them into the cornstarch and confectionary mixture.

To try to keep things as sanitary and safe as possible, have students wear plastic gloves and give them serrated plastic knives which will do a good job of cutting the marshmallows

This was one of the first things I tried to make and was somewhat skeptical but very surprised at the results. Making marshmallows proved to be one recipe that needed two people. This recipe was from the Food Network's Alton Brown.

http://www.foodnetwork.com/recipes/alton-brown/homemade-marshmallows-recipe/index.html

I followed it pretty much to the letter (I didn't have kosher salt so I used regular) and it turned out great.

Materials: 3 pkgs. (1oz.) unflavored gelatin, 1cup cold water, 1.5 cups granulated sugar, 1 cup light syrup, 1/4 tsp. kosher salt, 1 tsp. vanilla extract, 1/4 cup confectionary sugar, 1/4 cup cornstarch, nonstick spray

1. Put the gelatin into the bowl of a stand mixer along with ½ cup water. You will need the whisk attachment of your mixture.
2. In a small saucepan combine the remaining ½ cup water, sugar, corn syrup, and salt.
3. Place over medium high heat cover and let cook 3-4 minutes.
4. Uncover and clip on candy thermometer and cook until mixture reaches 240º F- about 7-8 minutes. When the mixture reaches the temperature immediately remove from heat.
5. Turn your mixer onto low and slowly pour in the sugar syrup down the sides of the bowl and into the gelatin. Once all the syrup is in raise the speed to high.
6. Continue mixing until the mixture becomes very thick and lukewarm temperature, approximately 12 - 15 minutes.
7. Add vanilla during the last minute of whipping. Prepare the pan. Combine the cornstarch and confectioner's sugar in a bowl. Spray a 13 by 9 inch metal baking pan with nonstick spray. Add some of the cornstarch and sugar mixture in the pan and cover the sprayed pan bottom and sides. Keep the rest of the mixture to use later.
8. Pour the marshmallow mixture into the pan using a lightly oiled spatula to spread it evenly in the pan. Dust the top of the mixture with a light cover of the sugar-cornstarch mixture.
9. Let the marshmallows set at least 4 hrs to overnight. (I let mine sit overnight).
10. When you are ready to take the marshmallow loaf out of the pan run a knife around the sides and if necessary loosen the bottom with a spatula. I found the loaf came out easily and I put it on a cutting board.
11. Then you can cut the loaf in 1inch squares and dust them in the confectionary sugar-cornstarch mixture basically to cover the sticky sides where the marshmallows have been cut. Store in an airtight container for up to 3 weeks.

Recipe: Caramels

There are many recipes for caramel and many variations from individual candies to caramel apples, and fancy mixtures with nuts and creamy centers. I tried this recipe for "soft" caramels because I was looking for a candy that would not be too hard to chew and this recipe promised to be soft and not too sticky. I was a little intimidated to start this recipe fearing that I would burn the cream-milk mixture while waiting for the rest of the ingredients to boil.

This is another recipe in which a lot of potential problems with students being passive observers could be eliminated by including them in the preparation of the caramels. A few students could help mix and stir the

recipe and another student could watch the thermometer. Students may have a bit if trouble cutting these and you will have to determine whether they can do this. Obviously students could help wrap the candies and in all the recipes students might make labels with catchy names for the class made treats.

Materials: 2 cups whipping cream, 1/2 cup sweetened condensed milk; 2 cups light corn syrup, 1/2 cup water, 2 cups sugar, 1/2 cup butter

Process:

1. Butter a 9-inch square baking pan and set it aside
2. In a 1-qt. saucepan, combine the cream and milk.
3. Place on low heat and let it get warm but not boil.
4. In a 4-qt. saucepan, combine corn syrup, water, and sugar.
5. Place on a high heat and keep stirring with a wooden spoon until it is well mixed. Try to keep water crystals from gathering on the sides of the pan by washing down the sides of the pan with a wet pastry brush.
6. Hang on the candy thermometer and cook over medium heat until the temperature reaches 250? F (120C) or firm-ball stage.
7. Then stir in the butter and warm cream-milk mixture. The temperature will decrease. Stirring constantly until the thermometer reaches 244? F (120C) or firm-ball stage.
8. Pour into the pan. Don't scrape the bottom of the pan. Cool overnight and then cut into 1-inch squares. Wrap in wax paper (I used plastic wrap).

