JOURNAL OF MICROBIOLOGY & BIOLOGY EDUCATION
DOI: https://doi.org/10.1128/jmbe.v21i3.2225

JMBE Journal of Microbiology & Biology Education

Supplemental Materials

for

Student-Scientist Curriculum: Integrating Inquiry-Based Research Experiences and Professional Development Activities into an Introductory Biology Laboratory Course

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Received: 27 July 2020, Accepted: 2 November 2020,
Published: 21 December 2020

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Appendix 1: Syllabus

Sample Syllabus: BIOL 1202 - Principles of Biology: Molecules & Cells

Student-Scientist Lab Curriculum

LABORATORY INSTRUCTOR
Name:
Email
Phone:
Office Hours:

TEACHING ASSISTANTS
Name:
Email
Phone:
Office Hours:

BIG IDEAS: *Students will understand:*

1. **ENERGY**: All living organisms need a continual supply of energy for growth and reproduction.
2. **NATURE OF SCIENCE**: The application of the scientific process enhances the interpretation of the biological concepts.
3. **BIOLOGICAL SYSTEMS**: All life on earth shares the basic characteristics of life and is interconnected.

LEARNING OBJECTIVES: Upon completion the student-scientist curricula, students will be able to:

- use Microsoft Excel to analyze data and create graphs
- properly operate a micropipette
- properly operate a compound microscope
- interpret data
- document inquiry-based research in a laboratory journal
- prepare research proposals for hypothesis-driven inquiry-based research experiments
- create posters to communicate their scientific findings
- exhibit and collaboratively present student-scientist poster to peers and STEM faculty
- design and conduct inquiry-based experiments using the scientific process

SUPPLEMENATARY RESOURCES: *These books are recommended for additional reading*.

- How to Write and Illustrate a Scientific Paper by Bjorn Gustavii, 2008, 2nd ed.
- Statistics Explained: An Introductory Guide for Life Sciences by Steve McKillup, 2005.

LAB GRADE EVALUATION: As indicated in your BIOL _____ course syllabus, your lab participation grade is ____% of your overall BIOL ____ grade. Your lab grade will be determined based on the table below:

LABORATORY PARTICIPATION GRADE	
Lab Attendance: ___% Pre-Lab Assignments: ___% Lab Journal: ___% Mini-Posters: ___% Student-Scientist Project: ____%	___%

STUDENT-SCIENTIST CURRICULUM LABORATORY SCHEDULE

DATE	LAB SKILLS	TOPIC	LABORATORY EXCERISE
Jan 12	Lab Safety	Introduction to CURE Lab Lab Safety Rules Assessments & Waivers	Laboratory Safety & Rules Assessments Waivers
Jan 19	Statistics Data Analysis	Data Analyses Microsoft Excel Interpreting Figures	**In Lab Assignments**: ***Short Course Tutorials***: HHMI Microsoft Excel Data Analysis – Blackboard Assignment & ***Worksheet***: Intro to Statistics and Data Analysis
Jan 26	Scientific Method Research Proposal	Scientific Method Research Proposals	**In Lab Assignment:** Research Proposal Intro to Statistics and Data Analysis Worksheet **DUE** Short Course Tutorials : HHMI Microsoft Excel Data Analysis **DUE** (Blackboard)
Feb 2	Micropipettes Lab Journals	Enzyme Activity Micropipette Lab Journals	**Pre-lab Assignment**: Micropipette Video and Questions Lactose Intolerance Research Proposal DUE **In Lab Assignment**: Lactase Activity Assay *Class Data for Analysis*
Feb 9	Mini-Posters	Mini-Posters Results and Discussion	**Pre-Lab:** Complete Lab Journal **In Lab Assignment:** Revisit data analysis & Create Mini-Poster
Feb 16	Microscopy Micropipettes Wet Mount Slides	Microscopy Micropipettes Yeast Enzyme Inhibition	**Pre-lab Assignment:** Microscope Video and Questions **In Lab Assignment**: Microscopy, Enzyme Inhibition and Cell Viability Assay Lactose Intolerance – Collaborative Mini-Poster DUE Individual Lab Journal DUE Peer-Self Reflection Worksheet **Due**
Feb 23	Micropipette pH Strips Statistics Data Analysis Mini-Poster Lab Journals Research Proposal	Enzyme Inhibition Yeast Fermentation	**Pre lab Assignment:** *Alcohol Fermentation and Enzyme Inhibition Research Proposal "Which Beer is Best"* **In Lab Assignment**: *Cell viability assay followed by Fermentation Assay - Class Data for Analysis* Microscopy and Cell Viability Assignment **DUE**
Mar 2	Scientific Method Microscope	Student-Scientist Project (SSP) Research Proposal	**In Lab Assignment**: Prepare Research Proposal for SSP Alcohol Fermentation and Enzyme Inhibition Group Mini-Posters **DUE** Alcohol Fermentation and Enzyme Inhibition Lab Journal **Due** Peer-Self Reflection Worksheet **Due**
Mar 9	Research Proposal	SSP Research Proposal Review	**Pre-lab Assignment:** Draft of Research Proposal for SSP **In Lab Assignment:** Mock Review Panel of SSP Proposals
Mar 23 Mar 30 Apr 6	Micropipette Microscope Lab Journals	Student-Scientist Projects Cell Viability Assay Fermentation Assay	**Lab Assignment**: Conduct Student-Scientist Project **Revised SSP Research Proposal - DUE** **The data collected will be used for data analysis**
Apr 13	Final Posters	Create SSP (Final) Poster	**Lab Assignment**: Create Student-Scientist Posters
Apr 20	Final Posters	Post-Assessments Revise SSP (Final) Posters	**Lab Assignment**: Revise Student-Scientist Posters **Construct Final Posters – Due Mon April 14 by 12 pm**
Apr 27	Final Poster Presentations	SSP Poster Presentation Competition	**Simulate a Poster Competition at a Scientific Conference** Student-Scientist Project Lab Journals DUE Peer-Self Reflection Worksheet **Due**

Appendix 2: Introduction to statistics and data analysis worksheet and answer key

Name_____ Lab Section_____

INTRODUTION to STATISTICS and DATA ANALYSIS

Instructions: Use the raw data below to complete the data tables provided below. Use the background information to explain your results.

Background Information: ***Lactose intolerance*** is a human digestive system disorder that occurs when the cells in the small intestine produce low amounts of the enzyme lactase. Lactase is needed in order to hydrolyze the milk sugar lactose; it breaks lactose sugar down into glucose and galactose. These monosaccharides (glucose and galactose) are absorbed from the intestine into the bloodstream. When a ***lactose intolerant*** individual eats or drinks dairy products containing a large amount of lactose, there is not enough lactase in their small intestine to hydrolyze the lactose. Therefore, the lactose passes into their colon without being broken down and the bacteria living in the colon begin to ferment the lactose. Unfortunately, when bacteria metabolize the lactose it produces a lot of gas, which can cause cramping, pain, gassiness, and diarrhea. While most human infants produce lactase, not all adults do. Lactose intolerance between different racial groups is highly variable, but unusually rare in Northern European and some African countries. Populations that produce lactase into adulthood tend to be those with a long history of drinking fresh milk. However, the United States is a multicultural population with ancestries from all over the world. Even Though the percentage of lactose intolerance adults in the United States ranges between 11 to 20%, this number reflects an average across people of many different ethnic backgrounds (Jarvis and Miller, 2002 and Sahi 1994).

References:

1. Jarvis, JK. and GD Miller. 2002. Overcoming the Barrier of Lactose Intolerance to Reduce Health Disparities. Journal of the National Medical Association. 94:55-66
2. Sahi, T. 1994. Hypolactasia and Lactase Persistence: Historical Review and Terminology. Scandinavian Journal of Gastroenterology. 29(202): 1-6.

Patient Number	Race	Glucose Conc. After 7mins (mg/dL)
1	Hispanic-American	500
2	Hispanic-American	500
3	Hispanic-American	1000
4	Hispanic-American	500
5	Hispanic-American	1000
1	African-American	250
2	African-American	250
3	African-American	500
4	African-American	100
5	African-American	1000
1	European-American	1000
2	European-American	1000
3	European-American	1000
4	European-American	500
5	European-American	1000
1	Asian-American	0
2	Asian-American	0
3	Asian-American	250
4	Asian-American	500
5	Asian-American	0

1. Using Excel, calculate the sample size, mean, standard deviation, and standard error for each racial group. Input the data in the table below. (16pts)

Sample	**Sample Size** (n)	**Mean** (mg/dL)	**Standard Deviation**	**Standard Error**
Hispanic American				
African American				
European American				
Asian American				

2. We don't know what results to expect for any of these groups, so we don't have a control group for comparison. Instead, you should compare the different groups against each other using the online t-test calculator (http://www.graphpad.com/quickcalcs/ttest1/?Format=SEM). Input the p-values in data table below. (12 pts)

t-test p-values	Hispanic-American	African-American	European-American	Asian-American
Hispanic-American				
African-American				
European-American				
Asian-American				

3. Using excel, create a bar graph with the standard error bars. The graph can be attached to this assignment on a separate sheet. The bar graph should include the x and y axes with titles and units, a legend if needed, graph title. (20 pts)

Explanation of Data

1. A brief overall summary of your data. Discussion the descriptive statistics provided in table and the graph created using excel. (12 pts)

2. What does your p-value tell you about the different ethnic groups? Discuss if these groups are significantly different or not? (10 pts)

Name_____ Lab Section_____

INTRODUTION to STATISTICS and DATA ANALYSIS - Key

Instructions: Use the raw data below to complete the data tables provided below. Use the background information to explain your results.

