Development of food processing laboratory exercises as a method for gaining undergraduate research experience

by

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Abstract

Undergraduate research experiences are important in teaching research skills. Opportunities to participate in research projects with faculty members can be limited. Studies have found that course-embedded research opportunities serve as meaningful experiences for students if structured properly. Research was conducted to determine if selected exercises performed in an undergraduate food processing laboratory could serve as undergraduate research opportunities.

Rolled sugar cookies were prepared according to AACC Method 10-50.05 using sucrose and alternative sweeteners, and evaluated for physicochemical and sensory attributes. Objectives were to evaluate the functional properties of alternative sweeteners in reduced-sugar cookies. Nine variations were prepared: control (C), Splenda for baking (S), Equal for baking (E), Truvia (T), Sweet'N Low (SNL), and 1:1 mixtures of sweeteners and sucrose. Cookies were characterized on width-to-thickness (W/T) ratio, moisture loss, color, hardness, fracturability, and sensory attributes. Significance level was determined by ANOVA and post-ANOVA Tukey's multiple comparison tests. W/T ratios of T (7.2), T+sucrose (7.4), and C (7.8) were similar, but different from all other treatments. Color was similar for all treatments (ΔE: 80.190–84.075). T had greatest hardness (6878 N) and E had greatest fracturability (4622 N). The presence of sucrose decreased the fracture force (1359-1732 N). Control sensory attributes (appearance, texture, flavor, sweetness, and aftertaste) (6.07-6.89) significantly differed from alternative sweetener treatments (2.62-6.43). Physiochemical and sensory attributes of T+sucrose were closest to the control. This exercise introduced students to standard methods of sample preparation and physical and sensory analysis.

Gluten-free sorghum breads, with varying inclusions of waxy sorghum flour, were prepared using an optimized gluten-free sorghum bread formulation (70% sorghum flour, 30% potato starch). Objectives were to determine the differences in physiochemical and sensory properties of sorghum bread with different waxy sorghum inclusions. Four treatments were prepared: control (0% waxy sorghum) (C), 15% waxy sorghum (15W), 25% waxy sorghum (25W), and 35% waxy sorghum (35W). Bread was characterized on loaf height, crust and crumb color, water activity, hardness, cohesiveness, springiness, and sensory attributes. Significance level was determined by ANOVA and post-ANOVA Tukey's multiple comparison tests. Average loaf height was greatest for 35W (56.23 mm) and smallest for C (53.72 mm). C had the greatest average color change of the crust (ΔE=74.98) and crumb (ΔE=66.41). Average water activity remained constant (0.98-0.985). 15W had the greatest hardness (1060.98 N) and cohesiveness (0.91). C and 25W had the greatest springiness (0.69). 25W had the greatest sensory acceptability (6.0 out of 9). This exercise introduced students to research skills and challenges associated with gluten-free bread production.

Student observations and perceptions about each of the previously mentioned exercises were assessed using surveys for each exercise. Questions were formatted on a Likert scale in four sections: demographics, physical and sensory properties, research and writing skills, and food processing knowledge. Sixty-five percent or more of students completing each survey gave positive responses. The large number of positive student responses indicate that students perceived each exercise as a beneficial learning experience. Students believed the exercises taught them important information about food processing, research principles, and scientific communication.

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Dedication

To my late grandfather, Dr. Lowell Moser, for always encouraging my scientific curiosity and introducing me to my love of agricultural sciences. He was always a resource in my pursuit of education, and I would not be where I am today without his support. To my family, for giving me every opportunity and encouraging me to pursue my education. To my boyfriend, for supporting me every step of the way and always reminding me of my goals.

Chapter 1 - Introduction

Overview

Hands-on learning is a proven method of encouraging students to think critically about real-world problems, and improve their retention of knowledge and communication skills (Hollis & Eren, 2016). Hands-on activities encourage active learning, which in turn promotes higher-order thinking and an improved ability to apply knowledge to real-world issues (Arthurs & Kreager, 2017). Laboratory sections are often the best way to implement active learning and hands-on exercises for students enrolled in science-based college courses. Laboratory sections are often smaller groups of students, which leads to increased one-on-one time with students and a better environment for active learning (Freeman et al., 2014).

Undergraduate food science students are encouraged to engage in research opportunities outside of the courses in which they are enrolled (Taraban & Logue, 2012). In these research opportunities, students work closely with a faculty member to design, generate, collect, and analyze data related to a pertinent topic in food science. Undergraduate research gives students an introduction to research, experimental design, data analysis, and standard methods of analysis. These skills are a vital part of understanding food science principles and succeeding in food science careers. However, due to circumstances outside undergraduate students' control, opportunities for one-on-one research with faculty are limited. Often, there are more students eager to participate in their own research project than there are faculty members with the time and funding to support. In addition, the quality of undergraduate research experiences hinges on effective student mentoring by faculty members (Taraban & Logue, 2012). This leaves many students without the support they need to conduct research and gain the laboratory experience that universities and employers are looking for.

Fundamentals of Food Processing is an undergraduate course offered at Kansas State University that introduces students (most often sophomore-level undergraduates) to different food processing techniques and parameters. This course also includes a weekly, two-hour laboratory period where students gain hands-on experience performing benchtop-scale applications of food processing techniques. When adequate instructions and discussion of laboratory techniques are presented to students prior to and during the exercise, it is believed these laboratory exercises can mimic larger research experiments, and create abbreviated versions of undergraduate research.

Two food science laboratory exercises were designed and implemented in the laboratory of the Fundamentals of Food Processing course at Kansas State University. In one exercise, rolled cookies were prepared using different alternative sweeteners and combination of the sweeteners with sucrose in order to investigate the functional differences between sugar and alternative sweeteners. In the second exercise, loaves of gluten-free sorghum bread were prepared using different percent inclusions of waxy sorghum to determine if the inclusions of waxy sorghum had positive effects on bread quality.

Detailed printed instructions were provided to students prior to each laboratory period as well as additional verbal instructions given before and during the course of each exercise. Students were informed that their work in these exercises would be collected and used in a thesis research experiment. Experimental design and purpose of replications were discussed during the laboratory to help students understand the importance of the exercise and why they should perform it carefully. The laboratory was performed, and physical and sensory analyses were performed by students for both exercises. Students also were given detailed instructions and rubrics to write memo-style laboratory reports over the data collected and observations made

during the exercises. Students were given two weeks to complete their laboratory reports. Student data was collected from the laboratory reports for statistical analysis. The exercise was repeated in triplicate by the GTA in a controlled environment. Controlled data was collected for statistical analysis. In addition, the student data and controlled data were statistically analyzed for similarities, to determine if student data was statistically similar to data generated by a trained researcher.

After students had completed all exercises for the semester, surveys were distributed by the GTA to assess student perceptions of the effectiveness of each laboratory exercise. The surveys were designed to assess how well students met the learning outcomes presented for the course, and if they gained or improved any research skills by participating in these exercises.

Objectives

Three main objectives were determined for this research study. The first was to provide students an opportunity to participate in a version of undergraduate research in a course laboratory setting, when such opportunities are limited. The second objective was to provide laboratory exercises for professors and teachers looking to incorporate new food processing laboratories into their curriculum. These two laboratory exercises, along with provided data, give teachers a resource for innovative laboratory exercises that teach students about ingredient functionality in a hands-on manner. The third objective determined the physiochemical and sensory differences in both cookies made from alternative sweeteners and/or sugar and gluten-free sorghum bread with waxy sorghum inclusions.

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Chapter 2 - Review of Literature

Education

Active Learning and Hands-On Activities

In recent years, "active learning" in the classroom has gained popularity among faculty who are looking to use alternative teaching techniques in the classroom. However, some still remain skeptical and call it a fad or trend, viewing homework and laboratories as active learning opportunities (Prince, 2004). Active learning is defined as "any instructional method that engages students in the learning process (Prince, 2004, p. 223)." While educators could argue this definition could include homework, it is more widely accepted that active learning refers to activities that are performed during class time. Student activity and engagement in learning are the pillars of active learning, meaning students do not only passively absorb information provided in traditional lectures (Prince, 2004). Collaborative and cooperative learning also can be incorporated into the classroom to enhance active learning activities. Both collaborative learning and cooperative learning involve student working together in small groups to pursue a common goal. Cooperative learning differs in that, even though students work together, they are evaluated as individuals (Prince, 2004).

Substantial amounts of data exist to support claims that active learning improves student understanding and retention of information learned in the classroom. Active learning has been found to increase student performance in STEM fields, while lecturing alone can increase failure by 55% (Freeman et al., 2014). Using a university physics course (Force and Motion Conceptual Evaluation) offered across the United States, researchers found that implementing new teaching methods that incorporate active engagement of students increased students' understanding of the concepts (Laws, Sokoloff, & Thornton, 1999). Using traditional lecturing alone, up to

approximately 55% of students understood critical concepts. However, when new methods were implemented that actively engage students in the learning process, the number of students who understood the same concepts rose to more than 90% (Laws, Sokoloff, & Thornton, 1999).

The active learning activities chosen in the classroom must be carefully designed to address key learning outcomes of the course. These learning activities need to promote active engagement by all students and enhance teaching (Wiggins & McTighe, 1998). Actively engaging students in the material being taught improves their retention of key concepts and improves their overall performance. Throughout the course of a lecture, student attention decreases dramatically and students subsequently lose retention of the material being taught. Immediately following a lecture, students remembered 70% of information provided in the first 10 minutes of class, but only 20% of information presented in the last 10 minutes (Hartley & Davies, 1978). Breaking up lectures with activities allows students to start fresh multiple times, prevents their minds from wandering, and keeps students better engaged in the learning process (Prince, 2004).

The myriad "active learning" activities that can be implemented in college classrooms are overwhelming and some instructors may struggle to pick the best activities for their class and structure them accordingly. In a review by Arthurs & Kreager (2017), a new framework for structuring active learning opportunities was proposed. They suggested the instructional decisions to enable active learning (IDEAL) theory. Within this framework, active learning is made up of three concepts: the activity, the strategy, and the approach. The activity is the lowest-level concept that addresses implementation of active learning activities. The strategy is the mid-level concept, connecting in-class activities to peer interaction and student engagement. The approach is the high-level concept that addresses instructional decisions that lead to enabling

active learning (Arthurs & Kreager, 2017). Instructors can begin thinking about their implementation strategy at any of the three levels and can move fluidly between all levels at any time, because they are all interconnected. The IDEAL theory serves to help instructors grasp the range of possibilities of active learning strategies and design their instructional methods. The authors believe the IDEAL theory is useful for instructors looking to design new instructional methods and discuss educational research topics (Arthurs & Kreager, 2017).

