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# Which Sweetener Is Best for Yeast? An Inquiry-Based Learning For Conceptual Change

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**Abstract**

One way to help students understand the scientific inquiry process, and how it applies in investigative research, is to involve them in scientific investigation. An example of this would be letting them come to their own understanding of how different variables (e.g., starting products) can affect outcomes (e.g., variable quality end products) (e.g., Cherif, Gialams & Siuda, 1998; Puche & Holt, 2012; Hazzard, 2012). In this inquiry based learning activity, students work logically and systematically to design a scientific study geared to investigate the question of sweetener preference for yeast. In doing this, they learn to use skills associated with inquiry such as problem solving and communication–--including the scientific practices of hypothesizing, investigating, observing, explaining, and evaluating (e.g., Cherif, 1988; NRC, 2011; Robinson, Nieh, & Goodale, 2012). They enforce their understanding of learned concepts and skills by communicating what they have learned through the process of writing a scientific paper aimed at publication in a peer reviewed scientific journal. In doing so, they learn how scientists practice science, learn cross-disciplinary science concepts and core ideas, and discover implications and applications for the results and findings of the investigative inquiry. In this paper, we also provide the necessary background and information teachers and student-teachers need to help them to feel confident and competent in carrying out the learning activities with their students and be able to answer unanticipated questions.

**Keywords:** Inquiry-based learning, student success, sweeteners, yeast, fermentation, scientific method

## 1.0. Introduction and Background

### 1.1. Yeast and Sugar

All living organisms use energy to grow, develop, and maintain themselves. They also use genetic material to control their biological activities and reproduce as part of an ever-evolving population. Yeast is no exception from this energy-based means of existence, despite its minute size. Yeast is composed of unicellular eukaryotic living forms that can break down carbohydrates to produce carbon dioxide and ethanol. Yeast belongs to the phylum Ascomycota in the kingdom of Fungi. Like all fungi, yeasts are saprotrophs. They obtain their nutrients from their environment by external enzyme secretion. Their cells vary in size from 3 to 5 µm in diameter. Even though it constitutes only a small portion of the fungal species, yeast is both an economically and ecologically important living organism. Yeast cells act as decomposers recycling the nutrients in the ecosystem. They are widely used in bread making, and in alcoholic beverages production. Yeast reproduces asexually and forms masses of tiny round or oval cells through a method called budding. The yeast cells are common in environments with high sugar concentrations, which they ferment anaerobically into carbon dioxide and alcohol. Thus, when placed in a sugar solution and an oxygen-free environment, these cells multiply and convert the sugar into alcohol and carbon dioxide through metabolic pathways in a process called fermentation. Long ago, humans discovered yeast as an essential fermentation agent and learned how to harness the process in producing baked goods and cheeses, and in the fermentation of plant juices that yield beer, wine, and spirits. Yeast is also mixed with some types of food for cattle in some parts of the world because it is a good source of vitamin $B_{12}$ and other B vitamins. Finally, yeast is also important in molecular biology research, medicine, and related fields because of traits that include the ability to live in a small space and to reproduce quickly. Indeed, the domestication of the yeast species ***Saccharomyces cerevisiae*** used by bakers and brewers has had a greater impact upon human culture and society than that of any disease or epidemic (Legras, J. et. al, 2007; Armstrong, 2012). Today, no one can even imagine human society living without yeast.

### 1.2. Sugar and Sweeteners

Carbohydrates are organic macromolecules consisting of atoms of carbon, hydrogen, and oxygen, with the hydrogen and oxygen most often being in the proportion of 2:1 respectively. In general, carbohydrates occur mainly as sugars, or as non-crystalline compounds such as starches and cellulose.

Carbohydrates can be classified according to the number of their building structural units. The simplest form of carbohydrates is the monosaccharides, or simple carbohydrates. These are made by plants and are formed from units that can exist in either a straight chain or a ring form. The backbone of the sugar molecule varies in lengths, containing as few as three carbons (a triose sugar), but more commonly, five carbons (a pentose) and six carbons (a hexose sugar) in length. Examples of monosaccharides are ribose, deoxyribose, glucose, galactose and fructose. When two monosacchrides are linked together they form the disaccharides. Examples of disaccharides are sucrose (glucose + fructose), maltose (glucose + glucose), and lactose (glucose + galactose).

Both mono- and disaccharides are sweet sugars, and are soluble in water. Many monosaccharides link together to form polysaccharides. Starch and glycogen are polysaccharides of α-glucose, and are the storage carbohydrates in plants and animals, respectively. Cellulose is another polysaccharide, a polymer of β-glucose, and is the main constituent of plant cell walls.

The common table sugar, or sucrose, is the most common disaccharide, and is present in many green plants. Sucrose is a non-reducing disaccharide that can be hydrolyzed by the enzymes, invertase or sucrase, or by diluted acids into its two components, glucose and fructose. Sucrose is commonly extracted commercially from sugar cane and sugar beets and appears as table sugar in almost every household or restaurant and in factories making cookies, candies, and related goods (Hobhouse, 1986; Rudin, 1997; Cohen, 2013).

Sucrose is a non-reducing sugar, simply because the linkage of glucose and fructose disguises the possible aldehyde group of glucose and the potential ketone group of fructose, so that no reduction occurs with oxidizing agents such as in Fehling's and Benedict's reagents (Hale and Margham, 1991). However, this is not the case in several other disaccharides such as maltose and lactose, which are called reducing sugars. This is because both the aldose and ketose sugars can be oxidized; as a result, they can reduce the alkaline copper solution in the Fehling's test and the Benedict's test.

Rapadura, or unrefined, evaporated cane juice, contains 90% sucrose. On the other hand, white sugar is highly refined by chemical process and contains 99% sucrose. It has been used widely as a sweetener, but has also served as a preservative in some foods. It is even seen as a part of the manufacturing industry for many plastics. It has also been suggested as a treatment for speeding up the healing process of a cut or wound; by simply mixing a cube of table sugar with canola or olive oil, and first-aid antibiotic ointment, and applying the mixture to cuts, scrapes, and burns healing time is shortened. Others have even suggested mixing sugar with iodine solution and applying the mixture to cuts or wounds to achieve the same outcomes. It is believed that the mixture prevents bacteria from getting the nutrients needed to grow and multiply (Editors of *Prevention*, 2009). (However, teachers and students need to be aware that raw iodine will burn the skin and tissue, and thus must not try this at home).
Today the average American downs 22.7 teaspoons of sugar (95.3g) a day. A major part of this intake comes from soft drinks; for example, one 12-ounce can of soda contains about 10 teaspoons (50.2g) of sugar.

**1.3. Sweeteners (Sugar Substitutes):**
Since the discovery and commercialization of normal sugar, with its inherent nutritional and health benefits, humans have started a continuous journey to search for sugar substitutes for various reasons, including health, commercial, finances, and production. The goal was, and still is, to duplicate these benefits in alternative forms, never losing the crucial taste component of ordinary sugar. Advances in organic and synthetic chemistry, which made it possible for natural products to be chemically synthesized, made the goal even more achievable. So far they have succeeded with a number of alternatives to the widely known common table sugar, to provide sweetness akin to human needs. The success has been accelerated by advances in organic chemistry, and the discovery that natural products can be chemically synthesized.

