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Confectionery Chemistry: Shifting the Contents of Chocolate

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Overview

There needs to be a shift in how chemical separations are taught in chemistry class. Seeing the value of separation techniques is difficult when students know so little about chemistry at the beginning of the year. I believe that the best way for the students to understand chemical separation is to reveal the chemistry to them in their lives instead of putting basic chemicals in their hands that they can hardly relate to. When teaching African American students, I think it is important to teach them in such a way that they inherit an education that rightfully belongs to them. In trying to emulate George Washington Carver, the famous agricultural chemist who developed uses for crops that would ultimately create an economy to free poor farmers from economic oppression, I want to show my students that the food chemistry is a creative discipline that is part of their inheritance. Thus, I will explain in this unit how food chemistry (such as chocolate and juice) can be a meaningful and effective way for students to learn the chemical separation techniques to manipulate mixtures.

Rationale

I am a teacher that loves creating new things and performing new tasks. However, I feel that the curriculum in the school district of Philadelphia really keeps chemistry teachers boxed into traditional chemistry that skims over applications. When I examine the curriculum and the textbooks, I realize that it is nearly identical to what I learned in school 15 years ago. As a teacher of a new generation of students, I feel obligated to teach students new ways of doing things. I believe it is a huge disservice to my students to offer them the exact same curriculum that I had in high school, when the truth is that they deserve better. If I am not living up to that task, then my university degrees and professional accomplishments carry no weight or power because I have not attempted to impart even a fraction of my professional learning experiences to the next generation of high school students. Failure to impart these experiences means that I am actually sending my students back in time to a darker past instead of advancing them towards a brighter future.

Some laboratory experiments will always be considered the classics, such as the flame test lab and electrical conductivity of salts, which establishes a foundation for understanding. However, if science is advancing and the laboratory experiments in high school remain unchanged, then students will always be living in the past. As I am entering into my third year of teaching chemistry, I have not found a way to meaningfully teach students about physical and chemical changes and chemical separation techniques. Oftentimes, food is used as examples, but unless my students are cooking for their younger siblings at home, many of them actually cannot relate to physical and chemical changes found in cooking. For too long, chemistry teachers have stuck with the familiarity of melting candles, heating of sucrose, and the frying of eggs that these examples have numbed the students' fascination with chemistry. Thus, it now becomes my responsibility to give them an authentic kitchen chemistry experience, rather than a list of fragmented objects and activities.

Lately across the US, the police brutality against African Americans have developed into the Black Lives Matter Movement. One of the things that this unit hopes to accomplish is to provide a context that will teach and motivate students toward a solution to the Black Lives Matter movement that begins with them, and not with a protest. Since the inspiration for this unit springs from George Washington Carver, I will use him as the example that students should follow if they want to experience liberation. In short, George Washington Carver did more than just invent uses for peanuts; his labors in the lab produced reasons for poor black farmers in the south to plant crops that were deemed useless. By creating a demand for those crops and their byproducts, farmers saw the opportunity to escape financial oppression. Thus, I want my students to see that in order to climb out of oppression, then one of the most valuable tools to shift an entire society of people out of oppression and into freedom is to use creativity. If students want to see a powerful demonstration of being delivered from the curse of police brutality, then African Americans should reconsider how their creativity is used. In my personal opinion, I find that that our creativity has only served to entertain people via the music industry, yet our influence in that stream of society still leaves us disrespected and dehumanized.

Black Lives Matter Movement

As has been taught in school for decades, African Americans have experienced different forms of racism for centuries. The Black Lives Matter (BLM) is the latest expression of concern beginning with Trayvon Martin's murder in 2012. According to the official BLM website, the scope of the organization goes beyond the senseless killings within the United States, but also to fight for the societal rights of all blacks in the categories of diversity, globalism, women, villages, families, restorative justice, collective value, and queer and transgender affirmation.

As an African American male science teacher, I boldly state that I do not fully agree with the complete agenda of the BLM. However, I would be culturally insensitive to ignore the cry of my people and not offer some type of solution or therapy for my students through my science teaching. I am one who grew up in Louisiana and experienced racism not only in the south, but also in California where I finished high school. I have attended both historically black and ivy league institutions and I know what it feels like to be the first African American leader within the microcosms that I have lived in. Although I will not mention much of W. E. B. DuBois and Booker T. Washington, I constantly walk the tightrope of their differing views concerning the education of African Americans. I feel like a Moses of Israel, who grew up familiar with Egyptian culture, yet a foreigner to his Hebraic roots. Thus, I am deeply convicted that I must use my ability to travel between different microcosms to find a solution that will transform the lives of African Americans. Thus, the closest individual that I can identify with is George Washington Carver, who used his scientific background to offer solutions that would transform black lives.