One thing which was included in the cookbook this recipe was taken from is that it is important to remember when making caramels not to scrape the bottom. The reason that is recommended is that by the time you reach the bottom of the pan the temperature of the mixture has already begun to decline and it may start to darken and have a stronger flavor. I found this to be true and just kept the rest in the pan. I must confess that I didn't use the 9" square pan but used an 8" square pan. The finished product looked good. I let it stand overnight - I made it and tried to cut it the next day and found it to be hard. I felt it probably hadn't set up so it was recommended to me to wait and try to roll it out. That worked and I was able to cut it up and it tasted good. [17]

I have to say that trying to cut and package these candies gave me more cause to admire all those who make candy. It was very time consuming and somewhat difficult to figure out how to wrap up the caramels so they wouldn't stick. I settled on plastic wrap which I had originally wrapped up my caramel block.

Recipe: Rock Candy

Rock candy is on if the oldest and purest forms of candy. When you make rock candy you can see the shape of sugar crystals on a larger scale. The string provides a place for the sugar crystals to latch onto. As the water evaporates tiny the sugar crystals will encrust the string. Two processes are happening: saturation and evaporation. The string is supersaturated with sugar so it cannot stay in liquid form so it will come out and

form crystals. Through evaporation more and more water will be removed from the solution so the crystals will continue to grow until the water is removed. The rock candy grows molecule by molecule.

Materials: 4 cups of sugar, 2 cups of water, a small saucepan, wooden spoon, candy thermometer, small, clean glass jar, measuring cup. Cotton string, a weight to hang on the string (such as a screw or galvanized washer), wax paper, a pencil or dowel (to suspend the string in the jar)

Process:

1. Heat the water in the saucepan until it comes to a boil
2. Completely dissolve the sugar in the boiling water, stirring continuously with the wooden spoon until the solution grows clear and reaches a rolling boil.
3. Remove the solution from the heat, and then carefully pour it into the jar. Cover the jar with a piece of wax paper.
4. Tie the weight to one end of the string, and the other end to the pencil. The sting should be about 2/3 as long as the jar is deep. Dip the string into the solution and roll it into some sugar. Allow it to dry.
5. Suspend the string into the solution and let it sit at room temperature undisturbed for several days.
6. At the end of the week the crystals should be growing with sharp right angles and smooth faces of various sizes. The shapes of the crystals will be determined by the way the individual sugar molecules fit together.

The string is put into the solution and then rolled into sugar in order to give the crystals a place to latch onto. The sugar crystals grow because as the water evaporates over time the sugar will become more saturated and crystals will cling to the string. There are many different recipes for rock candy. This recipe came from the Science of Candy: Rock Candy Recipe (http://www.exploratorium.edu/cooking/candy/recipe-rockcandy.html#).

Recipe: Saltwater Taffy

Taffy is cooked at the Soft-Crack stage when the water content is low. Taffy making provides interesting physical changes as it goes from liquid to a hard sticky candy. Students also get a chance to feel the changes as they pull the mixture with their hands. This recipe was taken from the Science of Candy web site at http://www.exploratorium.edu/cooking/candy/recipe-taffy.html

Materials: 2 cups sugar, 1cup light corn syrup, 3/4 cup water, 1teaspoons salt, 2 tablespoons margarine or butter, 1/4 to 1teaspoon flavoring (vanilla, peppermint extract, cinnamon oil, etc.), 3 drops food coloring (optional)

Procedure:

