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THE USE OF FOOD IN CHEMISTRY EXPERIMENTS TO
ENGAGE AND ENRICH THE TEACHING IN THE
CLASSROOM

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Brian Michael Topping

has been accepted towards fulfillment
of the requirements for the

Master of Science degree in Biological Science-Interdepartmental

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THE USE OF FOOD IN CHEMISTRY EXPERIMENTS TO ENGAGE AND ENRICH THE TEACHING IN THE CLASSROOM

By

Brian Michael Topping

A THESIS

Submitted to
Michigan State University
in partial fulfillment of the requirements
for the degree of

MASTER OF SCIENCE

Biological Science Interdepartmental

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ABSTRACT

THE USE OF FOOD IN CHEMISTRY EXPERIMENTS TO ENGAGE AND ENRICH THE TEACHING IN THE CLASSROOM

By

Brian Topping

Students often gain more knowledge out of hands on work. Labs and demonstrations increase knowledge often more than the book work and notes because they motivate interest and provide real world application. In an effort to incorporate labs into chemistry I have developed a unit centered on food in order to teach a variety of concepts and lab techniques to high school students. The study of food can be a tremendous motivator and help students take interest and ownership in the learning process. The unit was evaluated for its effectiveness through the use of a pre and post-test assessments as well as a post survey of students' attitudes towards labs and learning science. This study showed that students' overall conceptual knowledge of the various topics related to food increased as a result of this unit with evidence provided by the post-test scores.

ACKNOWLEDGEMENTS

I would like to extend my gratitude to the Towsley Foundation for their financial support during my studies at MSU as well as Merle Heidemann for her assistance through this process. I would also like to thank my chemistry students at Ovid Elsie High School for their hard work and interest in chemistry. Finally I would like to especially thank my wife, Katie and son Daniel for their support of all my endeavors big and small!

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INTRODUCTION

Statement of Problem and Rationale

When I set out to obtain my Masters of Science degree, I was teaching at a small district in southwest Michigan. I was teaching Biology, Chemistry, and Environmental Sciences, the bulk of which was Biology. I began my studies in the effort to obtain my masters in the Biological Sciences, which also was my undergraduate major. I then obtained a job at Ovid-Elsie Area Schools teaching only chemistry. As I continued through the program, I wanted to make the topic I choose for my Masters research apply to both Biology and Chemistry. This led to many ideas. I ultimately choose Food Chemistry as my focus because of its multidisciplinary nature.

As I designed the unit, it was my expectation that if I could engage students through hands-on applications as well as things that interested them, then the learning process would be enhanced. I designed a unit that included nine laboratory exercises that I expected would help accomplish this goal. Some of these labs were to establish what organic molecules are and the energy in food molecules. Others were to identify these molecules as students learned lab techniques. Many of the labs included notes and lecture to attempt to accommodate different learning styles. The unit focused around hydrocarbons, titrations to estimate ascorbic acid content, using indicators to identify food molecules, functions of enzymes, energy in foods, DNA extraction, products of biological processes, and chromatography of food dyes. My hypothesis was that by taking concepts that I had previously taught and adapting them to include food as a theme student achievement on the concepts of heat transfer, hydrocarbons, titrations, indicators, chromatography, enzymatic functions, and freezing point depression would dramatically increase.

THEORETICAL FRAMEWORK

Chemistry is the study of matter and the changes it undergoes. All too often when students begin my Introduction to Chemistry classes they have this idea that "I'll never need to know this stuff!" However, if presented properly they quickly see that many of the concepts are a part of so much of our everyday life. "The aim of science education is to help students develop an understanding of the natural world: what it contains, how it works, and how we can explain and predict its behaviour" (Psillos and Niedderer, 2002). Often times, due to time constraints in the classroom, we limit the hands on aspect of what we teach in order to "cover" material and not follow through on mastery of the concepts with all students. We acquire durable knowledge through the interaction of two factors (1) our ability to process and store information, and (2) the number and frequency of our academically oriented experiences (Marzano, 2003). However, "What seems to be critical is not sheer amount of experience but rather what one had been able to learn from and do with the experience" (Sternberg, 1985). Based on these ideas I felt that if I could find something that would interest students, such as the chemistry of food, the learning process of chemistry for the student would be facilitated. McManus, Dunn, and Denig (2003) found that biology students who learned using hands-on manipulative activities had higher science achievement and science attitude scores than students who learned using traditional lecture, reading, and discussion activities. This is certainly applicable to chemistry students. The also require topics that are linked to something from everyday life, and an increased number of experiences with the topic. Whenever a teacher decides to incorporate a large number of labs in a class, it is inevitable that results will vary wildly due to a variety of student errors such as poor procedures or accurate measurements. However, an interesting set of studies has shown that simply added student effort and interest will enhance achievement (Marzano, Pickering, and Pollock 2004).

Why food chemistry? Chemistry is the study of composition, structure, and properties of materials and the changes that they undergo. I chose to title this unit Food Chemistry to my students because "We also believe there is a link between the title and the expectation of the science experience to be fun for the participants" (Skluzacek 2010). According to Richard Owusu-Apenten (2005), by inserting the word "food" before "materials" leads to a reasonable definition for food chemistry.

Teachers are often confused about their role in instruction when students are engaged in hands-on-activity. Many teachers are concerned about an adjustment they may have to make in their teaching style to facilitate a hands-on program as well as how students will react to increased responsibility and freedom. An activity-oriented classroom, in which hands-on materials are made available to students, is often a very new experience for the teacher as well as for his students (Shymansky and Penick 1981). Before I did my research on this unit, I wanted to do a set of labs that caught the attention of students in my introductory level chemistry class. I tried to focus on four arguments related to labs and active learning as I completed this work (Bentley and Watts 1989). They are:

1. Passive learning is the staple diet for many learners in numerous classrooms.

2. Passive learning may suit some learners some of the time, but it is ineffective for many learners much of the time.

3. Active learning means involving learners fully in their own learning, moving some of the responsibility

for learning to the learner.

4. Encouraging active learning involves using different approaches to teaching.

Passive learning is characteristic of traditional lecture based teaching. This includes practice problems or book questions. Active learning sometimes called inquiry learning, engages the students and requires them to take part in the learning process through lab activities and student driven studies. In one of our units we were discussing freezing point depression, a concept in its simplest form is probably very easily grasped by many students through lecture. I wanted to involve active hands-on learning, so we set out to make homemade ice cream to demonstrate this concept. I had never had my students so interested in a topic and their test results showed a good grasp of the material. In my biology class I had the students set up and conduct their own experiment to demonstrate the importance of variables and controls involving vegetables in the greenhouse. Again, their interest and involvement was noticeably higher. This activity showed me the benefit of motivation and engagement through inquiry learning. As I did more research on this topic, I came across some literature involving food in the

classroom. Students certainly develop a more personal connection to chemistry. Taking familiar substances such as lasagna and discussing its chemical profile of fats, carbohydrates, and proteins and then tasting it enables the student to interact with
complex concepts and build their own concepts (Sterling and Davison, 1997).

Greater emphasis should be placed on learning the skills of investigation and inquiry in the study of science, with the laboratory and experimentation playing an important, but not exclusive, role (Fraser and Walberg 1995). While the food chemistry unit I set up may not be entirely student driven, I saw the motivation of food coupled with labs to involve active learning. This led me to increasingly try to incorporate the interests of my teenage students trying more hands-on activities as well as the incorporation of their interests. Through previous class work, I knew that when this thesis came about I had a good platform to use.

SCHOOL DEMOGRAPHICS

Ovid-Elsie Area Schools is a district that is about 25 miles northeast of Lansing, Michigan. It is about 10 miles east of St. Johns off US 127. It is an agriculturally based community that embodies the idea of hard work. The median income for a family is around $41,000 (IES 2010). 97% of the community has at least a high school diploma, however for many, this is their highest level of education, partly due to the high number of family farms in the area. Only about 10% of the population has a bachelors degree or higher. I did my study at the High School which houses about 600 students from grades 9-12. This number has been fairly consistent for many years. We are on a 3 by 5 trimester schedule. Students have 3 trimesters of 5 classes. Each class is 72 minutes in length with makes doing labs very convenient. It is a primarily Caucasian student population (95%).

I choose to target a group of upper level chemistry students for this study in a class called *Chemistry B*. This class is taught in one trimester. All students are required to take a trimester course called Introduction *to Chemistry* which is taught at the 10^{th} grade level with mostly concepts with little math and basic lab procedures.

Many of these students often go on to a trimester class called *Chemistry A* which covers some of the introductory concepts in more depth and higher rigor. About a third of the students from *Chemistry A* will go on to take *Chemistry B*. This course is an extension of *Chemistry A* continuing to cover mostly new topics and a few others with more depth and mathematical involvement. The majority of students taking this class are 11^{th} graders with a few upper level 10^{th} graders. Again, *Introduction to Chemistry* is a course in which material is first introduced without mathematical calculations, strictly concept driven. Chemistry A and B have a large amount of new material with some of the concepts of Introduction to Chemistry revisited involving more mathematical work.

FOOD CHEMISTRY SCIENTIFIC BACKGROUND

Students participating in this food chemistry unit were presented with lecture notes prior to doing the actual unit. After that, laboratory experiences were used to strengthen the different chemistry concepts they were learning about.

One concept commonly taught in high school chemistry is heat transfer. Heat transfer is the measure of heat passed from one substance to another since the conservation of energy law states that energy can not be lost. To teach these concepts students must understand the basic heat transfer equation.

$$Q = M * Cp * \Delta T$$

Where Q is representing heat lost or gained, M represents the mass of a substance, and ΔT represents the change in temperature. This leads to the Q = Q equation in which the heat from one substance is absorbed by another. A common way to show this principle is using what is called a bomb calorimeter. This is a device that will transfer the heat released by a substance to water. By measuring the change in Q of the water we will know the Q lost by the substance. In a high school setting often times we need to make a rough calorimeter to show this concept by placing a beaker or other container above the substance releasing the heat. By placing a known amount of water remembering that 1 ml = 1 gram and measuring the initial temperature and the final temperature after the reaction you can find the heat released. Some heat is lost to the surrounding air but it is still a very effective way to show the principle of heat transfer and provides good practice using the heat transfer equation and can compare relative heat/energy released.

Another concept discussed in my unit, as well as in most chemistry classes, is the basic structure of hydrocarbons. A hydrocarbon is a carbon compound, often in a chain, with bonded hydrogen atoms. As nomenclature is taught we often start with simple alkanes, alkenes, and alkynes. Functional groups are then introduced such as a hydroxyl group (-OH) replacing a hydrogen, ketones (=O) replacing hydrogens, and carboxylic acids (COOH). Other organic functional groups can be formed by combining different hydrocarbons. This then can lead to the formation of esters. Esters can be classified as aromatic hydrocarbons. They emit a strong odor, some pleasant others not. An ester is created by combining an alcohol with an organic acid. This process essentially links the alcohol to the organic acid via the oxygen in the alcohol.

This can be a very difficult concept for students to grasp and understand. Often times they can grasp the functional group involved but have trouble drawing its structure.