Use of Laboratory Exercises

Active learning is most effective in small groups. Laboratories often provided a smaller environment for students to interact and are hands-on that can serve as active learning opportunities. Laboratory exercises incorporate experiential learning into curriculum to help students understand real-world challenges. In a study by Hollis & Eren (2016), a laboratory was the subject of a study into the benefits of experiential learning. Students were divided into small teams and used the semester-long class to work on a real-world case study as a team. The case study required students meet and collaborate with real food industry professionals to answer questions and troubleshoot problems. At the conclusion of the course, students completed a survey evaluating the course on a five-point scale. Overall, the course received a mean rating of 4.25 with 5 being the highest possible score. Students' high rating of the course and its aspects indicated they responded positively to the course set-up and use of the case study as a learning tool (Hollis & Eren, 2016). In the professors' evaluation of the students, they found that students' critical thinking, scientific communication, and problem-solving skills were all enhanced through participation in the activity. Students' ability to use time wisely, quickly synthesize information, and effectively and efficiently communicate with their peers improved over the course of the semester (Hollis & Eren, 2016).

This exercise improved students' success skills. These success skills include critical thinking, communication, problem-solving, team work, and professionalism, and are deemed extremely important by many employers for new professionals to obtain early (Hollis & Eren, 2016). Improved student performance and enhanced information retention could be translated to improved experimental technique and data collection during laboratories and in future careers. It is important to expose students to current issues and trends in the food industry in order to provide opportunities for professional development. Giving students real-world examples based on current food industry trends helps them apply their knowledge to current problems and critically think about real solutions (Hollis & Eren, 2016). This gives students a head start to thinking about the challenges they will face in their future careers.

The hands-on aspect of laboratory education is significant in enhancing student learning. Researchers have found that when students physically experience the concepts they are learning about, their ability to integrate the information increases and their understanding of the subject is enhanced (Kontra, Lyons, Fischer, & Beilock, 2015). While hands-on laboratory exercises may not aid in students' understanding of scientific theory, these exercises teach students how to conduct science experiments. Laboratory exercises that actively engage students teach laboratory skills, research methods, and scientific processes that are best learned through doing, rather than lecturing. When laboratory exercises are combined with conceptual clarification of scientific theory, a link between ideas and real objects is formed in the minds of students; such exercises become valuable tools in science education (Leite & Dourado, 2013).

Institute of Food Technologists (IFT) Program Goals, Standards, and Essential Learning Outcomes (ELOs)

In order to maintain a position as an approved program, university food science programs must follow curriculum guidelines set forth by the Institute of Food Technologists (IFT). Approved programs exist at universities both in the United States and internationally. The guidelines for initial approval by IFT were updated in 2019 and include: administrative, physical, and curricular requirements; program goals; program standards; and essential learning outcomes (ELOs) (Institute of Food Technologists, 2019).

Administrative requirements by IFT include an organized department with acceptable facilities and an identifiable budget. Programs must also be an accredited educational institution and have student who have graduated from the program previously. Food science programs must also fulfill the following curricular requirements with specified minimum number of credit hours: general chemistry (6 hrs), organic chemistry (3 hrs), biochemistry (3 hrs), general biology (3 hrs), microbiology (3 hrs), human nutrition (3 hrs), calculus (3 hrs), general physics (3 hrs), statistics (3 hrs), written communication (2 hrs), and oral communication (2 hrs). Each of these curricular requirements has further requirements for course content (Institute of Food Technologists, 2019).

Further, IFT requirements for becoming an approved program include IFT program goals. These goals serve as the overall expectations of food science programs approved by IFT. The program goals set forth by IFT are as follows (Institute of Food Technologists, 2019):

1. Graduates are competent in core areas of food science.
2. Graduates can integrate and apply their knowledge.
3. Graduates are proficient communicators.

4. Graduates demonstrate professionalism and leadership skills.

Standards represent the academic content and skills covered by the program goals and serve as the framework for assessing ELOs (Table 2.1). ELOs address the knowledge and skills students should learn prior to the completion of the required course work (Institute of Food Technologists, 2019).

Table 2.1–Standards and Essential Learning Outcomes (ELOs)

Standards	Essential Learning Outcomes
Food chemistry (FC) The structure and properties of food components (water, carbohydrates, proteins, lipids, other components and food additives); the chemistry of changes occurring during processing, storage, and utilization.	Upon completion of the required course work in this topical area, students will be able to: FC.1. Discuss the major chemical reactions that limit shelf life of foods. FC.2. Explain the chemistry underlying the properties and reactions of various food components. FC.3. Apply food chemistry principles used to control reactions in foods. FC.4. Demonstrate laboratory techniques common to basic and applied food chemistry. FC.5. Demonstrate practical proficiency in a food analysis laboratory. FC.6. Explain the principles behind analytical techniques associated with food. FC.7. Evaluate the appropriate analytical technique when presented with a practical problem. FC.8. Design an appropriate analytical approach to solve a practical problem.
Food microbiology (FM) Microorganisms in food including beneficial, pathogenic, and spoilage; the influence of the food system on their growth, survival, and control.	Upon completion of the required course work in this topical area, students will be able to: FM.1. Identify relevant beneficial, pathogenic, and spoilage microorganisms in foods and the conditions under which they grow. FM.2. Describe the conditions under which relevant pathogens are destroyed or controlled in foods. FM.3. Apply laboratory techniques to identify microorganisms in foods.

	FM.4. Explain the principles involved in food preservation via fermentation processes. FM.5. Discuss the role and significance of adaptation and environmental factors (e.g., water activity, pH, temperature) on growth response and inactivation of microorganisms in various environments. FM.6. Choose relevant laboratory techniques to identify microorganisms in foods.
Food safety (FS) Hazards (physical, chemical, biological) associated with foods and the food system; their transmission and control.	Upon completion of the required course work in this topical area, students will be able to: FS.1. Identify potential hazards and food safety issues in specific foods. FS.2. Describe routes of physical, chemical, and biological contamination of foods. FS.3. Discuss methods for controlling physical, chemical and biological hazards. FS.4. Evaluate the conditions, including sanitation practices, under which relevant pathogenic microorganisms are commonly controlled in foods. FS.5. Select appropriate environmental sampling techniques. FS.6. Design a food safety plan for the manufacture of a specific food.
Food engineering and processing (FE) Food engineering principles; food preservation and processing; packaging materials and methods; cleaning and sanitation; water and waste management.	Upon completion of the required course work in this topical area, students will be able to: FE.1. Define principles of food engineering (mass and heat transfer, fluid flow, thermodynamics). FE.2. Formulate mass and energy balances for a given food manufacturing process. FE.3. Explain the source and variability of raw food materials and their impact on food processing operations. FE.4. Design processing methods that make safe, high-quality foods. FE.5. Use unit operations to produce a given food product in a laboratory or pilot plant. FE.6. Explain the effects of preservation and processing methods on product quality.

	FE.7. List properties and uses of various packaging materials and methods. FE.8. Describe principles and practices of cleaning and sanitation in food processing facilities. FE.9. Define principles and methods of water and waste management.
Sensory science (SS) Analytical and affective methods of assessing sensory properties of food.	Upon completion of the required course work in this topical area, students will be able to: SS.1. Discuss the physiological and psychological basis for sensory evaluation. SS.2. Apply experimental designs and statistical methods to sensory studies. SS.3. Select sensory methodologies to solve specific problems in food.
Quality assurance (QA) Principles of food quality control and assurance.	Upon completion of the required course work in this topical area, students will be able to: QA.1. Define food quality and food safety terms. QA.2. Apply principles of quality assurance and control. QA.3. Develop standards and specifications for a given food product. QA.4. Evaluate food quality assessment systems (e.g. statistical process control).
Food laws and regulations (FL) Government regulations required for the manufacture and sale of food products.	Upon completion of the required course work in this topical area, students will be able to: FL.1. Recall government regulatory frameworks required for the manufacture and sale of food products. FL.2. Describe the processes involved in formulating food policy. FL.3. Locate sources of food laws and regulations. FL.4. Examine issues related to food laws and regulations.
Data and Statistical Analysis (DS)	Upon completion the required course work and additional research activities provided from the program, students will be able to:

Collection, analysis, interpretation, and presentation of data.	DS.1. Use statistical principles in food science applications. DS.2. Employ appropriate data collection and analysis technologies. DS.3. Construct visual representation of data.
Critical thinking and problem solving (CT) Scientific reasoning through uncertainty in scientific and technical situations.	Upon completion of the required course work and additional activities provided from the program, students will be able to: CT.1. Locate evidence-based scientific information resources. CT.2. Apply critical thinking skills to solve problems. CT.3. Apply principles of food science in practical, real-world situations and problems. CT.4. Select appropriate analytical techniques when presented with a practical problem. CT.5. Evaluate scientific information.
Food Science Communication (CM) Oral and written communication.	Upon completion of the required course work and additional activities provided from the program, students will be able to: CM.1. Write relevant technical documents. CM.2. Create oral presentations. CM.3. Assemble food science information for a variety of audiences.
Professionalism and leadership (PL) Organization and project management; skills necessary to work and interact with individuals from diverse backgrounds.	Upon completion of the required course work and additional and leadership activities provided from the program, students will be able to: PL.1. Demonstrate the ability to work independently and in teams. PL.2. Discriminate tasks to achieve a given outcome. PL.3. Describe social and cultural competence relative to diversity and inclusion. PL.4. Discuss examples of ethical issues in food science.

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Kansas State Food Science Learning Outcomes

Fundamentals of Food Processing is a course offered at Kansas State University and was the focus of this thesis research. Learning outcomes and goals set forth in this course are based on the applicable IFT Standards and ELOs. Six student learning outcomes were outlined by instructors in the syllabus given to students and the assignments used to facilitate each learning outcome are listed (Table 2.2). Each learning outcome is created to organize the FDSCI 305 course in order to give students a more meaningful educational experience (Kansas State University, 2019).

Table 2.2–FDSCI 305 course learning outcomes.