George Washington Carver

When people talk about George Washington Carver, I believe his accomplishments have been minimized and simplified to something mundane, such as creating multiple uses for peanuts. His story is not often told from a heroic or activist perspective, even though he did not actively pursue either of those titles. Poor Southern farmers did not see any economic reasons to plant many of the crops that Carver worked with.

One account of Carver's life that I believe contains the solution to the BLM is that written by the American Chemical Society.[1] Carver's viewpoint insisted that blacks should abandon or postpone the idea of demanding political and social rights, believing that those rights would actually be a positive consequence of having developed economic independence. The premise is that any race that offers a meaningful contribution to society would remove itself from the spotlight of ostracization.

Carver focused on interracial cooperation and elevating former slaves out of an antiquated economy and into a new one. Carver believed in being a dedicated servant and scientist to his students. He accomplished his goal of creating an economy as an agricultural and food chemist. Carver was gifted in the area of building interdimensional gateways between the research world and the farming community, in which the poor farmer would benefit from the practices invented in the research world. During Carver's era, Europeans were implementing travelling schools, which Carver adopted in order to disseminate scientific information to the public.

Overall, my approach to designing this unit sets to accomplish many things. This unit will activate my power as a teacher to provide students with meaningful engagement and application of chemistry to produce a product that has a potential consumer demand. In addition, the unit seeks to follow Carver's pattern of disseminating information to the public.

Objectives

Student Audience

The unit is intended for students in grade 10, who attend classes together as an advisory or homeroom. Students have 60-minute class periods three days per week and 50-minute class periods twice weekly. An estimated 85% of the students are enrolled in algebra II, while the remaining students take geometry. The students enrolled in geometry are usually in the same homeroom, which typically hastens the pace of the class compared to sections without geometry students. Grade 10 students are also committed to the completion of a personal project as a requirement for finishing the International Baccalaureate (IB) Middle Years Program (MYP). Roughly 85% of the student population is African American. Roughly one-third of students are from the neighborhood, while the remainder come from around the city of Philadelphia.

Key and Related Concepts

In IB MYP, key concepts are words used to paint a broad picture of learning expectations that can be observed within and across disciplines. There are three fundamental key concepts that IB recommended in science:

change, relationships, and *systems*. Of the three fundamental key concepts recommended by IB, this unit will focus on the key concept of *change*.

Related concepts are more discipline-specific and allow for exploration of the key concepts in greater detail to cultivate students' conceptual understanding. The two related concepts selected for this unit's presentation are *interactions* and *form*.

Conceptual Phrase

The conceptual phrase is a generic statement that summarizes a concept, is nonspecific, and can be applied across multiple content areas and topics. The conceptual phrase developed for this unit is as follows: Changing interactions determine form. This conceptual phrase can be translated to topics, such as physical and chemical changes, thermodynamics, ion formation, or the redox reactions. Thus, students benefit from learning conceptual phrases because they potentially build continuity between old and new content.

Global Context

The IB program insists that subjects are taught within a context. This unit will address two of the six global contexts: personal & cultural expression and scientific and technical innovation. Through personal & cultural expression, students will study how a scientific example of creative expression is used to overcome economic oppression in the African American community. They will examine scientific principles in chemistry and evaluate the impact that the use of the principles has had on how humans adapt to oppression.

Inquiry Statement

The inquiry statement marries the conceptual phrase to the global context. It ultimately summarizes the unit in a way that students know the goals and expectations. Unlike the conceptual phrase, the inquiry statement is unique and specific to the unit, by which the statement may contain language specific to the course and/or content. Thus, the suggested inquiry statement for this unit is as follows: Changing molecular interactions through separation techniques has led to innovative breakthroughs in how we process food. Sometimes, the inquiry statement can also be written as a question as follows: How has our understanding of changing molecular interactions through separation techniques created an opportunity to shift a society into economic growth?

Overall, the objectives of this unit will include several points. First, students will be able to distinguish the differences between elements, compounds, pure substances and mixtures. The chemical separation techniques will also help students understand the difference between homogenous and heterogeneous mixtures. Finally, students will be able to explain how some heterogeneous mixtures can become homogenized and describe how chemical separation techniques can reverse the process.