Titrations are another concept taught in most high school chemistry classes. It is often introduced when learning about acid-base chemistry. However, the use of titrations can be expanded to include food composition as well. Lugol's solution will turn purple/black when it reacts with starch. When Lugol's and ascorbic acid (vitamin C) are combined in solution, a chemical reaction takes place. In this chemical reaction, the ascorbic acid molecule loses electrons, which are transferred to the iodine (Lugol's) molecule. This type of reaction is known as an oxidation/reduction reaction. The ascorbic acid is oxidized to dehydroascorbic acid, and the iodine is reduced to iodide ions. By measuring the amount of iodine needed to a known amount of vitamin C we can see just how much iodine is needed to react with the vitamin C. We know when this amount is reached because the brown color of the iodine will not disappear due to reduction. We can then titrate our iodine with an unknown strength solution of vitamin C to determine its concentration by adding some starch to the vitamin C solution. The starch will cause the titration to turn black when the vitamin C has been completely oxidized.

An easy way to test for the presence of a particular substance is to use an indicator. The way these indicators show the presence of the substance can sometimes be very complex, especially for high school students. There is value, however, in knowing what they can be used to test. For example, Lugol's iodine will indicate the presence of starch by turning blackish purple. Benedict's solution will indicate the presence of simple sugars by turning reddish orange after heating. Bradford's solution can indicate the presence of proteins by changing from a reddish color to blue. Indophenol can indicate the presence of vitamin C (ascorbic acid) by changing from a blue to clear. Silver Nitrate is a good indicator for sodium chloride (table salt) by changing from a cloudy clear solution to milky white because of the replacement reaction producing an insoluble precipitate silver chloride. Sudan III is a red indicator that binds to lipids and fats. The color doesn't change but makes the lipids stand out.

Fermentation is a concept discussed in biology. It also has chemistry aspects as well. When yeast is added to sugar water in a closed container the yeast can metabolize the sugar producing carbon dioxide and alcohol.

$$C_6H_{12}O_6 \rightarrow CO_2 + C_2H_5OH$$

This is the basic principle behind the brewing of beer and how homemade soda such as root beer is produced by using the naturally produced CO_2 to carbonate the drink.

DNA is a component of all cells on earth that serves as an information molecule. You can break open the cells with detergent by destroying the fatty membranes that enclose them as well as the nuclear membrane within the cell. The DNA is then released into the solution, but is still soluble in water. Detergent and salt also strip away proteins that are associated with the DNA molecules. DNA is not soluble in alcohol, but much of the rest of the cellular molecules are. By adding cold alcohol, DNA precipitates out of the solution.

Another concept discussed in this unit is the function of enzymes, biological catalysts. They can have many different functions, one of which is the disassembly of proteins. Collagen or gelatin is a very easy protein to obtain via Jell-O. When it is dissolved in water it strings together like a matrix of spaghetti noodles to trap the water. Some enzymes can be isolated from fresh fruit, such as bromelain from fresh pineapple. To show how the enzymes break down the gelatin you can place fresh pineapple in gelatin and watch as the gelatin begins to liquefy. This can also be used to discuss the effects of pH and temperature on enzymes as canned pineapple will not affect the gelatin because the enzyme is inactivated.

Chromatography is a very simple lab procedure used in chemistry classes. There are many forms of chromatography but one of the simplest is chromatographic separation by particle size. This process works well with ink, as it contains many different dyes which can be separated using some filter paper and a salt water alcohol solution. This solution will travel up the filter paper and dissolve the ink causing it to travel as well. The process of chromatography can also be applied to different dyes in foods. Dissolved dyes from M & M can be applied to filter paper and chromatographed in the same way. Brown and green colors work the best for illustrating separation because they are made up of more than one dye. The result of this separation is a piece of filter paper containing blue, red, and yellow bands.

The making of ice cream is based on a common chemistry concept known as freezing point depression, a property of solutions that causes the normal freezing point to be lowered. By adding salt to ice you prevent the water molecules from crystallizing allowing the temperature to decrease significantly below its normal freezing point. This process can be illustrated by making homemade ice-cream.

IMPLEMENTATION OF THE UNIT

This food chemistry unit was implemented in two sections of my Chemistry B class in the 2009-2010 school year. It is a trimester course made up of 72 minutes per day for 12 weeks. I chose to teach this unit at the end of the trimester before final exams and after discussing many of these principles prior to teaching the unit. The intent of this unit was to provide the students with a hands-on learning experiences relating to the concepts of heat transfer, hydrocarbons and esters, use of indicators, enzyme function, anaerobic respiration, chromatography, and freezing point depression. A total of 32 students give consent and assent to the study.

This unit was previously taught without data collection in 2007-2008 and 2008-2009 for a variety of reasons. In the first year, 2008, I only had one Chemistry B class and of the 20 or so students only 10 gave consent for using their data. In the second year, 2009, I again only had one chemistry B class, and it was made up of largely sophomores and foreign exchange students. I chose not to include these students' data because of the atypical nature of this class. In this school year, 2010, I had two classes that participated, which were fairly typical.

This year's 2009-2010 unit was conducted during the spring trimester from late April to early May. This also presented some problems because of the large number of school-based activities requiring students to be out of school and missed labs. I have chosen to include all 32 students who provided assent and consent even if they missed a day or two. Many of the students missing class completed the material on their own time. If they were excessively missing they were excluded from the study.

Students took a pre and post-test (Appendix C), consisting of 14 open ended questions, so the student can write as much information as they can. Students also took a post unit survey (Appendix B) consisting of 15 questions ranking what they enjoy and don't enjoy about the laboratory setting. The sequence of events for this unit is summarized in Table I. The unit was designed to require about two weeks to complete all activities and was based primarily on concepts that had already been discussed. For many of the labs, students had participated in discussions before doing the lab as well as during lab activities, such as chromatography lab, when students were waiting for results. The notes and discussions were presented through PowerPoint® notes, as well as through the pre lab write-up given the day before the lab. The concepts of heat transfer, chromatography, hydrocarbons, and enzymes had already been taught to them in the Introduction to Chemistry and Chemistry A course.

Table 1: Overview of Unit and Activities (State Standards expanded in Appendix F)

Day	Topics and Lab Activities Covered	State Standards Covered
Day 1	Introduced Food Chemistry Unit, labs, and expectations	C1.1C
Day 2	Reviewed heat transfer and how to make calculations using $Q=M*Cp*\Delta T$	C3.1X
Day 3	* Nut Lab (Set up basic calorimeter and calculate calories in nuts and other foods)	C3.1C
Day 4	Refreshed knowledge on Hydrocarbons and functional Groups	C4.2E, C5.8A, C5.8B
Day 5	* Ester Lab	C5.8
Day 6	* Vitamin C Titration Lab	C5.7A
Day 7	* Use of Indicators McMush Lab	C5.8C
Day 8	* McMush Lab Continued	C5.8C
Day 9	* Homemade Soda Lab (anaerobic respiration)	C4.5A, C5.2A
Day 10	* Strawberry DNA Extraction	C5.8C
Day 11	* Jell-O Lab (enzyme function)	C5.8C
Day 12	* M & M chromatography lab	C1.1C
Day 13	* Ice Cream Lab (Freezing Pt Depression)	C4.7A

Activities with an * were developed for this unit.

Description of Activities

Nut Lab (Heat Transfer) Appendix DI: This activity took two days. Calorimeters were explained by using heat transfer equations and working through practice problems. Students had worked with examples of heat transfer equations before this Food Chemistry unit. A variety of different nuts were used to determine caloric content. Most nuts worked well because of the high amount of oils in them, allowing them to burn easily. Some of the best nuts were peanuts, cashews, walnuts, Brazilian nuts, and almonds. Once students have determined the initial water temperature, they set the nut on fire using a lighter. We talked about a slight error due to the lighter and that it can be offset due to the large amount of energy we are losing to the open air around it. The set up is a paper clip stuck into a Styrofoam cup with a nut balanced on it. Over the nut is a beaker of water with 100 ml in it. Students are often confused by the large calorie numbers obtained. They investigate why they are so large, helping to illustrate the difference between scientific calories and food calories (kilo calories). Students wrote a lab summary on this activity including purpose, hypothesis, materials and methods, data, and conclusion.

Ester Lab (Hydrocarbons) Appendix DII: This activity was undertaken after a refresher on hydrocarbons and functional groups. I used it to make the concept more interesting and hands-on. Students were asked to make and identify a variety of esters using organic acids and alcohols. This isn't really a food lab, but it produces odors of many foods familiar to students. Students were asked to explain the difference between the original alcohol and acid functional groups and how they change when the ester is formed. Drawing out and manipulating the new ester formation was very challenging for them.

Vitamin C Titration (Titrations) Appendix DIII: Students reviewed their knowledge of titrations from acid base chemistry and performed them using a variety of fruit juices. It was difficult to find juices with varying vitamin C contents due to the fact that many juices are fortified with ascorbic acid. It may be beneficial to make your own juices from fresh fruits to get realistic readings. The titration was done using Lugol's solution as a reagent and indicator. Students won't notice a color change with the excess starch added until the acid was converted to ascorbate.

McMush Lab (Indicators) Appendix DIV: This easily was the favorite lab of the students. McDonald's® happy meals were blended and tested for the presence of different food molecules such as proteins, fats, starch, sugar, vitamins, and minerals. These molecules were not discussed much prior to this lab. It was a difficult lab to see colorimetric results on some tests using the indicators because of the dark color of the mush, but it was possible. Students enjoyed it, however, because they liked the idea of blending McDonald's® foods together and determining just how much fats there was in it.

Homemade Soda (Anaerobic Respiration) Appendix DV: We discussed the yeast as a living creature that must metabolize sugar to survive, and in the process, give off carbon dioxide and alcohol. Students were presented with information about respiration and fermentation. Students in groups of 2 or 3 made different flavors of soda. They were surprised by the high amount of sugar needed and the yeasty taste of the product. The finished product must be left in the fridge for at least 2 weeks or the flavors are very strong and yeasty.

Strawberry DNA Extraction (Solubility) Appendix DVI: We discussed the lipid bilayer around a cell as well as how DNA is a hydrocarbon with nitrogen bases. We crushed the cell walls and used detergent to break the cell and nuclear membranes. Then we precipitated with alcohol to bring the DNA out of solution. It produced a jelly like string in the solution which was the DNA.

Jell-O Lab (Enzyme Function) Appendix DVII: Students learned about the basics of enzyme function and used this lab to visualize enzymatic breakdown. Jell-O is made up of collagen, a connective protein. I explained that collagen gets dissolved and traps the water molecules as it sets. We crushed up fresh pineapple to get the bromelain enzyme and added it to our Jell-O molds. Students found the molds without pineapple set up and those with don't. We discussed specificity of enzymes and other examples, such as amylase.

M&M Chromatography (Chromatography) Appendix DVIII: In this activity we used chromatography to separate substances dissolved in a solution by size. The primary function of this lab was to show the lab technique of chromatography using something other then ink pens that would interest them. The bands that were present after running the dyes on the filter paper were not easy to see. If you looked closely reds, blues and yellows were observed.