Learning Outcome	Assignment/s
1. Students will be able to describe and explain the principles behind food processing techniques (freezing, dehydration, thermal processing, irradiation, and fermentation) and how they impact various food products.	Lecture exam and quiz questions: fill in the blank, multiple choice, matching questions, and essay questions. Discussion questions in lecture and lab.
2. Students will be able to describe and discuss how the addition of ingredients in food products changes physical and sensory properties as demonstrated in a laboratory setting.	Laboratory reports and laboratory exams.
3. Students will be able to identify the different departments and agencies responsible for food processing regulations and determine appropriate regulatory guidance for specific foods.	Lecture exam and quiz questions: fill in the blank, multiple choice, matching questions, and essay questions. Laboratory reports and laboratory exams.
4. Students will be able to analyze, evaluate, and interpret data collected in a laboratory setting and construct this information into a detailed laboratory report.	Laboratory reports.
5. Students will be able to develop flow diagrams with basic unit operations for different food products.	Laboratory reports, laboratory and lecture exams.
6. Students will be able to describe and justify various techniques and equipment used for processing food products.	Laboratory reports, discussion questions, and essay questions.

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Learning outcomes 1 (principles of food processing), 2 (ingredient effect on physical and sensory properties), 5 (flow diagrams of basic unit operations), and 6 (techniques and equipment used to process food products) address the "food engineering and processing" and "sensory science" standards required by IFT. Learning outcome 3 (departments and agencies responsible for food regulations) addresses the "food laws and regulations" standard. Learning outcome 4 (analyzing, evaluating, and interpreting laboratory data) address the "data and statistical

analysis" and "critical thinking and problem solving" standards. Laboratory activities are important educational tools used to facilitate learning outcomes 2, 3, 4, 5, and 6.

In addition to course learning outcomes, the Food Science Institute at Kansas State University has another set of learning outcomes, designed as goals for all students to develop during their education in the program. According to these five outcomes, program graduates should demonstrate proficient knowledge, critical thinking, communication, diversity, and academic and professional integrity ("Student Learning Outcomes," n.d.). Students should have sufficient knowledge of food chemistry and analysis, food safety and microbiology, food processing and engineering, and applied food science. They should be able to think critically, interpret information, solve problems, and make complex decisions. Students must be able to communicate effectively, in both oral and written forms. They must understand the skills needed to work in a diverse environment and the importance of academic and professional ethics ("Student Learning Outcomes," n.d.).

Sucrose

Structure

Sucrose ($C_{12}H_{22}O_{11}$) is a common disaccharide used in a variety of food applications. It is most commonly sourced from sugar cane or sugar beets. Sucrose is composed of a fructofuranose ring and a glucopyranose ring, joined together by a flexible glycosidic linkage (Figure 2.1). Due to its flexibility, sucrose has the ability to form crystalline structures by forming many weak hydrogen bonds between multiple sucrose molecules (Mathlouthi & Reiser, 1995). Sucrose molecules are densely packed in the crystalline structure, with each molecule surrounded by 12 others. This dense packing results in strong intermolecular associations that

ultimately lead to the formation of molecular layers. Molecules interact very tightly in these layers due to the activity of hydrogen bonds and van der Waals forces (Mathlouthi & Reiser, 1995).

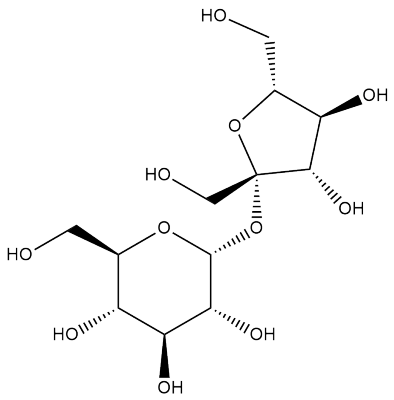

Figure 2.1–Chemical structure of sucrose.

In concentrated solutions, sucrose molecules form aggregates. If the solution becomes supersaturated, aggregates are more likely to grow and form sucrose crystals. The first step in the crystallization process is nucleation. In order for a stable nucleus to form, the molecules in solution must overcome an energy barrier. During nuclear formation, "there is a request of energy for the surface formation, whereas a part of energy released by molecules owing to the decrease in molecular motion" (Mathlouthi & Reiser, 1995, p. 50), as crystallization is an exothermic process. This ultimately leads to the transition from liquid solution to crystals. Once this energy level is attained, crystals can continue growing. However, any impurities that may be present in the solution will retard the rate of crystal development and change their morphology (Mathlouthi & Reiser, 1995).

Properties

Sucrose can exist as a crystalline structure (as previously discussed) or as an amorphous structure. Each form will have slightly different physical properties due to the varying conditions

each were produced under. Crystalline sucrose has a melting point of 186ºC, but can range from 182º-192ºC. The presence of any impurities, moisture, or non-crystalline structure within the sucrose crystals will change the melting point (Mathlouthi & Reiser, 1995). It is highly soluble in water. Sucrose also follows colligative properties, by elevating the boiling point and depressing the freezing point of water to below 0ºC.

Pure sucrose solutions exhibit Newtonian behavior. Fluids are said to be Newtonian when shear stress and shear rate are linearly related; as shear stress on the fluid increases, the shear rate increases proportionately (Mathlouthi & Reiser, 1995). However, as with many properties of sucrose, the presence of impurities will change the solution's behavior from Newtonian to pseudo-plastic or viscoelastic due to their variable associations with water. Pseudo-plastic behavior is observed "when the increase in shear stress gives more than a proportional increase in shear rate" (Mathlouthi & Reiser, 1995, p. 126).

Functionality in Food Applications

Sucrose is highly function ingredient, playing many critical roles in food applications. It can be added to almost innumerable food products successfully, including baked goods, icings, breads, and breakfast cereals. It can be added to heat-processed foods or foods that are not heated. Sucrose is heat-stable; it hydrolyzes (or "inverts") into a mixture of its components fructose and glucose. It breaks down to monosaccharides, meaning sweetness is not lost at high temperatures. Sucrose acts to lower the water activity of products in which it is added. It binds water molecules so they are less free to escape into the vapor phase. This acts to preserve food products that are susceptible to microbial spoilage by binding water so it is unavailable for bacterial growth. Sucrose has also been shown to exhibit some antioxidant properties. This helps

prevent flavor degradation of canned fruits and inhibits rancidity in cookies (Mathlouthi & Reiser, 1995).

Sucrose is an important component of the browning reaction that leads to golden-brown colors typical of baked food products. At high baking temperatures, sucrose inverts into a mixture of its components parts, fructose and glucose, called invert sugar. These reducing sugars react with amino groups present in the food matrix, forming a condensation product that is polymerized to form dark-colored compounds in the food product. This reaction is known as the Maillard browning reaction (Mathlouthi & Reiser, 1995).

Particles of sucrose are large and uniform, contributing to its bulking ability. Bulking ability contributes to a favorable rheology, viscosity, and final structure of baked products, confections, and breakfast cereals (Mathlouthi & Reiser, 1995; Davis, 1995). Additionally, sucrose has strong humectancy properties, meaning products made with sucrose show a resistance to drying out. This allows sucrose-containing products to be kept longer without staling. The bulking and moisture retention properties of sugar are not easily substituted for, contributing to sucrose's status as an important baking ingredient.

Addition of sucrose in baked cookie applications contributes to tenderness and spread of the final product. During baking, any previously undissolved sucrose dissolves causing the dough viscosity to decrease and act more fluidly. This phenomenon ultimately leads to spread during baking (Pareyt et al., 2009).

Flavor Enhancement and Sensory Properties

The typical use of sucrose is to sweeten foods. However, sucrose interacts with other ingredients to improve the flavor quality of many products. Sucrose can be used to decrease salty tastes, even in very small concentrations. It can help mask or balance bitter-tasting foods. In

acidic foods, sucrose exponentially decreases sour tastes with increased sucrose concentration (Mathlouthi & Reiser, 1995).

Different food additives in a food matrix can have different effects on the sensory profile of sucrose. Ethanol enhances the sweetness of sucrose, while addition of gums or thickening agents diminishes the sweetness. The color of a food product contributes to perceived sweetness. The color red in particular seems to enhance perceived sweetness, while yellow decreases it. Sucrose also acts synergistically with alternative or high-intensity sweeteners in small concentrations. These blends function to mask the bitter or off-flavors associated with these alternative sweeteners (Mathlouthi & Reiser, 1995).

Alternative Sweeteners

One group of sugar substitutes is alternative sweeteners, lower-calorie sweetening additives for food applications. Alternative sweeteners are not sugars, but rather alternative compounds that mimic sweetness of sugar with lower caloric density than sugars (Chattopadhyay, Raychaudhuri, & Chakraborty, 2014). One category of alternative sweeteners is high-intensity sweeteners, sweeteners with concentrated sweet taste that can be used in fractional amounts to impart the same level of sweetness as a greater amount of sugar (Chattopadhyay et al., 2014). In the United States, saccharin, aspartame, acesulfame potassium (Ace-K), sucralose, neotame, and advantame, are high-intensity sweeteners approved for use by the FDA (Acesulfame potassium, 2019; Advantame, 2019; Aspartame, 2019; Neotame, 2019; Saccharin, ammonium saccharin, calcium saccharin, and sodium saccharin, 2019; Sucralose, 2019). Additionally, many commercial sweeteners on the market may have added ingredients, such as bulking agents or bitter maskers, or contain a combination of different sugars and sweeteners. In-

depth descriptions of Sucralose, Aspartame, Acesulfame-K, and Saccharin follow. Stevia, while not artificial, is also discussed due to its common use as a natural sugar substitute.

Sucralose

Chemical Structure and Synthesis

Sucralose ($C_{12}H_{19}Cl_3O_8$) is an artificial, high-intensity sweetener derived from sucrose. It is created when three hydroxyl groups on sucrose are replaced with chloride ions (Chattopadhyay et al., 2014). Substitution can be achieved either by synthetic organic chemistry method or using microbial cultures or enzymes (Ager, Pantaleone, Henderson, Katritzky, Prakash, & Walters, 1998). In the synthetic organic chemical method, a sequence of targeted protection and deprotection steps of the hydroxyl groups converts the 4-hydroxy group to a chloro atom and inverts configuration of the molecule (Figure 2.2).