Background

To prepare myself for writing this unit, I want to create a context that is relevant to the student population. Thus, I will have to read about George Washington Carver's experiments and bulletins and his true history as an agricultural chemist. Students ought to be given an opportunity to truly understand the magnitude of his contribution to creating an economy. Secondly, I had to conduct research on the chemical separation techniques used in extracting fats. A prime example would be the cocoa bean. Finally, I conducted research on the different methods used to extract juices from fruits. The extraction of juices alone provides the setting for a variety of separation techniques commonly used throughout an introductory chemistry course. Overall, I want the students to experience the power of creating their own food products and for students to connect how chemical separation techniques can actually change how a food is marketed to an economy.

Phases of Matter

By the time this unit is taught, my students will already know the basics of chemistry such as the states of matter. In the past, I have never gone into the depth of solids and liquids at the beginning of the year even though I spend an entire unit just on gas laws during the spring. Therefore, concerning the liquid state, I will introduce to them terms such as solute, solvent, suspension, immiscible, emulsions. On the avenue of solids, I will also introduce the terms crystalline, amorphous, and polycrystalline. All of these words are necessary when talking about mixtures, especially in processing foods.

Solids can be classified into three organizational structures or phases. Solids are considered crystalline when its atoms or molecules are organized according to one general pattern. A primary example of a crystalline solid is table salt. If you had to picture this pattern on a macroscale, imagine a mound of oranges on display at the grocery store appearing stacked and organized. Solids are classified as being polycrystalline when there are multiple patterns found within the molecular structure. Examples include minerals and gems found in the earth's crust. An example of a polycrystalline food is Himalayan salt and a good representation of a polycrystalline material is a cookies 'n creme chocolate bar. Himalayan salts come in various shades of pink and also appearing colorless like table salt, which is a result of organized crystals, but with variations in the chemical composition in different locations of the salt crystals. In the cookies 'n creme chocolate bar, the white chocolate and the cookies represent two differently organized regions, yet they are mixed together.

Liquid mixtures can also have phases. A substance that is dissolved (solute) in another (solvent) typically makes a solution. Only one phase is present, which is a homogenous liquid. This is easily achieved with salt water and sugar water. However, when oil and water are mixed, they create a mixture known as a suspension. They separate because one is polar, the other is nonpolar, and they cannot achieve favorable interactions with each other, forming two distinct layers, in which oil would float on top. This separation is described as the two liquids being immiscible.

However, the food industry has created solutions where phases of matter can be trapped in spheres called colloids. These colloids are stable in the presence of an emulsifier, which arrange themselves at the junction where the two liquids meet because the emulsifier contains atoms that allow it to favorably react with both substances. This is common in mayonnaise, toothpaste, and cosmetic creams.

Basic Separation Techniques

This unit will look at classic separation techniques as well as a few that have been used in food chemistry. Provided that students have sufficient science exposure prior to high school, most students will have encountered six basic separation techniques that are taught throughout the physical sciences: flotation, sifting, magnetic, filtration, distillation/evaporation, and panning. Based on my short experience as a teacher, most students are unfamiliar with sifting because it differs from filtration and panning by sifting for objects of specific size. Students often recognize evaporation, but not distillation, since distillation is a process that typically involves an additional apparatus.

Microwave-Assisted Extraction

The first additional separation technique commonly used in the food industry is microwave-assisted extraction (MAE). MAE has been used to extract aromatic compounds from foods such as garlic, lavender flowers, and orange peel.[2] The advantages of using MAE are low solvent consumption, short extraction times, low energy consumption, and reproducibility.

Microwave ovens at home typically rely on water molecules present in food as a heat absorber. Solvents have a chemical property called a dielectric constant. The dielectric constant is a measure of a substance's ability to absorb energy while present in an electromagnetic field. Water has a high dielectric constant that causes it to absorb microwave radiation. The absorbed microwave energy is transformed into heat, which is why food becomes hot.

The type of solvent used in MAE is important. A molecule with permanent or induced dipoles will be rotated by the microwave's oscillating electromagnetic field. The rotation of the molecule as it moves in alignment with the electromagnetic field releases the energy in the form of heat.