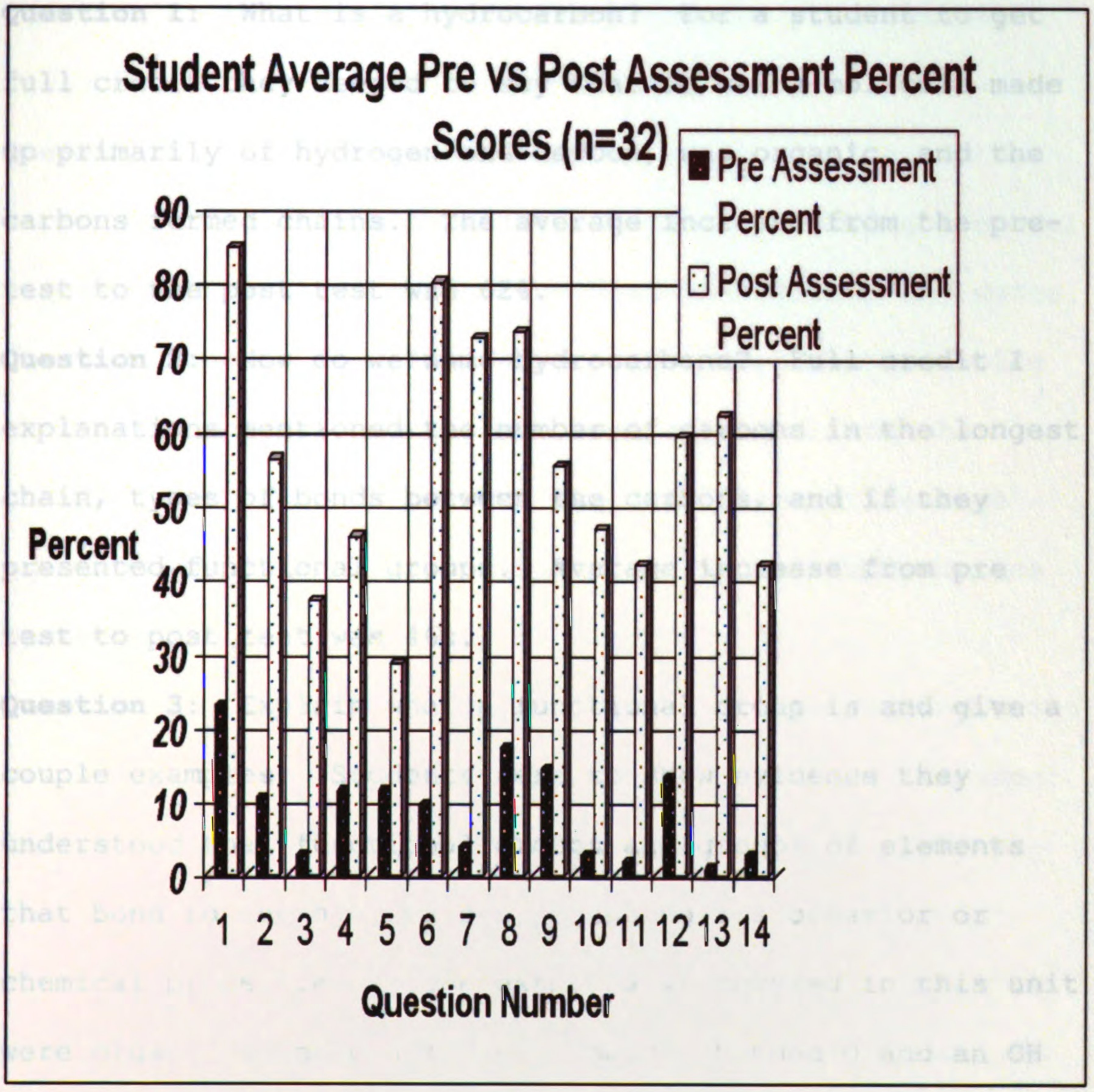
Ice Cream Lab (Freezing Point Depression) Appendix DIX:

This activity was used to teach freezing point depression. It was a good lab to end the food chemistry unit because it is not a difficult lab to set up and required the students to bring in a lot of their own materials. If timed correctly, students can make floats from their homemade pop and ice cream. Students made their own ice cream solution of sugar, milk and vanilla from the directions given to them. Students then took the temperature of just the ice before adding salt as well as after they noticed the ice cream solidifying. It can be a messy lab and could be altered into a whole class activity using an ice cream maker to limit the mess, but that would not be as much fun or hands-on.

DATA AND ANALYSIS

After reviewing assessments used for data collection in 32 consenting and assenting students, I graded their pre and post-tests (Appendix B) on a 3 point scale per question. If the student touched on an idea but didn't elaborate or explain, they receive a 1. If the student introduced an idea and had some explanation but could have given more information, they received a 2. If the student gave a complete answer with good explanations, they received a 3. The total number of possible points for the pre and post-test was 42. The results for each question are shown in Figure 1.

FIGURE 1: Pre and Post Assessment Question Comparison



Item Analysis

Question 1: What is a hydrocarbon? For a student to get full credit they needed to say that it was a molecule made up primarily of hydrogen and carbon, was organic, and the carbons formed chains. The average increase from the pre-test to the post test was 62%.

Question 2: How do we name hydrocarbons? Full credit I explanations mentioned the number of carbons in the longest chain, types of bonds between the carbons, and if they presented functional groups. Average increase from pre test to post test was 46%.

Question 3: Explain what a functional group is and give a couple examples. Students were to show evidence they understood that functional groups are groups of elements that bond to the hydrocarbon, changing its behavior or chemical properties. Some examples we covered in this unit were organic acids containing a double bonded O and an OH as well as alcohols containing an OH. Increase on this question from pre test to post test was 34%. It was low compared to other questions because students did not explain what they are and simply gave examples.

Question 4: What is a calorimeter? Students were to explain that it is a device used to measure heat released from a substance when that heat is transferred to water. Increase on this question from pre test to post test was 34%.

Question 5: How does a calorimeter work? Full credit explanations included that the substance producing the heat is below the water, and that as heat is released the water above it absorbs it. The temperature increases and using the heat transfer equation the heat released from the substance can be determined. Average increase for this question was only 17%. Generally, students' explanations lacked sufficient detail.

Question 6: Name the major molecules of food and the tests we can use to test for them. Complete responses included: carbohydrates (Iodine or Lugol's), sugar (Benedicts), proteins (Bradford's), vitamins and minerals (variable tests), and lipids (Sudan III). Increase from pre test to post test on this question was 70%. This is a large jump because it is a topic that they had never been introduced to prior to this food chemistry unit.

Question 7: What is an ester? Students were to explain that it is an aromatic hydrocarbon made from an organic acid and an alcohol. I originally expected them to know how to name them but it was too difficult for them to grasp for the time I had for instruction. Increase on this question was 69%.

Question 8: Do you think a McDonald's® meal is a balanced source of nutrients? This question was open to interpretation as long as they explained their reasoning using the science of food molecules. Most said "no" due to the high lipid and salt levels. Increase was 56% on this question.

Question 9: What is an enzyme? Students should know that it is a large protein molecule that acts as a biological catalyst. Improvement for this question was 41%. Many students didn't mention that enzymes are proteins.

Question 10: Describe how an enzyme works/functions and give and example. A full credit explanation included that enzymes are specific to certain substances and that they break substances down into smaller parts. The two examples we discussed in class and labs were amylase breaking down starches and bromelain in pineapple breaking down collagen. The increase on this question was 44%.

Question 11: When making homemade ice cream you add salt to ice. What conditions does this create and why? I wanted students to explain the process of freezing point depression. They needed to mention that it causes the temperature to go below zero because the salt interferes with the crystallization of the water. Increase was 40%.

Question 12: When we make homemade pop you need to add yeast to the mixture. What function does the yeast serve and why do we need to stop the reaction after only a few days? I wanted the students to understand that the yeast is a living creature, feeding on the sugar and producing carbon dioxide and if it's anaerobic, alcohol (Lee, 1983). That's why we need to stop it after a couple days. Increase on this question was 46%.

Question 13: Some drinks have more vitamin C than others. How could the amount of Vitamin C be determined in each drink? How much should we have each day? The students should explain the titration process using iodine and starch as titrant and indicator respectively. The ascorbic acid (vitamin C) will react with the iodine. Once the vitamin C is converted to ascorbate then the iodine will react with the starch showing a blue color. They should have indicated 60 mg per day as a vitamin C requirement as discussed within the lab. Increase was 61%.

Question 14: Define and explain the process of chromatography. The students should indicate that it was the separation of particles in solution by size (in this particular example). It could be a variety of other processes such as polarity, depending on what you are trying to separate. Many of the students didn't explain the process. Increase on this question was 39%. Overall the class average increased from a 3.7/42 average to a 23.8/42 average.

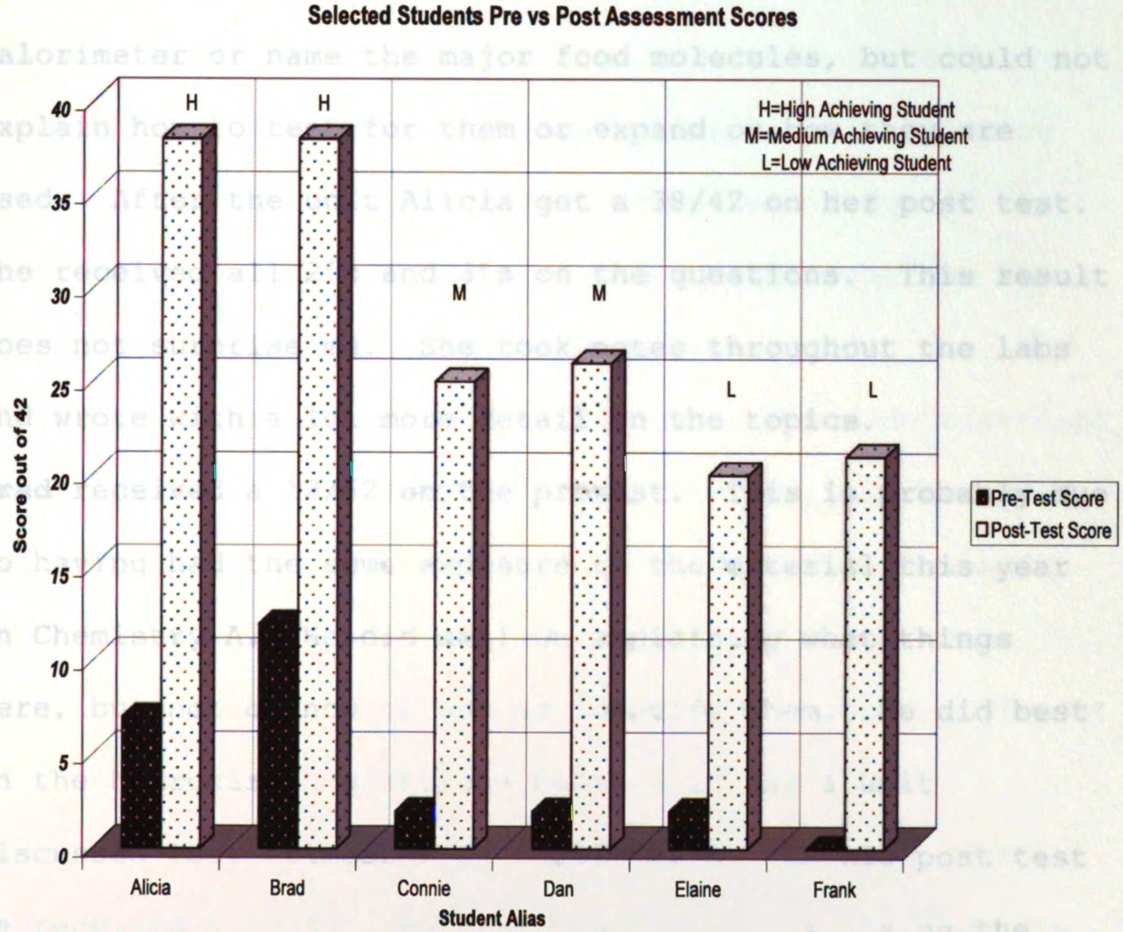
Analysis of Individual Students

I also choose to select six students, three male and three female, with varying skill sets to follow through this study. These are 2 each of high, middle, and low performing students based on previous performance on other class work in Chemistry B. I decided to do this because I felt that with these students the reader would get a good idea of how the whole class did regardless of typical achievement level. In Table 2 the students are listed with alias names to protect their identity. Figure 2 shows the pre and post test results for each student.