There are two types of sweeteners--- those which are natural, and those which are chemically synthesized; both are meant to provide a sense of sweetness, as detected on the taste buds of the tongue and the assimilation by the brain. Those that are not natural are, in general, called artificial sweeteners. While the majority of sugar substitutes have been approved for food use, some artificially-synthesized compounds are not yet approved for use (Wikipedia, 2012, ¶. 5).

Sweeteners can also be classified as high-intensity sweeteners and low-intensity sweeteners; this amounts to looking at their degree of effect on the taste buds of the tongue. For example, according to U.S. Food and Drug Administration, sugar substitutes that are known as high-intensity sweeteners are made from compounds with many times the sweetness of sucrose; this leads to a lesser amount being needed to provide the same intensity of taste. Examples of high sweeteners are: Saccharin©, Aspartame, Acesulfame Potassium (Ace-K)©, Sucralose©, Neotame©, Advantame©, Steviol©, and Luo Han Guo fruit extracts (that is also used as medicinal herb).
However, caloric offerings of these sweeteners vary, and thus need to be noted:

> *The sweeteners found in grains, dairy, meat, legumes, and some vegetables like squash, carrot, and yam strengthens the spleen-pancreas and helps build energy. These foods satisfy the sweet tooth. 'Empty sweets', to use a Chinese medical term, are those primarily composed of simple sugars (i.e., e.g., sweet fruits, juice, honey, sugar, and other sweeteners). These foods give a short term energy boost by increasing the amount of sugar in the blood. When concentrated or used in excess, sweets damage the spleen/ pancreas. Excessive use leads to chronic fatigue, bodily weakness, edema, and various digestive problems.* (Wood, 1999, p. 331)

This is in contrast to "sweeteners' composed of maltose, a disaccharide, which is relatively healthier. Barley malt and rice syrup, for example, take longer to assimilate than the more simple sugar molecules do" (Wood, 1999, p. 331). On the other hand, sweeteners that contain glucose, fructose, and sucrose are more problematic from a nutritional perspective simply because:

> *They are quickly absorbed into the bloodstream, stress the whole metabolism, and suppress the immune system. Such sweeteners cause the pancreas to secrete more insulin to monitor the amount of sugar going into the blood, and extra adrenaline from the adrenal glands is also mobilized to monitor the blood sugar level. Simple sugars provide a few hours of increased energy, which are followed by energy depletion and an emotional low apathy known as the "sugar blues." Thus sweeteners that contain sucrose are best used occasionally and with discretion. These include carob, date sugar, honey, maple syrup, rapadura, and sorghum molasses. (Wood, 1999, p. 331)*

Commercially speaking however, manufacturing companies use chemicals and mechanical processes to refine sugar. But unrefined sweeteners are less treated by chemicals, and thus are believed to have better health benefits, such as reducing pitta and vata (Wood, 1999). Furthermore, and chemically speaking, sucrose ($C_{12}H_{22}O_{11}$) or common table sugar, is a disaccharide, non-reducing, water soluble white crystal sugar used in sweetening. It is obtained from the juice of sugar cane or sugar beets and is formed by a condensation reaction between fructose and glucose. It is easily decomposed at $160^0$- $180^0$C. Sucrase, or invertase, is the enzyme that catalyzes the hydrolysis of sucrose into glucose and fructose. In summary:

> *Sugars are often said to be unhealthy, but there is no firm evidence that sugars are less appropriate than starches as a source of dietary carbohydrate for healthy people. However, there is some concern that the sugars that are added to foods during processing result in overeating and contribute to obesity.*

> *Highly sweetened foods such as candies and soft drinks also tend to be low in nutrients such as protein and vitamins, so people who eat large amounts of sugary foods are at risk for dietary deficiencies of these nutrients. (Armstrong, 2012, p.616)*

Even though, as Hobhouse (1986) argues, "long before sugar cane was distilled and crystallized, honey was the great sweetener – because the bee is a very efficient sugar concentrator" (p. 44), sugar is a product which is wholly superfluous in the diet, a luxury when expensive and a menace when cheap (p. xiv), was the first food (or drug), dependence upon which led Europeans to establish tropical monoculture to satisfy their own addiction" (p. 74), and the rest of the world followed. For example, and again noted here, the average American consumes about 22.7 teaspoons of sugar a day and a typical 12-ounce soda contains around ten teaspoons of sugar (Cohen 2013, p. 81). Since a teaspoon is equal to 4.2g, this is a lot of amount of sugar to be consumed daily.

## 2.0. Scientific Inquiry

In his book, *The Teaching of Science: 21st Century Perspective*, renowned educator Rodger Bybee (2010) has argued that to sustain the U.S. position as a global competitor, the needed workforce skills require that our nation focus on teaching science in an inquiry-based manner to our students. His reasoning is:

> *Inquiry shifts the focus of education to cognitive abilities such as reasoning with data, constructing an argument, and making a logically coherent explanation. On the most basic level, inquiry refers to the process of doing science. Inquiry-based learning engages students in the investigative nature of science. Using inquiry to teach science helps students put materials into context, fosters critical thinking, engages students more fully, resulting in positive attitudes toward science ... and improves communication skills ... (Bybee, 2010, p. 131)*

In performing the inquiry process students analyze data to answer a research questions and support their results with reliable evidence. They incorporate the scientific practices of hypothesizing, investigating, observing, explaining and evaluating as well as communicating findings (NRC, 2011). Furthermore, and because of the nature of scientific inquiry, while working to confirm their formulated hypotheses, students discover that the direction of the inquiry lesson is rarely predictable, and this unpredictability of science is part of its attraction and motivation for doing science (Cherif 1988; Cherif and Somervill, 1995; Cherif et al., 2010; Meyers et al., 2012; Maryellen, 2012).

To ensure student's success however, in inquiry based learning, teachers should keep in mind students' varied experiences and comfort levels with the inquiry process, and what educational goals they have in mind. Teachers should also consider how much information they should provide, and how much work students should initiate and do on their own. This helps achieve a meaningful student's engagement, as well as a higher rate of student success and desirable learning objectives and outcomes.

### 2.1. Student Level of Cognitive Involvement and Level of Independence In an Inquiry-Based Learning Process:

There is a positive correlation between student levels of cognitive involvement and the level of independence in an Inquiry Based Learning process. For each inquiry-based investigation there is a research question to be investigated, materials to be used, procedures and methods to be designed and applied, and results and outcomes to be achieved, inference and evidence-based conclusion to be generated, and implication, and application to be identified and communicated (table 1). To make this approach more productive, teachers need to give students more autonomy to decide on their own what questions to ask, what materials to use, what procedures to follow, and what types of results to aim for in planning and completing their investigation.

Table 1
Student Level of Independence in the Inquiry-Based Learning Process
(Modified from Cherif, 1988; Cherif & Somervill, 1995; Wheeler & Bell, 2012)

| Level of Inquiry | | What Students Were Provided To Start the Inquiry Activity | | | | |
|---|---|---|---|---|---|---|
| | | *Research Question* | *Needed Materials* | *Method, Procedures* | *Predicted Outcome* | *Lab Report, Paper, or Presentation Format* |
| *I* | **Practice:** *All Activities Specified* | Given | Given | Given | Given | Given |
| *II* | **Confirmation:** *All Activities Specified Except Lab Report Format* | Given | Given | Given | Given | |
| *III* | **Structured:** *Research Question*, Methods, *and Materials Specified* | Given | Given | Given | | |
| *IV* | **Guided:** *Research Question and Materials Specified* | Given | Given | | | |
| *V* | **Discovery:** *Only Research Question Provided* | Given | | | | |
| *VI* | **Open-Ended:** *No Specifications Given* | | | | | |

At the first "Student Level of Cognitive Involvement" in the "Investigative Inquiry Teaching Model" (as shown in Table 1) students carry-out pre-assigned activities. They are guided through a script to reach for or confirm pre-identified results and outcomes. However, at level six, which is the highest cognitive level of involvement, students select the problem they want to investigate, generate question they want to empirically answer, design the experiment they want to conduct, select the materials they want to use, and construct the procedures they want to follow. Then they conduct the experiment, gather the data and results to produce an evidence-based conclusion, and communicate their findings through presentations and publications (Cherif, 1988; Cherif and Roze, 2013).