Background Information: ***Lactose intolerance*** is a human digestive system disorder that occurs when the cells in the small intestine produce low amounts of the enzyme lactase. Lactase is needed in order to hydrolyze the milk sugar lactose; it breaks lactose sugar down into glucose and galactose. These monosaccharides (glucose and galactose) are absorbed from the intestine into the bloodstream. When a ***lactose intolerant*** individual eats or drinks dairy products containing a large amount of lactose, there is not enough lactase in their small intestine to hydrolyze the lactose. Therefore, the lactose passes into their colon without being broken down and the bacteria living in the colon begin to ferment the lactose. Unfortunately, when bacteria metabolize the lactose it produces a lot of gas, which can cause cramping, pain, gassiness, and diarrhea. While most human infants produce lactase, not all adults do. Lactose intolerance between different racial groups is highly variable, but unusually rare in Northern European and some African countries. Populations that produce lactase into adulthood tend to be those with a long history of drinking fresh milk. However, the United States is a multicultural population with ancestries from all over the world. Even Though the percentage of lactose intolerance adults in the United States ranges between 11 to 20%, this number reflects an average across people of many different ethnic backgrounds (Jarvis and Miller, 2002 and Sahi 1994).

References:

3. Jarvis, JK. and GD Miller. 2002. Overcoming the Barrier of Lactose Intolerance to Reduce Health Disparities. Journal of the National Medical Association. 94:55-66
4. Sahi, T. 1994. Hypolactasia and Lactase Persistence: Historical Review and Terminology. Scandinavian Journal of Gastroenterology. 29(202): 1-6.

Patient Number	Race	Glucose Conc. After 7mins (mg/dL)
1	Hispanic-American	500
2	Hispanic-American	500
3	Hispanic-American	1000
4	Hispanic-American	500
5	Hispanic-American	1000
1	African-American	250
2	African-American	250
3	African-American	500
4	African-American	100
5	African-American	1000
1	European-American	1000
2	European-American	1000
3	European-American	1000
4	European-American	500
5	European-American	1000
1	Asian-American	0
2	Asian-American	0
3	Asian-American	250
4	Asian-American	500
5	Asian-American	0

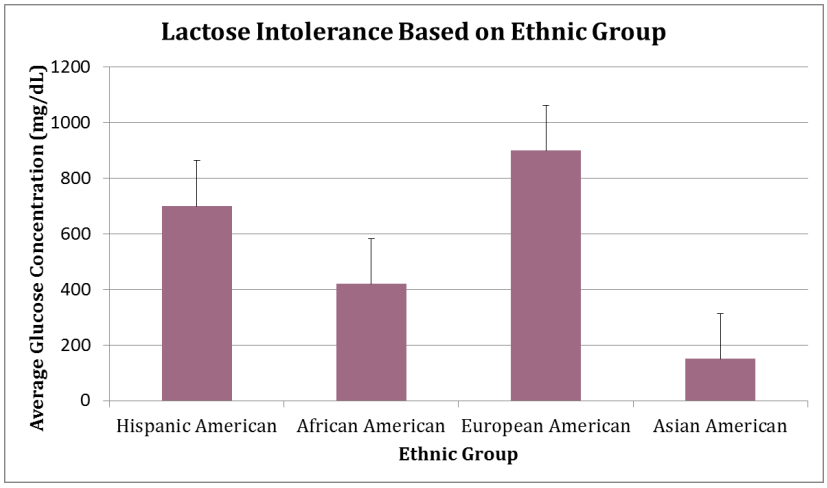
4. Using Excel, calculate the sample size, mean, standard deviation, and standard error for each racial group. Input the data in the table below. (16pts)

Sample	**Sample Size** (n)	**Mean** (mg/dL)	**Standard Deviation**	**Standard Error**
Hispanic American	5	700	273.86	122.47
African American	5	420	354.61	158.59
European American	5	900	223.61	100
Asian American	5	150	223.61	100

5. We don't know what results to expect for any of these groups, so we don't have a control group for comparison. Instead, you should compare the different groups against each other using the online t-test calculator (http://www.graphpad.com/quickcalcs/ttest1/?Format=SEM). Input the p-values in data table below. (12 pts)

t-test p-values	Hispanic-American	African-American	European-American	Asian-American
Hispanic-American		0.1998	0.2415	0.0083
African-American			0.0336	0.1878
European-American				0.0007
Asian-American				

6. Using excel, create a bar graph with the standard error bars. The graph can be attached to this assignment on a separate sheet. The bar graph should include the x and y axes with titles and units, a legend if needed, graph title. (20 pts)



Explanation of Data

3. A brief overall summary of your data. Discussion the descriptive statistics provided in table and the graph created using excel. (12 pts)

4. What does your p-value tell you about the different ethnic groups? Discuss if these groups are significantly different or not? (10 pts)

Appendix 3: Lactose intolerance lab set up

Lactose Intolerance Lab Preparation Information

1. Make 100mL solutions by dissolving lactose powder into water. Autoclave and store in fridge.
    - **White Milk**
2. Make a solution of **100% Lactaid** according to instructions on the box (2 tablets in 100 mL of water).
3. Use **100% Lactaid** solution to prepare **"single race"** solutions as shown in chart below. *Save the rest in fridge or freezer*.
4. Use the **"single race"** solutions to prepare **Multi-racial patient samples** that students will use in lab. See chart below. *Save the rest in fridge or freezer*

"Single-race" Solution	*Racial group*	***C2*** *Final lactaid concentration*	***V1*** *Volume of "100%" lactaid" solution (mL)*	***Water*** *(mL)*	***V2*** *Total Volume Needed (mL)*
1	European American	100%	*50*	*0*	*50mL*
2	African American	*50%*	*25*	*25*	*50 mL*
3	Hispanic American	*20%*	*10*	*40*	*50 mL*
4	Asian American	*10%*	*5*	*45*	*50 mL*
5	Native American	*5%*	*2.5*	*47.5*	*50 mL*

Multiracial Patient Samples	**Racial Combinations**	**Mix together as follows, total of 10mL**
Patient A	European-American African American	*5 mL Solution 1* *5 mL Solution 2*
Patient B	African American Hispanic	*5 mL solution 2* *5 mL solution 3*
Patient C	Asian American European American	*5 mL solution 1* *5 mL solution 4*
Patient D	African American Native American	*5 mL solution 2* *5 mL solution 5*

Supplies per Lab Bench

- 10 mL Milk per bench
- 1 Waste bucket labeled "WASTE" per bench
- 2 Micropipettes p1000 (pre-set to 500ul)and p200 (pre-set to 100ul) per bench
- Micropipette tips
- I Microfuge rack per table
- 5 mL each of Patient samples A, B, C, D per table (4 of each patient per group – bench)
- 5 mL of water labeled "negative control solution" (4 per group – table)
- 5 mL of 10% glucose labeled "positive control solution" (4 per group – table)
- 2 Containers of Glucose test strips per table
- 2 Timers per table
- 2 Permanent Markers per table

Appendix 4: Lactose intolerance research proposal grading rubric

LACTOSE INTOLERANCE RESEARCH PROPOSAL GRADING RUBRIC

USE YOUR OWN HANDWRITING FOR EVERYTHING (exception = printed charts and graphs)

EXPERIEMENTAL DESIGN ITEMS	Points Possible	Points Earned
Background Information *(4 pts each)* ▪ Background information should be written in clear and complete sentences. ▪ Explain what it means to be lactose intolerance. ▪ Explain the relationship between lactase and lactose intolerance. ▪ How do enzymes affect lactose intolerance? ▪ What is the importance of your experimental variables on lactose intolerance? ▪ What is the purpose of the experiment? ▪ List of the references you used to complete the background information section.	28	
Hypothesis: that matches your experimental design. *(3 pts each)* ▪ "***if then*** "statement that clearly maps out the experiment ▪ Explain the scientific reasoning behind your prediction	6	
Materials & Methods (*6 pts each)* ▪ Include all a list of materials need to conduct the experiment ▪ Using complete sentence in future tense, summarize how you will carry out the experiment	12	
Variables: Clearly describe, in complete sentences (*2 pts each)* ▪ Does the experiment design match your hypothesis? ▪ Control and Experimental (test) groups ▪ Independent variable(s) and Dependent variable(s) ▪ Standardized Variable(s)	12	
Data Analysis: Explain how you will record your data. (*3 pts each)* ▪ What will you measure? ▪ What equipment will you use to measure it? ▪ Which statistical methods will you use to analyze your data? ▪ Which websites or computer programs did you use to analyze your data?	12	
Conclusions (*5 pts each)* ▪ In order to **reject** your hypothesis, describe the data you would need to see. Explain your reasoning. ▪ In order to **accept** your hypothesis, describe the data you would need to see. Explain your reasoning.	10	
Total Points	**80**	