However, these synthetic chemical methods lack stereochemical and regioselective control, making the process much more difficult to properly perform. Using the enzymatic method is a much easier process than the original organic chemistry method required to produce sucralose. Enzymes are able to perform selective functionalization, providing the needed stereochemical and regioselective control to synthesize sucralose (Ager et al., 1998).

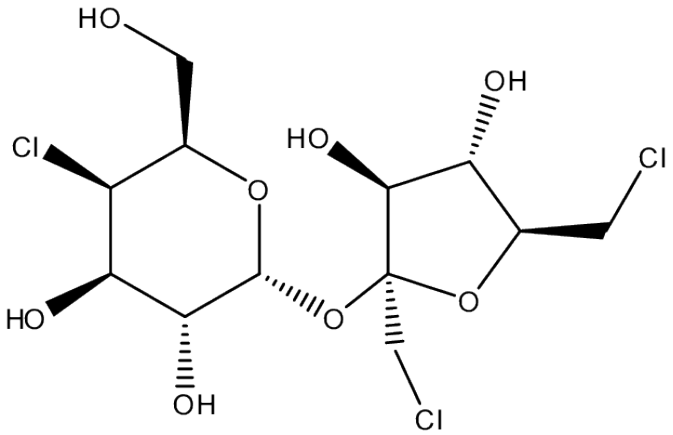

Figure 2.2–Chemical structure of sucralose.

Properties

Sucralose has a relative sweetness value of 600. This means it is 600 times sweeter than sucrose. The relative sweetness scale is based on sucrose, which sets the baseline of the relative sweetness scale at one (Chattopadhyay et al., 2014). Other artificial, high-intensity, or alternative sweetening agents are then ranked on the scale relative to sucrose. Sucralose has a high ranking relative to other sugars and sweeteners, making it very intense. Because sucralose has such a potent sweetness, a small amount is required to replace sucrose in food applications. However, this means that sucralose does not provide any bulking properties (Grotz, Molinary, Peterson, Quinlan, & Reo, 2016). Other bulking ingredients, such as maltodextrin, must be added to formulations that use sucralose to yield food products with acceptable sensory properties.

Though it is derived from sucrose, the human body does not recognize sucralose as sugar and therefore does not metabolize it to produce calories in the diet. Sucralose is poorly absorbed in the gastrointestinal (GI) tract, leading most consumed sucralose to be readily excreted intact. Additionally, sucralose does not degrade *in vivo* nor does it bind with proteins, making it very inert. These characteristics demonstrate the safety of sucrose, and no adverse effects have been noted in any clinical studies (Grotz et al., 2016). Clinical studies of human tolerance have observed both normoglycemic and diabetic individuals showed no affects when consuming three to seven times the estimated maximum daily intake of sucralose, even when consumed consistently up to six months.

Sucralose is soluble in water, regardless of temperature. It does not affect surface tension of the solution, meaning it does not cause excess foaming during mixing. It also has relatively low viscosity when mixed into solution, so no thickening issues arise when using sucralose solutions in food applications (Grotz et al., 2016).

Sucralose is also heat stable enough to be used in baked products. No studies have found evidence of sucralose breakdown or undesirable reactions with other ingredients at high temperatures. Sucralose also is stable in fermented baked systems. The structure of sucralose remains unchanged by yeast activity and does not interfere in the fermentation process. Due to this characteristic, it may be added to a food product at any stage of fermentation (Chapello, 1998).

Aspartame

Chemical Structure and Synthesis

Aspartame ($C_{14}H_{18}N_2O_5$) is a methyl ester formed from dipeptides of amino acids phenylalanine and aspartic acid (Figure 2.3). Aspartame is industrially synthesized by dehydrating aspartic acid into acid anhydride, then coupling it with phenylalanine (Ager et al., 1998). When coupled, synthetic reagents are used to protect the appropriate functional groups attached to the acids. The desirable, α-coupled products crystallize out of solution, leaving behind undesirable, β-coupled isomers (Ager et al., 1998). Two main processes are used to synthesize aspartame, the F-process and the Z-process. These processes are named after the respective protecting group of the aspartyl group.

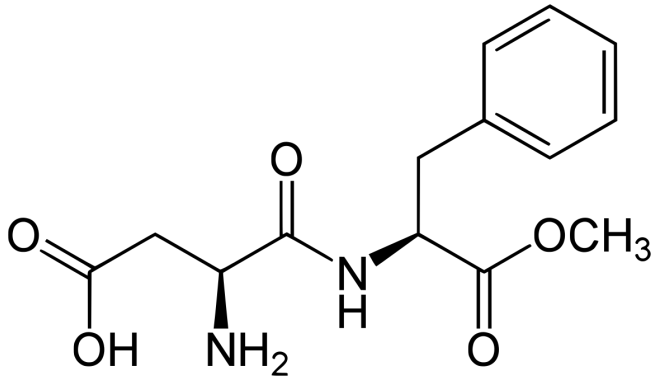

Figure 2.3–Chemical structure of aspartame.

Properties

Aspartame is a high-intensity sweetener, and ranks 180-200 on a relative sweetness scale compared to sucrose (Chattopadhyay et al., 2014). Compared to sucrose, its sweet taste lingers but takes longer for the consumer to initially taste (Ager et al., 1998). Though included in many "zero-calorie" food products, aspartame contains four kilocalories per gram (kcal/g). However, because its sweetness is highly concentrated, very small amounts are required to impart sweetness on a product and the calories from those amounts are negligible.

Aspartame has very low heat stability and is not a useful sweetener in baked or cooked food products. The ester group is especially susceptible to hydrolysis, and high temperature conditions accelerate such degradation. Once the degradation reaction begins, it proceeds rapidly, leading to a quick loss of sweetness in whatever food products aspartame was used to sweeten (Ager et al., 1998). Due to this property, aspartame is better suited for non-cooked products and is most commonly used in beverage applications.

Though aspartame imparts a strong sweetness in products in which it is incorporated, it lacks the functionality provided by sugars in food applications. Aspartame provides no bulk in food products and cannot contribute to product volume or structure, because such minute amounts of aspartame can replace much greater volumes of sugars (Holmer, 1984). Bulking agents, such as maltodextrin, are required when replacing sugars with aspartame. However, this is a desirable characteristic in some food applications where less bulk and higher nutrient density are desired. Sucrose binds water in food applications, lowering the water activity and extending the shelf life of food products (Holmer, 1984). However, aspartame cannot bind water and often produces food products with high water activities.

Health Controversy

Aspartame has been a controversial sweetener for many years. First discovered for its sweetening properties in 1965, aspartame has been approved for use in foods by the FDA since 1981 (Ager et al., 1998). Since approval for use, aspartame has been included in over 6,000 different food products. The components of aspartame are commonly found in many different food products and in greater quantities than in aspartame (Butchko et al., 2002). Upon ingestion, it is metabolized into its component parts, aspartic acid, phenylalanine, and methanol as would the same components from any other food product.

However, in the late 1970s, the safety of aspartame came into question in regards to carcinogenicity. Two studies conducted by John W. Olney (FDA, 1981; Olney, Farber, Spitznagel, & Robins, 1996) claimed that aspartame consumption was associated with increased risk in developing brain tumors and that the increasing occurrence of brain tumors in the United States was due to the approval of aspartame for human consumption (Butchko et al., 2002). Closer analyses of the 1981 FDA report showed significant problems with experimental design and data falsification. The FDA found that Olney inappropriately combined dose groups, performed flawed statistical analyses of data, misreported death dates of test animals, and misreported the historical incidence of brain tumors to be much lower than true trends (Butchko et al., 2002). In his 1996 study, Olney again stressed the connection between aspartame consumption and occurrence of brain tumors. The FDA again found that Olney omitted data that showed the incidence of brain tumors was historically higher than he reported and misinterpreted carcinogenicity studies with animals (Butchko et al., 2002). Due to their significant issues in data falsification and misreporting, both studies were invalidated.

In their own studies, both the FDA and the United States National Cancer Institute (NCI) found no association between the consumption of aspartame and development of cancer (brain tumors) in either animal or human subjects (Butchko et al., 2002). In addition, the biochemical mechanism of carcinogenicity claimed by these reports is not relevant regarding aspartame consumption. A study by Shephard, Wakabayashi, & Nagao (1993) and cited by Olney et al. (1996) found that nitrite reacts with aspartame and can develop mutagenic compounds when incubated with bacteria. However, when the same compounds were incubated with liver enzymes to mimic body conditions of the metabolism of aspartame, their mutagenic properties were significantly decreased (Butchko et al, 2002). It was also found the high nitrite conditions in which the compounds were incubated for the study were 10,000 times higher than true gastric levels, making the reported reaction rate 100 million times greater than the real reaction rate in the gastrointestinal system.

Acesulfame Potassium

Chemical Structure and Synthesis

Acesulfame potassium (Ace-K; $C_4H_4KNO_4S$) is a potassium salt of oxathiazinone dioxide (Figure 2.4). Its development as a sweetener resulted from the discovery of oxathiazinone dioxides (Clauss & Jensen, 1970). Methods of synthesis have evolved since its initial discovery. Historically, chlorosulfonyl or fluorosulfonyl isocyanate reacted with propyne, acetone, acetoacetic acid, t-butyl acetoacetate, or acetylacetone, yielding N-chloro or N(fluoro-sulfonyle) acetoacetamide. Methanolic potassium hydroxide was then applied to cyclize the compound into Ace-K (Ager et al., 1998). Another method involves using amidosulfonyl fluoride to treat diketene in the presence of nitrogen bases. However, these methods are difficult

because preparing and handling chlorosulfonyl or fluorosulfonyl isocyanate is difficult and limits their commercial practicality (Ager et al., 1998).

Currently, Ace-K is synthesized by using two equivalents of sulfur trioxide to treat acetoacetamide, resulting in the formation of N-sulfoacetoacetamide. This compound is then dehydrated by sulfur trioxide, forming oxathiazinone dioxide. Potassium hydroxide is then used to neutralize the compound to yield Ace-K (Chattopadhyay et al., 2014).

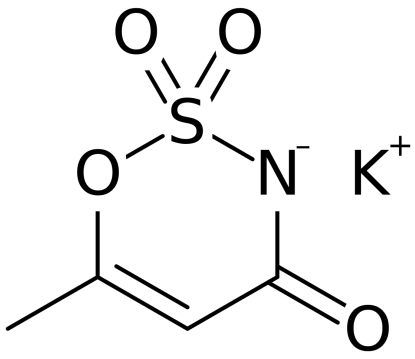

Figure 2.4–Chemical structure of acesulfame potassium (Ace-K).

