

THE CHEMIST'S COOKBOOK

Written by Amy Rowley and Jeremy Peacock

Annotation:

In this laboratory exercise, students will explore product formulation and quality control, perform metric conversions, and evaluate accuracy and precision as they follow a scientific protocol to prepare cookies.

Primary Learning Outcomes:

Students will be able to convert metric measurements to standard measurements.

Students will be able to define the terms *accuracy* and *precision*.

Students will be able to calculate the arithmetic mean and relative standard deviation of a dataset.

Students will be able to use relative standard deviation to describe the precision of a set of measurements.

Students will be able to calculate the mean percent difference between an observed mean and a given, standard value.

Students will be able to use mean percent difference to describe the accuracy of a set of measurements.

Students will be able to define the term *quality control* and describe its importance in the production of a food product.

Students will be able to explain the importance of product formulation in the design of a new food product.

Georgia Performance Standards:

Characteristic of Science

SCSh2. Students will use standard safety practices for all classroom laboratory and field investigations.

SCSh3. Students will identify and investigate problems scientifically.

SCSh4. Students will use tools and instruments for observing, measuring, and manipulating scientific equipment and materials.

SCSh5. Students will demonstrate the computation and estimation skills necessary for analyzing data and developing reasonable scientific explanations.

SCSh6. Students will communicate scientific investigations and information clearly.

Related Topics:

Metric Conversions

Data Analysis

- Accuracy and Precision
- Standard Deviation
- Mean Percent Difference

Duration:

Preparation: 70 minutes

Introduction: 30 minutes

Student Activity: 90 minutes

Conclusion: 30 minutes

Total Class Time: 150 minutes

Materials and Equipment:

- | | |
|--------------------------------|-------------------------------|
| 1. All-purpose flour | 11. Measuring spoons |
| 2. Baking soda | 12. Small mixing bowl |
| 3. Salt | 13. Large mixing Bowl |
| 4. Butter | 14. Mixing spoon |
| 5. Granulated [white] sugar | 15. Hand mixer |
| 6. Brown sugar | 16. 4 Non-stick baking sheets |
| 7. Imitation vanilla flavoring | 17. Oven mitts |
| 8. Eggs | 18. Oven |
| 9. Semi-sweet chocolate chips | 19. Balance |
| 10. Measuring cup | 20. Metric ruler |

Per Student:

1. *The Chemist's Cookbook* student handout

Safety:

The primary safety concern in this laboratory exercise is the heat produced during cooking. Ensure that students wear dry oven mitts and use caution when handling hot objects. Because students will consume the product of this activity, be sure to prepare the cookies outside the laboratory (*e.g.* in a home economics classroom or the school cafeteria). Use ingredients and equipment that are not used or stored in the laboratory.

Technology Connection:

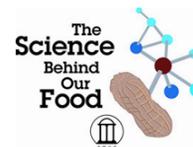
At the teacher's discretion, students may use calculators or computer spreadsheet software to complete required calculations.

Procedures:

This laboratory exercise is organized in three sessions as outlined below.

SESSION ONE:

- Introduce the activity to students by reviewing the introduction provided below.
- Provide students with *The Chemist's Cookbook* student handout and review the overall assignment.



- Instruct students to complete, as homework, the pre-laboratory assignment found on *The Chemist's Cookbook* student handout.

SESSION TWO:

- Have students complete the laboratory assignment and post-laboratory questions found on *The Chemist's Cookbook* student handout.

SESSION THREE:

- Conclude the activity as described in the conclusion below.

Teacher Preparation:

SESSION ONE:

Use the attached template to prepare a copy of *The Chemist's Cookbook* student handout for each student.

Estimated Time:

10 minutes

SESSION TWO:

Teacher Preparation:

The standard chocolate chip cookie recipe follows.

1. 2 $\frac{1}{4}$ c. All-purpose flour
2. 1 tsp. Baking soda
3. 1 tsp. Salt
4. 1 c. Butter, softened
5. $\frac{3}{4}$ c. Granulated [white] sugar
6. $\frac{3}{4}$ c. Packed brown sugar
7. 1 tsp. Vanilla extract
8. 2 Eggs
9. 12 oz. Semi-sweet chocolate chips

Following the procedures given on *The Chemist's Cookbook* student handout, this recipe will make approximately 36 cookies. Obtain enough of the above materials to allow each group to complete the full recipe. Arrange for access to the equipment listed above and arrange to complete the activity outside of the laboratory. Ideally, the activity can be completed in a home economics classroom that is stocked with the required measuring and cooking equipment. Prepare student stations by placing necessary materials and equipment at each station. *Note: This exercise may also be completed using store-bought cookies. Cookies purchased from a bakery generally exhibit greater variability and are preferable to commercially produced, brand-name cookies.*

Estimated Time:

60 minutes

Introduction:

Stop and think about opening a new bag of Chips Ahoy® chocolate chip cookies. Each cookie seems to be exactly the same shape, size, and color. Every cookie has just the right number of chocolate chips, and as you bite into each cookie, you get the same perfect crunch.