Additional Comments:

Appendix 5: Lab journal grading rubric

Lab Journal Grading Rubric

USE YOUR OWN HANDWRITING FOR EVERYTHING (exception = printed charts and graphs)

LAB JOURNAL ITEMS	Points Possible	Points Earned
Appearance (2 pts each) ▪ Table of contents is present and accurate ▪ Neat look, legible and pleasant to behold ▪ Pages are numbered ▪ Any charts, graphs, etc. are affixed inside the notebook (not sticking out) ▪ Permanent Ink Only	10	
Date for each entry	4	
Goal: *What you plan to accomplish today* ***during lab*****?**	4	
Notes (2 pts each) ▪ Record any notes you took during lecture ▪ Record any plans you made for designing experiments ▪ State your hypothesis ▪ Record data collected during the experiment ▪ Describe methods and procedures used during the experiment ▪ Make note of any problems or limitations during the experiment	12	
Results, Discussion and Reflection (2 pts each) ▪ Was the goal accomplished? ▪ Explain your results. ▪ Provide data tables with descriptive statistics (*mean, std. dev, std. error, n*) ▪ Provide data tables with p-values ▪ Provide an overall summary of your study. ▪ Do you accept or reject your hypothesis? ▪ What did you learn?	14	
Total Points	44	
***Bonus Points:** (1 pt. each) ▪ Pictures ▪ Figures ▪ Diagrams ▪ Signature on each page detailing the experiment		
Total Score		

Appendix 6: Mini-poster evaluations and mock review panels

Names of Group Members (Evaluators) _____ Date_____ Section_____

MINI-POSTER EVALUATIONS

Mock Review Panels of Final Posters from Previous Semesters

Write number assigned to the mini- poster that your team will be evaluating: _____

Evaluate the Mini-Poster. For each component of the Mini-Poster, circle a number 1-5.

1= Strongly Disagree**, 2**= Disagree, **3**= Neutral, **4**= Agree, **5**= Strongly Agree

Observations are clearly written and thoroughly explained	1	2	3	4	5
Hypothesis is clearly worded.	1	2	3	4	5
Hypothesis is detailed; explains the scientific reasoning behind the prediction.	1	2	3	4	5
Procedure is clearly worded and easy to follow.	1	2	3	4	5
Experimental approach is described accurately, including techniques	1	2	3	4	5
Experimental design match the hypothesis	1	2	3	4	5
Control and test groups match the hypothesis	1	2	3	4	5
Independent (IV), Dependent variable (DV), and Constants described accurately	1	2	3	4	5
IV and DV match the hypothesis	1	2	3	4	5
Statistical methods described accurately	1	2	3	4	5
Provide the websites and statistical software used to conduct the analysis	1	2	3	4	5
Tables organized, neat and easy to follow	1	2	3	4	5
Data tables contain the statistics (mean, n, std. dev, SEM and p-values)	1	2	3	4	5
Data tables includes units of measurement	1	2	3	4	5
Appropriate graph is used	1	2	3	4	5
Graphs contain a title, labeled X-axis and Y-axis with accurate units	1	2	3	4	5
Provides a detailed description of the results that matches the data	1	2	3	4	5
Provides a brief overall summary of the study that matches the data	1	2	3	4	5
Accurately accepted or rejected the hypothesis or found data to be inclusive	1	2	3	4	5
Future directions provided and explained	1	2	3	4	5

Add up the **TOTAL POINTS**: _____

MANDATORY: Write a few sentences of constructive feedback.

Appendix 7: Mock poster review panel follow-up self-reflection worksheet

MOCK POSTER REVIEW PANEL REVIEW FOLLOW UP SELF-REFECTION WORKSHEET

1. Did you find the mock review panel of final posters from previous semester's activity useful? Explain your answer.

2. After completing the mock review panel of final posters from previous semesters, would you say it was **EASY** or **CHALLENGING** for you to work together to agree on a final score for the mini-posters? Explain your answer.

3. After completing the mock review panel of final posters from previous semesters, how did you feel about providing constructive feedback to another student scientist? Explain your answer.

4. After completing the mock review panel of final posters from previous semesters, how confident are you in constructing a mini-poster worthy of receiving an A for your grade? Explain your answer. *(Scale of* ***1*** *= Not Confident;* ***2*** *= Somewhat Confident;* ***3*** *= Neutral;* ***4*** *= Confident;* ***5*** *Very Confident)*

Appendix 8: Lactose intolerance mini-poster grading rubric

Lactose Intolerance: MINI-POSTER GRADING RUBRIC		
POSTER ITEMS AND GRADING CRITERIA	**Points Possible**	**Points Earned**
Observations *(2 pts each)* ▪ Observations should be written in clear and complete sentences. ▪ Explain the importance of investigating lactose intolerance. ▪ Explain what it means to be lactose intolerance. ▪ What is the research objective for the experiment? ▪ Provide in-text citations and References in APA format	10	
Hypothesis: that matches your experimental design. *(2 pts each)* ▪ "***if then*** "statement that clearly maps out the experiment ▪ Explain the scientific reasoning behind your prediction	4	
Materials & Methods (*6 pts each)* ▪ Using complete sentence in past tense, summarize how you conducted the experiment ▪ Include all of the materials needed to conduct the experiment	12	
Experimental Design: Clearly describe, in complete sentences (*2 pts each)* ▪ Does the experiment design match your hypothesis? ▪ Control and Experimental (test) groups ▪ Independent variable(s) and Dependent variable(s) ▪ Standardized Variable(s)	12	
Data Analysis (*3 pts each)* ▪ What did you measure? ▪ What equipment did you use to measure it? ▪ Which statistical methods did you use to analyze your data? ▪ Which websites or computer programs did you use to analyze your data?	12	
Data Tables ▪ Complete, organized and neat tables *(2pts each)* ▪ Appropriate labels and units *(2 pts each)* ▪ Descriptive Statistics Data Tables *(10 pts each)* - Sample size, mean (average),Standard Deviation, and p-values	30	
Graphs ▪ Title and legend *(1 pt. each)* ▪ Labeled X-axis with units and Y axis with units *(1 pt. each)* ▪ Appropriate graph used of class data (with standard error bars) *(5 pts each)*	10	
Results ▪ Provides a detailed description of the results. (10 pts) ▪ Which group(s) were significantly different at a p-value <0.05? (3 pts) ▪ Which group(s) showed no significant differences? (3 pts) ▪ Did you experience any problems during the experiment? If so, how did you troubleshoot them? (4 pts)	20	
Conclusions ▪ Provide a brief overall summary of the study. 10 pts ▪ Should you **accept** or **reject** the hypothesis? Or is your data inconclusive? 5 pts ▪ Explain your reasoning. 5 pts	20	
Future Directions ▪ To **extend** your knowledge, what experiment would you like to do next? Briefly explain what else you'd like to discover, based on your results.	5	
Total Points	135	

Appendix 9: Preparation sheet for enzyme inhibition and yeast microscopy lab activity

Preparation Sheet for Enzyme Inhibition and Yeast Microscopy Lab Activity

YEAST:

1. Pick a large 3mm colony (clone 9 or clone 10) into 5 mL SD-Ura or SD-Leu or SD-Trp.
2. Shake ~20hr at 30 degrees.
3. Measure OD600, it should be at least 1.0.
4. Make aliquots, 90 microliters per tube, 2 tubes per bench.

SOLUTIONS

1. HCl 0.01M – make 5-10mL
2. Aliquot into tubes 50 microliters each, 2 tubes per bench.

Each bench needs:

- 2 markers
- 2 Waste buckets
- 2 p20 micropipettors
- Pipet tips
- 2 Microfuge tube rack
- 2 tubes of yeast, 90 microliters each
- 2 tubes of 0.1M HCl, 50 microliters each
- 2 tube of deionized water, 500 microliters each
- Slides and coverslips
- 2 tube of methylene blue
- glass waste beaker

Appendix 10: Altering enzyme activity on yeast cells, cell viability and microscopy lab worksheet

Altering Enzyme Activity on Yeast Cells, Cell Viability & Microscopy Lab Worksheet

OBJECTIVES

- Identify the parts of a light compound microscope
- Properly operate a light compound microscope
- Create a wet mount
- Explain altering enzyme activity on yeast cells
- Perform a viability assay to determine the number of *living* cells in a sample.
- Define "enzyme inhibition" and explain how to inhibit enzyme activity using hydrochloric acid (HCl)

BACKGROUND

YEASTS are unicellular Fungi, the simplest eukaryotic cells. They are easy to grow in a laboratory, since their nutritional requirements and environmental needs are few.