1. Butter a large baking sheet and set to the side.

2. Use a wooden spoon to stir in the corn syrup, water, butter, and salt. Place the saucepan over medium heat until the sugar dissolves.
3. Continue stirring until the mixture begins to boil. Stop stirring and let it cook undisturbed until it reaches about 270º F, or the soft-crack stage. Wash down the sides of the pan with a pastry brush dipped in warm water while the syrup cooks.
4. Remove the saucepan from the heat and add food coloring and flavoring. Stir gently, and then pour onto a greased marble slab or into a shallow greased cookie sheet to cool.
5. When the taffy is cool enough to handle, grease your hands with oil or butter and pull the taffy until its light in color and has a satiny gloss. You will need to have someone help with this step, which should take about 10 minutes.
6. Roll the pulled taffy into a long rope, about 1/2 inch in diameter, and cut it with greased scissors or a butter knife into 1-inch-long pieces. Let the pieces sit for about half an hour before wrapping them in wax paper or plastic wrap and twisting the ends of the wrapper.

Students should consider why they need to stop stirring the mixture after the syrup starts boiling? The molecules of sugar have split into fructose and glucose. Stirring can encourage them to reverse and reunite back into sucrose.

Why did the recipe require us to wash down the sides of the pan? There is a possibility that some grains of sugar could be clinging to the side of the pan. Even a few grains could encourage recrystalization.

Why does the recipe call for corn syrup? Once again the corn syrup contains long chains of glucose molecules which can prevent the sucrose from recrystalizing

Why do you have to pull the taffy? Pulling the taffy aerates it or allows tiny air bubbles throughout the candy and making it lighter and chewier.

This recipe can remade with some changes. Students could be put into groups and each might make one change in the recipe. Try leaving out the corn syrup. The candy will probably be crystallized. One group might try not pulling the taffy- what kind of texture will result? Try adding 1/8 teaspoon of baking soda before pouring out the syrup.

The fact that sugar solidifies into crystals is very important in candy making. There are basically 2 categories of candies - crystalline in which crystals are part of the final product such as fudge and noncrystalline which do not contain crystal, such as lollipops, caramel and taffy.

Recipe: Vassar Fudge

There are many recipes for fudge and I basically chose to make Vassar Fudge because its story is one of many that purport to explain where fudge originated. Supposedly a few coeds were trying to cook in their dorm when they came up with a concoction that turned out to be fudge. Rather than swear the coed said "Oh, fudge" and that name for this treat stuck. Check out the referenced endnote to get more specifics on the history of fudge. [18] The key to good fudge is in the cooling not cooking phase. You don't want to stir it too soon or you will get large crystals. By waiting until the mixture is about 110º F, you have less chance of creating

what is called a "seed" crystal. The "seed" can be a sucrose molecule, a bit of air, or dust particle that gets stirred into the mixture. If this crystal forms it can grow larger and the fudge will be grainy. The more you stir the more crystals you get but you will get a lot of tiny crystals so the mixture will be smooth. [19]

Materials: 2 cups sugar, 2 squares (1oz. size) unsweetened chocolate, 1cup light cream (whipped cream), and 1 tablespoon butter

1. Combine sugar, coarsely chopped chocolate and cream.
2. Cook over medium heat stirring only until sugar and chocolate melts.
3. Continue cooking until temperature reaches 238º F degree or a few drops in cold water forms a soft ball.
4. Remove from the heat and cool slightly.
5. Beat until fudge begins to harden, and then transfer to a buttered platter.
6. Cut into squares before the fudge is absolutely firm.
7. For Wellesley fudge - add ½ lb of marshmallows when candy is removed from the heat. There is also a more elaborate recipe for Smith fudge that includes molasses and brown sugar. http://www.thenibble.com/REVIEWS/MAIN/candy/old/history-of-fudge2.asp#tips
8. Most of the recipes listed for Vassar fudge are pretty consistent. I found this at http://www.gourmet.org/recipes/candies/vassar-fudge.

This is another activity where students could make both Vassar and Wellesley fudge and do a taste comparison. What does the marshmallow change the taste? Depending on the time you have you might also include Smith fudge.