Chemistry of Chocolate

There are mainly 3 types of commercialized chocolate depending on the fat content and the amount of cocoa solid. Dark chocolate contains the most cocoa solids. Milk chocolate contains between 20-30% cocoa solids. To improve the taste, vanillin and butyric acid are added. Finally, white chocolate contains no cocoa solids, but contains additions such as sugar and milk.

There are three types of molecules primarily found in foods: carbohydrates, fats, and proteins. Cocoa butter is classified as a triglyceride fat meaning that it is composed of a glycerol molecule and 3 fatty acids: palmitic (P), stearic (S), and oleic (O) acids. The most common symmetrical mono-unsaturated forms are POP, SOS, and POS.[3] Occasionally, cocoa butter will contain small quantities of triolein OOO, tripalmitin PPP, and tristearin SSS. Occasionally, there are small amounts of linoleic acid present.

Scientists have recently used MAE to isolate the fat contents of cocoa powder using a hexane/isopropanol solvent and cocoa nibs using petroleum ether solvent.[4] Results revealed the accuracy of fat separation using MAE is just as efficient as other processes. Hexane is a nonpolar molecule with a dielectric constant of 1.9, while polar molecules like isopropanol, petroleum ether, and water have dielectric constants of 18.3, 4.3, and 80.4, respectively.[5] A solvent with a low dielectric constant is considered relatively unaffected by microwaves. Since hexane is a nonpolar molecule and cocoa butter is also nonpolar, the cocoa butter will be extracted from the cocoa powder. The MAE speeds up the extraction process by heating the polar water and isopropanol molecules in the mixture.

Since this unit is designed for African American students, the extraction of fat from cocoa is essential in producing cocoa butter, a common cosmetic product used by that community. In the event that this unit is not administered to African American students, the other common product of cocoa butter is white chocolate. Thus, teaching this advanced separation technique has relevance in simply making other candies and desserts.

Separation Techniques used in Processing Fruit Juices

There are four basic methods for producing fruit juices.[6] Juice extraction by pressing is the most common separation technique and is mostly associated with juices that still contain pulp, such as orange juice. This is accomplished mechanically by applying a force to the outside of the fruit to create enough tension to drain out the liquid, called the juice yield. The juice yield can then be used as is, or further treated with other separation techniques.

The type of fruit typically determines whether or nor is it readily consumable or needs additional processing. The categories are citrus, pomaceous fruits, stone fruits, grapes, and berries. Fruits such as apples and oranges are consumable without additives. However, berries such as black and blueberries are acidic berries that requires a sugar syrup or a juice concentrate in order to be enjoyable. The most common concentrate additives are apple and grape. Fruit pulps can also be used to create nectars by adding a type of sugar syrup.

Juice extraction via water solvent relies on molecular diffusion of the fruits components. The rate of diffusion, or diffusion coefficient, and the permeability of the cell walls are controlled between temperatures of 50-70 °C.[6] Also, increasing the available surface area of the fruit by chopping the fruit in the smaller pieces improves the transfer process. The most common but subtle example of extraction via water solvent is in restaurants. Oftentimes, customers will order a glass of water with lemon. Some will mechanically squeeze the lemon, while others will simply let the lemon juice naturally diffuse into their beverage. Hotels often have a mini-concession table in their lobbies with water containing fruits such as lemons, limes, oranges, strawberries, and cucumbers, to provide a refreshing welcome to innstayers. Boiling lemon in water has also become common due to the belief that drinking lemon water in the morning helps to remove toxins from the body, balancing alkalinity, and ultimately improving the immune and digestive systems.

Juice clarification involves an additional step after extraction via pressing out the water solvent. Usually, there are still plant particles present in the juice. Oftentimes, parts or all of the plant particles are removed from the mixture to improve taste, color, and odor. Scientists will continue to improve the quality of the juice with the addition of enzymes to break down larger particles or clarifying agents that will further precipitate unwanted particles. Clarification can also occur mechanically with centrifugation or filtration.

Juice concentrate is produced using evaporation, freezing, and microfiltration techniques. Evaporation risks losing some of the benefits while freezing risks retaining small plant matter. Microfiltration has a distinct advantage in which microbes can be filtered out of the juice concentrate.