- They prefer to grow at 20-30°C, but can tolerate a range of growth temperatures between ~4 – ~45°C. Temperatures that are too high or too low may interfere with enzyme function.
- Yeast need a source of energy and can metabolize various carbohydrates including monosaccharides, disaccharides and some polysaccharides for this.
- Yeast need peptides or amino acids synthesize their own proteins. They need a supply of nitrogen and phosphorus to synthesize their nucleic acids.
- Yeasts require an appropriate concentration of salts and various other ions, to maintain an osmotically and chemically favorable environment.
- Having the proper pH is a major aspect of maintaining a chemically favorable environment. Inside cells, enzymes can become unfolded or denatured at the wrong pH, which reduces or eliminates their activity.

YEAST VIABILITY – Viability refers to the ability of yeast cells to stay alive. Yeast are easy to grow but, also easy to injure or kill by removing what they need. For instance, yeast cannot live if their enzymes cannot function. In this activity we will alter the pH of yeast liquid cultures, which inhibits enzyme activity. Then we will determine if the viability of the yeast was impacted by the change in pH.

MEASURING YEAST VIABILITY –The simplest way to measure yeast cell viability is using a light microscope and a simple stain called ***methylene blue***, which stains DEAD yeast cells. When methylene blue is able to enter yeast cells it will make them appear blue. Yeast cells that are alive will appear clear or opaque because they are able to break down the methylene blue and so it disappears. Cells that are dead are unable to break methylene blue (or anything else) down – they have no metabolic activity. To measure yeast cell viability methylene blue is added to cells, then cells are observed using a light microscope and counted. Figure 1 shows what yeast cells would look like during a typical methylene blue viability assay, a viewed under conditions similar to what you will use. To calculate percent viability, simply divide the number of live (unstained) cells by the total number of cells seen and multiply by 100.

Percent Viability = (number of live cells/total number of cells) X 100

BASIC CHEMISTRY REVIEW!
(http://www.chem.purdue.edu/gchelp/howtosolveit/Equilibrium/Calculating_pHandpOH.htm)

Calculating pH. To calculate the pH of an aqueous solution you need to know the concentration of the hydronium ion in moles per liter (**molarity**). The pH is then calculated using the expression:

$$pH = - \log [H_3O^+].$$

Example: Find the pH of a 0.0025 M HCl solution. The HCl is a strong acid and is 100% ionized in water. The hydronium ion concentration is 0.0025 M. Thus: pH = - log (0.0025) = - (- 2.60) = 2.60

PROCEDURES (*Work in groups of 2.)*

Treat yeast with HCl to inhibit enzyme activity

1. Locate 2 microfuge tubes containing yeast.
2. Using the p20 micropipette, add 10 microliters of HCl to one tube and 10 microliters of water to the other tube.
3. Vortex tubes ~10 sec to resuspend the yeast (disperse the cells evenly in the liquid).
4. Let tubes incubate on your bench for at least 20 minutes.

Preparing and viewing wet mount (live) yeast slides

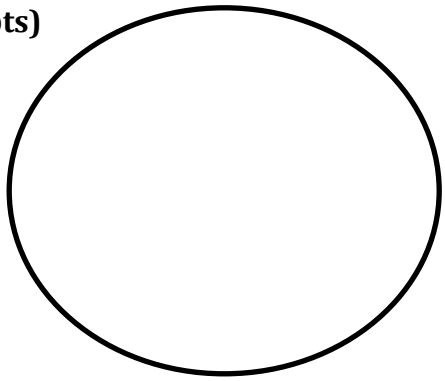
1. Label one empty glass slide for each tube of yeast.
2. Vortex the yeast tube.
3. Add 5 microliters of yeast to the slide then add 5 microliters of methylene blue on the slide. **AVOID BUBBLES!**
4. Following the procedure demonstrated in blackboard, carefully place a coverslip at a 45 degree angle at the edge of the liquid on the slide. Slowly and carefully, let the coverslip gently fall over the liquid to cover it. ****ANGLE and SLOW is important to reduce the chances of bubbles**.
5. Examine slide in a microscope, moving from total magnification of 40X → 100X → 400X.
6. Count a total of 50 cells per slide for the viability assay.
7. Enter data in Table 1.

MICROSCOPE IMAGES OF YEAST SUSPENDED IN HYDROCHORLIC ACID AND WATER

Use the microscope to draw the yeast cells suspended in water and yeast cells suspended in HCl using the 40X objective lens (label each drawing with its TOTAL magnification).

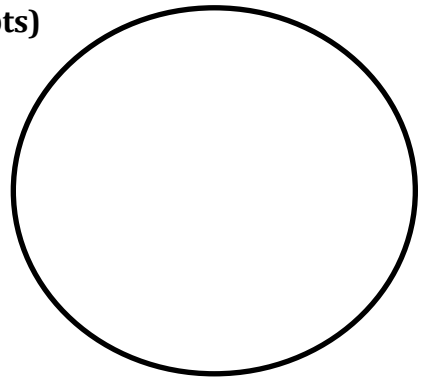
Indicating which yeast cells are dead or alive by labelling them on your drawings (**4pts**).

_____ X (2pts)



HCL Yeast Sample

_____X (2pts)



Water Yeast Sample

RAW DATA TABLE

Table 1: Yeast Survival in Water and HCL after a 20 Minute Incubation Period (**16 pts**)

Yeast Sample	# Live Cells	# Dead Cells	Total	% Live Cells
Water				
HCL				

POST-LAB QUESTIONS

5. Explain your results. Compare and contrast the survival of yeast resuspended in HCL and water. Specifically, discuss the effect of HCl on yeast survival and enzyme activity? (**30 pts**)

6. Did you experience any problems while conducting this experiment? If so, how did you troubleshoot them? (**5 pts**)

Appendix 11: Alcohol fermentation and enzyme inhibition research proposal grading rubric

ALCOHOL FERMENTATION AND ENZYME INHIBITION RESEARCH PROPOSAL

USE YOUR OWN HANDWRITING FOR EVERYTHING (exception = printed charts and graphs)

EXPERIEMENTAL DESIGN ITEMS	Points Possible	Points Earned
Background Information *(4pts each)* ▪ Background information should be written in clear and complete sentences. ▪ In your own words, summarize the alcoholic fermentation process. ▪ Describe the environmental conditions that will cause yeast to carry out alcohol fermentation. ▪ Discuss how an enzyme inhibitor that alters pH could stop enzymes from working. ▪ In your own words, explain the incident at the brewery (**THE CASE**) ▪ What is the purpose of the experiment? ▪ List of the references you used to complete the background information section.	28	
Hypothesis: that matches your experimental design. *(5 pts each)* ▪ "***if then*** "statement that clearly maps out the experiment ▪ Explain the scientific reasoning behind your prediction	10	
Materials & Methods (*6 pts each)* ▪ Include all a list of materials need to conduct the experiment ▪ Using complete sentences in future tense, summarize how you will carry out the experiment	12	
Variables: Clearly describe, in complete sentences (*2 pts each)* ▪ Does the experiment design match your hypothesis? ▪ Control and Experimental (test) groups ▪ Independent variable(s) and Dependent variable(s) ▪ Standardized Variable(s)	12	
Data Analysis: Explain how you will record your data. (*4 pts each)* ▪ What will you measure during this experiment? ▪ What equipment will you use to measure it? ▪ Explain why you will use the equipment. ▪ Explain how you plan to use it. ▪ Which statistical methods will you use to analyze your data? ▪ Which websites or computer programs did you use to analyze your data? ▪ Explain why you will use them to analyze your data.	28	
Conclusions (*5 pts each)* ▪ In order to **reject** your hypothesis, describe the data you would need to see. Explain your reasoning. ▪ In order to **accept** your hypothesis, describe the data you would need to see. Explain your reasoning.	10	
Total Points	**100**	

Appendix 12: Alcohol fermentation and enzyme inhibition mini-poster grading rubric