Table 2: Selected Student Profiles

Name (Grade)	Student Description (Strengths and Weaknesses)
Alicia (Junior)	This student is a high achiever. Very punctual and gets assignments done as soon as possible. Involved in many extracurricular activities but not sports.
Brad (Sophomore)	This student is much like Alicia.
Connie (Sophomore)	This student is a typical middle performing student. She is not afraid to ask for help. Involved in a lot of athletics. Sometimes gets off task due to socializing.
Dan(Sophomore)	This student is very involved in Future Farmers of America. Is quiet and on task and willing to ask for help but can struggle with tests.
Elaine (Sophomore)	This is a student that really has a difficult time focusing in class. Isn't involved in any extracurricular activities. Very shy and doesn't ask for help.
Frank (Junior)	This student enjoys hands on activities but really struggles with notes and written work. Not involved in many extracurricular activities.

FIGURE 2: Selected Students' Pre and Post-Assessment Scores



Alicia got a 7/42 on her pretest. She was able to get a few points on definition type questions, such as what is a calorimeter or name the major food molecules, but could not explain how to test for them or expand on how they are used. After the unit Alicia got a 38/42 on her post test. She received all 2's and 3's on the questions. This result does not surprise me. She took notes throughout the labs and wrote with a lot more detail on the topics.

Brad received a 12/42 on the pretest. This is probably due to having had the/some exposure to the material this year in Chemistry A. He did well on explaining what things were, but not on how to use or identify them. He did best on the hydrocarbon questions because it was a unit discussed last trimester in Chemistry A. On his post test he received a 38/42. He also didn't get any 1's on the post test and did a good job of elaborating on the chemical procedures we used for the unit.

Connie only received a 2/42 on the pretest. She knew that esters had odors and that McDonald's hamburgers were high in fats. She didn't elaborate on any concepts and didn't know any of the lab techniques, but she did attempt to answer every question. On her post test she received a 25/42. She was able to get at least 1 point on every question and did a good job on the questions that involved pre lab notes.

Dan also scored 2/42 points on the pre test. He did attempt to answer every question but was mostly guessing. On his post test he got a 26/42. He showed a lot of improvement on the questions regarding lab technique but could have explained the procedures better.

Elaine received a 2/42 on the pre test. She didn't attempt every question even though she was asked to. On her post test she got a 20/42. She attempted every question and missed receiving any points on only two of them. Her detail was lacking but she did mention some aspects of most of the concepts.

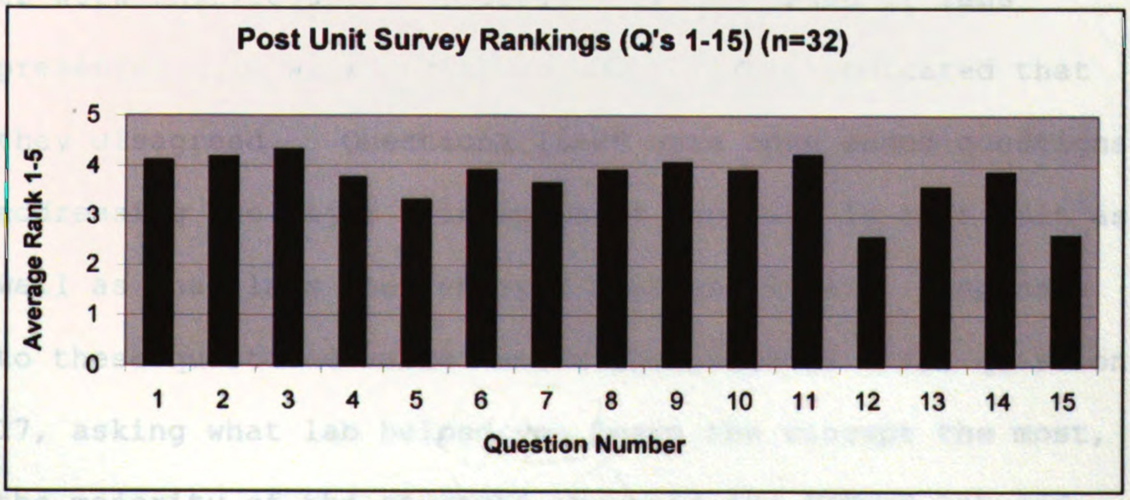
Frank did not get any points on the pre test. He didn't attempt many of the questions and was way off on those he did. This fits his typical learning on other concepts he has trouble grasping. He can quickly give up. On the post test, however, he scored a 21/42. He earned full credit on a few questions. For most questions he was able to recall the concept and give some explanation but lacked sufficient detail and accuracy for full credit.

Analysis of Post Unit Survey

At the conclusion of the unit the students took a 20 question survey (Appendix B) where they ranked the things that they enjoy and don't enjoy about a lab based unit. Fifteen of the questions were to be ranked from 1 to 5 with 5 representing that they strongly agree with the statement and 1 representing that they strongly disagree. Information from the survey will be used to help guide development of other lab based units. I also included each of the labs we did to determine if they remembered the basic principles addressed in each and if they liked a particular lab or not.

Figure 3 shows the results of the first 15 questions of the survey. Complete results are found in Appendix EII.

Figure 3 Post Unit Survey Results for Questions 1-15



The highlights of the survey results show that after this unit, students identify chemistry as an aspect of everyday life, and that chemistry labs are helpful in their learning. Students also indicated that they learned a lot of material through the lecture portion of the class and that the labs were a good reinforcement strategy. They also enjoyed the group learning aspect that labs present. Questions five, twelve, and fifteen had lower scores than the other questions. Question five asked if lectures and labs are connected. Student responses stated that they were neutral. This may have been because these labs were based on concepts from previous course work and there was a time gap from the lecture portion. Question twelve asked if they would prefer individual lab work. As discussed earlier they enjoyed the group work aspect and didn't want to work individually. Question fifteen asked if labs presented more work for the student. They indicated that they disagreed. Questions 16-20 were open ended questions addressing the major principles of each lab in this unit as well as what labs they enjoyed most and least. Responses to these questions varied among the students. For question 17, asking what lab helped you learn the concept the most, the majority of the students answered the *McMush* lab and the *Ice Cream* lab. Nearly all students said that these labs helped them learn a particular aspect of chemistry. Some students said that the least helpful lab was the strawberry lab, without explanation, but most didn't give any explanation.

CONCLUSION

My objective was to develop a unit revolving around food to improve student comprehension of different chemical concepts and laboratory techniques. Overall, this unit was successful in increasing student knowledge on topics that typically students in my class had struggled with. Those topics were heat transfer and caloric energy, enzyme function, hydrocarbons and functional groups, and freezing point depression. Evidence of this growth can be found by looking at student pre and post test results (Figure 1) which showed growth in knowledge of the different concepts addressed. Also, by looking at the post unit survey (Figure 3) students generally enjoyed the lab-based unit as well as the group work that it entailed, despite the fact that they said it created more work for them compared to a traditional lecture based unit. This unit provided a hands-on approach and interested them by making it meaningful through the food aspect. Growth in knowledge was dramatic and every student's scores went up, some less than I expected and others more.

Some of the literature I found when researching this unit said that increasing the frequency of academic experiences would show growth in student achievement. I attribute some of this growth and retention to this increased number of times the topic is covered. This unit also fostered other questions that interested the students regarding food. Questions such as what is the content of other vitamins and minerals in different foods that were not discussed. These questions provide teaching moments that are student driven and relate to inquiry teaching. One of which was students wanted to investigate other nutritional substances such as potassium in bananas. The four arguments I focused on by (Bentley and Watts 1989), for the development of this unit, I believe hold true. By undertaking this unit I had to change the way I taught these topics from previous years. It involved more active learning and students learned throughout the course of the unit.

In prior years of teaching, I noticed that students are more invested in the learning when it involves something of interest to them. The literature by (Sterling) regarding food use in chemistry was correct in this assumption based on observations of student interest through this unit. This unit was designed to encourage student learning by incorporating nine more food based labs that were developed for this research project.

The biggest challenge in implementing this unit was the time crunch that ensued by trying to get in nine labs Over a two week time period. This crunch was not only on material being covered but on the instructor, due to set up and break down of labs every day. Students were very excited to be engaged in lab activities at the start of the unit. As it progressed, some students began to feel overwhelmed by the large number of labs in such a short time frame. This was evident to me through observations of student behavior. By the end of the two weeks students were not as focused on accuracy and precision and more on simply finishing the lab.

If I were to engage in another formal study of this topic I might have explained each lab and notes before doing hands on work and then had them take the pre test. This would indicate how much the lecture portion affected scores and then they could have taken the post test after the labs to determine their increase in knowledge. That would have shown how large a role the labs really had or if they were just fun for them. As for changes in particular labs, I would probably remove the strawberry lab from future iterations of this unit. It is hard to explain the chemistry and biochemistry involved in this activity for such young students with limited interest. That is part of the reason that when developing this activity it was simplified a great deal. In the next teaching of this unit I will try different types of "happy meals" such as chicken nuggets in the McMush lab. The burger in the meal makes the blended mush very dark and difficult to get good colorimetric results with the indicators used. The Vitamin C lab functions well in its current form and is a good lab for practicing titrations. The Ice Cream Lab also met instructional goals and worked well. I might, however, move the soda lab ahead of other labs in the unit so that we could use the product with our ice cream. The M & M ® lab worked well, although students need to make sure they put a large concentrated dot on their sheet to get good results. Lastly, the Jell-O ® lab worked well. However I will have the students explore the effects of acidity and temperature on enzyme function when I use it again. This is an aspect that could be incorporated fairly easily through the use of buffers and water baths.

Based on the data presented in the pre and post test assessments and the post unit surveys, I believe that by implementing the food chemistry unit student comprehension of related concepts and ideas increased. This makes the development and implementation of this unit a worthwhile addition to Chemistry B. My objective for developing this unit as well as meeting the instructional goals was achieved.

APPENDIX A
CONSENT-ASSENT FORMS
Using Food to Engage Learning in Chemistry
Parent Consent and Student Assent Form

I am currently enrolled as a graduate student in Michigan State University's Department of Science and Mathematics Education (DSME). My thesis research is on the use of food to improve student understanding of a variety of chemistry concepts. Some components will involve looking at food as not only something to eat but the wide range of chemistry that is involved in its composition as well as the making of food to show various chemical reactions.