A Healthy Balance: Chocolate, Fat, and Juice

Now that we have looked at chocolate and juices, we can begin to explore the relationships between the two. Since chocolate is high in fat and sugar, food scientists have sought to develop a healthier chocolate. By using a Pickering stabilizer, scientists, such as Stefan A. Bon, began with substituting water in place of fat through emulsification.[7,8] However, the dispersion of water in chocolate risks the structural stability of the chocolate, meaning that it will not maintain its ‘snap’. Bon has also taken it a step further by infusing juices into chocolate using chitosan, a popular polysaccharide used in the biomedical field to reduce bleeding and to deliver drugs through the skin. With this discovery in mind, the idea of making infused chocolate confectionaries lends itself directly to the study of mixtures, their phases, and the chemical separation techniques used to manipulate them into desired products.

Classroom Strategies

This unit will use primarily hands-on laboratory strategies to help students grasp the concepts. Since students' lifestyles and cultures vary drastically, I cannot fully rely on every student being able to identify physical and chemical changes in cooking when the truth is their experience in those areas may be limited. By giving the students the experiences in class, they can draw their own conclusions and extrapolate new ideas.

My classroom and lab are fully integrated. There are 8 lab stations for student placement. Seats are assigned for instructional groups consisting of four students. Due to the number of students seated at each station, it is only natural that they will be talkative. Therefore, I try to give the students opportunities to engage in conversation every 10-12 minutes whenever my lessons include lectures during direct instruction. Otherwise, I encourage my students to work in groups all the time.

I will begin the unit with George Washington Carver and the legacy that he left. As previously stated, this will be the context that will hook students into believing that cooking involves chemistry. By looking at Carver's accomplishments as a solution to overcoming oppression, I want students to see that they too have opportunities to overcome oppression using a skillset to create something that the world has never seen before. This unit is to guide them through the process of what it means to use chemistry to create a product that has a potential market.

To help introduce the unit as well, I will use an inquiry-based activity. I will use the 5E model where students will follow a series of steps to separate a mixture and record their observations. Since part of the separation process will require 24 hours to pass, I can have the students begin the laboratory activity at the beginning of class and introduce to them the terminology and concepts as they go through each step of the separation process.

Another strategy I would like to implement is having professionals model their own products. I want to find people who are in the food services business who could actually verify the use of the chemical separation techniques. I would like to put together a series of videos where these restaurant owners would prep their ingredients or drinks and use them to engage the students, create virtual homework assignments, and allow the business owners to advertise their product. I want students to see that the use of chemical separation techniques is essential to providing a quality product and service for humanity.

The last strategy is to give the students a performance-based assessment in which students will engage the design process and publish their work for the public. The inspiration of this assessment will be based on the television show, Chopped. After having been taught the chemical separation techniques for processing fruit juices and chocolates, students will be given basket ingredients to draft a recipe and create a fruity beverage or fruit-infused chocolate dessert of their choosing. Students will use technology to record the processes involved and will publish the series to the web. I decided to include a social media component because I personally believe that teachers ought to demonstrate how social media ought to be used and give students an opportunity to positively exercise that right.

Inquiry Questions

A common instructional strategy is the questioning technique. While it is common to pose questions orally in a classroom, the IB program encourages the use of inquiry questions with the intent to provide a roadmap or study guide of the unit. Ultimately, by providing the students a truncated version of the unit, the inquiry questions give students a sense of what they will ultimately be assessed on.

Factual Questions

- What are the differences between pure substances and mixtures?
- Can mixtures consist of matter in more than one state?
- What are solvents?
- What are emulsifiers?

Conceptual Questions

- How do separation techniques rely on physical properties and chemical properties?
- What is the difference between a state of matter and a phase?
- What is the difference between a polar and nonpolar substance?
- Which conditions result in the most effective separation process?

Debatable Questions

- Can all mixtures be separated?
- How have our personal food preferences developed along with our understanding of materials?
- Does our understanding the nature of mixtures improve our ability to express creativity in cooking?
- Is protest the best way to prove that our lives matter?
- If Carver used science to overcome financial oppression, then could we apply this today in the BLM movement?

Activity 1: Confectionery Chemistry, Round 1 – Microwave-Assisted Extraction of Fat from Chocolate

For the Teacher: Before beginning this activity, students should already be able to state the three states of matter and differentiate between physical and chemical properties of substances. I would use this as an inquiry lesson on homogeneous and heterogeneous mixtures. Students would begin class with this activity. As they reach different stages of the activity, there are moments that lend themselves to dialogue with the students and this time can be used to elaborate on the process of separating fat from chocolate. When elaborating, this is the opportunity to introduce vocabulary such as phases, immiscibility, emulsifier, etc.