ALCOHOL FERMENTATION AND ENZYME INHIBITION MINI-POSTER GRADING		
POSTER ITEMS AND GRADING CRITERIA	**Points Possible**	**Points Earned**
Observations *(2 pts each)* ▪ Observations should be written in clear and complete sentences. ▪ What is fermentation? ▪ Explain the incident at the microbrewery. **(IN YOUR OWN WORDS!)** ▪ What is the purpose of the experiment? ▪ Provide in-text citations and references in APA format	10	
Hypothesis: that matches your experimental design. *(2 pts each)* ▪ "***if then*** "statement that clearly maps out the experiment ▪ Explain the scientific reasoning behind your prediction	4	
Materials & Methods (*6 pts each)* ▪ Using complete sentence in future tense, summarize how you will carry out the experiment	6	
Experimental Design: Clearly describe, in complete sentences (*2 pts each)* ▪ Does the experiment design match your hypothesis? ▪ Control and Experimental (test) Groups ▪ Independent Variable(s) and Dependent Variable(s) ▪ Standardized Variable(s)	12	
Data Analysis (*3 pts each)* ▪ Which statistical methods did you use to analyze your data? ▪ Which websites or computer programs did you use to analyze your data?	6	
Data Tables (one for fermentation pH and cell viability) ▪ Complete, organized and neat tables *(1pt each)* ▪ Appropriate labels and units *(1 pt. each)* ▪ Descriptive Statistics Data Tables *(10 pts each)* - Sample size, Mean (average),Standard Deviation, Standard Error of the Mean and p-values	45	
Graphs (one for fermentation pH, and cell viability) ▪ Title and legend *(1 pt. each)* ▪ Labeled X-axis with units and Y axis with units *(1 pt. each)* ▪ Appropriate graph used of class data (with standard error bars) *(5 pts each)*	27	
Results ▪ Provides a detailed description of the results. (10 pts) ▪ Which group(s) were significantly different at a p-value <0.05? (3 pts) ▪ Which group(s) showed no significant differences? (3 pts) ▪ Did you experience any problems during the experiment? If so, how did you troubleshoot them? (4 pts)	20	
Conclusions ▪ Provide a brief overall summary of the study. (10 pts) ▪ Should you **accept** or **reject** the hypothesis? Or is your data inconclusive? (5 pts) ▪ Was an inhibitor added to the suspected medium? If so, what evidence do you have to support your findings? (5pts) ▪ Do the results support the claims of the brewery concerning the alleged contamination of the medium? (5 pts) ▪ Should the employee be compensated for loss of work and rehired? Why? (8 pts)	33	
Total Points	153	
***Bonus Points**: (1 pt. each) ▪ Pictures ▪ Diagrams		

Appendix 13: SSP research proposal preparation follow-up self-reflection worksheet

Name _____ **Section_____**

STUDENT SCIENTIST RESEARCH PROPOSAL PREPARATION FOLLOW UP SELF-REFLECTION WORKSHEET

1. How beneficial did you find preparing your research proposal before starting your student scientist project (SSP)? Explain your answer. *(Scale of **1** = Not Beneficial; **2** = Somewhat Beneficial; **3** = Neutral **4** = Beneficial; **5** Very Beneficial)*

2. After preparing a research proposal, would you say it was **EASY** or **CHALLENGING** to work together to design a detailed experiment? Explain your answer.

3. How useful was the constructive feedback provided the committee that reviewed your proposal? Explain your answer. *(Scale of **1** = Not Useful; **2** = Somewhat Useful; **3** = Neutral; **4** = Useful; **5** Very Useful)*

4. After preparing a research proposal, how confident are you in carrying out your experiment? Explain your answer. *(Scale of **1** = Not Confident; **2** = Somewhat Confident; **3** = Neutral; **4** = Confident; **5** Very Confident)*

5. Did you feel like a student scientist while completing your research proposal? Explain your answer.

6. Discuss additional knowledge you gained from preparing the SSP research proposal.

Appendix 14: SSP research proposal grading rubric and mock peer-review panel feedback worksheet

TITLE OF STUDENT SCIENTIST RESEARCH PROPOSAL:

RESEARCH PROPOSAL GRADING RUBRIC CRITERIA *TYPED ONLY*	**Points Possible**	**Points Earned**
Background Information *(4pts each)* ▪ Background information should be written in clear and complete sentences. ▪ What is yeast fermentation? ▪ Explain the effects of your independent variable on yeast fermentation. ▪ Explain how the independent variable in your study potentially impact the enzymatic activity during yeast fermentation? ▪ What is the importance of your experimental variables on yeast fermentation? ▪ What is the purpose of the experiment? ▪ Provide in-text citations and references in APA format	28	
Hypothesis: that matches your experimental design. *(5 pts each)* ▪ "***if then*** "statement that clearly maps out the experiment ▪ Explain the scientific reasoning behind your prediction	10	
Materials & Methods (*6 pts each)* ▪ Include a list of all the materials need to conduct the experiment ▪ Using complete sentence in future tense, summarize how you will carry out the experiment	12	
Variables: Clearly describe, in complete sentences (*2 pts each)* ▪ Does the experiment design match your hypothesis? ▪ Control and Experimental (test) groups ▪ Independent variable(s) and Dependent variable(s) ▪ Standardized Variable(s)	12	
Data Analysis: Explain how you will record your data. (*4 pts each)* ▪ What will you measure during this experiment? ▪ What equipment will you use to measure it? ▪ Explain why you will use the equipment. ▪ Explain how you plan to use it. ▪ Which statistical methods will you use to analyze your data? ▪ Which websites or computer programs did you use to analyze your data? ▪ Explain why you will use them to analyze your data.	28	
Conclusions (*5 pts each)* ▪ In order to **reject** your hypothesis, describe the data you would need to see. Explain your reasoning. ▪ In order to **accept** your hypothesis, describe the data you would need to see. Explain your reasoning.	10	
Rough Draft Attached	10	
Reviewer Comments - Rough Draft	10	
Total Points	**120**	

ADDITIONAL COMMENTS WILL BE PROVIDED ON THE BACK SIDE OF THIS DOCUMENT

COMMENTS AND SUGGESTIONS FOR SCIENTISTS

The reviewers need to provide a detailed explanation for their scores.

Does the title accurately describe the research study?

Introduction:

Hypothesis:

Methods and Materials:

Variables:

Data Analysis:

Conclusions:

Should this research proposal receive funding? Explain your answer.

Appendix 15: SSP poster grading rubric

STUDENT-SCIENTIST PROJECT – POSTER GRADING RUBRIC

**YF = Yeast Fermentation and CV= Cell Viability*

***IV = Independent Variable, DV = Dependent Variable, EG = Experimental Groups, C= Constants, and CG = Control Groups*

STUDENT NAME_____ **Judge's Name**_____

***Task Description**: A Poster Presentation environment similar to a Scientific Meeting is simulated for the student will act as scientist and present purpose, methods (including data analysis), results and conclusion (implications of the experiment) of your Student-Scientist project to the NCCU scientific community.*

Criterion	Exemplary =4	Competent = 3	Developing = 2	No Attempt = 1	Score
PRESENTER TOTAL POINTS = 12	☐ Confident ☐ Knowledgeable about project topic and accurate ☐ Answered questions with the correct explanation and elaboration	☐ Timid (Nervous) ☐ Comfortable with the topic and accurate ☐ Comfortable with answering questions but little elaboration	☐ Hesitate (Second guessing themselves) ☐ Uncomfortable with the topic, but the content is questionable ☐ Uncomfortable with answering questions and does not elaborate	☐ Unprepared ☐ Do not know the concepts associated with the project ☐ Does not answer questions	
PRESENTATION OF THE RESEARCH TOTAL POINTS = 24	☐ Title specific and informative ☐ Each author name is provided ☐ Text font size is appropriate and consist for each section ☐ Presentation is organized and easy to read ☐ Written in clear English with no grammatical errors ☐ Professional Attire	☐ Title specific, but not informative ☐ One author name is omitted ☐ Text font size is appropriate but not consist for each section ☐ Presentation is organized and somewhat easy to read ☐ Written in clear English with limited grammatical errors ☐ Business Casual Attire	☐ Title not specific nor informative ☐ Two author names are omitted ☐ Text font size is not appropriate but inconsistent for each section ☐ Presentation not easy to follow ☐ Written in clear English with several grammatical errors ☐ Semi-Business Casual Attire	☐ No Title ☐ Two or more author names are omitted ☐ Text font size is not inappropriate ☐ Presentation is unorganized and difficult to follow ☐ Not written in clear English and not grammatical correct ☐ Casual Attire	
PROJECT DESIGN TOTAL POINTS = 16	☐ Project accurately introduced with purpose of experiment ☐ Methods summary completely explained and accurate ☐ Hypothesis provided and justified ☐ Each variable clearly defined (IV, DV, EG, C and CG)	☐ Project sufficiently introduced with purpose of experiment ☐ Methods summary missing key components but accurate ☐ Hypothesis provided but poorly justified ☐ One variable group not defined	☐ Project inadequately introduced with purpose of experiment ☐ Methods summary missing key components and inaccurate ☐ Hypothesis with no justification ☐ Two or more variable not defined	☐ Project poorly introduced and does not contain a purpose of experiment ☐ Methods incomplete and inaccurate ☐ No Hypothesis ☐ No defined variables	