Data for the study will be collected from standard student work generated in the course of teaching this unit such as pre and post tests, lab activities, quizzes, and surveys. I am asking for your permission to include your child's data in my thesis. Your child's privacy is a foremost concern. During the study, I will collect and copy student work. These assignments will have the student's name removed prior to use in the study. All of the work being collected will be stored in a locked drawer until my thesis is finished and will be shredded at that time. In addition, your child's identity will not be attached to any data in my thesis paper of in any images used in the thesis presentation. Your child's privacy will be protected to the maximum extent allowable by law.

Participation in the study is completely voluntary. Students who do not participate in the study will not be penalized in any way. Students who do not participate in the study will still be expected to participate in class and complete all assignments. Students who do participate in the study will not be given extra work to complete. You may request that your child's information not be included in this study at any time and your request will be honored. There are no known risks associated with participating in this study. Participation in this study may contribute to determining if using food to teach chemistry will increase chemistry comprehension in high school students.

If you are willing to allow your child to participate in the study please complete the attached form and return it to me by April 1st 2010. Please seal it in the provided envelope with your child's name on the outside of the envelope. The envelopes will be stored in a locked drawer and opened after the unit is completed. Any work from a student who is not to be included in the study will be shredded.

If you have any questions about the study, please contact me by e-mail at briant@oe.edzone.net or by phone at (989) 834-2271. Questions about the study may also be directed to Dr. Merle Heidemann at the DSME by email at heidema2@msu.edu, by phone at (517) 432-2152, or by mail at 118 North Kedzie, East Lansing, Michigan 48824. If you have any questions or concerns regarding your rights as a study participant, or are dissatisfied at any time with any aspect of this study, you may contact - anonymously, if you wish - Peter Vasilenko, Ph.D., Director of the Human Subject Protection Programs at Michigan State University, by phone at (517) 355-2180, by email at irb@msu.edu, by fax at (517) 432-4503, or by mail at 202 Olds Hall, East Lansing, MI 48824.

Thank You,

Mr. Brian Topping
Chemistry Teacher
Ovid-Elsie High School

Parent Consent

I voluntarily agree to allow________________________ to participate in this study. (print student name)

Please check all that apply:

_______I give Mr. Topping permission to use data generated from my child's work in chemistry class to be used in the thesis project. All data from my child will remain confidential.

_______I do not wish to have my child's work used in this thesis project. I acknowledge that my child's work will be graded in the same manner regardless of participation in the study.

_______I give Mr. Topping permission to use pictures of my child during his work on this thesis project. My child will not be identified in these pictures.

_______I do not wish to have my child's picture used at any time during this thesis project.

__________________________________ ________________

(Parent/Guardian signature) (date)

Student Assent

Please check all that apply:

_______I give Mr. Topping permission to use data generated from my child's work in chemistry class to be used in the thesis project. All data from my child will remain confidential.

_______I do not wish to have my child's work used in this thesis project. I acknowledge that my child's work will be graded in the same manner regardless of participation in the study.

_______I give Mr. Topping permission to use pictures of my child during his work on this thesis project. My child will not be identified in these pictures.

_______I do not wish to have my child's picture used at any time during this thesis project.

I voluntarily agree to participate in this thesis project.

(Student signature) (date)

APPENDIX B

Assessment Questions

1. What is a hydrocarbon?

2. How do we name hydrocarbons?

3.Explain what a functional group is and give a couple of examples.

4. What is a calorimeter? If it helps you may draw a picture.

5. How does a calorimeter work?

1. Name the major molecules of food and the tests can we use to test for them.

7. What is an ester?

8. Do you think a McDonald's meal is a balanced source of nutrients? Explain (name molecules).

9. What is an enzyme?

10. Describe how an enzyme works/function and give an example.

11. When making homemade ice cream you add salt to ice. What conditions does this create and why?

12. When we make homemade pop you need to add yeast to the mixture. What function does the yeast serve and why do we need to stop the reaction after only a few days?

13. Some drinks have more vitamin C than others. How could the amount of vitamin C be determined in each drink? How much should we have in our diets/day?

14. Define and explain the process of chromatography?

APPENDIX C

Chemistry Survey

Rate the following questions on a scale from 1-5.

1 - Strongly Disagree
2 - Disagree
3 - Neutral/No opinion
4 - Agree
5 - Strongly Agree

1. Chemistry relates to everyday materials.
5 4 3 2 1

2. Chemistry can be better understood if it relates to everyday things.
5 4 3 2 1

3. Chemistry courses should offer lab activities that relate to everyday materials.
5 4 3 2 1

4. Chemistry courses should offer more lab activities overall.
5 4 3 2 1

5. Lectures and labs are connected.
5 4 3 2 1

6. Chemistry labs have increased my understanding of the content matter.
5 4 3 2 1

7. I learn more through lab than lecture.
5 4 3 2 1

8. Labs have increased my interest in science.
5 4 3 2 1

9. The best experiments are those that are very structured and already written out for me to follow.
5 4 3 2 1

10. I like labs that are open ended and allow me to test many things.
5 4 3 2 1

11. I prefer working in groups in the lab.
5 4 3 2 1

12. I prefer working individually in the lab.
5 4 3 2 1

13. I am more focused on lab work if I know I will be tested on it.
5 4 3 2 1

14. I am able to remember concepts when I have performed a related experiment.
5 4 3 2 1

15. Experiments are more work than they are worth.
5 4 3 2 1

16. Briefly explain the basic chemical principles each of the following labs:

Vitamin C lab:

Calories in Nuts:

McMush Lab:

Root beer lab:

Pineapple Jell-O Lab:

Strawberry DNA:

Ester Lab:

Ice Cream Lab:

Candy Chromatography:

17. Which lab helped you learn a particular concept the most and why?

18. Did the use of food help you in learning chemistry concepts? Explain.

19. What lab was not useful in helping you learn the concept and why?

20. Would you like to have learned about another aspect of food science that we did not cover? If yes what topic?

APPENDIX DI
Nut Lab

Objective
To determine the Calories in a variety of different nuts.

Introduction
When we eat food, our bodies convert the stored energy, known as **Calories,** to chemical energy, thereby allowing us to do work. A **calorie** is the amount of heat (energy) required to raise the temperature of 1 gram (g) of water 1 degree Celsius (°C). The density of water is 1 gram per milliliter (1g/ml) therefore 1 g of water is equal to 1 ml of water. When we talk about caloric values of food, we refer to them as Calories (notice the capital "C"), which are actually kilocalories. There are 1000 calories in a kilocalorie. So in reality, a food item that is listed as having 10 Calories has 10,000 calories. Calories are a way to measure the energy you get from the food you eat.
For this lab exercise, you will indirectly measure the amount of Calories in couple of food items using a homemade calorimeter. A **calorimeter** is a device that measures the heat generated by a chemical reaction, change of state, or formation of a solution. There are several types of calorimeters but the main emphasis of all calorimeters is to insulate the reaction to prevent heat loss. By measuring the change in temperature (ΔT) of a known volume of water, you will be able to calculate the amount of energy in the food tested because the heat gained by the water will equal the heat lost by the food item:

$$Q_{\text{lost by food}} = Q_{\text{gained by water}}$$

The energy gained by the water can be calculated as follows:

$$Q_{water} = (m)I(\Delta T)$$

where **Q** is the heat gained in calories (cal); **m** is the mass of water in grams (g); **c** is the specific heat capacity of water (1 calorie/g °C); and Δ**T** is the change in temperature in degrees Celsius (°C).

Materials:
Ring Stand
Clay Triangle
Graduated cylinder
Water bottle with distilled water
Coffee can or beaker
Cork or Styrofoam with wire attached
Thermometer (in °C)
Lighter
Safety glasses
Materials in lab:
Cashews
Peanuts
Almonds
Walnuts
Popcorn
Scale

CAUTION!!! Flames will be used and items may be hot!
All long hair must be tied back.

Procedure
1. Of the 5 types of nuts you will be testing, hypothesize which one will have more Calories (energy) per gram. Record your prediction.
2. Obtain a weigh boat and determine its weight. Record your data.
3. Obtain a sample of each nut and using the same weigh-boat, determine the weight of the each. Record your data.
4. Using the graduated cylinder, measure out 100 ml of distilled water from the water bottle and pour it into the small metal can or beaker.
5. Measure the initial temperature of the water (T_i). Record your data.

6. Gently wrap the wire attached to the cork or Styrofoam around the nut. It is better to have the nut at a slight angle. If it breaks, use another one; however, you will have to reweigh the new sample.
7. Place the cork with the nut on a nonflammable surface. Put on your safety glasses and light the nut. It may take a while for the nut to catch on fire.
8. Then carefully balance the small can or beaker with water on the ring stand.
9. Allow the nut to burn until it goes out. If possible try to keep an eye on it and if it goes out quickly (less than a minute), relight the nut.
10. Once the nut has finished burning, carefully remove the small can or beaker. Caution! The cans or beakers and water will be warm!
11. Using the thermometer, **carefully** stir the water and then measure the temperature again (T_f). You may have to leave the thermometer in the water for a while in order to get the highest reading. Record your data.
12. Calculate the change in energy of the water (Q). This is the same as the change in energy of the nut. Divide by the mass of the nut and you have the energy per gram.

Make a lab report with a data table and all calculations. Be sure to show all work. Also in your conclusion discuss the following questions:

1. Are your numbers reasonable? Why or why not. If they seem off what reasoning can you give as to why?
2. Possible errors made.
2. What is it in the nut that gives us the energy?

APPENDIX DII
Scratch 'n Sniff Ester
Lab Activity
Taken From: Source unknown

Materials

- 5 test tubes
- Stirring rod
- Hot plate (or ring stand, burner, and wire screen)
- Boiling stone (if available)
- 150 mL Beaker
- Eyedropper or pipette
- 10 mL graduated cylinder
- Evaporating dish
- 5 card pieces

Safety Guidelines:

1. Put on your safety goggles and wear them until everyone has finished the lab and the chemicals are put away.
2. Be extremely careful with the concentrated sulfuric acid. It can cause serious chemical burns.
3. Never smell the odors directly, use the wafting method demonstrated during the pre-lab.

Procedure:

1. Prepare the hot water bath as outlined below:
   α. Fill the 150 mL beaker with 75 mL of water and add the boiling stone.
   β. Set the beaker on the hot plate and bring the water to a gentle boil.
   χ. If you are using a ring stand place the wire mesh on the ring, then place the beaker on top. Light the burner, adjusting the flame to an appropriate height and temperature, and place underneath.
2. Label 5 test tubes A to E.
3. Have your partner stay by the water bath while you go to the chemical bench.

4. Using the appropriate eye droppers, add 10 drops of each alcohol to the test tubes as outlined in the observation data table. Waft the air towards you as demonstrated and record the odors.
5. You stay by the water bath and have your partner record the odors of the carboxylic acids before they add 5 drops of each acid to the appropriate test tube (refer to the observation data table).
6. Carefully mix the substances, rinsing the stirring rod between test tubes.
7. VERY CAREFULLY add 4 drops of concentrated sulfuric acid to test tubes B, C, D, and E. Do not add any to test tube A.
8. Carefully mix the substances, rinsing the stirring rod between test tubes.
9. Place the test tubes in the water bath for approximately 5 minutes.
10. Label 5 cards with the names and formulas of the resulting esters. Include their accompanying letter from the observation table.
11. Remove the test tubes from the hot water bath.
12. Add 10 mL of cold water to the evaporating dish and pour in the contents of one test tube, gently swirling to mix the solution. Waft the air towards you and record the odors.
13. Using the pipette place two drops on the appropriate card.
14. Rinse out the pipette and evaporating dish and repeat for each test tube.
15. Coat the smelly cards with gelatin and put in the fridge to set.
16. Once set, scratch the cards with something sharp to release the scent.