For the Student: Welcome to the first round of Confectionery Chemistry! The goal of round 1 is to use the microwave oven as a tool for removing fat from chocolate and to determine how much fat is in the sample of chocolate provided. Participants are expected to follow the procedures to isolate chocolate and then calculate how much was removed. The team that is closest to the true value of fat content will win the first round.

Materials

Dark, milk, and white chocolate, olive oil, 91% or higher isopropanol, microwave safe mini-containers (~100 mL), graduated cylinders or measuring spoons, balance, plastic knives or scalpels, microwave oven (adjustable power output of 250 W and below).

Procedures for Microwave-Assisted Extraction

Preparing chocolate for microwave-assisted extraction

1. Obtain a piece of chocolate (dark, milk, or white) and record your observations of the chocolate in the table following the procedures (OBS 1).
2. Tare/zero a balance. Measure ~5 g of chocolate on the balance. Record your exact measurement.
3. Transfer the 5-gram sample of chocolate into a small microwaveable container (~100 mL in size).
4. Add 1 mL of water to the container containing chocolate.
5. Add 30 mL of olive oil to the container.

Preheating chocolate for fat extraction

1. Adjust the power of the microwave oven to 250 W or less. For a 700 W microwave oven, the microwave oven must be set to 30% power, which is the equivalent of 210 W. You must follow your microwave oven's specific instructions to adjust the power output.
2. Place the container containing chocolate, water, and olive oil into the microwave oven and run the microwave oven for 60 seconds.
3. Allow the mixture to rest for 120 seconds before handling.
4. Gently swirl the mixture for 30 seconds and record your observations (OBS 2).
5. Add 10 mL of isopropyl alcohol.
6. Vigorously agitate the mixture for 30 seconds.

MAE and fat determination from chocolate

1. Adjust the power of the microwave oven to its lowest setting. The recommended power output is 25 W or 10% power. (This experiment was tested to work with a 70 W power output).
2. Place the mixture back into the microwave oven for 360 seconds (6 minutes).
3. When the microwave oven is finished, allow the mixture to rest for 120 seconds (2 minutes) before handling.
4. Remove the mixture from the microwave oven and record your observations (OBS 3).

Separation of chocolate layer from mixture

1. Place the lid onto the container and transfer the contents into a freezer overnight.
2. On the following day, remove the containers from the freezer. Remove the lid and record your observations (OBS 4).
3. Remove frozen solid from the container. Using a butter knife (spatula-like tool) separate the chocolate from the olive oil layer.
4. Measure the mass of the chocolate removed using a balance.
5. Calculate the mass of fat removed and its percentage. Compare calculation to contents of food label.

Data Table

Construct a data table that collects the following information: Initial mass of chocolate squares, Final mass of chocolate, Calculated mass of fat extracted, and Percent of fat extracted.

Observations (OBS)

1 Describe physical properties of the chocolate.
2 Describe **chocolate/oil/water** mixture after heating and swirling.
3 Describe **chocolate/oil/water/isopropanol** mixture after heating.

4 Describe the **frozen** chocolate/oil/water/isopropanol mixture.
5 Draw a diagram of the frozen mixture. Label each separation. Be sure to identify any visible cocoa fat.

Analysis Questions

- On a scale of one to 5, how would you rate the procedure to remove fat from chocolate in terms of ease.
- If you were trying to reduce the fat in chocolate, would you recommend this procedure? Explain your reasoning.
- Predict what would happen to the taste of the chocolate if the fat is reduced.

Activity 2: Confectionery Chemistry, Round 2 – Concentrate on the Juice

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Welcome to round 2 of Confectionery Chemistry! In this round, contestants will use fruits and separation techniques to create their own 16-ounce non-alcoholic juice beverage from scratch. Contestants may use a drink recipe found online or make up their own. The only additional additives that will be provided are water, sugar, and salt. Contestants must use 1-2 fruits. Basic fruits such as lemons, oranges, grapes, etc. will be provided with advance notice. Exotic fruits, such as pomegranates and dragonfruit must be provided by the contestant. Other ingredients may be used at the expense of the contestants. Contestants will be provided 15 minutes class time to research a recipe and provide their list to the teacher. Contestants will be taught how chemical separation techniques are used for juice extraction. On the following day, contestants will put their knowledge to the test in creating their beverage.