Thus it depends on which of these six categories are used by students before engaging in an investigative inquiry. There are 4 to 6 levels of inquiry (dependent upon your source), but all involve students in analyzing data to answer a research question, supporting their results with reliable evidence, formulate the best explanation of what's going on, and coming up with evidence-based conclusions to achieve a higher rate of desirable outcomes and learning objectives (Cherif, 1988; Cherif & Somervill, 1995; Wheeler & Bell, 2012). Wheeler and Bell (2012), and Bell, Smetana, and Binns (2005) identified and named the following four levels of inquiry: confirmation, structured, guided, and open. Based on the type of students and their level of academic abilities, instructors can choose to use inquiry investigations at any of these four levels: *confirmatory, structured*, *guided*, and *open* (Table 2).

### 2.2. Pedagogical Approach for Investigating Which Sweet Is Good for Yeast

The activity can be conducted successfully in various formats based on the number of students in a given class and the resources that are available for students (including time, space, and potential lab materials and equipment). We will describe two approaches and talk in detail concerning one of them.

#### 2.2.1. First Pedagogical Approach:

In the first approach, the class is divided into groups of six students working together to test each of the sweeteners as well as the control group (yeast + water). The students in each group have the choice of investigating all the tested sweeteners in one experiment or dividing the sweeteners into two groups and testing each group once. In both cases they have to include the control group. At the end, they compile and record their results, analyze their data, discuss the findings, make inferences, and generate an evidence-based conclusion. Then they can communicate their findings in a paper intended for publication in a peer reviewed scientific journal, and in preparing a presentation intended to be given at a scientific conference.

**Table 2**
Different Levels of Inquiry *(Wheeler and Bell 2012, p. 34)*

| **Different Levels of Inquiry** | | | |
|---|---|---|---|
| | ***Inquiry Level*** | ***What Teachers Provide*** | ***Student Expectations*** |
| ***I*** | ***Confirmatory*** | Research question, method, procedures, materials, & solutions | Use materials and procedures to investigate the already identified outcome and to confirm a previously taught relationship, conclusions, or finding |
| ***II*** | ***Structured*** | Research question, method, procedures, & materials | Use the materials and procedures to investigate the research question and to determine the expected outcome and solution |
| ***III*** | ***Guided*** | The expected outcome & solution | Develop the method, procedures, and determine the needed materials to investigate the research question and to determine the expected outcome & solution |
| ***IV*** | ***Open*** | (Do teachers provide the topic for which the students have to design their own investigation? For example Respiration) | Form the research question, develop the method and procedures, identify the needed materials, and experimentally come up with expected outcomes & solutions |

#### 2.2.2. Second Pedagogical Approach:

In this approach, the class is divided into groups of 2-3 students. The number of the groups depends upon how many students are in the class. The members of each group work together to test only one sweetener and the control group (yeast + water). Thus, each sweetener is tested independently by at least two groups of students. The members of each group compile and record their results to analysis data, discuss the findings, make inferences, and generate evidence-based conclusions. At the end, the members of the groups, who tested the same sweetener, meet and compare results and findings. This approach can give the students the opportunity to learn about systematic error and random error. For their data analysis, they can calculate the average/mean volume of carbon dioxide produced from all groups and discuss the distribution of their individual values around the mean value. This would be an introduction to standard deviation. They then hold an open discussion on the interpretation of their results, inferences, and conclusions. The members involved in independent testing of the same sweetener give a brief presentation in the class about their findings and results. After this, all students in the class are re-divided into groups of six students, one from each tested sweetener. These include Splenda©, Sweet'N Low©, Equal©, Stevia Extract©, Truvia©, and common table sugar. Each group meets to discuss how they are going to communicate their findings in two ways, either in a collaborative written paper intended for publication in a peer review scientific journal, or as a prepared presentation intended to be given at a scientific conference. In both cases, the students identify applications for their findings, the implications of their results, and suggest how to engage in further related research and investigation. This is very important because in doing science, the scientific method is not the only endeavor that scientists employ. They also report their results to the scientific community through publication in peer-reviewed journals or at appropriate science conferences (Cherif, Siuda, & Movahedzadeh; 2011; Cherif & Roze, 2013).

## 3.0. Designing and Conducting The Inquiry Investigating

### 3.1. Materials:

Access to the following materials and equipment should be easily available for the students of each group. Based on the inquiry level the students are planning to engage in, the members of each group make the decision of which materials and equipment they would like to use to investigate their research question. If time permits, the students could be asked to justify why and how each selected item and/or equipment will be used in their inquiry. Students need to use Table 3 to complete this required task.

#### 3.1.1. Per-group of Four Students:

1. A few packages of Splenda©, Sweet'N Low©, Equal©, Stevia Extract©, Truvia©, and common table sugar. (Or teachers can select their own favorite sweeteners to investigate if they choose to do so).
2. Package of dry active yeast (Rapidrise©)
3. Seven flasks, medium test tubes, 10 –mL graduated cylinders or clear plastic cups (50ml)

4. Source of water (warm and at room temperature) and Vegetable oil.
5. Thermometer and pH paper strips or pH meter
6. Teaspoon and 2 dropper pipettes
7. Equipment to measure the amount of gas produced. These can vary from simple round small birthday party balloons, gas syringe, and graduated cylinder or to more sophisticated equipment such as pressure or carbon dioxide sensors.
8. Graduated cylinder
9. Magnifying glass or dissection microscopes

Table 3
Students' selected items and equipment and their justification for use in the experiment

| Selected Materials and Equipment | | | | | |
|---|---|---|---|---|---|
| Chosen Item | How to Use | Why | Chosen Item | How to Use | Why |
| | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |

**3.2. Procedures:**

**3.2.1. The Physical Properties of the Tested Sweeteners:**

Obtain one package of each of the following sweeteners listed in table 4, including common table sugar. Open and pour each one into a separate Petri dish. Then examine the physical proprieties of each--- including color, shape, texture, and the intensity of the sweetness (if you are allowed to taste them). Record your observations in Table 4 below.

Table 4
Physical Properties of Tested Sweeteners

| Sweeteners | | Color | Shape | Texture | Particle's Size | Intensity of the Sweetness or Additional Properties |
|---|---|---|---|---|---|---|
| *1* | *Table sugar* | | | | | |
| *2* | *Splenda©* | | | | | |
| *3* | *Sweet'n Low©* | | | | | |
| *4* | *Equal©* | | | | | |
| *5* | *Stevia Extract©* | | | | | |
| *6* | *Truvia©* | | | | | |

**If time and space permit, teachers may want to ask students to also test for the intensity of the sweetness of each sweetener.*

**3.2.2. Generating Informative Predictions:**

Based on your own knowledge and experience, the physical properties of the investigated sweeteners (Table 4), as well as the information in appendix 1, predict which of the following sweeteners the yeast would like the most: Splenda©, Sweet'N Low©, Equal©, Stevia Extract©, Truvia©, and common table sugar. Record your predictions and the justification for generating these predictions in Table 5.