Observation Data Table:

Test Tube	Alcohol	Odor	Carboxylic Acid	Odor	Ester	Odor
A no sulfuric acid	Isopentyl Alcohol (3-methyl-1-butanol)		Acetic Acid (ethanoic acid)			
B	Isopentyl Alcohol (3-methyl-1-butanol)		Acetic Acid (ethanoic acid)			
C	Isobutyl alcohol (2-methyl-1-butanol)		Propanoic Acid			
D	Ethyl Alcohol (ethanol)		Butanoic Acid (Butyric Acid)			
E	Methyl Alcohol (methanol)		Salicylic Acid			

General Observations:

Scratch 'n Sniff Ester
Lab Write-Up

When you have completed the lab activity and have cleaned your workstation you may begin working on your lab write up. Only one write-up needs to be submitted per workgroup.

1. Title Page including:
   a. Lab name
   b. Partner's name(s)
   c. Date

2. Pre-lab worksheet individually completed by each workgroup member

3. Summary that includes a:

   a. Brief summary of Scratch 'n Sniff stickers.
   b. Comparison between Sticker A and the other stickers.
   c. Comparison of how well your stickers worked to how well you expected them to.
   d. Comparison between the odor of the products in the evaporating dish and as stickers.
   e. Comparison between the odor of the reactants and products.

4. Questions
   a. What is the purpose of Test Tube A? Is sulfuric acid (H_2SO_4) included in the products?
   b. Was there a reaction in test tube A? How do you know?
   c. Why did we put the test tubes in a hot water bath?
   d. If you were to redo the lab, what would you do differently?
   e. In some cases the odor of the synthesized ester does not exactly match the odor of the fragrance found in nature. What might be a possible explanation?

APPENDIX DIII

Measurement of Vitamin C in Fruit Juices

Adapted from Stephen Fuller

Introduction:

Vitamin C, also known as ascorbic acid is a necessity for the human body. In this lab you will use your knowledge of titrations to calculate the amount of vitamin C in a variety of different fruit juices. We will use iodine solution as our titration solution and starch as the end-point indicator. As the ascorbic acid reacts with the iodine it gets oxidized and the iodine is reduced. Reduced iodine can't react with starch. Thus the titration will not come to completion until the all the ascorbic acid has reacted and a purple color will appear.

Purpose:

To test the concentrations of vitamin C in a variety of different fruits or juices to see which variety has the greatest concentration of vitamin C.

Materials:

Fruit Juices (apple, orange, grape) from concentrate
Vitamin C standard solution (from Vit C tablet) (1mg/mL)
Starch solution (1%)
Iodine Solution
Hydrochloric acid 1M
Distilled water
50 mL burette
Ring stand and burette clamp
Graduated cylinders
Erlenmeyer flasks
Beakers

Preparing Solutions:

Vitamin C Standard:

Dissolve 1 vitamin C tablet into distilled water. 1mL of water for each mg of vitamin C present.

Starch Solution:

Mix ½ teaspoon of soluble starch (cornstarch or potato starch) with 100 mL of distilled water and heat until it dissolves. Be careful not to heat to a boil.

Iodine Mixture:

Dissolve 0.6g of potassium iodide (KI) in 500 mL of distilled water. Then dissolve 0.6g of iodine crystals (I_2) in 50 mL of ethanol. Mix the two solutions together and dilute until final volume is 1.0L.

Hydrochloric acid:

This solution will already be prepared for you due to the danger of concentrated acid!

Procedure:

1. Using a graduated cylinder obtain 10 mL of the vitamin C standard you prepared and place it in a 250 mL Erlenmeyer flask. Then add 20 mL of distilled water. This simply helps to see the reaction; water does not react in this experiment.

2. Add 2 drops of the 1M HCl and 15 drops of starch solution to the vitamin C standard.

3. Fill a 50 mL burette with iodine solution and record the initial volume on the burette.

4. Place the flask containing the standard sample under the burette and begin your titration. Be sure to use the techniques we used when doing titrations to ensure you don't add to much iodine. Once you have a slight purple color your titration is finished. Record the final volume.

5. Repeat 2 more times to get an average amount used.

6. Using a clean 10 mL graduated cylinder repeat the above procedure but instead of using 10 mL of the vitamin C standard use the fruit juice samples made according to the directions on the can. 3 trails for each type of fruit juice.

Data:

Include all data in your lab report. Show all calculations!!!

Calculations:

3. Calculate the volume of iodine solution used for each trial.

4. Find the average of each sample. (Add volumes from 3 trials and divide by 3)

5. Using proportions we can calculate the amount of Vitamin C in your fruit juices. To do this you can use the following formula:

$$\textbf{X mg} = \frac{\textbf{(average iodine used for fruit juice (mL)) (10 mg)}}{\textbf{Average iodine used for the standard solution (mL)}}$$

6. Based on your calculations which juice contained the most vitamin C?

7. The minimum daily requirements (US RDA) for vitamin C are 60 mg/day. How much of your juice would you need to drink to get your 60 mg/day?

APPENDIX DIV

McMush Lab

Adapted From: Various Sources

Overview

Everything you eat is composed of three major components: carbohydrates, proteins, and fats. The cells in all living things contain these macromolecules as well as nucleic acids and inorganic compounds such as vitamins and minerals.

In order to release energy from food, the body must be able to break the food into these basic compounds and then further reduce them to the molecular level. The body can absorb food only when it is at the molecular level.

Carbohydrates are a source of "quick" energy for the body. The building blocks of carbohydrates are simple sugars like glucose. Starches are carbohydrates known as polysaccharides. Polysaccharides or starches are stored by plants for an energy reserve and are formed when many single sugars are joined together. A single starch molecule consists of hundreds of glucose molecules.

The building blocks of **proteins** are amino acids. In order for your body to manufacture the specific proteins it needs, the protein eaten in the diet must be broken down into amino acids ready for reassembly into proteins.

Fats (lipids) are important to your body because they are used to make up part of the cell membrane. Ingested fats provide the raw materials for making our own fats and cholesterol. Cholesterol is essential for making the steroid hormones such as testosterone, estrogen, and progesterone.

In addition to the organic compounds, the human body needs **minerals** and **vitamins**. One mineral needed is sodium chloride or table salt. Sodium is the main component of the body's extra cellular fluids and it helps carry nutrients into the cells. Sodium also helps regulate other body functions, such as blood pressure and fluid volume. A vitamin needed in the human diet is Vitamin C. Vitamin C (Ascorbic acid) is a vitamin that functions in the synthesis of collagen (essential component of bones, skin, tendons, etc). It is found in citrus fruits. A deficiency of Vitamin C results in scurvy.

Materials

Per Group

- 8 test tubes
- McMush solution
- Tube Rack
- filter paper
- distilled water
- Cheese Cloth
- Paper towels
- beaker for distilled water
- 2 beakers for McMush solution
- test-tube clamp
- Pipets

Chemicals for Tests

- Sudan III Fat Stain
- Bradford's Solution
- Benedict's Solution
- Silver Nitrate Solution
- Lugol's Iodine (IKI)
- Indophenol Solution

Procedure

- Your instructor will perform several tests (controls) using various reagents. **Record** the results of these tests in Table 1.
- In Table 2, **predict** the results of each test that will be done. Use **+** for a positive result and **−** for a negative result. Record your test results.
- Your instructor will perform the control tests using water. Record these results in Table 2 after you make your predictions.

CAUTION: The reagents you will be using in the following procedures may be corrosive, poisonous, and/or irritants; they may damage clothing. Avoid skin and eye contact. If contact occurs, notify your instructor.

Preliminary Procedures

1. Label the micro centrifuge tubes as follows:

C = carbohydrate	G = glucose
P = protein	V = vitamin C
L = lipid	S = salt

2. Add 12 drops of the McMush solution to each tube.
3. Add the appropriate reagent to the micro centrifuge tube to test for each of the organic and inorganic compounds.

4. I will do the water tubes on Day 2.

BE VERY SURE THE LIDS OF THE TUBES ARE SNAPPED ON TIGHTLY PRIOR TO MIXING

- **CARBOHYDRATE:** Add 2-4 drops of **IKI** to tube C. The solution will turn from yellow-gold to blue-black if a carbohydrate (specifically starch) is present.

- **PROTEIN:** Add 10-15 drops of **Bradford's** solution to tube P. The solution will turn from red to purple if a protein is present.

- **LIPID:** Add 5 drops of **Sudan III** to tube L and mix vigorously. The solution will turn pale yellow if no lipids are present. It will make two layers if lipids are present. The top layer containing the lipid will be pale pink to orange. To quantify amount of lipids add 100 mL of McMush to a 500 mL beaker. Boil for 15 minutes, be sure it doesn't boil over. Then put into refridgerator overnight. The next day calculate the percent lipids by volume. The lipids will be found on the top layer.

- **GLUCOSE:** Add 12 drops of **Benedict's solution** to the G tube. Swirl to mix and place into hot water bath for 5 minutes or so. The blue solution will turn orange-yellow if glucose is present. ***BE VERY CAREFULL REMOVING THE TUBE FROM THE HOT WATER. USE PROPER SAFETY EQUIPMENT.***

- **VITAMIN C:** Add 1-2 drops of **indophenol solution** to tube V. The indophenol will turn colorless if vitamin C is present in the solution. Ignore the intermediate pink stage.

- **SODIUM CHLORIDE:** Add 6 drops of **Silver nitrate** to tube S. Silver nitrate forms a white precipitate when added to sodium chloride.

Part E: Clean-up

- Discard all used tubes and pipets in designated container. Place clean tubes in basket for next class.

- Put clean pipets in basket.

- Wash the beakers with soapy water, rinse and place in basket.

- Put the basket (clean and ready for next class) back on the prep table.

- Wash your table with a soapy cloth to remove any harmful chemicals.

- Complete the lab report and turn in as soon as you are finished.

McMush Laboratory Report

Data:

Table 1 - Reagent Tests of Known Organic Compounds

Organic Compound / **Food Tested**	**Reagent**	**Food Appearance before Testing**	**Reagent Appearance Before Testing**	**Positive Test Result Color**
Carbohydrate (Starch) / *Corn Starch Solution*	Lugol's Solution IKI			
Protein / *Gelatin*	Bradford Solution			
Lipid / *Mineral Oil*	Sudan III Solution			
Glucose / *Glucose Soln*	Benedict's Solution			
Vitamin C / *Citric Acid*	Indophenol			
Sodium Chloride / *Salt H_2O*	Silver Nitrate			

Table 2 - Analysis of Organic Compounds in McMush

Predict if McMush and water (control) will contain any of the compounds in the table. Use **+** for YES and **−** for NO. Test the McMush and use **+** for a positive result and **−** for a negative result.