Properties

Ace-K rates about 120 on the relative sweetness scale, making it 120 sweeter than sucrose. It is the most widely used oxathiazinone dioxide sweetening agent because it has a pure sweet taste without off-flavors or aftertastes (Ager et al., 1998). Ace-K is often used at lower levels and blended with other alternative sweeteners to attain very high sweetness levels and improve sweetener quality (Klug & von Rymon Lipinski, 2012). The most common sweetener blended with Ace-K is aspartame. The blend of aspartame and Ace-K provides synergistic sweetness enhancement, making the blend up to 300 times sweeter than sucrose, while these two sweeteners alone have much lower relative sweetness values. Additionally, blending Ace-K with other high-intensity sweeteners improves the sweetness quality imparted on sweetened products.

Blending with Ace-K changes the intensity profile of the sweeteners being blended, often giving it sensory properties closer to sucrose (Klug & von Rymon Lipinski, 2012).

Ace-K is both water soluble and soluble in alcoholic solutions with high water contents (Klug & von Rymon Lipinski, 2012). This is contrasted to other alternative sweeteners, most of which have poor solubility in water (Ager et al., 1998). Ace-K is also stable, even at the high temperatures used in normal food-processing conditions. Even pasteurization and ultra-high temperature (UHT) processing conditions result in no loss of Ace-K. This implies that Ace-K maintains its sweetness in baked food products, as baking temperatures are lower than the extremely high temperatures used in UHT. However, like many high-intensity sweeteners, Ace-K lacks bulking abilities in food products. If Ace-K is substituted for sucrose in formulations, suitable bulking agents must be added to create acceptable products (Klug & von Rymon Lipinski, 2012). Studies suggest a combination of Ace-K and sugar alcohols provides both sweetness and bulk in reduced-calorie baked goods.

Stevia

Structure and Processing

Stevia ($C_{20}H_{30}O_3$) is a natural sweetener harvested from the leaves of *Stevia rebaudiana*, a plant native to South America. The sweet taste imparted by stevia comes from ten identified steviol glycosides in *S. rebaudiana* (Figure 2.5). These glycosides differ based on the number and type of sugars attached to the steviol backbone (Table 2.3). While the leaves of *S. rebaudiana* has been used for over a century in Paraguay and Brazil for their sweet taste, stevia's specific use as a sweetener in Western diets is newer (Carakostas, Prakash, Kinghorn, Wu, & Soejarto, 2012). Early stevia production and safety research focused mainly on stevioside.

However, rebaudioside A and steviol glycoside mixtures, both of purity greater than 95%, are commercially available today (Carakostas et al., 2012).

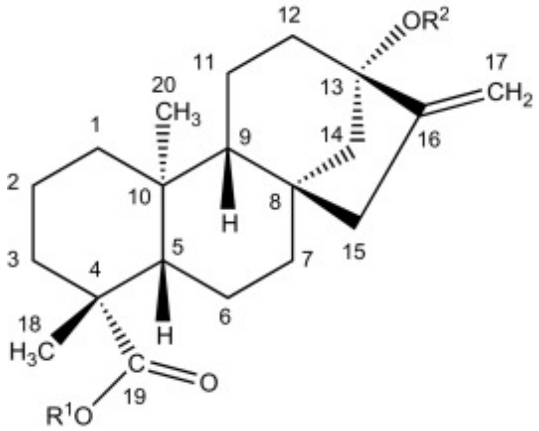

Figure 2.5–Chemical structure of steviol, the central core of all steviol glycosides (R^1=OH, R^2=H). R^1 and R^2 will vary, depending on the specific steviol glycoside.

Table 2.3–Comparison of steviol glycosides structures and sweetness potency (sucrose=1).

Compound	R-Groups in Steviol Backbone		Sweetness Potency
	R_1	R_2	
Dulcoside A	β-glc-	α-rha-β-glc-	30
Rebaudioside A	β-glc-	$(β\text{-glc})_2$-β-glc-	200-300
Rebaudioside B	H	$(β\text{-glc})_2$-β-glc-	150
Rebaudioside C	β-glc-	(β-glc, α-rha-)-β-glc-	30
Rebaudioside D	β-glc-β-glc-	$(β\text{-glc})_2$-β-glc-	221
Rebaudioside E	β-glc-β-glc-	β-glc-β-glc-	174
Rebaudioside F	β-glc-	(β-glc, β-xyl)-β-glc-	200
Rubusoside	β-glc-	β-glc-	114
Steviolbioside	H	β-glc-β-glc-	90
Stevioside	β-glc-	β-glc-β-glc-	150-250

Note. Reprinted from *Alternative Sweeteners: Fourth Edition*, by L. O'Brien-Nabors. Copyright 2012 by CRC Press.

Stevia plants can be grown all over the world, but most commercial stevia plants are grown in China. The leaves naturally contain 7-15% steviol glycosides, however breeding has

increased this content to 13-20%. Traditional extraction of steviol glycosides (stevioside and rebaudioside A) from stevia leaves requires a two-step process. First, glycosides are extracted with water and then dried. Then, the extracts are further purified using alcohol/water crystallization (Carakostas et al., 2012).

In modern extraction methods, hot water extraction of the leaves results in a "primary extract" that is separated from wastes via flocculation. The glycosides are concentrated by passing the extract through adsorption resins and eluting with alcohol, followed by a drying step. Finally, the dried eluate is re-dissolved into an alcohol solution and recrystallized (Carakostas et al., 2012). Individual steviol glycosides can be separated out using further chemical methods. To isolate stevioside, the crystalline solid is refluxed in a methanol solution then cooled. The filtrate from this process can also yield rebaudioside A. To specifically isolate rebaudioside A, the recrystallized solid is directly crystallized with alcohol. Methanol is the traditional solvent, but research has found using ethanol may increase yield (Carakostas et al., 2012).

Properties

The relative sweetness of stevia varies based on which steviol glycoside(s) is present. Table 2.1 lists the sweetness potency of each of the ten steviol glycosides that can be isolated from the stevia plant leaves. Rebaudioside A is the most potent steviol glycoside, rating up to 300 on the relative sweetness scale. Stevioside follows, with relative sweetness value rating up to 250 (Carakostas et al., 2012). When used at low levels, stevia imparts a clean, sweet flavor. However, negative flavor attributes can be detected when larger quantities of stevia are used. Most people report bitter and anise-like flavors, especially in products containing stevioside. Rebaudioside D has a sweet, clean taste without bitter notes. However, rebaudioside D is present

in very low levels in the leaves of currently available stevia plants and is not commercially available as a pure extract (Carakostas et al., 2012).

Both stevioside and rebaudioside A are readily soluble in water. Additionally, solution viscosity increases as more stevia is added. Stevia is very storage stable and can be stored at ambient temperatures for at least two years. It is heat-stable, meaning the compounds do not break down when exposed to high temperatures. It can withstand high baking temperatures and extreme pasteurization temperatures without significant loss of sweetness (Carakostas et al., 2012).

Steviol glycosides are hydrolyzed when consumed, but pass through the GI tract intact with little to no absorption. No studies have found any indication that the glucose moieties released from steviol glycosides during hydrolysis are absorbed. Rather, it is hypothesized that this glucose supplies energy to colonic bacteria. Finally, no evidence exists to suggest that steviol glycosides accumulate *in vivo* with repeated consumption, contributing to its safety as a food additive (Carakostas et al., 2012).

Saccharin

Chemical Structure and Synthesis

Saccharin ($C_7H_5NO_3S$) is one of the longest used artificial sweeteners and was discovered in 1878 at Johns Hopkins University (Figure 2.6). Three forms of saccharin exist, each with their own unique properties: sodium saccharin, calcium saccharin, and saccharin acid. Two methods are available to produce saccharin: the Remsen and Fahlberg process and the Maumee process. In the Remsen and Fahlberg process, toluene is treated with chlorosulfonic acid, making ortho- and para-toluene sulfonyl chloride which is then treated with ammonia. This treatment yields ortho-toluenesulfonamide and para- toluenesulfonamide. These two compounds are separated

and ortho-toluenesulfonamide is oxidized, forming saccharin acid (Ager et al., 1998). Further processing through dissolution, concentration, and crystallization steps will form sodium or calcium saccharin (Bakal and Nabors, 2012).

The Maumee process was developed much later, in the 1950s, by the Maumee Chemical Company. In this continuous process, purified methyl anthranilate is first diazotized to 2-carbomethoxybenzene-diazonium chloride, followed by a sulfonation step. Subsequent oxidation forms 2-carbomethoxybenzenesulfonyl chloride. This intermediate compound is amidated then acidified, yielding insoluble saccharin acid. Addition of sodium hydroxide and calcium hydroxide will form sodium and calcium saccharin (Bakal and Nabors, 2012).

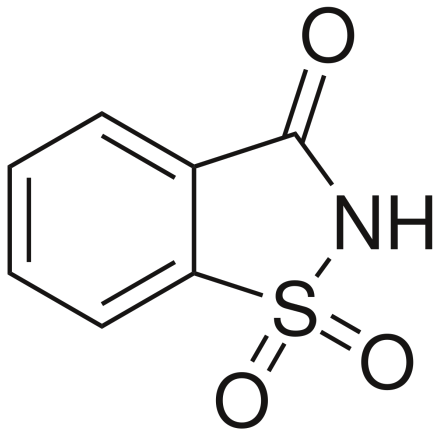

Figure 2.6–Chemical structure of saccharin.

Properties

Saccharin is a non-nutrative sweetener that is 300 times sweeter than sucrose, regardless of which of the three forms of saccharin. Each form of saccharin imparts a very sweet taste without calories. However, many people report bitter or metallic off-flavors associated with saccharin, making it less favorable than other alternative sweeteners. To correct this issue, saccharin can be blended with other sweeteners or masking agents to improve the aftertaste and mask bitterness. Almost any approved artificial sweetener and sugar can be blended

synergistically with saccharin, except Ace-K. Additionally, cream of tartar is the most common masking agent used (Bakal and Nabors, 2012).

