Guilt-free Chocolate: Introducing Freshmen to Chemical Engineering

Kathryn A. Hollar, Mariano J. Savelski, and Stephanie Farrell
Department of Chemical Engineering
Rowan University
Glassboro, NJ 08028

Abstract

Food processing is an excellent topic to introduce early in the engineering curriculum, as students are familiar with many food products but often do not realize that chemical engineers are responsible for many of the processing and packaging steps in this industry. We have developed a hands-on experiment to introduce freshman engineering or high school students to chemical engineering principles and measurements through chocolate coating of cookies. Student groups will melt chocolate and coat commercially-available cookies, then perform several measurements and calculations. This paper details the experimental set-up and analysis of the module and discusses more advanced experiments that can be incorporated throughout the curriculum.

Introduction

At Rowan University, Engineering freshmen are introduced to engineering principles through a two-course sequence of known as Freshmen Clinics. These clinics, the first two semesters in an innovative eight semester multidisciplinary engineering design and practice, project-oriented course sequence that is a hallmark of the Rowan Engineering program, are common to all engineering majors. The first semester introduces students to all four engineering disciplines represented at Rowan (Chemical, Civil and Environmental, Mechanical, and Electrical and Computer Engineering) and focuses on engineering measurements. In the second semester of the freshmen year, student teams work on reverse engineering of processes or products (beer production, bread making, coffee brewing, electric toothbrush)[1, 2]. This hands-on minds-on approach gets the students excited about engineering. It also helps narrow the gap between a high school level perception of what engineering is and the reality of engineering.

Demonstration of engineering principles and science fundamentals through everyday processes or products engages students more in the learning process. The Chemical Engineering Department at Rowan has successfully used this approach by incorporating the bread-making process, reverse engineering of coffee makers, beer production, and the illustration of chemical engineering principles in the human body into the Chemical Engineering curriculum, particularly at the freshman level [1-4].

The first semester of Freshmen Clinic offers students and introduction to engineering measurements specific to all four disciplines. Students meet once a week for a fifty minutes lecture and again for a three-hour lab. The lecture period is used to discuss topics such as unit conversion, college survival skills, problem solving and safety. In the laboratory section, students work in teams of three to five and rotate throughout the engineering disciplines every three weeks. During the chemical engineering three-week lab modules, students perform measurements such as concentration, blood pressure and flow rate, temperature, exercise related energy expenditure, dissolution rates, and polymer coating thickness of washers in fluidized beds. The students are also introduced to the importance of modeling, curve fitting, and data representation.

The chocolate manufacturing process offers a unique sequence of chemical engineering unit operations. These operations can be isolated to demonstrate different chemical engineering fundamentals. The raw material, *cocoa bean*s, undergoes many diverse processing steps depending on the desired final products. An overview of the chocolate manufacturing process is shown in Figure 1. Briefly, fermentation and drying of the cocoa beans is followed by shelling, roasting, grinding to obtain a chocolate liquor which is 55 % cocoa butter. A series of separation and mixing processes are used to obtain the final product whether it will be cocoa butter, cocoa powder or other consumer products such as milk or dark chocolate.

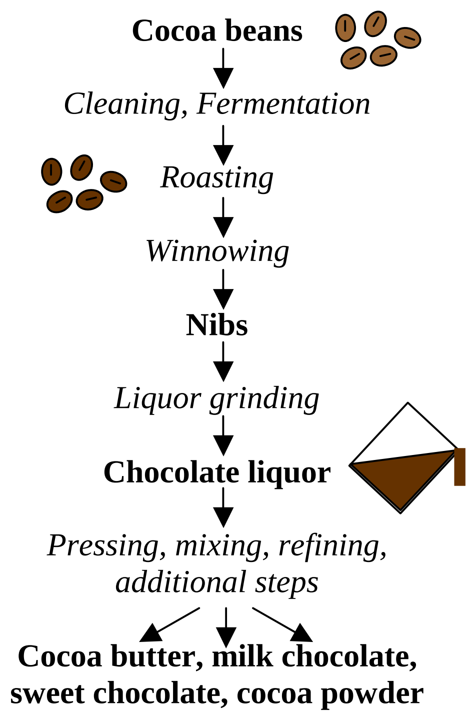

Figure 1: Overview of chocolate manufacturing process (adapted)[5].

Chocolate Coating Experiments for Freshmen

Many of the engineering principles involved in the unit operations of chocolate manufacturing are too complex for freshmen students. However, chocolate is an ideal substance for introducing such diverse concepts as melting point, fluid properties, good manufacturing practices (GMPs), packaging, and statistics. We have developed a simple and inexpensive experiment appropriate for students at this level that reinforces the themes of engineering measurements, teamwork, data analysis and representation, and safety.

Goals specific to this module are:

- Introduce engineering students to food processing and GMP protocols,
- Emphasize problem-solving skills
- Perform measurements and a simple statistical analysis of data.

The experiment requires no specialized equipment and is simple to implement. The equipment and supplies provided to the students include:

- Microwave oven
- Glass bowls
- Kitchen utensils
- Trays and wax paper
- Refrigerator
- Balance
- Calipers
- Cookies
- Chocolate

Before beginning the experiment, the chocolate manufacturing process is presented as a series of unit operations, and student teams are asked to speculate on characteristics of the equipment required for each unit operation and if possible draw analogies between common household appliances and industrial equipment. GMP protocols are introduced by asking students teams to list food handling considerations in their own homes. Their responses are used as the basis for a class discussion of how these basic principles are implemented on an industrial scale.