Criterion	Exemplary =4	Competent = 3	Developing = 2	No Attempt = 1	Score
RESULTS TOTAL POINTS = 12	☐ Results clear, consistent and accurate ☐ Includes all statistics (mean, std. dev. and p-values) for YF and CV ☐ Significant differences between the groups are clearly indicated (both YF and CV)	☐ Results vague but accurate ☐ Missing some statistical results but both YF and CV ☐ Significant differences between the group are vague for YF and CV	☐ Results confusing but accurate ☐ Only statistics for either yeast fermentation or cell viability are discussed ☐ Significant differences between the groups indicated for either YF or CV	☐ Results are contradictory and inaccurate ☐ Statistics missing for both YF and CV ☐ Significant differences are not explained or poorly explained	
CONCLUSIONS AND FUTURE DIRECTION TOTAL POINTS = 20	☐ Overall study is clearly accurately summarized ☐ Major implication of research stated ☐ Hypothesis accepted or rejected clearly stated ☐ Clearly describe limitations ☐ Suggest a clear and accurate future research question	☐ Overall study is vaguely summarized ☐ Major implications of research are vague ☐ Hypothesis accepted or rejected is vaguely stated ☐ Vaguely describe limitations ☐ Suggest a vague question for future research	☐ Overall study inadequately summarized ☐ Major implications of research incomplete ☐ Hypothesis inadequately accepted or rejected ☐ Inadequately describe limitations ☐ Random, unrelated future research question	☐ Overall study summary not provided ☐ Major implications not stated ☐ Hypothesis accepted or rejected not stated ☐ No limitations ☐ No future research question	
FIGURES TOTAL POINTS = 16	☐ Neat and easy to read ☐ Accurate descriptive titles for both figures ☐ X and Y axis labeled clearly with the proper units. ☐ Mean & error bars accurately displayed for both YF and CV	☐ Neat, but unclear ☐ Accurate descriptive titles for one figures ☐ X and Y axis labeled clearly without the proper units. ☐ Mean & error bars accurately displayed only on one figure	☐ Neat and Confusing ☐ Inaccurate descriptive titles for one or both figures ☐ X and Y axis not labeled clearly but contains the proper units ☐ Mean accurately displayed but error bars missing	☐ Not neat and confusing ☐ No descriptive titles for figures ☐ X and Y axis without labeled axis and units ☐ Graphs do not accurately represent the data	
TABLES TOTAL POINTS = 16	☐ Neat and easy to read ☐ n-values provided and correct ☐ Mean, Stdev & SEM accurately displayed with units (both YF & CV) ☐ p-value table with descriptive title (both YF and CV)	☐ Neat, but unclear ☐ n-values provided but partially correct ☐ Mean, Std. dev. & SEM accurately displayed but no units (both YF & CV) ☐ p-value table without descriptive title (both YF & CV)	☐ Neat and Confusing ☐ n-values provided by not correct ☐ Mean, Std. dev & SEM accurately displayed with units only on one table ☐ p-value table for either YF or CV	☐ Not neat and confusing ☐ Missing n-values ☐ Mean, Std. dev & SEM not accurately displayed on one or both YF & CV tables ☐ Missing or incomplete p-values	
EXTRA CREDIT TOTAL POINTS = 4	☐ Microscope slide pictures with total magnification and descriptive title	☐ Microscope slides with total magnification but a poorly written title	☐ Microscope slides without total magnification but a poorly written title	☐ Microscope slide without a title or total magnification	
Additional Comments:					**TOTAL POINTS** **/116**

Appendix 16: Example of SSP poster competition winner ("Exemplary")

Soda Sugar Effects on Fermentation Rates

Department of Biological & Biomedical Sciences, North Carolina Central University, Durham, NC

Introduction

Yeast are single-celled eukaryotic organisms that reproduce asexually by budding in aerobic or anaerobic environments. Yeast need a carbon source for energy such as glucose. Glycolysis is used to breakdown the molecule of glucose into the two pyruvate molecules with the net of the two ATP produced during this cycle.

Under anaerobic conditions yeast carries out the metabolic process that converts sugar into acids, gases, or alcohol. Saccharomyces *cerevisiae*, commonly known as Baker's yeast is used to carry out fermentation to produce wine, beer, bread, etc.

In this study the sugar content effect on yeast was investigated. The sodas ginger ale, coke and sprite were used to supply the sugar source for the yeast to carry out fermentation process called yeast fermentation. Yeast fermentation was used to determine which soda would produce a higher carbon dioxide volume based off its their sugar content.

Objectives

The objective of this experiment is to determine the effect of the sugar content in ginger ale, coke, sprite on yeast fermentation (CO_2 volume produced during 50 minutes monitoring period) and cell viability(percentage of live cells after 30 minutes).

Hypothesis

Under anaerobic conditions, if saccharomyces cerevisiae is added to the different sodas (ginger ale, coke and sprite), then the soda with the highest sugar content would produce a faster fermentation rate and a higher cell viability. Sprite contains the highest sugar content than the other sodas therefore, it will produce a faster fermentation rate and a higher cell viability.

Experimental Design

Independent variable: The sugar substrates in the different types of soda solutions.
Dependent variables: CO_2 concentration when the samples are fermenting after being put in the incubator set at 30°C and cell viability when using a microscope.
Standardized Variables: The amount of time spent while the fermentation apparatuses were in the incubator set at the 30°C, the type of yeast used and the amount of solution for the experimental variables and controls.
Control groups: the positive control is glucose and the negative control is water.
Experimental groups: Ginger ale Soda, Coke Soda, and Sprite Soda

Methodology

3mL of 20% yeast solution was added to individual 15mL tubes containing 10mL of the control solutions (water and glucose) and the sodas (ginger ale, coke, and sprite). The 15mL tubes containing the yeast mixtures were then inverted into a individual 50 mL tube to assemble fermentation apparatus and to simulate an anaerobic environment. The fermentation apparatuses were then placed in an incubator set at 30°C so they can maintain a constant temperature.

This incubation period was 50 minutes. Every 10 minutes the fermentation apparatuses were taken out to measure its CO_2 volume. After 30 minutes, 10 microliters was taken out of each yeast mixture from each apparatus and placed into the microcentrifuge tube containing the corresponding dilution solution. 5 microliters was taken out of each microcentrifuge tube and placed on an individual microscope slide and stained with 5 microliters of methylene blue. Each slide was placed under a compound microscope to determine the survival percentage of the yeast cells**. Statistical Methods**: standard deviation, mean, variance, and other functions in Microsoft Excel were used to present and interpret the data. Graphpad was used to conduct a t-test of the p-values for comparing the to the sodas to each other and to glucose.

Results and Discussion

The yeast fermentation rates and cell viability of the different types of sodas were compared based on there sugar content. On average coke produced the highest CO_2 volume(1.38mL ± 0.46mL). Therefore sprite soda produced the lowest CO_2 level(0.83mL ± 0.18mL). When analyzing the cell viability of the soda samples by using a microscope and we were able to see that Ginger Ale on an average was higher for the amount of live cells being (13.50% ± 12.02%) and Sprite soda was the lowest being (5.50% ± 3.54%). When calculating the p-values of sodas, it was determined they were not significantly different to each other because they value showed value higher than 0.05.

Yeast fermentation of data table yeast mixtures for glucose and sodas. (Table 1)

Yeast Mixtures	Mean & Standard Deviation(mL)	SEM
Ginger Ale	1.10mL ± 0.28mL	0.20
Coke	1.38mL ± 0.46mL	0.33
Sprite	0.83mL ± 0.18mL	0.13
Glucose	1.90mL ± 0.99mL	0.70

Yeast cell viability data table of the yeast mixtures for glucose and sodas(%). (Table 3)

Yeast Mixture	Mean & Standard Deviation(%)	SEM
Ginger Ale	13.50% ± 12.02%	0.085
Coke	8.50% ± 7.78%	0.055
Sprite	5.50% ± 3.54%	0.025
Glucose	1.50% ± 2.12%	0.015

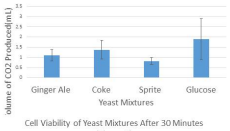
Yeast fermentation t-test results of the yeast mixtures for glucose and sodas(mL). (Table 2)

	Ginger Ale	Coke	Sprite	Glucose
Ginger Ale		0.5460	0.3639	0.3864
Coke			0.2550	0.5665
Sprite				0.2697
Glucose				

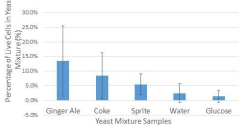
Yeast cell viability t-test results of the yeast mixtures for glucose and sodas(%). (Table 4)

	Ginger Ale	Coke	Sprite	Glucose
Ginger Ale		0.6703	0.4619	0.2989
Coke			0.6688	0.3445
Sprite				0.3040
Glucose				

CO_2 Production After Fermentation (Figure 1)

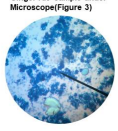


Cell Viability of Yeast Mixtures After 30 Minutes (Figure 2)

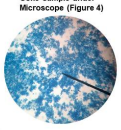


Conclusions

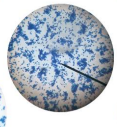
Ginger Ale Sample under Microscope(Figure 3)



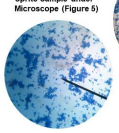
Coke Sample under Microscope (Figure 4)



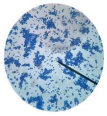
Glucose sample under Microscope (Figure 7)



Sprite Sample under Microscope (Figure 5)



Water sample under Microscope (Figure 6)



Our study shows that yeast fermentation rates and cell viability rates varied at differently in ginger ale, coke and sprite. In conclusion our hypothesis was rejected because coke actually produced a higher fermentation rate and cell viability even though coke did not contain as much sugar as sprite. These findings are important because people who enjoy making homemade sodas can find it very useful for natural carbonation. A limitation for this experiment would be not using a high amount of samples. If more samples were used results and data would be more accurate to analyze. Future Studies: Research shows that by making homemade sodas can be temperature dependent on the yeast fermentation. The same can said with the production of wines.