Sodium saccharin is the most widely used form of saccharin for food products because it is the easiest to produce and has favorable properties. It is highly soluble in water and very stable. Dry saccharin is shelf-stable and stable under high temperature conditions used in food processing. Saccharin can be incorporated into baked food products without noticeable loss of sweetness. Aqueous saccharin solutions are also stable over a wide pH range (Bakal and Nabors, 2012).

Application of Different Sweeteners in Baked Products

Many challenges exist when replacing sucrose with an alternative sweetener(s) in reduced-calorie baked products. Sucrose provides many critical functional properties, such as bulking ability, favorable flavor profile, stability, tenderizing properties, and facilitating aeration of batters (Bakal, 2012; Psimouli & Oreopoulou, 2012).

One critical issue with alternative sweeteners is the lack of bulking ability by many alternative sweeteners. Very small portions of alternative sweeteners are needed to impart the same sweetness potency as compared to a large amount of sucrose. Therefore, bulking agents are often added to dough or batters of baked goods. Developments in the use and availability of polyols and polydextrose have provided the food industry with sweet bulking agents that do not contribute significant calories to products. Fibers have also been proven to work as added bulking agents in baked goods (Bakal, 2012).

The flavor profile of baked products made from alternative sweeteners also causes problems. Most artificial sweeteners are inferior to sucrose in term of taste, and may even impart negative flavor profiles or aftertastes. The strongest tool for addressing this issue is combining

sweeteners to create a new flavor profile and attempt to mask any off flavors from each individual sweetener. Often, combinations of alternative sweeteners exhibit a synergistic effect, making the blend taste better than the individual sweeteners alone. In addition, it has been observed that relative sweetness of an artificial sweetener decreases as the concentration increases (Bakal, 2012). This means less of each type of sweeteners is required to impart the same final sweetness when a blend of two or more sweeteners is used compared to only one alternative sweetener.

Stability can be another concern, especially regarding aspartame. Alternative sweeteners must be chosen carefully in order to produce high-quality end products. While most alternative sweeteners can withstand high baking temperatures, aspartame is not heat stable and breaks down when exposed to high temperatures. The correct choice of sweetener or sweeteners must be made when developing reduced-sugar products.

Gluten-Free Bread

Gluten-free foods, particularly gluten-free breads, are especially difficult to produce. Gluten is a critical ingredient in bread formulations to give bread its characteristic texture and rise during baking. While some food additives can be added to gluten-free formulations to improve their quality, no other additives have been found that can fully replace gluten in terms of functionality (Capriles & Arêas, 2014).

Gluten is a highly functional ingredient and is extremely difficult to replace in foods, especially bread (Delcour & Hoseney, 2010). Gluten is a protein in wheat that provides bread with its unique structure when developed with water and work (kneading). Gluten is composed of the gliadin and glutenin fractions and each contributes important properties (Capriles & Arêas,

2014; Delcour & Hoseney, 2010). Gliadin is the prolamin fraction of gluten, and provides gluten with its sticky and viscous properties. Glutenin is the glutelin fraction of gluten, and provides gluten with its elastic properties. Combined, gliadin and glutenin help to form viscoelastic dough that can be stretched and molded (Capriles & Arêas, 2014; Delcour & Hoseney, 2010). The gliadin and glutenin fractions cross-link with one another via disulfide bonds during baking. This chemical reaction allows the dough to continue to cover the expanding air cells within the dough and create stable pockets of air in the baked bread (Delcour & Hoseney, 2010).

Without gluten, bread dough is unable to retain gases and does not rise well. Gluten-free breads require additional ingredients and processing in order to produce a palatable loaf of bread (Delcour & Hoseney, 2010; Capriles & Arêas, 2014). Gluten-free breads are made from batter with more added water than typical bread dough. The increased amount of water creates a suspension that traps limited air during mixing. Without gluten, the batter is not viscoelastic and therefore cannot retain any gas that is produced during leavening. The air that is entrapped from mixing forms only a few, unstable air pockets. This leads to a number of quality defects, including low loaf volume, weak crumb structure, dry and crumbly texture, excessive cracking of the crust, poor mouthfeel, off flavors, and increased rate of staling (Capriles & Arêas, 2014).

Ingredients

Though gluten can never be fully replaced in bread formulations, specific ingredients and additives may be added in order to improve the quality of gluten-free breads. These include different functional ingredients such as flours, starches, hydrocolloids, and eggs.

Flours and Starches

The most widely used cereal flours for gluten-free bread production are corn and rice flours (Capriles & Arêas, 2014). Rice flour is a popular choice because it is inexpensive, widely

available, and does not impart a noticeable taste or color on gluten-free rice bread formulations. But, rice flour has extremely poor functional properties and poor-quality proteins. When using rice flour, other additives must be included to produce an acceptable loaf of bread. Corn flour is another choice, but presents a different set of issues when applying to gluten-free bread applications. Corn flour has a noticeable yellow color and distinct flavor, making it more difficult to incorporate in bread formulations. Wheat, rye, barley, and crossbred varieties of these cereal grains all contain gluten and gluten-like compounds, making them unusable in gluten-free bread applications. Oats have also been used in gluten-free bread production, however its use is controversial. Oat flour is used for its great nutritional properties; oats contain β-glucans, which aid in reducing cholesterol and controlling blood glucose levels. Oat flour also has been shown to improve the quality of gluten-free breads, including acceptable loaf volume and softer crumb. However, oats can contain or be contaminated with gluten, rendering it no longer gluten-free (Hüttner, Dal Bello, & Arendt, 2010; Kim & Yokoyama, 2011).

Other cereal grains, pseudocereals, legumes, nuts, and fruits can also be used to produce gluten-free breads. Sorghum, millet, and teff are all gluten-free cereals. Sorghum will be discussed in more detail later. Millet and teff are most commonly used to produce flatbreads. However, breads produced with 100% teff have significantly reduced aromatic sensory quality (3.8 out of 9 (hedonic scale)) compared to whole wheat bread (6.7) and sorghum bread (5.5) (Hager et al., 2012). Amaranth, buckwheat, and quinoa are pseudocereals used to produce gluten-free bread. Pseudoscereals resemble cereal grain in terms of composition and usage, but differ in their genetics. Amaranth is the most studied pseudocereal due to its high nutritional value, including high levels of proteins, essential amino acids, fatty acids, minerals, and bioactive components (Capriles & Arêas, 2014). A study found that using amaranth, buckwheat,

or quinoa significantly increased ($p<0.01$) the protein content compared to a control gluten-free bread made from potato and rice starches (Alvarez-Jubete, Arendt, & Gallagher, 2009). Bread made with 50% amaranth had the highest protein value at 11.6%, compared to 4.2% protein content in the gluten-free control bread. This is followed by 50% quinoa (10.6%) and 50% buckwheat (8.4%) formulations. This study also found these pseudocereals produced bread with significantly greater ($p<0.01$) ash (amaranth: 3.3%; buckwheat: 2.6%; quinoa: 3.1%) and fat (amaranth: 8.8%; buckwheat: 7.5%; quinoa: 8.6%) contents and three times more fiber (amaranth: 17.2%; buckwheat: 23.3%; quinoa: 16.1%) than the gluten-free control (ash: 2.3%; fat: 6.7%; fiber: 7.6%) (Alvarez-Jubete, Arendt, & Gallagher, 2009). Another study found pseudocereals produce bread with softer crumb texture, and buckwheat and quinoa yield gluten-free bread with greater loaf volume (buckwheat: 1.63 ml/g; quinoa: 1.40 ml/g) than gluten-free bread made with potato and rice starches (1.29 ml/g) (Alvarez-Jubete, Auty, Arendt, & Gallagher, 2010).

Many novel gluten-free flours have been derived from products such as cassava, flaxseed, chia seeds, soy, chickpeas, chestnuts, and unripe bananas. However, these novel flours typically cannot be used alone and require other gluten-free flours or extra processing (heat treatment). For example, raw soy-based flours yield bread with a more favorable appearance (7.25 out of 9) and higher loaf volume (2.96 cm^3/g) than those made with heat-treated soy flour (appearance: 1.75-3.62; loaf volume: 1.81-2.25 cm^3/g). However, raw soy flours impart a “beany” odor and flavor to bread. Heat-treatment is used to remove these unfavorable sensory properties, but leads to bread with decreased quality (Shin, Kim, & Kim, 2013). Chia flour can be incorporated into rice flour gluten-free breads at levels up to 14% while maintaining similar loaf volume (1.69 cm^3/g) and crumb firmness (15.89 N) compared to gluten-free rice control bread (loaf volume:

1.69 cm^3/g; firmness: 15.22 N) (Sandri, Santos, Fratelli, & Capriles, 2017). Fourteen percent chia flour was also incorporated without causing significant changes ($p>0.05$) compared to rice flour gluten-free bread; the loaf volume (1.69 cm^3/g) was the same for both 14% chia flour and 100% rice flour gluten-free bread and the crumb firmness of 14% chia bread was only 0.67 N greater than the control (Sandri, Santos, Fratelli, & Capriles, 2017).

Gluten-free breads can also be formulated using starches. Potato, corn, rice, and tapioca starches are all popular options. While it is possible to formulate gluten-free bread from a single starch, these formulations often require additional ingredients in order to create quality loaves of bread with acceptable sensory properties. Many food companies utilize proprietary blends of potato, corn, rice, tapioca, and pseudocereal starches to produce the best quality gluten-free breads with acceptable loaf volume, texture, color, and flavor (Pszczola, 2012). Blended starches work synergistically to compensate for properties that a single starch alone may lack. Blends may be created to increase nutrient value, mimic properties of wheat-based products, or enhance functional properties (Pszczola, 2012).

Hydrocolloids

Hydrocolloids, commonly referred to as gums, "comprise diverse water-soluble polysaccharides with different chemical structures providing a range of functional properties that make them widely used in the food industry" (Anton & Artfield, 2008, p. 14). Hydrocolloids have the ability to modify starch gelatinization and extend product quality past expected expiration dates. They interact with water to forms gel networks, subsequently increasing batter viscosity. This provides added strength for the batter to capture expanding air cells, increasing the gas retention capability of the batter during the proofing and baking process. Hydrocolloids also act as binding agents and can be thought of as a substitute for gluten (Anton & Artfield,

2008). Overall, this improves loaf volume, structure, crumb texture, and appearance of gluten-free breads (Capriles & Arêas, 2014).