Table 5
Student's Generated Predictions and Justifications of which Sweeteners the Yeast Likes the Most

| Prediction Status | Generated Prediction | Justification Based Prediction |
|---|---|---|
| Initial Prediction | | |
| Modified Prediction | | |
| Final Prediction | | |

### 3.3. Starting the Investigation:

#### 3.3.1. Before You Start:

After the instructor reviews safety procedures, including wearing goggles and aprons, the members of each group work together to:

1. Write the research question in the form "What is the effect of changing X on the changes of Y as measured by (name your tool and your units)?"

   'X' is the independent variable, and is in this case the type of Sweeteners, and 'Y' is the dependent variable, and is in this case fermentation rate of yeast. The fermentation of yeast can be determined by measuring the amount of carbon dioxide produced, or the level into which the generated bubbles rise in the test tube, beaker, and plastic cup.

   It depends on the type of resources and equipment teachers have in their schools, there are many ways to measure the amount of gas produced in a chemical reaction. Here are some examples:

   - A gas syringe connected by a rubber tubing or glass tube to an Erlenmeyer flask [Students need to measure the change of volume per unit time (Figure 1).]
   - Measuring the volume of water displaced by the gas produced using the following assembled apparatus of an inverted burette or an inverted graduated cylinder. [The students need to record the change of volume per unit time (Figure 2).]
   - Measuring the pressure of the gas produced per unit time using a pressure sensor connected to the flask [The students need to record the pressure of the gas produced over time (Figure 3).

Figure 1

Figure 1: A gas syringe connected by a rubber tubing or glass tube to the flask

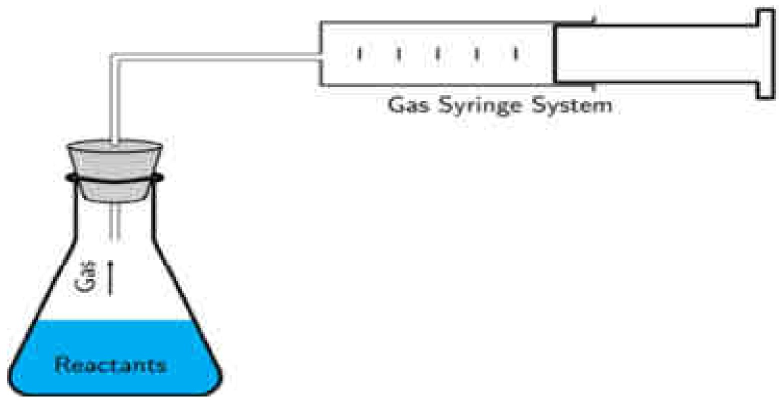


Figure 2

Figure 2: An inverted burette or Erlenmer flask connected to BMP vial

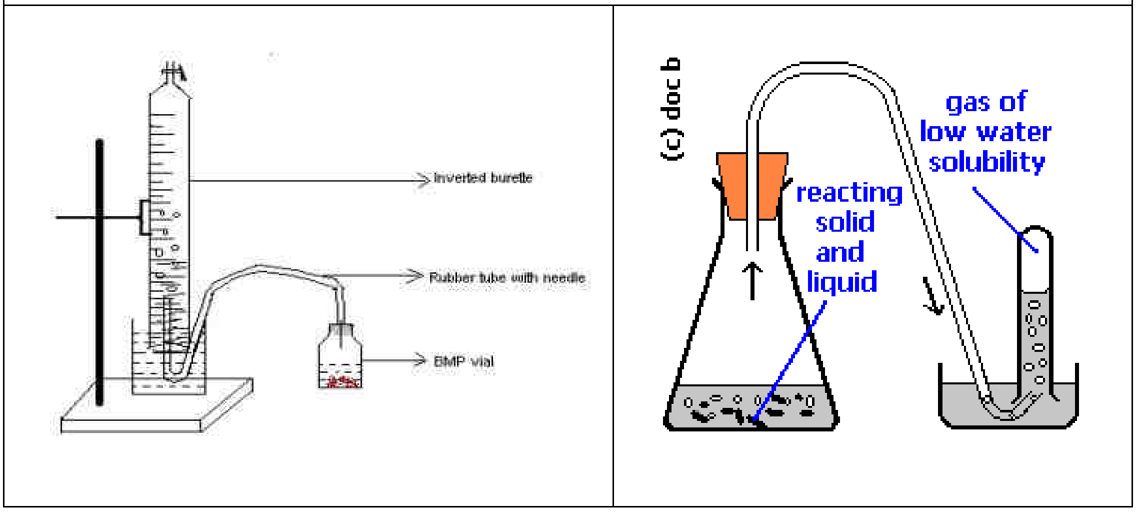
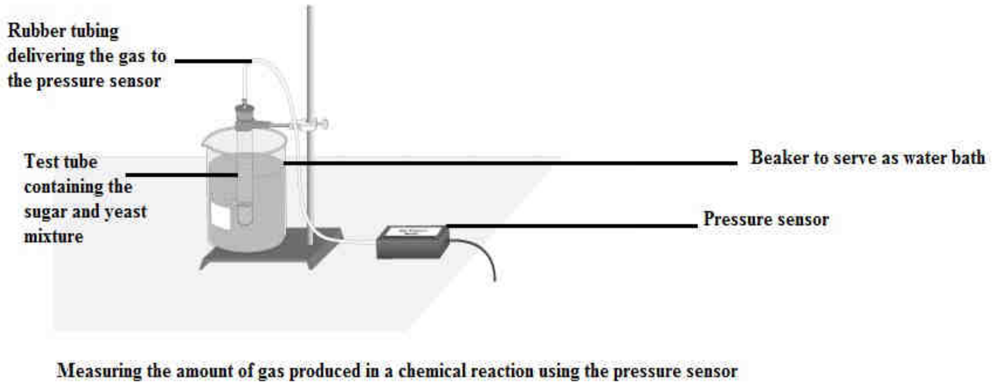



Figure 3

Figure 3: A pressure sensor connected to a flask




2. Design an experiment to conduct, determine the procedures to employ, identify and select the materials, tools, and instruments needed to conduct the experiments. It is important that all factors affecting the dependent variable must be controlled. In this specific experiment, the volume of carbon dioxide can be affected, other than by the type of sugar, by the following factors. These are variables that need to be controlled throughout the experiment. Have the students list all the factors that affect the dependent variable, explain why they need to be controlled and suggest specific ways to monitor and control them throughout the experiment.