References & Acknowledgements

- https://www.fatsecret.com/calories-nutrition/sprite/sprite-(12-oz)
- http://www.thekitchn.com/summer-recipe-fresh-peach-soda-recipes-from-the-kitchn-192849

We would like to acknowledge the funding from HHMI Precollege and Undergraduate Science Education Program (Grant # 52007553.

Appendix 17: Example of SSP categorized as "Competent"

The Best Substrate For Fermentation

Department of Biological & Biomedical Sciences, North Carolina Central University, Durham, NC

Introduction

- Yeast fermentation is an anaerobic process where glycolysis is yielded, allowing a yeast solution to produce ethanol and carbon dioxide.
- The three natural sweeteners used were agave, honey, and maple syrup. Saccharomyces cerevisiae will be the yeast solution tested during the experiment.
- The monosaccharides that compose honey and maple syrup include glucose and frutose, sucrose.
- Agave stems from the cactus agave tequilana in Mexico. The carbohydrate composition is 70% frutose.
- The three natural sweeteners can be used in the manufacturing of beer and juices as a sweetener substitution.
- The GI (glycemic index) is lower in substrates that avoid crystallization and are in a loose or raw form. All three substrates have a low GI. GI rates determine how blood levels elevate due ton glucose in the blood stream levels.

Objectives

- The purpose of the experiment is to determine which natural sweetener will have the greatest effect on yeast fermentation in saccharomyces cerevisiae; in addition to calculating cell viability of substrates after a 30 min interval has passed.

Hypothesis

- If the substrate honey has a higher carbohydrate composition of glucose then more carbon CO_2 bubbles will be produced during fermentation.

Experimental Design

There was both a positive and negative control used during the experiment. The positive control is glucose and this is because there needs to be a presence of sugar in the experiment. The negative control is H_2O because it breaks down glucose. The independent variables of this experiment are the substrates maple syrup, honey, and agave. Our dependent variables are the cell viability, CO_2 production, and fermentation. The experimental group includes substrates: agave, honey, and maple syrup. These substrates will be tested in order to see which will affect the yeast fermentation process. The standardized variables are time allotted during the incubation process. Methylene blue and the amount of the sweeteners used to conduct the experiment are also standardized variables.

Methodology

- First, use a micropipette to transfer 3mL of yeast culture into a 15mL conical tube. In that same tube there will be 10mL of each substrate mixture. Pour yeast/experimental mixture into a 15mL tube with holes in the cap. Place each tube upside down into a fermentation apparatus. Mark along the sides to indicate the volume. Place the tubes into a tube rack and place the rack into an incubator set to 30°C. You will check the tubes every 10 minutes for a total of 50 minutes and collect the volume of how much CO_2 is produced. After 30 minutes, create a wet mount for each substrate mixture. You will add 5mL of the dilution solution and substrate mixture onto the slide and 5mL of methylene blue. You will check the cell viability of each wet mount. At the end of the three week period, we will normalize our data and average out the two sets of data collected from two groups. We averaged out our cell viability as well as yeast fermentation data collected over the 50 minute trial. Microsoft Excel was used to calculate descriptive statistics and Graphpad was used to determine the P-values of both the yeast fermentation and cell viability.

Results and Discussion

Table One: P-Values of Cell Viability in Substrates

T-Test P-values	Maple Syrup	Honey	Agave	Glucose
Maple Syrup		0.0505	0.0001	0.0451
Honey			0.0001	1.0000
Agave				0.0001
Glucose				

Table 1: This table displays the p-values of the cell viability for the 3 substrates and positive control over a 3week period. Maple Syrup and honey, as well as glucose and maple syrup was statistically significant. This shows us that our hypothesis was incorrect and that maple syrup affected the CO2 production in yeast fermentation.

Table 2: Descriptive Statistics Of Substrates

Descriptive Statistics	Agave	Honey	Syrup	Glucose
X	10mL	8.75mL	9.25mL	11mL
X	10.5mL	9.75mL	11.75mL	11.5mL
X	10.25mL	9.75mL	10.5mL	8.25mL
Average	10.25mL	9.42mL	10.5mL	10.25mL
STDEV	.25mL	.60mL	1.25mL	1.75mL
Standard Error	0.14mL	0.33mL	0.72mL	1.01mL

Table 2: This chart is the yeast fermentation average over a 3week period. In the table above the descriptive statistics are included. We averaged out the volume for each substrate and positive control over the three week period. Above, the descriptive statistics include standard deviation, average, and standard error.

Table 3: P-Values of Yeast Fermentation

AGAVE	HONEY	SYRUP	GLUCOSE
	0.0433	0.7084	1.000
		0.1703	0.8239
			0.1703

Table 3: This table displays the average p-values of the a three week period. In the table above honey is statistically significant.

Figure 1 Which Substrate will affect Yeast Fermentation?

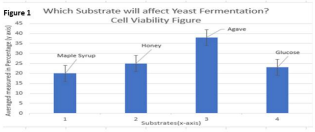


Figure 1: This figure displays the cell viability average of the three substrates and the positive control. The average shows us which substrate had the highest and lowest amount of alive cells in this experiment. The average displays Maple Syrup had the least amount of live cells under the microscope. Agave had the highest amount of live cells out of the 4 tested variables. This supports the fact that maple syrup was the substrate that affected the yeast fermentation process. The average is measured in percentage.

Figure 2: Average of Yeast Fermentation for Substrates

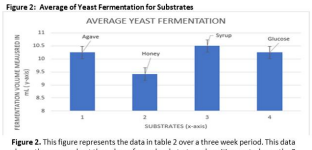


Figure 2. This figure represents the data in table 2 over a three week period. This data shows the averaged out the volume for each substrate and positive control over the 3 week period. Above, the descriptive statistics include standard deviation, average, and standard error.

Table 4: Descriptive Statistics of Cell Viability

Descriptive Statistics	Agave	Honey	Syrup	Glucose
Week 1	36	24.5	20	22
Week 2	37.4	23	21.5	24
Week 3	36	24	21.5	22
Average	36%	24%	22%	23%
Standard Deviation	1.72240 1	1.16904 5	1.632993 /	1.04880 9
Standard Error	0.70316 7	0.47726 1	0.666667	0.42817 4

Table 4: This chart represents the cell viability over a three week period. Above displays the descriptive statistics of cell viability for the three substrates and positive control. We averaged out our viability in order to find the average, standard deviation, and standard error. One can see that Maple Syrup had the lowest amount of live cells.

Conclusions

- Using the bakers yeast, the results show that maple syrup goes through the fermentation process the quickest (10.5mL) while the honey goes through fermentation the slowest (9.42mL). With agave and glucose in the middle (10.25mL)
- The hypothesis was incorrect, Maple Syrup had the most amount of CO_2 bubbles by 1.08mL from honey which was the least amount. This is because maple syrup has the highest carbohydrate composition of glucose
- These results are important because a natural sweetener such as maple syrup can be used instead of the processed sugar we use today.
- Limitations with the experiment was not having the incubator at 30°C the entire time through the intervals. This is because there were other groups using the incubator. Another limitation was not having the exact measurements while using the micropipettes during the transfer process to do the microscope slides because the substrate would get stuck on the side of the tube. This limited the results because not all of the sample would be on the microscope slide. So the cell viability may have been thrown off a little.
- **Future Studies**: Instead of doing a 50 minute trial, we would test it for a hour so that we can get a better representation of the CO_2 production. If we conducted this experiment for a month would that change our results?

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We would like to acknowledge the funding from HHMI Precollege and Undergraduate Science Education Program (Grant # 52007553.

Appendix 18: Example of SSP categorized as "Developing"

How Does Various Temperatures Effect Yeast Fermentation and Cell Viability.

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Introduction

Saccharomyces cerevisiae otherwise known as baker's yeast, is used in winemaking, baking, and brewing. Saccharomyces cerevisiae is not only used for food and drink consumption but it can be used as over the counter medicine for common colds and flu symptoms.

•This yeast ferments differently when it is under different temperatures. The research question of this experiment is: How does various temperatures effect yeast fermentation and cell viability? Saccharomyces cerevisiae was used in this experiment. When temperatures are high, yeast tend to ferment quickly but when temperatures are low yeast takes a longer time to ferment. temperatures also plays an effect on the cell viability rate. If temperatures are too high, or too low the cells may be killed. It is imperative to know the effect temperatures have on yeast fermentation, because it will allow you to know what environment is best to produce yeast in.

•This experiment was conducted for the purpose of determining whether yeast fermented faster in hot(60°C), cold(9°C), or room temperatures(22°C).

Objectives

- Our objective is to find the optimal temperature for yeast fermentation
- We are researching this to see how various temperatures affect the yeast fermentation process.
- These various temperatures being an ice bath(9°C), room temperature(22°C), and a hot bath(60°C)

Hypothesis

•If the yeast is fermented at various temperatures being 9°C, 22°C, 60°C and they all have different outcomes, then it can be assumed that the yeast ferments better in one temperature than the other based off the average fermentation rate, and cell viability

•There are optimal growing temperatures that yeast thrive in which is between (20°C-30°C). Outside of those optimal temperatures the yeast fermentation process will be hindered. If the temperature becomes too low around (10°C), then the enzyme reaction will slow to a point where it won't work. If the temperature becomes too high around (40°C), then the enzymes will denature and unfold and becomes inactive.