	CARB		PROTEIN		LIPID		GLUCOSE		VITAMIN C		SODIUM CHLORIDE	
Tube	C	W	P	W	L	W	G	W	V	W	S	W
Prediction												
Results												

Analysis of Results:

1. Summarize how effectively you were able to predict the results of these tests.

2. Were you surprised by the results of any of your tests? Explain.

3. What was the control for your tests? Why did you use this control?

4. The instructor performed a series of tests at the beginning of class. Why?

5. What organic and inorganic components were present in the McMush solution?

6. Which parts of the Happy Meal probably contained these compounds?

7. What possible errors might have occurred in this lab and why? Be sure to talk about the analysis of fat/lipid content.

APPENDIX DV

HOMEMADE SODA LAB

Modified from: David B. Fankhauser

Introduction:

Fermentation has been used for thousands of years for raising bread, fermenting wine, and brewing beer. The products of the fermentation of sugar by baker's or brewing yeast *Saccharomyces cerevisiae* (a fungus) are ethyl alcohol and carbon dioxide. Carbon dioxide causes bread to rise and gives effervescent drinks their bubbles. This action of yeast on sugar is used to 'carbonate' beverages.

Materials:

* clean 2 liter plastic soft drink bottle with cap.
* funnel
* measuring cup
* 1/8 tsp measuring spoon
* 1 Tbl measuring spoon
* 1 cup table sugar
* Root beer extract or other soda flavoring (can be purchased at Michigan Brewing Co.)
* Brewing or Baking Yeast
* Water

Procedure:

1. Add 1 to 1.5 cups of sugar to your 2 liter bottle using your funnel.

2. Dissolve 1/8 of a tsp of yeast in some warm water in your measuring cup.

3. Add 1 tbl spoon of your root beer or soda flavoring to the 2 liter bottle and sugar.

4. Fill 2 liter bottle ¾ of the way up with water and shake to dissolve the sugar.

5. Add your yeast solution to the bottle and top off with water leaving only a small pocket of air (about .5 inches).

6. Place bottle in a box so that if it explodes the mess will be contained. Check daily to ensure the pressure isn't getting to great

8. Once bottle has reached a pressure that the bottle feels stiff place in the refrigerator for 2 weeks to slow/kill off the yeast. This will ensure a better flavor.

Data:

Write a lab report on this lab. Be sure to include the reaction occurring in the bottle as well as time required for each step.

APPENDIX DVI

DNA Extraction: Strawberry

Taken From: Science Behind Our Food

Background:

The long, thick fibers of DNA store the information for the functioning of the chemistry of life. DNA is present in every cell of plants and animals. The DNA found in strawberry cells can be extracted using common, everyday materials. We will use an extraction buffer containing salt, to break up protein chains that bind around the nucleic acids, and dish soap to dissolve the lipid (fat) part of the strawberry cell wall and nuclear membrane. This extraction buffer will help provide us access to the DNA inside the cells.

Pre-lab questions:

1. What do you think the DNA will look like?

2. Where is DNA found?

Materials:

heavy duty Ziploc bag
1 strawberry
10 mL DNA extraction buffer (1ml soap, 1ml salt, 8ml water)
cheesecloth
funnel for filtering
50mL vial / test tube
glass rod, inoculating loop, or popsicle stick
20 mL ethanol (cold)

Procedure:

1. Place one strawberry in a Ziploc bag.
2. Smash/grind up the strawberry using your fist and fingers for 2 minutes. *Careful not to break the bag!!*
3. Add the provided 10mL of extraction buffer (salt and soap solution) to the bag.
4. Kneed/mush the strawberry in the bag again for 1 minute.
5. Assemble your filtration apparatus with cheesecloth over the funnel.
6. Pour the strawberry slurry into the filtration apparatus and let it drip directly into your test tube.
7. Slowly pour cold ethanol into the tube. OBSERVE
8. Dip the loop or glass rod into the tube where the strawberry extract and ethanol layers come into contact with each other. OBSERVE

Conclusions and Analysis

9. It is important that you understand the steps in the extraction procedure and why each step was necessary. Each step in the procedure aided in isolating the DNA from other cellular materials.

Match the procedure with its function:

PROCEDURE	FUNCTION
A. Filter strawberry slurry through cheesecloth	___ To precipitate DNA from solution
B. Mush strawberry with salty/soapy solution	___ Separate components of the cell
C. Initial smashing and grinding of strawberry	___ Break open the cells
D. Addition of ethanol to filtered extract	___ Break up proteins and dissolve cell membranes

2. What did the DNA look like? Relate what you know about the chemical structure of DNA to what you observed today.

3. Explain what happened in the final step when you added ethanol to your strawberry extract. (*Hint*: *DNA is soluble in water, but not in ethanol*)

4. A person cannot see a single cotton thread 100 feet away, but if you wound thousands of threads together into a rope, it would be visible much further away. Is this statement analogous to our DNA extraction? Explain.

5. Why is it important for scientists to be able to remove DNA from an organism? List two reasons.

10. Is there DNA in your food? ________ How do you know?

APPENDIX DVII
Jell-O Lab

Jell-O consists of proteins called collagen. Collagen is a triple helix protein found in animals. Collagen's main function is a major component of connective tissue in the skin and provide a framework for various organs (holds them in place). When you make Jell-O you need to add hot water to dissolve the collagen protein molecules. Under heat the three stranded protein unwraps. As it cools, water is trapped between the strands forming a gel like substance. You can think of it like spaghetti noodles hardening up on a plate trapping molecules between them. We need many kinds of proteins to survive and each has a different function but for this lab we will only look at collagen.

Enzymes are often called biological catalysts. They help speed up bodily processes and remove or break down certain toxins such as alcohol as well as many other functions. Enzymes themselves are almost always proteins. For example when you chew your food your body makes an enzyme called amylase to assist in the break down of starches (complex sugars). It gives the body a head start to the digestion process. Plants also make enzymes. One that we will look at is Bromelain. This a protein made by many tropical fruits such as pineapple and kiwi. It is an enzyme that breaks down collagen. This makes pineapple a very good meat tenderizer.

Materials needed:
1 box of Jell-O or Gelatin
1 can of pineapple
1 fresh pineapple
2 bowls

Procedure:
Make your box of Jell-O or gelatin according to the directions on the box and then evenly split the amount of Jell-O into the two bowls.
To one of the bowls add the canned pineapple.
To the other add the fresh pineapple.
Store in the fridge over night for observation tomorrow.

You need to write summary of your results. Be sure to explain what happened in the two bowls. Include possible errors.

APPENDIX DVIII

Chromatography Candies with Compared to Reese's Pieces of M & M®

Adapted from: Various Sources

Introduction

Colors in candies are due to synthetic dyes that have been approved by the Food and Drug Administration (FDA). Sometimes the colors, such as greens and browns are mixtures of several dyes. In this laboratory we will separate the colors in M & M® candies and Reese's Pieces® by means of paper chromatography. Differences in the molecular size and solubility of the dyes will enable us to make the separation. The smaller, more soluble dyes, will travel up the paper faster than dyes that are less soluble and larger.

Purpose

To determine if the brown coloring matter in M & M® candies is the same as the brown coloring matter in Reese's Pieces®, at the same time, other candy colors will be chromatographed to determine their component colors.

Safety

1. Wear protective goggles throughout the laboratory activity.
2. Do not eat any of the candy used in the laboratory activity.

Procedure

1. Obtain 3-4 brown M & M® candies. Place them in a small evaporating dish and place a few drops of tap water on them. Stir around with a toothpick to extract the color. As soon as the colored layer is extracted, remove the pieces from the dish with forceps and discard them. Be careful not to extract the candy too much because you don't want any of the chocolate in the solution.

2. Repeat with some brown Reese's Pieces® in a second evaporating dish. Use clean toothpicks for each dish.

3. Obtain a piece of chromatography paper that will accommodate spots of both candy colors. Cut it into a 5″x5″ square if it is not already done for you. Draw a light **pencil** (DON'T USE PEN!!!) line about 3 cm from the bottom edge of the paper and initial the paper in one upper corner. Put pencil dots on the original pencil line, about 3 cm apart. Label each as M & M® and Reese's Pieces as well as the initial color of the dye.

4. Using small capillary tubes place spots of each color on the labeled dot. The spots should be about 1 cm in diameter, and must not overlap. Let dry and apply more sample, keeping the spots as small as possible. Repeat until you have placed about 5-6 spots on each dot to make a concentrated sample.

5. Obtain the proper container for the chromatography (beaker or jar) and pour in a 1M NaCl solution until it is about 1 cm deep. Fold the paper so it will stand up on it own in the beaker. Be sure that the lower end of the paper is just touching the solution, and that the solution does not reach the colored spots.

6. When the solution rises to within 3 cm of the top of the paper, remove the paper from the solution and allow it to dry. Mark the position of the solution on the paper with a light pencil line.

7. Compare the chromatograms for each dye to determine if the candies contain the same dyes.

8. Thoroughly wash your hands before leaving the laboratory.

Data Analysis and Concept Development

Notice the number and colors of the spots on the two chromatograms. Draw circles around the spots that are common to the two candies. The spots must be the same color and must have traveled the same distance up the paper.

1. Is a pure brown dye used to color the candies?
2. If you wished to produce a green dye, what colors would you use?
3. Suppose you were given an unmarked bag of one of these candies. How could you distinguish chemically whether the contents were M & M's® or Reese's Pieces®?

Implications and Applications

1. How could chromatography be used to distinguish some look-alike candies?
2. How could you tell which dyes were present in the candies?

APPENDIX DIX

Ice Cream Lab

Background

Colligative properties depend on the number of particles dissolved in a given mass of solvent. Three types of colligative properties are vapor-pressure lowering, boiling-point elevation, and freezing-point depression. This lab will focus on freezing-point depression. The freezing point is the temperature at which there is an equilibrium between the solid and liquid phases of a substance. The temperature when this occurs is specific for different substances. The freezing point depression is the difference in temperature between the freezing point of a solution and that of the pure solvent. The presence of a solute (salt) in water disrupts the formation of the solid ice crystals thus lowering the freezing point. You will use freezing-point depression to make ice cream.

Procedure

1. Each person will make a baggie (snack size, Ziploc brand) of ice cream; you will put 2 or 3 baggies in one big bag (gallon size freezer bags work best, any brand). I will have measured out a ½ cup milk, 1 tablespoon sugar, and ¼ teaspoon vanilla into a small bag and zip it (make sure it is sealed well).

2. Take the large bag and fill it with 2 or 3 scoops of ice cubes. Add 2 small scoops of rock salt.

3. Place the 2 or 3 small bags in the large bag; try to spread them out a bit. Seal the large bag. Make sure the small bags are still zipped; otherwise salt water will get mixed with your ice cream and that won't taste very good!

4. Shake gently for about 10-15 minutes or until the ice cream inside begins to harden. It could take longer than that however. Don't give up! Continue to keep the ice covering the small bag. IF YOUR SALT/WATER BAG BEGINS TO LEAK HOLD IT OVER THE SINK. IF YOUR SALT/WATER BAG LEAKS, THEN THROW IT AWAY AT THE END OF THE HOUR. **SAVE SALT/WATER BAGS THAT DO NOT LEAK!!**

5. Open the large bag when your ice cream has hardened. Take the temperature of the ice/salt solution. Record the temperature.