Table 6
Potential factors affecting the dependent variable in proposed Experiment

| Factor | Why it needs to be controlled | How will it be controlled |
|---|---|---|
| Temperature | Temperature is a factor affecting the rate of enzyme's activity The volume of a gas is directly proportional to temperature (Charle's Law) | The flask where the fermentation is taking place needs to be placed in a water bath set between 30-35 $^{o}$ C. A thermometer is placed in the water bath and the temperature needs to be monitored. Room temperature where the experiment is taking place needs to be monitored and recorded. |
| Volume and concentration of the sugar/sweetner solution used | If more sugar is available to the yeast cells there will be more carbon dioxide produced | Equal volumes of equal concentrations of each type of sugar and sweeteners used for each experiment. |
| Amount of yeast used | The enzyme concentration is a factor that affects the rate of an enzyme-catalyzed reaction. Yeast cells provide the enzymes for the sugar fermentation and all experiments need to have the same amount of yeast cells. | A yeast suspension of equal concentration is to be used in all experiments. 1% yeast solution is to be prepared and equal volume of this suspension to be mixed with the sugar solution. |
| pH of the reaction | Enzymes are pH specific. The enzyme invertase exhibits relatively high activity over a broad range of pH (3.5--5.5), with the optimum near pH=4.5 | 2 mL of a buffer solution of 4.5 is to be added to each experiment |
| Pressure | The volume of carbon dioxide can be affected by the pressure (Boyle's law) | A barometer in the classroom is used to record the atmospheric pressure and record it during the experiment. |

3. Seek approval and the 'green light' to start the investigation. In order to get the green light to begin, the students must:
    a. Present the design of their experiment to the instructor.
    b. Identify correctly the dependent, independent and controlled variables.
    c. Identify the materials and equipment they want to use and why.
    d. Pass a safety check list.
    e. The members of each group have already agreed to work collaboratively by assigning each one of them a given role to play throughout the inquiry instigation.

### 3.3.2. Conducting the Experiment:

As the experiment begins, it must be noted that this is a group work and all members of the group must investigate their research question. In addition, the teacher will be making observations on how the investigation is moving forward, whether or not the safety procedures are being followed, assessing the manipulative skills of the students and if the members of each group are working together collaboratively. The teacher will be available to answer questions, but only after s/he redirects each question being asked back to the students, and does not answer any question that requires a yes or no.

### 3.3.3. Recording Data and Results:

Students will use Table 7 and 8 to record their data and results. Depending upon which pedagogical strategy the teacher uses, the members of each group will sit together at the end of their experiments to discuss their results, various possible inferences, and what they interpret as evidence-based conclusions. It is important for them to discuss implications and applications related to their results and findings. It is also important to see if they are able to suggest further related research and investigative opportunities.

After these discussions, it is time for the groups to discuss how they are going to communicate their findings. This can be accomplished in two ways; in a collaborative written paper intended for publication in a peer reviewed scientific journal, or in a well prepared presentation intended to be given at a scientific conference. After all, in doing science, the scientific method is not the only endeavor of scientists doing science. Scientists apply the scientific method to generate evidence-based conclusions, communicate results to the scientific community, and identify implications of results to engage in further related research and investigation (Cherif, 1998b; Cherif & Roze, 2013).

### 3.4. Communicating Results and Writing an Investigative Inquiry Report:

#### 3.4.1. Communicating Results:

In addition to analyzing data, students must also formulate the best explanation of what they observed and discovered, and communicate the explanation of their results (Deutsch, 2011; Lefever, 2013). To assist in this, each group is asked to prepare a data table, graph, or other visual representation showing their results and any relationships derived from the data. Students should work together to develop scientific explanations based on their observations and findings. As the physicist David Deutsch (2011) has argued, explanations have a fundamental place in understanding the universe and the world around us – and that improving them is the basic adaptable principle of all successful human endeavors throughout human history. The formation of new explanations and dropping bad ones is at the core of science and one of the outlining conditions under which progress takes place. It is because of a need to generate a depth of understanding for our physical world that will encourage students to spend time engaging in open discussions. It is here that they are able to explore their individual and collective interpretations and explanations of their work.

Students will present their results in a graph. A successful completion of empirical testing by any group of students should result in data that can also be presented in a graphical form. For example, the data and the graph below (Table 9 and Figure 4), were obtained by a group of grade 11 students in the American Community School (ACS) of Athens using two-coordinate graphs that shows the relationship between variables in an experiment. The students conducted a similar experiment, but with different type of sugars. Their results can be used as an example, by teachers planning to do this experiment, as it gives an idea on how the results can be processed and presented by the students during this inquiry investigation. The ACS students used different types of sugars. The table shows the initial rate of reaction of all the sugars and of the control, and was obtained from the slope of the change of pressure of carbon dioxide between 30 seconds to 5 minutes of the average values of three trials. The graph shows Average Initial Pressure vs. Time for Sugars and Control.

Table 7
Recording Experimental Results and Observations

| **Flasks/ Beaker with** | **Qualitative data*: Observations** | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | *0 minute* | *2 minute* | *4 minute* | *6 minute* | *8 minute* | *10 minute* | *12 minute* | *14 minute* | *16 minute* |
| *Water* | | | | | | | | | |
| *Common Table Sugar* | | | | | | | | | |
| *Splenda©* | | | | | | | | | |
| *Sweet' n Low©* | | | | | | | | | |
| *Equal©* | | | | | | | | | |
| *Stevia Extract©* | | | | | | | | | |
| *Truvia©* | | | | | | | | | |

*qualitative data may include the speed at which the gas bubbles are produced, the turbidity of the mixture, the foam forming on top of the mixture and/or the smell of the solution (NO direct sniffing of any chemical because there is the risk of damaging the mucous membranes or your lungs. The proper technique is to cup the hand above the container and waft the air toward the face.)

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Table 8
Recording Experimental Results and Observations

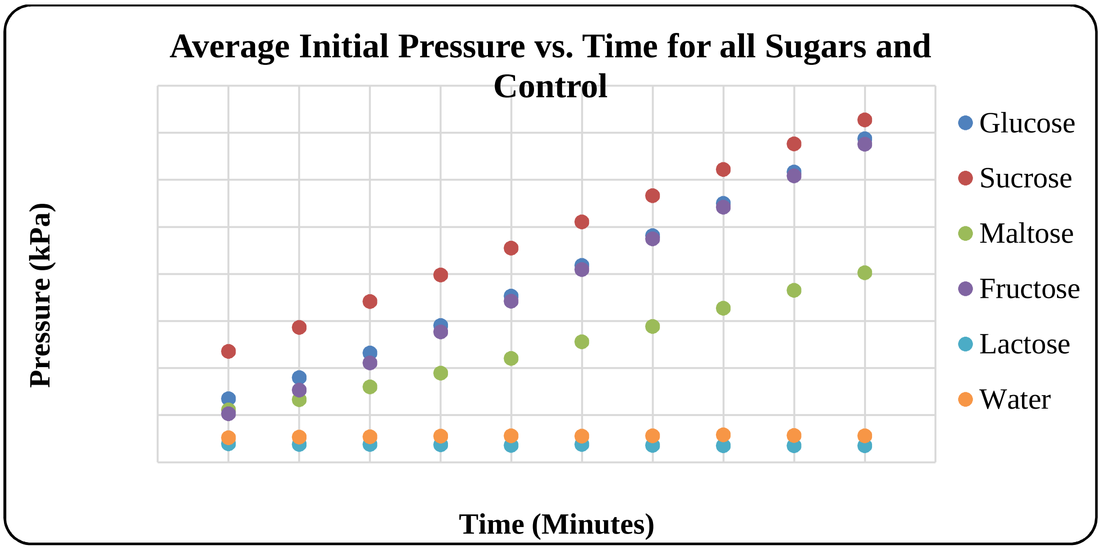
| Flasks with / Time/min | Volume (or Pressure) of carbon dioxide produced ± 0.01/mL (± 0.05 KPa) Produced in 20 minutes | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | **Time by 2-minutes** | | | | | | | | | | |
| | 0 | 2 | 4 | 6 | 8 | 10 | 12 | 14 | 16 | 18 | 20 |
| *Water* | | | | | | | | | | | |
| *Common Table Sugar* | | | | | | | | | | | |
| *Splenda©* | | | | | | | | | | | |
| *Sweet'nLow©* | | | | | | | | | | | |
| *Equal ©* | | | | | | | | | | | |
| *Stevia Extract©* | | | | | | | | | | | |
| *Truvia©* | | | | | | | | | | | |