Experimental Design

The control group for this experiment is the room temperature deionized water. The experimental group and the independent variable for this experiment is the 9° C cold bath, 22°C room temperature and the 60°C heated bath. The dependent variable for the experiment would be the fermentation rate of the 20% yeast and 5% glucose solution. The standardized variables would be the amount of time to ferment the 20% yeast, 5% glucose, dilution solution and deionized water.

Methodology

- Use a transfer pipette to transfer 3 mL of the 20% yeast solution directly into the 15 mL conical tube containing 10 mL of 5% glucose solution.
- Shake and pour 20% yeast and 5% glucose solution into 15 mL tube with holes in cap
- After pouring solution into the slip conical tube over and invert tube
- Take initial volume and place fermentation apparatus in incubator, refrigerator, and heated bath.
- Every 10 minutes mark the volume of the rate of fermentation for 50 minutes
- After 30 minutes of fermentation make a wet mount from the fermentation apparatus that was place in the incubator, refrigerator, and heated bath. Using 10 µl of the yeast solution and 10 µl of the dilution solution. Mix and take 5 µl of that solution. And stain with 5 µl of 0.1% methylene blue
- Place experimental solution back in its appropriate place and examine wet mounts under the microscope
- During this experiment, we used measured the fermentation rate of saccharomyces cerevisiae and the cell viability of fermented saccharomyces cerevisiae.
- The website that we will be using to analyze the data is graphpad. We will be using graphpad to conduct the test which will compare the means of the experimental group and the control group and calculate the p-values. We will also be using microsoft excel to, we will be using microsoft excel to calculate the mean, standard deviation, standard error of the mean, and to create graphs.

Results and Discussion

Figure 1 Fermentation Rate

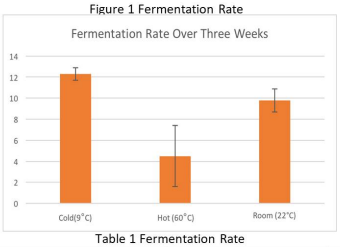

Figure 2 Cell Viability Percentages

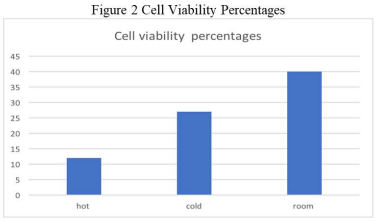

Table 1 Fermentation Rate

experimental variables	Sample size	Mean	Stdev	Std Error
Cold(9°C)	6	12.3	0.6	.3
Hot(60°C)	6	4.5	2.9	1.2
Room temp(22°C)	6	9.8	1.1	.5

Table 2 Cell viability

experimental variables	Cell viability
Cold	27%
Hot	12%
Room temperature	40%

- Figure 1 is a bar graph that shows the results of the yeast fermentation in different temperatures.
- Table 1 is a table that shows the summary of the data collected over the three week period
- Figure 3 is a bar graph that shows results of the cell viability from the total amount of live and dead cells from the three weeks of research.
- Table 2 displays the percentages of the cell viability in the samples
- The hot temperature samples had an average of 12.5 ml yeast fermentation after 3 weeks of collecting data.
- The room temperature samples had an average of 9.8 ml yeast fermentation after 3 weeks of collecting data.
- The cold temperature samples had an average of 4.5 ml yeast fermentation after 3 weeks of collecting data.

The experimental groups were extremely significantly different from the control. The p-values were less than 0.05.

Conclusions

- Overall results show that yeast ferments faster in hot temperatures (60°C). Room temperature (22°C) had an average of 9.75ml fermentation, cold temperature (9°C) had a average of 4.45ml, and the hot temperature (60°C) had a an average of 12.25ml. Results prove that the higher temperature worked as an enzyme, while the colder temperature worked as an inhibitor. This is proven because the higher the temperature the faster the yeast fermented , but for the lower temperature the yeast barely fermented. For cell viability, results showed that yeast is mostly likely to have a higher cell viability rate in room temperature, which is understandable because the optimum temperature for yeast is 20-30°C. Room temperature (22°C) had a cell viability rate of 40%, hot temperature (60°C) had a cell viability rate of 12 % , and cold temperature (9°C) had a cell viability rate of 27%. Room temperature had a higher cell viability rate than the other two experimental variables, because it was placed in the optimum temperatures, so the cells were able to thrive. The hot temperature, and cold temperature were not the appropriate environment for the yeast so they were killed.
- Our hypothesis was accepted because the he data showed that one of the temperatures in fact did act more as an inhibitor than the other two different temperatures causing for a lower fermentation rate and lower cell viability in the yeast cell. This is because the the temperature would have acted as an enzyme and slowed the reaction down.
- These results are important because they can be used to effectively ferment yeast. These results will allow bakers, and anyone else know at what temperature yeast ferments the best, and the worst.
- Limitation during this experiment includes :the incubator being left open, timers not being set, the hot bath was not prepared, the thermometer was broken for the cold samples.
- At what room temperature degrees does yeast ferments the best. We would like to perform the same experiment with the variable being room temperature at different degrees.

References & Acknowledgements

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We would like to acknowledge the funding from HHMI Precollege and Undergraduate Science Education Program (Grant # 52007553.

Appendix 19: Student self-reflection responses about student-scientist curriculum

QUESTION: "Did you find the mock review panel of final posters from previous semesters activity useful?"

Yes (96%)

- I found it useful because it made me see what should and shouldn't be included in the poster. It gave me kind of a sense of structure when approaching the mini posters/final posters.
- The mock review panel was very useful. I was able to see two examples of a mini poster. One poster was an effective example and the other one was an ineffective poster. I was able to judge both posters and see what is expected of us on our own mini posters. One poster provided too much information while the second one provided enough and was better to understand.
- I can see the mistakes made by other people and ensure that those same mistakes are not made on mine. As well as, I can see an example of what it should like and see the perspective of the grader, which should help my score tremendously.

Somewhat (4%)

- Slightly, however, I still feel as only experience will benefit me better.

QUESTION: "Did you feel like a student-scientist while completing your research proposal?"

Yes (68%)

- This is the first "real" project where we are carrying out the experiment by ourselves rather than following set guidelines and rules.
- Lessons were learned such as learning to research background info like a regular scientist would.
- I did feel like a student scientist. I read background information and worked on conducting our own experiment. It was very hands on.

Somewhat (9%)

- I believe that I still need more experience to feel like a student scientist.
- I'm just starting to do such experiments. I'll wait until I get in my junior year to confirm that.

No (23%)

- I was just trying to finish the work.
- I was confused and I am really lost. Luckily my group members help me out when I need it.
- I felt like a panicked college student.

QUESTION: "Did you feel like a student-scientist while completing your research experiment?"

Yes (77%)

- I was not only conducting an experiment, but I was also following the scientific process, like as scientists.
- Completing my experiment on my own allowed me with the opportunity to be independent and collecting the results from the experiment which we created.
- You have to have critical thinking in order to process what is really happening. A scientist student project is more challenging than a regular project. In our previous experiment, you gave us the data but on this one we had to build it on our own.

Somewhat (13%)

- We did deal with experimental equipment, but the setting did not feel scientific.
- I sort of felt like a scientist it definitely showed me how scientist do what they do. I don't feel that being a scientist is something I'm interested in.
- Sort of because we normalized data, and used a micropipette

No (10%)

- During the research experiment, I was more focused on trying to finish than trying to understand what I was doing.
- This was more so just for a grade.
- My group members helped me a lot. I'll prefer if the teacher demonstrated how to carry out the experiment before we do it ourselves.

QUESTION: "After completing the student-scientist project, what are your thoughts about executing the scientific process and conducting a research project?"

Positive (58%)

- This project has made me look at science in a different way. If asked to do this project again, I would quickly do so.
- It has given me confidence to conduct research projects in the future.
- My thoughts are clearer on how to carry out an experiment. I understand there is a lot of work to do for student scientist projects, but I am looking forward to doing more.

Neutral(43%)

- It requires patience and more importantly background knowledge about the experiment.
- The scientific process and conducting a research project takes a lot of time and planning for it to be successful.
- I think it requires much more writing and paying attention to detail than I first thought.

Negative(15%)

- It is a lot of work.
- It is a long and tedious process that requires a lot of work.
- That project was stressful.

QUESTION: "Would you recommend a student-scientist curriculum to your friends?"

Yes (78%)

- My friends would benefit from this lab. Although the lab required lots of patience, students were able to gain knowledge, presentation skills and research skills.
- It is a good experience. Especially, if you've never took part in a lab.
- I would because you learn some great skills that you may not gain from a traditional lab.

Somewhat (22%)

- It was an exhausting.
- It is too stressful and takes a lot of time from other classes.
- It is stressful, extremely time consuming, and ask for too much effort and hard to do