At the conclusion of the discussion, each team is provided with several cookies of the same kind. The weight of each cookie is recorded and the average and the standard deviation are calculated. Using a microwave, the chocolate is melted, and the cookies are dip-coated and then cooled in the refrigerator. Once cookies are cooled, the weight of each coated cookie is recorded and the same statistical parameters calculated. Student use these data to calculate an average coating thickness and to recalculate a nutritional label.

To calculate a new nutritional label, students must convert the fat, protein, carbohydrate, and calorie information for the chocolate and the cookie to a per gram basis, then determine the contribution of the cookie and chocolate coating each category. While cookies are cooling, student teams work to propose a method for calculating each quantity. Each team briefly presents their method, providing a simple context for discussing problem-solving.

Using the calculated average value for the coated cookie and the information in Figures 2 and 3, student teams recalculate a nutritional label for a serving size of **2 cookies** based on the knowledge that each gram of fat contains 9 calories, each gram of protein contains 4 calories, and each gram of carbohydrate contains 4 calories. The students' new label must include grams and percent daily values of total fat, saturated fat, cholesterol, sodium, total carbohydrates, dietary fiber, sugars, and proteins, as well as percent daily values of vitamin A, vitamin C, iron, and calcium.

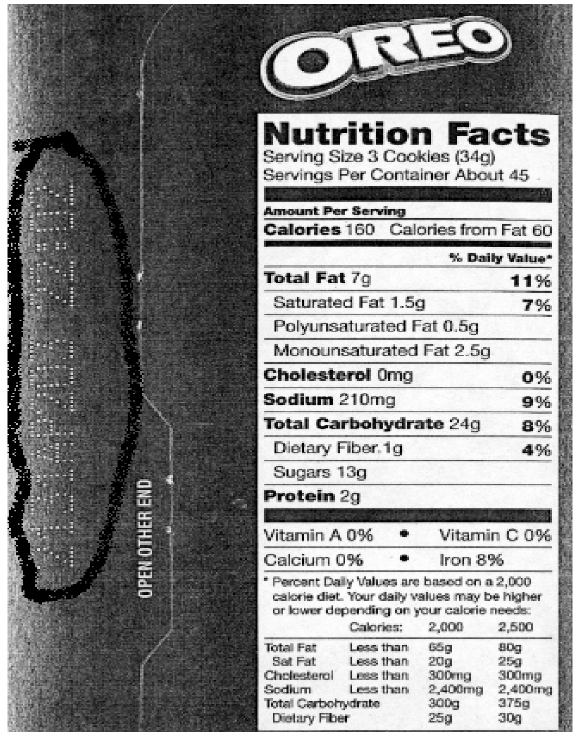

Figure 2: Nutritional label for oreo cookies

Figure 3: Label for semi-sweet chocolate

Students find that there are some discrepancies in the labels presented to them; for instance, the sum of the calories from total carbohydrates, fat, and protein do not equal the available calories stated on the label. Student teams must propose possible reasons for this discrepancy, and incorporate this in their discussion in the report. This exercise and the statistical analysis of final cookie weight and coating thickness introduce the issue of quality control and packaging. Students calculate average values for the nutritional label, and must decide which cookies to reject using the standard deviation.

Report

Student teams are required to submit a report a week after the completion of the lab. The reports are required to contain the following information:

1. An introduction explaining the objectives of the experiment and some background on chocolate.
2. A brief materials and methods, including some commentary on GMPs
3. A results and data analysis section in which a recalculated nutritional label and statistical analysis is presented. A brief explanation of the team's method for

recalculating the nutritional label, as well as some commentary on possible reasons for any trends observed should be included in this section.

4. A conclusions and recommendations section that includes some discussion on how to make the chocolate coating process more consistent.
5. An appendix with raw data and sample calculations.

Extension of Experiment

If the laboratory period permits, the effect of power input of the microwave, fat composition of the chocolate, and mixing on melting time can be investigated.

Results and Student Responses

This experiment was performed this semester with second-semester Freshman students in Freshman Clinic II. In the two sections of the course in which this experiment was implemented, students work in faculty-selected teams of 3 or 4 all semester on either reverse engineering the beer brewing process or demonstrating engineering principles by reverse engineering the human body. The chocolate experiment was designed to fit into this curriculum and generalize some of the topics being covered in each section. In the beer brewing modules, student teams discuss packaging, marketing, and GMPs. In the human body modules, student teams study metabolism, work, and mass transfer principles as they relate to the human body. Students found the chocolate experiment a “fun and exciting” introduction to food processing. The discussion of chocolate processing was lively and focused, and students showed a genuine interest in how food is manufactured.

References

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Biographical Information

KATHRYN A. HOLLAR is an Assistant Professor of Chemical Engineering at Rowan University. She received her B.S. in Chemical Engineering and English at North Carolina State University in 1993, and her Ph.D. in 2001 from Cornell University.

MARIANO J. SAVELSKI is an Assistant Professor of Chemical Engineering at Rowan University. He received his B.S. in 1991 from the University of Buenos Aires, his ME in 1994 from the University of

Tulsa and his Ph.D. in 1999 from the University of Oklahoma. His technical research is in the area of process design and optimization with over seven years of industrial experience. His prior academic experience includes two years as Assistant Professor in the Mathematics Department at the University of Buenos Aires, Argentina.

STEPHANIE FARRELL is Associate Professor of Chemical Engineering at Rowan University. She received her B.S. in 1986 from the University of Pennsylvania, her MS in 1992 from Stevens Institute of Technology, and her Ph.D. in 1996 from New Jersey Institute of Technology. Stephanie's has research expertise in the field of drug delivery and controlled release, and she is currently focusing efforts on developing laboratory experiments related to membrane separations, biochemical engineering,and biomedical systems, for all level students at Rowan.