We have all come to expect perfection in our foods. That means that food manufacturers must dedicate more and more resources to delivering consistently high quality foods with no mistakes and no excuses. All food companies employ some form of **quality control**, *i.e.* a system by which a desired standard of quality in a product or process is maintained. No matter what form a quality control system takes, the foundation is formed by solid, science-based product formulation. When developing a new food product, the product formulation provides a standardized recipe and protocol for production of a high-quality product. In order to maintain product consistency, samples of the product are regularly evaluated against standards for size, shape, color, flavor, texture, and nutrient content. Any products found that do not meet these standards are never allowed to reach the consumer. Thus, a well-tested product formulation is the basis for any successful new product.

Explain to students that in this activity, they will perform their own quality control as they follow a standard formulation to make chocolate chip cookies and then evaluate their cookies against product standards. In particular, students will compare the average mass and average diameter of their cookies to standard values. Any time we wish to evaluate observed values against a standard, there are two critical concepts to keep in mind: accuracy and precision. **Accuracy** refers to the extent to which a measurement agrees with the true value or standard. To use a classic example, if a marksman takes several shots at a bulls-eye, accuracy describes how close those shots are to hitting the bulls-eye. In this activity, accuracy will refer to how close students' cookies are to matching product standards. **Precision**, on the other hand, refers to the extent to which individual measurements of the same quantity agree. In our classic example, precision refers to how close the marksman's shots are to one another. In this activity, precision will refer to the consistency of students' cookies (*i.e.* How much do mass and diameter vary between individual cookies?).

Note: In order to evaluate the accuracy and precision of their cookie production, students will use the statistical concepts of arithmetic mean, mean percent difference, and relative standard deviation. Students will also use the concept of mean percent difference. Before assigning these calculations, review or introduce these concepts to your students. For the purposes of this activity, *mean* (\bar{X}) is taken to be the average value of a set of numbers and is calculated using the following equation,

$$\bar{X} = \frac{(x_1 + x_2 + \dots + x_n)}{n}$$

where x_1 ; x_2 ; \dots ; x_n are the individual observations and n is the total number of observations.

Accuracy of students' cookie production will be evaluated by comparing the mean values of mass and diameter to the respective standards by calculating the *mean percent difference (MPD)*, which is calculated using the following equation,

$$\text{MPD} = \frac{\bar{x}_{\text{obs}} - x_{\text{Std}}}{x_{\text{Std}}} \hat{=} 100\%$$

where \bar{x}_{obs} is the observed mean and x_{Std} is the standard value.

The precision of students' cookie production will be evaluated by calculating the standard deviation of the data sets for mass and diameter, respectively. *Standard deviation* (s) is a measure of how a set of data varies from its mean and is given by the equation

$$s = \sqrt{\frac{(x_1^2 + \dots + x_n^2) - \frac{(x_1 + \dots + x_n)^2}{n}}{n - 1}}$$

where x_1 ; x_2 ; \dots ; x_n are the individual observations and n is the total number of observations.

In order to obtain a more meaningful value for precision, standard deviation can be adjusted by calculating the *relative standard deviation* (RSD). RSD expresses standard deviation as a percentage of the mean and is given by the following equation.

$$\text{RSD} = \frac{s}{\bar{x}} \hat{=} 100\%$$

Estimated Time:

30 minutes

Student Activity:

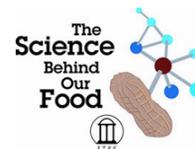
Pre-Laboratory Assignment:

Students should...

1. Familiarize themselves with the laboratory procedures.
2. Write in their laboratory notebooks an introduction summarizing the information presented to them during the introductory lecture.
3. Write in their laboratory notebooks the purpose, materials, procedures provided on *The Chemist's Cookbook* student handout.
4. Review the list of reagents and identify and record in a table in their laboratory notebooks the common name of each ingredient.
5. Convert all metric values found in the reagent list and procedures to their standard equivalents and record in a table in their laboratory notebooks. (*Show all calculations.*)

Laboratory Assignment:

Students should follow the laboratory procedures set forth in *The Chemist's Cookbook* student handout and prepare a laboratory report communicating their results.