Xanthan gum, guar gum, carboxymethylcellulose (CMC), carrageenan, locust bean gum, agar, and hydroxypropyl methylcellulose (HPMC) are all hydrocolloids that can be used to improve gluten-free bread formulations. CMC and HPMC are reported to be the most promising hydrocolloids in terms of gluten replacement. Cato, Gan, Rafael, and Small (2004) found that hydrocolloids CMC and HPMC can be used to produce high quality gluten-free rice breads at levels as low as 0.8% and 3.3%, respectively. With these respective levels of CMC and HPMC, gluten-free white rice breads can have similar loaf volumes (106 cm^3) compared to a control breads made with 70% wheat and 30% rice flours (110 cm^3) and 60% wheat and 40% rice flours (106 cm^3). Additionally, these incorporations of CMC and HPMC produced gluten-free white rice bread with similar firmness (1.8 N) to a 100% wheat control (1.5 N) (Cato et al., 2004). Even in wheat-based breads, HPMC has shown great promise as an ingredient to improve bread quality. Bread baked with HPMC had significantly increased ($p<0.05$) volume (HPMC=5.16 cm^3/g, Control=4.66 cm^3/g) and reduced crumb hardness (HPMC=200.5 g, Control=282.7 g) compared to the control. HPMC also aids in reducing staling rate and improving sensory properties (Bárcenas & Rosell, 2005). This study suggests HPMC is able to retard the staling process in bread because it slows the diffusion of water out of the crumb, keeping the bread moist and soft longer.

Eggs

Eggs play an important role as emulsifying agents in gluten-free bread formulations. Eggs have strong foaming and emulsifying properties, forming cohesive films that aid in gas retention and stable foaming during the baking process. This ultimately leads to bread with a

favorable crumb structure. Eggs' emulsifying properties also aid in reducing the staling rate of gluten-free breads. Emulsifiers are amphiphilic, meaning they orient themselves along the interface of two immiscible phases. They act to retard staling by interacting with starch molecules, reducing the speed of staling, and increasing water retention in the crumb (Capriles & Arêas, 2014).

Eggs have been shown to increase specific volume in gluten-free sorghum bread. A thesis research project by Bize (2012) found that using 20%, 25%, and 30% egg in gluten-free bread formulation resulted in specific loaf volumes of 2.90 cm^3/g, 2.94 cm^3/g, and 2.95 cm^3/g, respectively. This is compared to a specific volume of 2.84 cm^3/g for the control gluten-free sorghum bread with 0% egg. This thesis also found that adding egg to gluten-free sorghum breads positively affects hardness (517.6 g force) and crumb structure (smaller cell sizes) compared to the 0% egg control (hardness=659.3 g force; larger, uneven cell sizes).

Sorghum

Sorghum is a gluten-free cereal grain that is gaining popularity as an ingredient in gluten-free breads. It has wide genetic diversity and varies in size, shape, and color. It is the fifth most popular cereal worldwide and is most popular as an ingredient in Africa and Asia (Rooney & Waniska, 2000). Sorghum is categorized into types based on the color of the pericarp; it can be white, red, yellow, bronze, or brown (Delcour & Hoseney, 2010; Dykes, Rooney, Waniska, & Rooney, 2005). All sorghums contain phenolic compounds, which is affected by their variety and growing conditions. Total phenolic contents of sorghum can range from 2.1 mg gallic acid equivalents (GAE)/g in white sorghums up to 8.9 mg GAE/g in dark-colored sorghums with thick pericarps. It is noted that dark sorghums with thin pericarps have similar total phenolic contents to white sorghum varieties (Dykes et al., 2005). Some sorghum varieties contain very

high levels of proanthocyanidins, commonly called condensed tannins. Sorghum varieties with darker-colored (red) pericarp may have up to 15.5 mg of these condensed tannins per gram, compared to almost zero mg of condensed tannins per gram in white sorghums (Dykes et al., 2005). Phenolic compounds in sorghum help protect the crop against insects and disease, making them "bird-resistant" (Delcour & Hoseney, 2010; Dykes et al., 2005). They also act as antioxidants *in vitro*, contributing to a decrease in free radicals and therefore a decreased risk of some chronic diseases, including cancer, rheumatoid arthritis, and cataracts (Awika, Rooney, Wu, Prior, & Cisneros-Zevallos, 2003; Dykes et al., 2005; Parr & Bolwell, 2000).

However, condensed tannins give red sorghum varieties a very bitter flavor, making it unappealing for most food applications (Delcour & Hoseney, 2010). The choice of sorghum variety is important when formulating gluten-free bread recipes. With its lower phenolic and condensed tannin contents, white sorghums are less bitter and are better-suited for consumption. Genetic hybrids of sorghum have been studied to determine which are best for gluten-free breadmaking. In one study, researchers found no significant differences ($p>0.05$) were found between any hybrids for loaf volume (1.77-1.84 mL/g), loaf height (7.0-7.5 cm), bake loss (13.4-14.7%), or water activity (0.986-0.988) (Schober, Messerschmidt, Bean, Park, & Arendt, 2005). However, significant differences ($p<0.05$) between hybrids were noted for crumb color and crumb hardness (7.5-21.6 N). White sorghum hybrids had more variability in hardness, with both extremes in texture range from white hybrids. Red sorghum hybrids varied less, and produced bread with greater and more consistent hardness (Schober et al., 2005).

Concerns Associated with Sorghum Consumption

One serious concern with sorghum consumption is the prussic acid content of sorghum grain. Sorghum may contain toxic levels of prussic acid (cyanide). The digested prussic acid is

released into the system of the consumer (human or animal) and can cause lethal cyanide poisoning. This creates significant health problems, especially for grazing livestock. However, selective breeding has created new lines of sorghum crops that have completely eliminated prussic acid from the grain (Dahlberg, Berenji, Sikora, & Latković, 2011; Department of Economic Development, 2017). Additionally, careful management of grazing livestock and controlling of the amount of sorghum animals consume in a single feeding can prevent illness in livestock (Department of Economic Development, 2017).

Nitrate poisoning through sorghum consumption is another concern. Sorghum can contain elevated levels of nitrates that can lead to nitrate poisoning in consumers. Nitrates accumulate heavily in sorghum due to increased soil nitrate, moisture stress, cloudy weather, and application of fertilizers and herbicides. Careful monitoring of growing conditions and discarding sorghum with higher nitrate levels can help minimize this risk (Department of Economic Development, 2017).

Uses of Sorghum

Sorghum is a drought-tolerant cereal crop that requires little water to grow efficiently, making it ideal for areas with rising populations with little access to water. Because of this characteristic, it is widely used as a food crop in parts of Africa and Asia (Taylor, Schober, & Bean, 2006). In the United State and Europe, sorghum grain is primarily used for livestock feed. The stems and foliage of sorghum plants are often used for silage and hay. However, there is much greater potential for sorghum grains aside from feed alone (Taylor, Schober, & Bean, 2006).

Sorghum has potential for use in producing bioethanol. Significant research is still being conducted to learn more about using sorghum for bioethanol production. The starch content of

sorghum is very similar to that of corn, giving it similar fermenting properties to corn bioethanol (Taylor, Schober, & Bean, 2006). Sorghum grain has also been found to have other favorable characteristics for bioethanol production, including high sugar accumulation, ability to produce high biomass, and rapid growth. Specifically, sorghum's drought tolerance has drawn considerable attention to sorghum's potential as an ingredient for bioethanol in arid regions (Nghiem, Montanti, & Johnston, 2016).

Sorghum is also gluten-free and can be used for the flour portion in gluten-free food applications. Traditionally, sorghum is used in fermented and non-fermented food products in Africa and Asia, such as flatbreads, porridges, couscous, beverages, and beers (Dahlberg, Berenji, Sikora, & Latković, 2011). The use of sorghum for human food in developed countries is less popular due to the high concentration of tannins that makes sorghum taste bitter. However, development of white sorghum lines has created bland sorghum flours that have more favorable sensory properties (Taylor, Schober, & Bean, 2006). Food products that use sorghum flour include breads, tortillas, chips, cakes, cookies, and noodles (Zhu, 2014).

Gluten-Free Sorghum Breads

When producing gluten-free breads with sorghum flour, it is most often combined with corn, rice, potato, or cassava starches and may be native or pregelatinized. The type of starch used has a significant impact on the properties of the batter and baked bread. According to a study by Onyango, Mutungi, Unbehend, and Lindhauer (2011b), using 30%, 40%, and 50% pregelatinized cassava starch in gluten-free sorghum bread formulations produced firm and inelastic batter that closely mimics a wheat bread dough. However, after baking, the crumb was very wet, giving it a sticky texture, undesirable pore formation, and causing loaves to collapse minutes after removing from the oven. Using native starch produced a fluid batter, typical of

gluten-free breads, which could retain fine dispersions of carbon dioxides during proofing and baking. Ultimately, formulations including native starch produced baked loaves with softer and more desirable crumb texture compared to the wet and sticky texture of sorghum bread made with pregelatinized starch (Onyango, Mutungi, Unbehend, & Lindhauer, 2011b). A tandem study found that including cassava starch at 50% with sorghum flour yielded the best quality bread (Onyango, Mutungi, Unbehend, & Lindhauer, 2011a).

Regular Versus Waxy Sorghum

Sorghum is a starchy cereal grain, with 82.3% of each kernel composed of starchy endosperm. The endosperm is opaque with many intergranular spaces between starch granules. Starch granules in sorghum are approximately 20 μm in diameter and are polygonal or spherical (Delcour & Hoseney, 2010).

Starch is primarily composed on polymeric carbohydrates. These polymers are made up of α-D-glucopyranosyl units amylose and amylopectin. Amylose is a mostly linear polymer made up of α-D-glucose linked by α-1,4 bonds, with each chain varying from 500 to 6,000 units long. Twenty-five to fifty-five percent of the molecules on each chain have occasional α-1,6 branch points. However, amylose chains are so long and branch points are so few that each molecule behaves like a linear chain. (Delcour & Hoseney, 2010). Amylopectin is a highly branched polymer composed of α-D-glucose linked primarily by α-1,4 bonds. Four to five percent of the glycosidic bonds are α-1,6 linkages and each chain is only 20-25 units long (Delcour & Hoseney, 2010). Three types of chains make up amylopectin molecules. A chains are the outer-most chains and do not have any α-1,6 branch points. B chains are intermediate; they contain both α-1,4 and α-1,6 bonds. The C chain anchors the amylopectin molecule; it contains

α-1,4 and α-1,6 linkages as well as the molecule's singular reducing group (Delcour & Hoseney, 2010).