Table 9
The initial rate of reaction of all the sugars and the control obtained from the slope from the first 30 seconds to 5 minutes along with the average values.

| Initial Rate of Fermentation (± **0.05** ***kPa*/min**)* | | | | |
|---|---|---|---|---|
| Sugar | **Trial 1** | **Trial 2** | **Trial 3** | **Average** |
| Sucrose | 1.83 | 2.42 | 2.369 | 2.201 |
| Glucose | 2.58 | 2.54 | 2.333 | 2.486 |
| Lactose | 0.01 | 0.05 | 0.011 | 0.024 |
| Maltose | 1.40 | 1.31 | 1.200 | 1.305 |
| Fructose | 3.71 | 2.842 | 1.195 | 2.582 |
| Water | 0.05 | 0.017 | 0.009 | 0.027 |

- (It is important to note that the uncertainty of the instrument and value it measures must have the same decimal places. In this case it is 0.05 kPa, therefore all values of the pressure must have two decimal places ONLY)

Figure 4
Average Initial Pressure vs Time for Sugars and Control
(as measured by grade 11 students in ACS Athens)




### 3.4.2. Writing an Investigative Inquiry Report:

In this activity, the students are asked to prepare an investigative inquiry lab report in the form of a scientific paper written specifically for publication in a peer-reviewed scientific journal. In addition, students are asked to write a scientific paper and seek peer review for their paper from their classmates, and then submit this paper to their teacher for classroom publication.

This is another challenge for the students, because in order for them to do so, they need to: (a) know how to prepare and write a sound scientific paper, (b) know how to submit this paper, (c) begin to understand what to expect after submission for publication, and (d) see the value of peer review in obtaining evidence-based conclusions and maintaining the integrity of scientific results. These additional steps help students see the relationship between scientific inquiry and scientific publications, which is one of the main avenues to communicate scientific results and discoveries among scientific communities, which in turn helps in the advancement of science. (Cherif, 1998b; Belk & Borden, 2009; Cherif, Siuda, & Movahedzadeh, 2013).

Therefore, upon successful completion of their experiments students of each group:

- Communicate their findings by writing a scientific paper suitable for publication in a peer-reviewed journal (They include in their manuscript abstract, introduction, method and procedures, results, analysis, conclusion and recommendation)
- Submit their written scientific paper to their teacher for review (Their paper may be (a) accepted with no changes, (b) accepted with changes and revisions, or (c) rejected for publication.)

Furthermore, upon completion of writing and submitting their scientific paper for publication, the students will evaluate their investigation by answering the following questions:

1. Were you able to repeat and replicate the experiments for each tested item?
2. Were you able to disapprove and reject your original prediction?
3. Why do you think the process of peer review is important in the scientific endeavor?
4. Was your paper:
    a. Accepted without revision? Explain why, in your opinion.
    b. Accepted with revision? Explain why.
    c. Rejected for publication? Explain why.

**4.0. Assessment and Follow Up Question.**

**4.1. Follow Up Questions:**

The following are questions looking at the process of scientific research and inquiry. Have students discuss these in groups, and possibly present their answers to the class.

1. Why do scientists often try to disprove, rather than prove, a given scientific discovery, hypothesis and/or theory?
2. When do you think a hypothesis becomes a theory?
3. Explain how the design of an experiment can affect the quality of the outcome in testing a hypothesis.
4. Explain how the repeatability of experiments in science can decrease our skepticism in, and increase our acceptance of the outcomes and the evidence-based conclusions of science experiments and discoveries.
5. What additional experiment(s) could you conduct to support your findings?
6. If you could do this all over again, what would you do differently?
7. How important is the peer review process for the integrity of evidence-based conclusions and for the advancement of science?
8. Why do people often trust the information presented in scientific journals, while scientists always question this information.
9. Why is it very important that a generated hypothesis (tentative explanation) be testable and falsifiable for a scientific observation or question?
10. Why do you think, for example, adding a layer of vegetable oil above the sugar and yeast mixture in every experiment, was a must?
11. What have you learned from engaging in this activity, both via conducting the laboratory experiment(s), and in writing the paper intended for publication in a scientific journal?

**4.2. Assessments:**

Students are assessed for four criteria aiming to measure students' learning, as well as to help improve the teaching and the condition for student learning:

- Lab experimental design, conducting the experiment, and recording results and findings
- Explanation, interpretation and effective communication of experimental results and findings
- Identifying the implication of results, applications for findings, and suggestions for engaging in further related research and investigation
- Discussion questions during and after the completion of the investigative inquiry

**4.2.1. Lab experimental design, conducting the experiment, and recording results and findings:**
How well the members of a group:
- Identify variables
- Control non-tested variables
- Design a lab that gives reliable results
- Conducted their experiments
- Gather and record correct data and findings
- Conduct and complete the overall lab experiment
- Verify their findings

**4.2.2. Explanation, interpretations, and communication of results and findings:**
How well the members of a group:
- Analyze and interpret the data correctly
- Provide reasonable explanations for the findings supported by reliable scientific evidence
- Reach a valid and an evidence-based conclusions
- Effectively communicate their investigative inquiry results and findings through writing scientific papers for publication. This includes describing and discussing the experimental design, results, and conclusion of the each experiment
- Effectively communicate their investigative inquiry results and findings through a presentation in a scientific conference (classroom). This includes describing and discussing the experimental design, results, and conclusions of each experiment
- Prepare a data table, graph, or other visual representation to show their results and any relationships derived from the data
- Conduct and complete the overall lab experiment

**4.2.3. Identifying implications of lab results and identifying further related research:**
How well the members of a group:
- Identify implications of results
- Suggest applications for findings
- Suggest ways for engaging in further related research and investigation
- Conduct and complete the overall lab experiment

**4.3. Discussion questions during and after the completion of the investigative inquiry activity**:
How well the members of a group:
- Engage in the discussion questions
- Raise additional relevant questions during the discussion question
- Utilize their experimental design, results, and conclusions of the each experiment during the discussion
- Conduct and complete the overall lab experiment

When all the students finish their scientific presentation in the classroom describing their experiment, findings, and evidence-based conclusions, implications, etc., the class discussion will start focusing on the strengths and weaknesses of different experimental approaches and what these experiments show us about what type of sweeteners yeasts like the most.

Here, students and the teacher can assess, if needed: *" (1) Correct identification of variables, (2) control of non-tested variables, (3) reliability of the data based on the number of trials and so on, (4) student conclusions, and (5) student ideas on how to make the experiments stronger"* (Robinson, Nieh, & Goodale, 2012, p.4*55).* If time allows, students can complete a modified experiment in the next class period.

For those teachers and educators who are interested to see an example of successful rubric that can be used to grade the lab reports of open-ended inquiry, can see an appendix 6 from ACS Athens.