Estimated Time:

90 minutes

Conclusion:

Compile class data on the board. Discuss with students their accuracy and precision in making cookies. Also discuss measures taken by the food industry to ensure the quality and consistency of their products.

Estimated Time:

30 minutes

Assessment:

Assessment should be based on *The Chemist's Cookbook* Scoring Rubric provided on page 28.

References:

- Christen, G.L. and J.S. Smith (Eds.). 2000. *Food Chemistry: Principles and Applications*. Science Technology System, West Sacramento, California.

THE CHEMIST'S COOKBOOK *Scoring Rubric*

CRITERIA	10	9-8	7-5	4-0	SCORE
Introduction	Introduction is a clear, concise, and thoughtful description of the laboratory exercise. It reflectively shows how the laboratory exercise fits into the curriculum.	Introduction is a brief description of the background of the laboratory exercise.	Introduction is too brief, unrelated to the laboratory exercise, or provides little or no background information.	Introduction is a copy of the material provided or is missing.	_____ Comments:
Purpose	Purpose of the laboratory exercise is clearly identified and stated.	Purpose of the laboratory exercise is identified, but is stated in a somewhat unclear manner.	Purpose of the laboratory exercise is partially identified, and is stated in a somewhat unclear manner.	Purpose of the laboratory exercise is erroneous or missing.	_____ Comments:
Materials	All materials and equipment used in the laboratory exercise are clearly and accurately described.	Almost all materials and equipment used in the laboratory exercise are clearly and accurately described.	Most of the materials and equipment used in the laboratory exercise are accurately described.	Many materials or equipment used in this laboratory exercise are described inaccurately or are not described at all or are missing.	_____ Comments:
Procedures	All procedures are listed in clear steps. Each step is numbered and is a complete sentence.	All procedures are listed in a logical order, but steps are not numbered and/or are not in complete sentences.	All procedures are listed but are not in a logical order or are difficult to follow.	Procedures do not accurately list the steps of the experiment or are missing.	_____ Comments:

Data Collection	Data is accurate and is presented in a professional manner. Data is recorded with appropriate precision. Graphs and tables are correctly labeled and titled.	Data is accurate and recorded with the appropriate precision. Graphs and tables are labeled and titled.	Data is accurate and recorded with the appropriate precision. Graphs and tables are not used or are incorrectly labeled and titled.	Data are not shown or are inaccurate.	_____ Comments:
Data Analysis	All calculations are shown and the results are correct and labeled appropriately.	Some calculations are shown and the results are correct and labeled appropriately.	Some calculations are shown and the results are labeled appropriately.	No calculations are shown or results are inaccurate or mislabeled.	_____ Comments:
Results	MPD \leq 10% RSD \leq 10%	10% < MPD \leq 25% 10% < RSD \leq 25%	25% < MPD \leq 50% 25% < RSD \leq 50%	MPD > 50% RSD > 50%	_____ Comments:
Discussion	Discussion is a clear, complete, and thoughtful response to the post-laboratory questions. Discussion is written in paragraph form and is free of grammar and spelling errors.	Discussion is a sufficient but brief response to the post-laboratory questions. Discussion is written in paragraph form but is somewhat unclear.	Discussion is unclear or a superficial or inaccurate response to the post-laboratory questions. Discussion may not be written in paragraph form or may contain many grammar and spelling errors.	Discussion disregards post-laboratory questions, shows little effort, or is missing.	_____ Comments:
Safety	Laboratory exercise is	Laboratory exercise is	Laboratory exercise is	Safety procedures were	

	carried out with full attention to relevant safety procedures. No part of the laboratory exercise posed a safety threat to any individual.	generally carried out with attention to relevant safety procedures. No part of the laboratory exercise posed a safety threat to any individual, but at least one safety procedure was not followed.	carried out with some attention to relevant safety procedures. No part of the laboratory exercise posed a safety threat to any individual, but several safety procedures were not followed.	ignored and/or some aspect of the laboratory exercise posed a threat to the safety of the student or others.	_____ Comments:
Participation	Student used time well in the laboratory and focused attention on the exercise. Student cleaned and returned all equipment to its proper location.	Student used time pretty well in the laboratory and stayed focused on the exercise most of the time. Student cleaned and returned all equipment to its proper location.	Student did the laboratory exercise but did not appear very interested. Focus was lost on several occasions. Student cleaned and returned all equipment to its proper location.	Student participation was minimal, or student did not clean and return all equipment to its proper location.	_____ Comments:
Total Score (out of 100):					_____

THE CHEMIST'S COOKBOOK *Student Handout*

Introduction:

Stop and think about opening a new bag of Chips Ahoy® chocolate chip cookies. Each cookie seems to be exactly the same shape, size, and color. Every cookie has just the right number of chocolate chips, and as you bite into each cookie, you get the same perfect crunch.