6. Remove the small bags and rinse them off. Enjoy your ice cream!!!!

7. Save the large bag and spoons. Throw away the small bag when finished and clean up all your messes such as spilled mild or dripped ice cream.

Pre-lab Questions

1. What is the purpose of this lab?

2. What is a colligative property (the definition)?

3. What are three important colligative properties (examples)?

4. What will happen if you do not seal the inner bag properly?

5. What will happen to the freezing point of water (ice) after you put salt with it?

Data Table

temperature of ice/salt mixture =

Data Analysis

1. At what temperature does water normally freeze?

2. What was the temperature of the ice salt mixture?

3. Read this carefully. How does the freezing temperature of water **compare** to the temperature of the ice/salt mixture? (show both temperatures and compare)

4. Explain what has happened in the bag. What does the sodium chloride do? (Do **NOT** tell me the freezing temperature went down, tell me **why**!

5. Provide another example of when people use freezing-point depression in real-life.

APPENDIX EI
STUDENT RESULTS PRE AND POST ASSESSMENT SCORES

Student	Pre-test Score	Post-test Score
1	4	21
2	1	24
3	7	38
4	12	38
5	12	37
6	7	33
7	5	28
8	3	29
9	3	25
10	2	20
11	5	22
12	1	16
13	1	22
14	6	30
15	0	21
16	7	24
17	0	20
18	0	6
19	2	25
20	4	26
21	1	16
22	4	22
23	3	24
24	1	9
25	0	16
26	1	18
27	12	39
28	3	18
29	1	20
30	2	26
31	1	23
32	6	13
33	4	22
34	2	30
35	9	25
Average Score	3.77	23.60

APPENDIX EII
POST UNIT SURVEY RESULTS

Student #	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	4	4	4	4	4	4	4	4	4	4	4	2	4	3	2
2	4	4	4	5	2	5	5	5	4	4	5	2	5	4	3
3	5	3	4	4	4	5	4	5	3	3	3	3	4	5	2
4	4	5	5	2	2	4	4	3	5	1	4	2	4	4	3
5	5	5	5	5	4	4	4	5	5	5	4	4	3	5	2
6	5	5	5	3	4	4	1	3	5	2	3	4	4	3	3
7	5	4	5	3	4	2	3	4	4	5	5	4	1	4	3
8	4	4	5	5	3	5	5	4	4	3	5	1	3	4	1
9	3	2	4	4	4	3	4	4	5	4	5	1	3	4	3
10	4	4	5	2	2	2	2	2	4	3	5	1	2	2	3
11	4	4	5	5	4	4	5	5	5	4	5	2	4	3	2
12	4	5	4	3	4	3	3	3	4	4	5	1	4	4	3
13	4	5	4	3	4	4	3	3	4	5	5	2	4	4	3
14	5	5	5	4	4	5	3	4	4	3	4	2	4	5	2
15	3	3	4	5	3	4	5	4	3	4	4	2	3	3	2
16	5	5	5	4	3	4	5	5	5	4	5	2	3	5	3
17	4	5	5	5	4	5	5	5	5	5	5	3	5	4	1
18	3	4	4	3	3	3	3	3	3	3	3	3	5	3	3
19	4	5	4	3	4	4	3	3	4	5	5	2	4	4	3
20	4	4	4	5	3	4	5	5	5	3	5	2	3	4	2
21	4	4	5	5	2	5	5	5	4	5	4	2	3	5	2
22	4	4	5	5	3	3	3	4	3	3	4	5	4	3	3
23	4	5	5	4	4	4	4	4	5	4	5	1	4	4	3
24	4	4	5	5	3	5	5	4	4	4	5	1	3	5	2
25	5	5	5	4	5	5	1	5	5	5	5	1	5	5	2
26	5	5	4	3	4	4	3	4	3	4	4	2	4	4	3
27	4	5	4	3	4	4	3	3	4	5	5	2	4	4	3
28	4	5	3	3	4	3	5	4	4	4	4	5	4	3	4
29	5	5	3	4	2	4	3	4	5	5	5	1	3	4	1
30		1	1	2	2	2	2	3	3	3	2	4	4	3	5
31	4	5	4	4	3	3	4	4	4	5	5	3	5	4	3
32	5	3	4	5	5	5	5	3	4	5	3	5	4	5	3
33	5	4	5	3	4	5	3	5	5	5	2	5	3	4	2
34	5	5	5	4		5	5	5	4	4	5	3	2	4	3
35	3	1	4	1	2	2	1	1	1	2	1	5	2	2	3
	4.11	4.17	4.34	3.77	3.31	3.91	3.66	3.91	4.09	3.91	4.23	2.57	3.6	3.89	2.6

APPENDIX EIII
STUDENT RESULTS FOR EACH QUESTION PRE TEST

Student	Pre 1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	0	1	0	1	1	0	0	1	0	0	0	0	0	0
2	0	0	0	0	0	1	0	0	0	0	0	0	0	0
3	2	0	0	1	1	1	1	1	0	0	0	0	0	0
4	2	2	2	1	2	1	1	1	0	0	0	0	0	0
5	2	2	0	1	2	1	0	1	1	1	0	1	0	0
6	1	0	0	0	0	0	1	1	1	0	0	2	1	0
7	0	0	0	1	1	0	0	1	1	0	0	1	0	0
8	2	0	0	0	0	0	0	1	0	0	0	0	0	0
9	0	0	0	0	0	1	0	0	1	1	0	0	0	0
10	0	0	0	0	0	0	0	1	1	0	0	0	0	0
11	0	0	0	1	1	0	0	1	0	0	0	1	0	1
12	0	0	0	0	0	0	0	0	1	0	0	0	0	0
13	0	0	0	0	0	0	0	0	0	0	0	1	0	0
14	2	0	0	0	1	0	0	0	2	0	1	0	0	0
15	0	0	0	0	0	0	0	0	0	0	0	0	0	0
16	2	0	0	1	0	0	0	0	0	0	1	2	0	1
17	0	0	0	0	0	0	0	0	0	0	0	0	0	0
18	0	0	0	0	0	0	0	0	0	0	0	0	0	0
19	0	0	0	0	0	0	1	1	0	0	0	0	0	0
20	2	0	0	0	0	0	0	1	1	0	0	0	0	0
21	0	0	0	0	0	1	0	0	0	0	0	0	0	0
22	0	0	0	1	0	1	0	1	0	0	0	1	0	0
23	1	0	0	0	0	0	0	1	1	0	0	0	0	0
24	0	0	0	0	0	0	0	0	0	1	0	0	0	0
25	0	0	0	0	0	0	0	0	0	0	0	0	0	0
26	0	0	0	0	0	0	0	1	0	0	0	0	0	0
27	2	2	1	1	2	1	0	1	1	0	0	1	0	0
28	2	0	0	0	0	0	0	1	0	0	0	0	0	0
29	0	0	0	0	0	0	0	1	0	0	0	0	0	0
30	0	0	0	1	0	0	0	0	0	0	0	1	0	0
31	0	0	0	0	0	0	0	0	0	0	0	1	0	0
32	2	2	0	1	0	1	0	0	0	0	0	0	0	0
33	0	0	0	0	0	0	0	1	2	0	0	1	0	0
34	0	0	0	0	0	0	0	0	1	0	0	1	0	0
35	2	2	0	1	1	1	0	0	1	0	0	0	0	1
	0.69	0.31	0.09	0.34	0.34	0.29	0.11	0.51	0.43	0.09	0.06	0.40	0.03	0.09

APPENDIX EIV
STUDENT POST TEST SCORES FOR EACH QUESTION

Student	Post 1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	3	0	1	1	1	2	2	3	0	0	2	3	2	1
2	3	2	0	1	3	0	2	3	2	2	1	1	3	1
3	3	3	2	3	3	3	3	3	2	3	2	3	3	2
4	3	3	2	2	3	3	3	3	2	2	3	3	3	3
5	3	2	3	2	2	3	3	3	3	2	2	3	3	3
6	3	0	3	2	2	3	2	3	2	2	2	3	3	3
7	3	2	2	1	0	3	3	3	1	3	2	1	2	2
8	2	2	2	1	2	3	2	3	2	3	2	2	2	1
9	2	2	1	2	1	2	2	3	2	3	0	2	2	1
10	3	1	1	1	1	2	2	2	2	1	0	0	3	1
11	2	2	1	1	0	3	2	2	2	0	1	3	2	1
12	3	2	0	1	0	2	2	1	2	0	1	0	1	1
13	3	2	0	1	0	3	3	3	3	0	1	1	1	1
14	3	2	2	1	1	3	3	3	1	2	2	3	2	2
15	3	3	0	1	0	2	2	2	2	2	0	2	1	1
16	2	0	1	1	2	3	2	1	2	2	2	3	2	1
17	3	2	1	1	1	1	3	1	2	0	1	0	3	1
18	1	0	1	0	0	0	0	0	2	0	1	1	0	0
19	3	2	1	2	1	3	3	2	1	1	1	2	2	1
20	3	3	0	2	0	2	2	3	0	1	2	3	3	2
21	2	1	0	2	2	1	2	0	1	1	1	2	0	1
22	1	1	1	1	2	3	2	3	1	2	1	1	2	1
23	3	2	0	2	0	3	2	3	3	0	1	1	3	1
24	2	0	0	1	0	3	0	1	0	0	1	1	0	0
25	2	1	0	1	0	3	1	3	1	0	1	1	1	1
26	2	2	1	1	0	3	3	3	2	0	0	0	0	1
27	3	3	2	3	2	3	3	3	3	3	2	3	3	3
28	3	2	1	1	0	3	1	1	1	1	1	1	1	1
29	2	0	1	1	0	1	3	3	2	2	2	2	1	0
30	2	1	2	2	0	3	2	2	2	2	2	2	3	1
31	3	2	1	1	0	3	2	2	1	2	1	1	2	2
32	2	3	0	1	0	1	2	0	1	1	1	1	0	0
33	2	2	1	1	0	2	2	3	2	2	0	3	1	1
34	3	2	2	2	1	3	2	2	2	3	1	2	2	1
35	3	2	3	1	0	3	3	1	1	1	1	2	3	1
	2.54	1.69	1.11	1.37	0.86	2.40	2.17	2.20	1.66	1.40	1.26	1.77	1.86	1.26

Appendix F - State Standards Covered (MDE)

C1.1C Conduct scientific investigations using appropriate tools and techniques (e.g., selecting an instrument that measures the desired quantity—length, volume, weight, time interval, temperature—with the appropriate level of precision).

C3.1C Calculate the ΔH for a chemical reaction using simple coffee cup calorimetry.

C3.1X Hess's Law

C4.2E Given the formula for a simple hydrocarbon, draw and name the isomers.

C4.5A Provide macroscopic examples, atomic and molecular explanations, and mathematical representations (graphs and equations) for the pressure-volume relationship in gases.

C4.7A Investigate the difference in the boiling point or freezing point of pure water and a salt solution.

C5.2A Balance simple chemical equations applying the conservation of matter.

C5.7A Recognize formulas for common inorganic acids, carboxylic acids, and bases formed from families I and II.

C5.8A Draw structural formulas for up to ten carbon chains of simple hydrocarbons.

C5.8C Recognize that proteins, starches, and other large biological molecules are polymers.

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