Recipe: Caramel Popcorn

Sometimes called "Cracker Jacks" there are many variations of this recipe which was taken from Creative Kids: Simple Cooking Fun. [20] This is a very easy recipe and children and adults will love it. The problem for cooking it in the classroom will be putting the mixture into the oven for an hour. Even a toaster oven will not hold the amount you would need for a class. The most practical thing to do unless you can get access to a school cafeteria oven is to make some beforehand to share with the children.

Materials: 3/4 cup unpopped popcorn kernels popped (about 7.5 quarts), 1cup (2 sticks) butter, 2 cups brown sugar, 1/2 cup light corn syrup, 1tsp salt, 1 tsp. vanilla, 1 tsp. baking soda, 1 cup peanuts, optional

1. Preheat oven to 200º F. Pop your corn and place in a large bowl
2. Melt butter and then add brown sugar, light corn syrup, and salt.
3. Heat for about 5 minutes stirring occasionally.
4. Add vanilla and baking soda. Mix thoroughly and pour over popcorn

5. If you add nuts place them in a small bowl and heat them so they will not shock the syrup's temperature.
6. Mix everything thoroughly and spread into a couple of roasting pans. I used a couple of aluminum foil pans. Just make sure the popcorn is in a deep pan so you can turn it easily.
7. Place the popcorn into the oven and heat for 1 hour, stirring every 15 minutes.
8. Remove the popcorn and let it cool. Store it in airtight containers.

Recipe: Lollipops

Definitely the highest temperature I cooked at was when I made lollipops. I also learned how right the advice was in most of the recipes that it is difficult to make lollipops in humid weather. I made the pops and they were not bad but leaving them out they started to run - I was skeptical about putting them in the fridge but finally did. Hopefully, before I try them again, I will get some lollipop molds. The only ones I could find were recommended for chocolate which is melted at a much lower temperature. The other consideration I haven't gotten to fully explore is the question of flavoring. I tried making orange pops. Some flavors are considered to be lighter and they recommend you use more while others that are stronger need less. This is something you may have to experiment with to find what you prefer.

Materials: 1 cup sugar, 1/3 cup corn syrup, 1/2 cup water, 1/4 tsp. cream of tartar, 1/4 to 1 tsp flavoring, food coloring

Process:

1. Turn a cookie sheet upside down and cover it with parchment paper. Spray it with oil. The upside down cookie sheet helps to cool the pops.
2. In a pan over medium heat cook the sugar, corn syrup, water, and cream of tartar. Stir with a wooden spoon. If sugar crystals are on the sides of the pan wash down the sides with a wet pastry brush. Stop stirring as soon as the mixture starts to boil.
3. Place a candy thermometer into the pan and let it cook until it reaches 300º F.
4. Remove immediately from the heat and let it cool to about 275º F before adding flavoring and food color
5. Working quickly, add flavoring and food color. Spoon into prepared molds or pour onto the greased parchment paper
6. Let the pops sit for about 10 minutes and then wrap them in plastic bags, or cellophane and store in a dry place.

Usually the way to discourage crystallization is to add an acid such as lemon juice or cream of tartar. When this is done the sucrose breaks up into two simpler sugars: fructose and glucose. The larger sucrose crystals have a harder time forming when glucose or fructose is present. Another way to do this is to add a non sucrose sugar like corn syrup. Most lollipops contain as much as fifty per cent corn syrup to prevent crystals from ruining the texture of the candy.

Extending the Unit and Conclusions

As I reach the end of this unit, I find that there are still so many possibilities that I have not been able to investigate. I think there are a lot of extensions in writing, math and social studies that have not been thoroughly fleshed out but could be easily added. Students could write about their favorite candies; do surveys and graphs of favorite candies among the school population, and possibly hold a class fair in which they present their findings about the history of candy to their peers.

The unit has sought to show students that temperature and its effect on something as seemingly simple as sugar could develop into a whole industry of candy making. Hopefully, they will also learn, as I have how much we take simple pleasures for granted - like the lollipop or a simple marshmallow. The unit doesn't begin to suggest the many kinds of candies that one could make from gummy worms to chocolate caramels. That is one area I did not explore - chocolate. However, it would be easy enough to try some of the recipes here and include the addition of a chocolate covering as a final step.