Because we have all come to expect perfection in our foods, food companies must employ strict quality control measures in order to maintain product consistency. Product samples are regularly evaluated against standards for size, shape, color, flavor, texture, and nutrient content. Thus, a well-tested product formulation is the basis for any successful new product.

In this activity, you will perform quality control as you follow a standard formulation to make chocolate chip cookies and then evaluate your cookies against product standards. You will compare the average mass and average diameter of your cookies to standard values.

Purpose:

To follow a standard formulation to produce a consistent, high-quality food product—chocolate chip cookies.

Pre-Laboratory Assignment:

1. Familiarize yourself with the laboratory procedures.
2. Write in your laboratory notebook an introduction summarizing the information presented to you during the introductory lecture.
3. Write in your laboratory notebook the purpose, materials, procedures provided.
4. Review the list of reagents below. Identify and record on the student handout the common name of each ingredient.
5. Convert all metric values found in the reagent list and procedures to their standard equivalents and record on the student handout.

Useful Conversions:

1 cup = 8 fl. oz. = 16 tbsp. = 48 tsp. = 237 mL

Density of butter = 0.954 g/mL

1 lb. = 454 g = 16 oz.

Materials and Equipment:

Equipment:

- | | |
|------------------------------|------------------|
| 1. Measuring cup | 8. Oven mitts |
| 2. Measuring spoons | 9. Oven |
| 3. Small mixing bowl | 10. Balance |
| 4. Large mixing Bowl | 11. Metric ruler |
| 5. Mixing spoon | |
| 6. Hand mixer | |
| 7. 4 Non-stick baking sheets | |

Reagents:

Metric Value	Description	Standard Value	Common Name
533.25 mL	Finely milled wheat grains		
5 mL	NaHCO ₃		
5 mL	Iodized, granular NaCl		
226 g	80% Milkfat, water-in-oil emulsion		
177.75 mL	Granular, crystalline sucrose		
177.75 mL	Sucrose-molasses mixture		
5 mL	Vanillin-ethanol solution		
2	Unfertilized reproductive bodies of <i>Gallus domesticum</i>		
340 g	Semi-sweet <i>Theobroma cacao</i> chips		

Procedure:

1. Preheat oven to 191°C (_____ °F).
2. Combine reagents 1, 2, and 3 in a small mixing bowl and set aside.
3. Soften reagent 4 by heating in a microwave oven for 60 seconds (_____ min.).
4. Thoroughly mix reagents 4, 5, 6, and 7 in a large mixing bowl.
5. Add reagent 8, one at a time, to the large mixing bowl, mixing thoroughly after each addition.
6. Gradually add mixture from step 2 to the large mixing bowl and continue mixing.
7. Gently stir reagent 9 into the large mixing bowl.
8. Place 30-mL (_____ tbl.) portions of cookie dough onto ungreased baking sheet.
9. Bake in 191°C (_____ °F) oven for 600 seconds (_____ min.) or until golden brown.
10. Let stand to cool completely.

Data Collection:

1. Record below the total number of cookies made by your group.
2. Select a sample of 10 cookies and set aside for quality control evaluation.



3. Measure the mass (to the nearest gram) and the diameter (to the nearest 0.1 cm) of each of the 10 sample cookies and record values in a table (Table 3) in your laboratory notebook.

Data Analysis:

(Show all calculations.)

1. Calculate and record the mean (average), standard deviation, and relative standard deviation of your sample masses.
2. The standard mass value for this chocolate chip cookie protocol is 31 g. Calculate and record the mean percent difference between the mean mass of your cookies and the standard mass value.
3. Calculate and record the mean (average), standard deviation, and relative standard deviation of your sample diameters.
4. The standard diameter value for this chocolate chip cookie protocol is 9.7 cm. Calculate and record the mean percent difference between the mean diameter of your cookies and the standard diameter value.

Post-Laboratory Discussion:

Write in your laboratory notebook a discussion of your findings and conclusions. Be sure to answer in your discussion the following questions.

1. Define quality control.
2. Why is quality control important in food production?
 - a. Define accuracy and precision as they relate to food quality control.
3. Using the mean percent differences calculated for mass and diameter, respectively, describe your accuracy in making cookies.
4. Using the relative standard deviations calculated for mass and diameter, respectively, describe your precision in making cookies.
5. How might you improve the accuracy and precision of your cookie-making process?
6. How do you think food scientists at Nabisco®, the makers of Chips Ahoy® cookies, ensure the quality and consistency (*i.e.* accuracy and precision) of their products?
7. Name another area in which quality control is very important and explain why.