## 5. Making Connection and Follow Up Assignments and Investigation

### 5.1. Follow-up Investigation:
From what we have noticed from conducting this investigative inquiry with students in the past, students are able to deduct the concept of fermentation; in addition, they understand that yeast needs sugar as a source of energy to grow and develop, and in the process of engaging in the fermentation reaction gas is released.

While all of the students agreed that the gas produced was carbon dioxide, they all struggled with the collection and measurement of the gas. Also, they struggle with how to demonstrate beyond smelling that alcohol was also produced. They went back for 30 minutes to discuss this problem. When all the groups were ready, they reconvened and each group presented their suggestions of how to collect and measure the produced gas. After a lengthy discussion back and forth, the students decided to repeat the same set of experiments conducted as in their first investigative inquiry, but this time they would use:

- Graduated cylinders, flasks, or marked test-tubes in which to add the yeast to the water and tested sweetener
- Balloons to prevent the gas from escaping and at the same time use the size of the inflated balloon to measure the amount of gas produced
- Use the rise of the foam within the test-tubes, graduated cylinders, or flasks, to measure the amount of gas produced

While all students agreed that this was the best way to measure the gas produced during the yeast's metabolic activity in the experiments, they disagreed on which device was more efficient in this task --- that is, graduated cylinders, flasks, or marked test-tubes. They were also aware that some of the gas will escape in the process. Some students liked the graduated cylinder because it already has the measuring scale printed on its side and is narrow in size. Others didn't like to use the graduated cylinder because it doesn't have a smooth round mouth. These students decided to use flasks because it was easier to place a balloon on the smooth round part of the flask. Yet one more group decided to use test-tubes instead of the graduated cylinders or flasks. This group was aware that the test-tubes were not marked along their length by inches or millimeters, but preferred to use rulers and markers to make their measurements. After all these obstacles were satisfactorily resolved the groups went back and conducted their own investigative inquiries and were able to measure the amount of carbon dioxide produced during the experiments. The groups came together and again shared their findings with the rest of the class. Finally, every group wrote a short paper intended for publication in a peer-review scientific journal.

### 5.2. Making The Connection: Possible Discussion Questions:

1. Why do think glucose is the preferred source of energy for the brain and an important source of energy for all cells?
2. What do you think will happen when a cell cannot get enough glucose?
3. Is there a type of cell that can operate both with and without the presence of oxygen? What does this mean?
4. What is the relationship between glucose, insulin, and diabetes?
5. Compare and contrast dependent vs independent variables in regards to this guided inquiry investigation. Compare and contrast these two variable types in a broad sense.
6. What do we mean by each of the following terms? Discuss these terms as related to their part in the above inquiry; that is, how they affected the outcome of the yeast's growth and the chemical reactions involved in their growth:
   a. Sugar free
   b. No sugar added
   c. Calorie free
   d. Zero calories
   e. Diet soda
7. Propose three ways in what and how can you cut back on sugar from your daily diet and still keep your sweet tooth happy?

### 5.3. Follow-up Homework Assignment:

#### 5.3.1. Old Habits Die Hard:

You are a very close friend of Jansen, who you have been studying with for a number of years. One night while you are studying for a biology exam, Jansen's grandfather asks him to go to the store and buy him Sweet'N Low© for his decaffeinated tea. Both of you went to the store nearby and bought Sweet Plus©, simply because it was cheaper, and also because the corner store doesn't carry Sweet'N Low©. Upon arriving back home, the two of you give the sweetener to his grandfather but the grandfather was very unhappy, and indeed very upset. He demanded that his grandson goes back and returns the Sweet Plus© and gets him Sweet'N Low©. Jansen turned to you for help to explain to his grandfather that these two types of sweeteners are really the same, and also have the same color "red-pink" package. How are you going to explain to the grandfather these two have the same content, color package and thus are the same?

### 5.3.2. How Can This Happen?

Sonya, who was born and raised for a number of years in Asia before moving to the USA, still remembers how her grandmother used to prepare dough for bread without adding the yeast, and yet achieved the same outcome as what her mother has been doing with yeast when baking bread here in the states. Sonya remembered that her grandmother use to cut dates into very small pieces, put them into water, added a little bit of sugar and salt, and kept the mixture in a closed container for 3-4 hours. Then she took this liquid and used it to prepare the dough for making bread. What do you think was in the liquid that caused the dough to rise, and for the bread to come out the same way as using yeast (fluffy and tasty)?

## 6. Conclusion and Final Remark:

If we want American students to be highly competitive in the global marketplace, what assets need to be nurtured and supported? In regards to this question, consideration must be made to not only the school learning environment, but also how to succeed in that environment? What traits must be acquired to be successful in this ever changing dynamic? Students need to both master the fundamentals of a general education as well as being able to think critically and solve problems effectively. The mastery of fundamentals is necessary if a student is to be able to think critically and be able to solve problems effectively. The ability to think critically is necessary in order to be able to master the core concepts and the fundamentals of college life.

Teaching students to think and solve problems efficiently requires teaching more in-depth, rather than going for more breadth in knowledge. Inquiry-based learning provides the opportunity for students to achieve both. Students really connect to inquiry-based learning which helps them develop integrated problem-solving skills and core concept acquisition. Critical thinking is a wonderful tool for student success.

We designed this investigative inquiry activity because we want to inspire an interest in science among students through the engagement in investigative inquiry. We want students to walk away with new understanding of investigative work and with an interest in science through these kinds of investigative inquiries. We also want students to take away from this investigative inquiry that science isn’t just in the lab; it is also related to everyday’s life activity and affects everyone, even those who don't pursue a career in science. We also want teachers to use this activity as a starting point to approach other topics such as health, food and nutrition, nutrition-based diseases, alcohol abuse, and so on.