- Extraction by Pressing
- Extraction via Water Solvent
- Clarification via Filtration

Activity 3: Confectionery Chemistry, Round 3 – Juice Infused Chocolate

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For the Teacher: This will be one of the summative assessments for the unit. After having learned to identify mixtures and their homogenous and heterogeneous components, students will now create homogenous chocolate infused with fruit juice. So that time is not wasted, it is important to have many of the materials prepped in advance. Also, having access to two microwave ovens will speed up this process and reduce student idleness. Once the confectionaries have been cooled, invite 3-4 teachers to class to help judge the final competition.

For the Student: Welcome to the final round of Confectionery Chemistry! In this round, you will take your juice extract from round 2 and combine it with chocolate to create a juice-containing chocolate confectionary. The goal is to infuse a fruity flavor into the chocolate, maintain the structural integrity of your treat, and ultimately, reduce the fat content of the chocolate by 40%! In the competition, you must use an electronic device to vlog your progress, which will be compiled into a YouTube video.

Materials

- Ascorbic Acid Solution Stock: Dissolve a 2.12 grams (1/2 tsp) of L-ascorbic acid powder in 240 mL (1 cup) of water for a concentration of ~0.05 M and a pH of 3.15.
- Chitosan Powder: When mixing chocolate with liquid, the expectation is that the chocolate will get softer and acquire a lower melting point. However, the chitosan acts as an emulsifier to trap juice in droplets and also preserve the structural integrity of chocolate.
- Preparation of Juice: Heat 79 mL (1/3 cup) of beverage to 40 °C. Measure 1.4 grams (1/2 tsp) of chitosan. Thoroughly agitate by shaking in a closed container or a drink mixer. To assist with dissolving the chitosan and maintaining a native pH, add 15 mL (1 tbsp) of the L-ascorbic acid solution.
- Baker's Chocolate: In order to see a noticeable difference, a chocolate with high fat content must be used. Hershey's Semi-Sweet Cooking Chocolate bar is great choice to start with. Each piece weighs about 14 grams and contains 4 grams of fat, which is ~30% of the whole bar. Each student group should get about 50 g of chocolate to work with. Using the aforementioned chocolate bar, that is 4 squares of chocolate totaling 56 grams, containing 16 grams of fat. If using a different chocolate, it is vitally important to note how much fat is actually present per serving of chocolate.
- Drink mixer or frother: The juice being infused into the chocolate needs to be mixed evenly. A drink mixer, such as the Matcha DNA mixer, is a small and inexpensive device. It is needed in two stages: to mix the chitosan with the juice concentrate and L-ascorbic acid and to mix the juice into the chocolate. You should demonstrate this with the students because it can get rather messy. Mixing the juice will create a lot of froth, while mixing the chocolate requires more patience as the mixer will actually reduce in speed when it comes into contact with the chocolate.
- Microwave oven (adjustable power of ~700 watts and lower): The key to preventing the chocolate from burning is to heat the chocolate at a low power setting in the microwave oven. Since the chocolate will not be in the presence of a solvent, it needs to be heated at ~700 watts to start the melting process quickly. Once the chocolate is actually melted, it must be reheated in the microwave oven at lower powers (~250 watts). Chocolate melts with the assistance of human body heat. Therefore, in order to melt the chocolate without burning it, the temperature must not exceed 46°C or 115°F.

Procedure: Preparing chocolate emulsions

Remove the chocolate from the microwave oven. Melted chocolate is very viscous and you may be unable to tell if it is melted until you perturb it with a mixer. Use the handheld drink mixer or milk frother to assist in stirring the chocolate. The key to keeping the chocolate intact is heating it for short periods of time and at a lower power without burning it. Once the chocolate is actually melted, it must be reheated in the microwave oven at lower powers (~250 watts).

Once the chocolate is melted, add the fruit juice containing chitosan and mix using a drink mixer. The fat content of your chocolate becomes important here. For example, if you are using 56 grams of chocolate, as previously suggested, then there is 16 grams of fat present. The recipe requires a ratio of juice emulsion equal to that of the fat content. Therefore, students will need to add roughly 15-16 mL of juice. The assumption is that most juices have a density slightly greater than 1.0 g/mL. After mixing, close the container and allow the chocolate emulsion to rest for 10 minutes. Then store in the refrigerator.

Notes

1. "George Washington Carver." American Chemical Society. Accessed August 18, 2017. https://www.acs.org/content/acs/en/education/whatischemistry/landmarks/carver.html.
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Annotated Bibliography

Teacher Resources

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chemical variations found in cocoa butter.