Lesson Plan #1: Comparing Sweeteners (based on "The Cookie Test" experiment from Simple Kitchen Experiments by Muriel Mandell p. 26-27)

Obj. Students will make and compare 3 batches of cookies made from the same recipe using white sugar, brown sugar and then honey.

Materials: 1.5 cups of flour, 1.5 sticks of butter or margarine, 2 tablespoons white sugar, 2Tablespoons brown sugar, 1 tablespoon honey, 1.5 teaspoons lemon juice, bowl, mixer or wooden spoon, cookie sheet

Procedure:

1. Preheat oven to 350º F (175º C).
2. Soften the margarine or butter at room temperature.
3. Use a wooden spoon or food processor to cream a half stick (4 tablespoons of butter with the white sugar. Add a half tsp. of lemon juice. Gradually mix in a half cup of the flour. Continue mixing until the dough is smooth and beginning to form a ball.
4. Repeat the process with the brown sugar and honey.
5. Drop rounded teaspoons of the dough onto a cookie sheet about 2 inches apart.
6. Press each cookie flat with the back of the spoon. Each batch makes about a dozen cookies. Bake about 15 minutes or until the cookies are light brown.
7. Let them cool. Then taste and compare.

Results: What the experiment shows is that the sweetness of each of the cookies is the same; however, the taste is different. Because honey attracts water more than either white or brown sugar the cookies made with it should be moister than the others. Brown sugar retains some of the dark syrup from another stage of sugar

refining so it offers a more complex flavor than white refined sugar. [21] The brown sugar cookies have a strong taste of molasses and are chewier than the white sugar cookies.

Lesson Plan #2: Candy Timeline

Obj.: To have students do some preliminary research on the place and development of specific candies in order to create a timeline

Materials: Access to internet, library and other resources. A classroom sized chart that can be used to construct a timeline. The timeline could hang from a rope extending across the classroom or on a long paper stretched onto a bulletin board or wall.

Prior to students doing the actual research you will have to set up the timeline structure hopefully with the help of students. The timeline can extend from ancient times to the present. A good reference is the book Sweet!: The Delicious Story of Candy by Ann Love & Jane Drake. There are also a few web sites that chronicle the history of candy. http://inventors.about.com/gi/dynamic/offsite.htm?zi=1/XJ&sdn=inventors&cdn=money&tm=33&gps=201_6_1916_995&f=20&tt=2&bt=0&bts=1&zu=http%3A//www.candyfavorites.com/shop/history-american-candy.php and the History of Candy http://www.tqnyc.org/2007/NYC074098//thehistoryofcandy.html

Procedure:

1. Have a chart ready of system for students to construct the physical timeline depending on your classroom.
2. Give students the name of a famous candy M&M, Pez, Conversation Hearts, or person in the history of candy i.e. Milton Hershey, Walter Diemer, and Thomas Adams.
3. Have students research what contribution the person made or when the candy and under what circumstances it was developed.
4. Give students a place to record their information. When everyone has completed their research return to the classroom timeline and post the information.
5. Discuss what they learned and what they notice about the timeline.

Lesson Plan #3: Potato Marzipan Sculptures

Obj. students will make a version of marzipan which is a candy used to make decorative shapes and figures.

Materials: 1 small potato, lightly salted water, 1.5 cups powdered sugar, 1tsp. almond flavoring, 1 tbs. powdered sugar

1. Boil the potato with enough salted water to half cover it. Cook about 20 minutes or until tender.
2. Cool the potato until you can handle it.
3. Mash the potato on a piece of wax paper.
4. Take 2 tbs. of the potato and mix it with the powdered sugar a little at a time until it forms a creamy paste.
5. Add enough sugar to make a stiff dough - like clay.
6. Add the almond flavoring.
7. Shape the dough into people, animals, fruits or vegetables. Paint with food coloring (you may want to tone down the colors with some water) and a small brush.
8. Let them dry and cover tightly before storing in the refrigerator

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Endnotes

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[18] http://www.thenibble.com/REVIEWS/MAIN/candy/old/history-of-fudge2.asp

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