**Acknowledgment:**

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## Appendixes

### Appendix 1 - Sweeteners

| | Name of Product | Package Color & Net Wt. | Listed Ingredients | Nutritional Facts as Listed on the Package |
|---|---|---|---|---|
| 1 | ***Sweet'n Low©: Zero calorie Sweetener*** | Pink 0.035 OZ (1g) | Natural Dextrose, Soluble Saccharin, Cream of Tartar, Calcium Silicate (an anti-caking agent). | Calories 0, Total fat 0g (0% DV), Sat. Fat 0g (0% DV), Trans Fat 0g, Sodium 0mg (0% DV), Total Carb. Less than 1 g (0% DV), Sugars Less than 1 g, Protein 0g, Present Daily Values (DV) are based on a 2,000 calorie diet. (For more information go to: (sweetnlow.com) |
| 2 | ***Splenda: No Calorie Sweetener*** | Yellow 0.035 OZ (1g) | Dextrose with Maltodextrin, Sucralose. | Calories 0, Fat Cal. 0, Total fat 0g (0% DV), Sat. Fat 0g (0% DV), trans fat 0g, Cholest. 0mg (0%DV), Sodium 0mg (0% DV), Total Carb. less than 1g (0% DV), Fiber 0g (0%DV), Sugar less than 1g, Protein 0g, Vit. A (0%DV), Vit. C (0%DV), Calcium (0%DV), and Iron (0%DV). Present Daily Values (DV) are based on a 2,000 calorie diet. (For more information go to: (not listed on the package) |
| 3 | ***Equal©: 0 Calorie Sweetener*** | Blue 0.035 OZ (1g) | Dextrose with Maltodextrin, aspartame | Calories 0, Total fat 0g (0% DV), Sodium 0mg (0% DV), Total Carb. less than 1 g (0% DV), sugars less than 1 g, Protein 0g. Not a significant source of calories from fat, saturated fat, trans fat, cholesterol, dietary fiber, vitamin A, vitamin C, calcium and Iron. Present Daily Values (DV) are based on a 2,000 calorie diet. Claim: Suitable for people with diabetes. (For more information go to: (not listed on the package) |
| 4 | ***Stevia Extract: 100% Natural, Zero Calories*** | Green 0.035 OZ (1g) | Dextrose, Stevia Extract (Retina) | Calories 0, Total fat 0g (0% DV), Sat. Fat 0g (0% DV), Sodium 0mg (0% DV), Total Carb. less than 1 g (0% DV), Sugars less than 1 g, Protein 0g. Present Daily Values (DV) are based on a 2,000 calorie diet. |
| 5 | ***Stevia Extract©: A Dietary Supplement*** | White 0.035 OZ (1g) | Organic Stevia Extract (*Stevisrebaudiana*), Tice Maltodextrin, and Silica. | Calories 0, Total Carb. 1 g (,1% DV), Certified Organic Stevia Extract (*Stevisrebaudiana*) (Leaf) 85 mg (t). Present Daily Values (DV) are based on a 2,000 calorie diet. Daily Value not established. |
| 6 | **Truvia©** | White with green writing 0.123 OZ (3.5g) | Erythritol, stevia leaf extract, natural flavors. | Calories 0, Total Fat 0g (0% DV). Sodium 0mg (0% DV), Total Carb. 3g (1% DV), Erythritol 3g, Protein 0g. Present Daily Values (DV) are based on a 2,000 calorie diet. Claim: Suitable for people with diabetes. (For more information go to: truvia.com). |
| 7 | ***Common Table sugar*** | | | |

### Appendix 2:
### Fermentation (For Teachers)

While there is 1,500 species of yeast currently described, the yeast species *Saccharomyces cerevisiae*, is the main champion of fermenting agent. By fermentation, the yeast species *Saccharomyces cerevisiae*, converts carbohydrate to carbon dioxide and alcohol, and for thousands of years the carbon dioxide has been used in baking and the alcohol in alcoholic beverages. Legras, J. et. al (2007). Fermentation is one of many metabolic pathways in living organisms. This particular pathway is one that does *not* involve the use of oxygen. In fact, oxygen's presence will force the chemical reaction to *not* occur. Thus, this anaerobic cellular process leads to differing ending products than the typical aerobic respiration chemical process that many know of. Respiration is an exothermic chemical reaction releasing heat. It is quite efficient, as all intermediary molecules (such as pyruvate) in the total process, are completely broken down and used to generate all the energy that is possible from the starting reactant (glucose). The reaction in its entirety is shown below. Note that the intermediary reactants and products that come initially from glucose are not shown. The biochemical reaction steps are not covered here. Nevertheless, the process of respiration and its inherent beauty can be seen in this balanced equation:

$$\mathbf{C_6H_{12}O_6\ (s) + 6\ O_2\ (g) \rightarrow 6\ CO_2\ (g) + 6\ H_2O\ (l) + heat}$$

On the other hand, fermentation is much more inefficient and lacks the 'chemical beauty' of the above respiration reaction. Without oxygen's presence, the intermediary molecule (pyruvate) is not transported into the mitochondrion but stays in the cytoplasm and is transformed into wastes. These waste products are ethanol and carbon dioxide. This particular process of fermentation involving yeast is termed 'alcoholic' or 'ethanol fermentation'. This chemical reaction involves yeast alcohol dehydrogenase and is paramount to the continuation and survival of the liquor industry. Beer, wine, spirits, and other alcohols would not exist without this particular enzyme. Other fermentation processes can occur, based primarily on the enzymes involved in a particular organism. This can lead to end products such as acetic acid, butyric acid, and lactic acid. The important point to remember is that there is no oxygen involved. Fermentation is a process that occurs only in the absence of oxygen. It is imperative to remember that the absence of oxygen in the respiration process clearly minimizes the efficiency of this reaction. Thus yeast, in the process of fermentation, does not produce all the energy that could be harnessed. The reaction is written below. Note that pyruvate, in the presence of carbon dioxide and water, are still left and underutilized for energy.

*$C_6H_{12}O_6$ + 2ATP + 2ADP + 4NADH ------> $2C_2H_5OH$ (ethanol) + $2CO_2$ (carbon dioxide) +4ATP + $2H_2O$ (water) + $4NAD^+$*

Trefil and Hazen (2010) sum it up quite succinctly: "The chemical energy in alcohol is left behind by the yeast cells that make it – energy that the cells could not use because they were not able to metabolize it" (p. 460). Such is the best an organism as simple as yeast can accomplish. It is in no way as advanced as its multicellular counterparts, with more advance organelles that allow for a streamlined efficiency in energy production.

### *Appendix 3*
### Guided Inquiry Questions In Teaching Science Concepts As proposed by Cherif (1988, 1993a, 1998a)

| | **Guided Inquiry Question In Teaching Science Concepts** | **The Nature of the Question** | **The Aim and Objective of The Question** |
|---|---|---|---|
| 1 | What do you think will happen given this set of conditions? (If, for example, X is added to Y?) | Predicted question | To arouse interest, stimulate thinking and provide predictions. |
| 2 | What actually happened? | Descriptive-discovery question | To build an awareness of what actually happened. |
| 3 | How did it happen? | Holistic - descriptive question | To establish in students' minds the cause and effect relationship;<br>To think of all the processes that took place as a total integrated whole;<br>To provide general understanding of the process taking place and resulted in what actually happened. |
| 4 | Why did this happen? | Causal question or reasoning explanation | To develop and apply some kind of mental analysis that enables students to generate a reasoned and testable hypotheses (tentative explanations) using their ideas, experiences and understanding. |
| 5 | How can we find out which of these hypotheses is the most reasonable? | Experimental question | To provide the opportunity to actually plan and carry out experiments of their own;<br>To gain the skills of designing experiments, testing hypotheses, reasoning, and debating results. |
| 6 | How can you relate the investigated idea, concept, or principle to your daily lives? | Idea-application or testing-understanding question | To understand the idea or the concept under investigation;<br>To master the inquiry processes;<br>To apply reasoning patterns in other situations;<br>To accept science as a way of knowing and understanding. |

**Appendix 4**
**Making the Connection**

Ask students to conduct a research to find out the relationship between:

1. The sugar's history and the history of humanity.
2. The European's addiction to tea in the eighteenth century and its effect on the sugar's history.

**Appendix 5**
**What Can I Do For Mt Dough!**

Ask each student to talk with an elderly person in his/her home to find out what usually people do when they want to make bread and are out of yeast for their dough. The following class meeting, ask each student to share what he or she found out with the rest of the class. Then divide the class into 4-5 groups and ask each group to write an article to the local newspaper about what to do when you are out of yeast for your dough. You can share with your students the following which is cited from Don Earnest, (2005).

> *"If you have some powdered vitamin C (or citric acid) and baking soda on hand, you can use a mixture of the two instead. Just mix in equal parts to equal the quantity of yeast required. What's more, the dough you add it to won't have to rise before baking." (p. 63).*