- ElKhori, Sandra, JR Jocelyn Paré, Jacqueline MR Bélanger, and Elevina Pérez. "The microwave-assisted process (MAP TM1): Extraction and determination of fat from cocoa powder and cocoa nibs." *Journal of food engineering* 79, no. 3 (2007): 1110-1114. This is the initial article that inspired the first activity in the unit. Procedures for classroom use were adapted from this source.
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Appendix/Standards

Standards

The Core Curriculum of the School District of Philadelphia is aligned to the Pennsylvania Department of Education Standards Aligned System. The standards include instruction on the following topics: chemistry, physics, and environmental science. This unit will also align with Common Core and Next Generation Science Standards.

Pennsylvania Standards

3.1.10.A: Discriminate among the concepts of systems, subsystems, feedback and control in solving technological problems.

3.1.10.B: Apply mathematical models to science and technology.

3.2.C.A3: Describe the four normal states of matter in terms of energy, particle motion, and phase transitions.

3.2.C.A6: Compare and contrast scientific theories. Know that both direct and indirect observations are used by scientists to study the natural world and universe. Identify questions and concepts that guide scientific investigations. Formulate and revise explanations and models using logic and evidence. Recognize and analyze alternative explanations and models. Explain the importance of accuracy and precision in making valid measurements. Examine the status of existing theories. Evaluate experimental information for relevance and adherence to science processes. Judge that conclusions are consistent and logical with experimental conditions. Interpret results of experimental research to predict new information, propose additional investigable questions, or advance a solution. Communicate and defend a scientific argument.

3.4.10.A: Apply knowledge of mixtures to appropriate separation techniques.

3.7.10.B: Apply appropriate instruments and apparatus to examine a variety of objects and processes.

Common Core Standards for Science and Technical Subjects

CC.3.5.11-12.A: Cite specific textual evidence to support analysis of science and technical texts, attending to important distinctions the author makes and to any gaps or inconsistencies in the account.

CC.3.5.11-12.C: Follow precisely a complex multistep procedure when carrying out experiments, taking measurements, or performing technical tasks; analyze the specific results based on explanations in the text.

CC.3.5.11-12.H: Evaluate the hypotheses, data, analysis, and conclusions in a science or technical text, verifying the data when possible and corroborating or challenging conclusions with other sources of information.

CC.3.6.11-12.B: Write informative/explanatory texts, including the narration of historical events, scientific procedures/ experiments, or technical processes.

CC.3.6.11-12.C: Produce clear and coherent writing in which the development, organization, and style are appropriate to task, purpose, and audience.

CC.3.6.11-12.H: Draw evidence from informational texts to support analysis, reflection, and research.

Next Generation Science Standards

PS1.A: Structure and Properties of Matter: Plan and conduct an investigation to gather evidence to compare the structure of substances at the bulk scale to infer the strength of electrical forces between particles. The structure and interactions of matter at the bulk scale are determined by electrical forces within and between atoms. [Clarification Statement: Emphasis is on understanding the strengths of forces between particles, not on naming specific intermolecular forces (such as dipole-dipole). Examples of particles could include ions, atoms, molecules, and networked materials (such as graphite). Examples of bulk properties of substances could include the melting point and boiling point, vapor pressure, and surface tension.] [Assessment Boundary: Assessment does not include Raoult's law calculations of vapor pressure.]

Eligible Content

CHEM.A.1.1.1: Classify physical or chemical changes within a system in terms of matter and/or energy.

CHEM.A.1.1.2: Classify observations as qualitative or quantitative.

CHEM.A.1.1.3: Utilize significant figures to communicate the uncertainty in a quantitative observation.

CHEM.A.1.1.4: Relate the physical properties of matter to is atomic or molecular structure.

CHEM.A.1.2.1: Compare properties of solutions containing ionic or molecular solutes (e.g. dissolving, dissociating).

CHEM.A.1.2.2: Differentiate between homogeneous and heterogeneous mixtures (e.g. how such mixtures can be separated).

CHEM.A.1.2.3: Describe how factors (e.g. temperature, concentration, surface area) can affect solubility.

CHEM.A.1.2.4: Describe various ways that concentration can be expressed and calculated.

CHEM.A.1.2.5: Describe how chemical bonding can affect whether a substance dissolves in a given liquid.