Amylose-to-amylopectin ratios depend on the type of grain in which the starch is found. The proportion of each component greatly affects the functional properties of the starch. Amylose has the ability to form complexes, or clathrates, with compounds such as iodine, organic alcohols, or fatty acids (Delcour & Hoseney, 2010). Amylopectin, the major component of most starches, is related to the crystalline structure, gelatinization, retrogradation, and pasting properties of starch (Han et al., 2008).

The differentiation between regular and waxy starches depends on the amylose-to-amylopectin ratio in the starch. In most regular starches, 20-30% of the carbohydrates are made up by amylose while the other 70-80% of the molecule is composed of amylopectin. Waxy starches are cereal starches that are almost 100% amylopectin (Delcour & Hoseney, 2010). Regular sorghum starch has been found to have an amylose content of 30.43%, similar to corn (30.91%) and wheat (30.57%) starches. Waxy sorghum, on the other hand, has amylose content below detectable levels. The distribution and length of side chains in waxy sorghum is also similar to waxy corn starch (Han et al., 2008).

Additionally, studies have found that combining waxy sorghum traits with high protein digestibility traits into a single sorghum variety forms softer and less sticky starch pastes more suited for dough-based products. These varieties have higher peak pasting viscosity and flour-water solubility than regular sorghum varieties without high protein digestibility (Elhassan, Emmambux, Hays Peterson, & Taylor, 2015). Compared to the peak pasting viscosity of non-waxy sorghum varieties without high protein digestibility (879-1267 mPa-s), waxy sorghum varieties with high digestibility ranged from 1424 to 1759 mPa-s. Waxy, highly digestible

sorghum starch also had decreases stickiness (0.038-0.045 N) compared to the regular sorghum starch (0.136-0.300 N) (Elhassan et al., 2015). However, little information is available regarding how these properties affect the final baked products from these improved doughs.

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Chapter 3 - Development of a laboratory exercise to investigate the functionality of alternative sweeteners in rolled cookies

Introduction

One important ingredient in rolled cookie formulations is sugar, and sucrose is commonly used (Kweon, Slade, Levine, Martin, & Souza, 2009). Sucrose is a highly functional ingredient, and contributes to key physical and sensory characteristics of cookie dough and baked cookies. Sucrose acts as a plasticizer during baking as well, decreasing dough viscosity and dissolving into the dough during the mixing process. Any intact sucrose in cookie dough dissolves during baking (Pareyt et al., 2009). This fluidity causes the cookies to spread in the oven, with higher concentrations of sucrose correlating with greater spread (Pareyt et al., 2009). Cookies expand in the oven, followed by a structural collapse and recrystallization of dissolved sucrose. These phenomena are believed to give sugar snap cookies their characteristic cracked appearance on the top, but it is still debated whether structural collapse or sucrose recrystallization is the primary mechanism (Slade & Levine, 1994; Pareyt et al., 2009). Sucrose is a critical component of the Maillard browning reaction, giving sugar cookies a golden-brown color during baking (Ameur, Mathieu, Lalanne, Trystram, & Birlouez-Aragon, 2007). These characteristics contribute to expected final-product quality of sugar-snap cookies, including crisp texture and storage stability (Slade & Levine, 1994).

Hands-on learning is a proven method of encouraging students to think critically about real-world problems and improve their retention of knowledge and communication skills (Hollis & Eren, 2016). Hands-on activities encourage active learning, which in turn promotes higher-order thinking and an improved ability to apply knowledge to real-world issues (Arthurs & Kreager, 2017). In the academic world, many faculty members have embraced active learning in

their own classrooms and laboratories. Defined as "any instructional method that engages students in the learning process," active learning requires students to immerse themselves in the learning experience and think critically about learning objectives (Prince, 2004). The overall goals of active learning are to improve student activities and engagement in learning, contrasted with the passive environment associated with traditional classroom learning (Prince, 2004).

Given these observations, laboratory sections are often the best way to implement active learning and hands-on exercises for students enrolled in science-based college courses. Cooperative and collaborative learning are related learning styles that focus on small group environments as represented by laboratory sections. Cooperative learning is defined as a learning environment where students work together toward a common goal while being evaluated separately on their performance. Collaborative learning is a broader category encompassing any learning activity where students work together (Prince, 2004). These types of learning incorporate teamwork into the framework of hands-on learning and require students to work together on a common project. Laboratory exercises provide instructors with ways of teaching students about approved and standard methods of testing. Exercises like these show students how to correctly analyze different food products and introduces them to the resources for finding standard methods. These skills are an important part of food science education to prepare students for real-world job experiences.

The objectives of this study were to 1) provide an innovative laboratory exercise for professors and teachers of food science courses to implement in their own classrooms; and 2) to include a data set collected from both students and a trained researcher to assist in understanding typical data that should be yielded from this exercise.

Materials and Methods

Experimental Design

The laboratory exercise was first offered in spring 2018 and students were given two laboratory periods to complete the eight treatments. In spring 2019, it was determined that students could adequately complete all eight treatments in one laboratory section, with each group preparing two treatments. Nine treatments with varying amounts of sugar and/or alternative sweeteners were prepared: cane sugar as control (C), Splenda for baking (S), Equal for baking (E), Truvia (T), Sweet'N Low (SNL), mixtures (1:1 sweetness) of S and sugar (S+S), E and sugar (E+S), T and sugar (T+S), and SNL and sugar (SNL+S). Sweeteners were chosen based on commercial popularity and as demonstrations for students. Splenda for baking is made up of sucralose, a popular sugar alternative used in baked goods, and maltodextrin as a bulking agent. Equal for baking contains aspartame, acesulface potassium (Ace-K), and maltodextrin for bulking. Aspartame is a popular sugar alternative in the beverage industry, but it is not heat stable and therefore not a good option for use in baked products. Stevia (Truvia) has functional properties more similar to sucrose, plus the addition of erythritol in Truvia enhances its functionality in baked products. Sweet'N Low is not available commercially as a blend for baking and has very little bulking ability.

Four replications of the eight alternative sweetener treatments were performed by undergraduate students (n = 4). Four lab sections of the Fundamentals of Food Processing course at Kansas State University represented each of the replications. The four replications of the control were prepared by the graduate teaching assistant (GTA) to provide control data for the students. Eight laboratory groups containing two to three students were formed in each section.

Materials

Formulations with supplier information for each treatment and the control are provided in Tables 3.1 and 3.2. Ingredients for the experiment were purchased from a local grocery store (Manhattan, KS). Equipment included mixing bowls, spoons, disposable pipettes and weigh boats, rolling pins, 7 mm diameter round wooden dowels, 7.5 cm circular cookie cutters, scales (Ohaus, Parsippany, NJ), stand mixers with flat paddle attachment (KitchenAid Artisan, Model No. KSM150PSWH, St. Joseph, MI), stainless steel baking trays (The Vollrath Co., L.L.C., Sheboygan, WI; USA PAN, Crescent, PA), baking ovens (Whirlpool Model RF367LXSB, Benton Harbor, MI), cooling racks, plastic wrap (Handi-Film, Handi-foil of America Inc., Wheeling, IL), parchment paper (Reynolds Consumer Products LLC, Lake Forest, IL), and low density polyethylene (LDPE) bags (Ziploc, SC Johnson, Racine, WI).

Analytical equipment needed to collect data included digital calipers (Tool Shop, Eau Claire, WI), 12-inch rulers with cm/mm on one side, portable HunterLab MiniScan EZ colorimeter (Model No. 4500L, Reston, VA), Texture Technologies Corp texture analyzer with 30 kg load cell and flat blade attachment (TA-XT2, Scarsdale, NY), and Exponent Stable Micro Systems texture analysis software (Godalming, Surrey GU7 1YL, United Kingdom).

Table 3.1–Formulations of cookies made with 100% alternative sweeteners.

Ingredient	Supplier	Amount (g)				
		Control	Splenda for baking	Equal for baking	Truvia	Sweet' N Low
Shortening (soybean oil, hydrogenated palm oil, palm oil, mono and diglycerides, TBHQ, citric acid)	The Kroger Co., Cincinnati, OH	64	64	64	64	64
Sugar	Great Value, Wal-Mart Stores, Inc., Bentonville, AR	130	-	-	-	-
Splenda for Baking (maltodextrin, sucralose)	McNeil Nutritionals LLC, Fort Washington, PA	-	16.2	-	-	-
Equal for Baking (maltodextrin, aspartame, acesulfame potassium)	Merisant US, Inc., Chicago, IL	-	-	15.2	-	-
Truvia (erythritol, stevia leaf extract, natural flavors)	Cargill, Inc., Minneapolis, MN	-	-	-	60	-
Sweet'N Low (nutritive dextrose, saccharin, cream of tartar, calcium silicate)	Cumberland Packing Corp., Brooklyn, NY	-	-	-	-	16
Iodized salt (salt, calcium silicate, dextrose, potassium iodide)	The Kroger Co., Cincinnati, OH	2.1	2.1	2.1	2.1	2.1
Sodium bicarbonate	Arm & Hammer, Church & Dwight, Co., Inc., Ewing, NJ	2.5	2.5	2.5	2.5	2.5
Dextrose solution[1]	STALEYDEX 333, Tate & Lyle, Decatur, IL	33	33	33	33	33
Water		16	64	64	64	64
All-purpose flour (bleached wheat flour, malted barley flour, niacin, iron(reduced), thiamin mononitrate, riboflavin, folic acid)	Great Value, Wal-Mart Stores, Inc., Bentonville, AR	225	225	225	225	225

Total	472.6	406.8	405.8	450.2	406.6

[1]Dextrose solution = 8.9 g dextrose in 150 mL water.

Table 3.2–Formulations of cookies made with alternative sweeteners and sucrose blends.

Ingredient	Amount (g)			
	Splenda for baking + sugar	Equal for baking + sugar	Truvia + sugar	Sweet'N Low + sugar
Shortening (soybean oil, hydrogenated palm oil, palm oil, mono and diglycerides, TBHQ, citric acid)	64	64	64	64
Sugar	65	65	65	65
Splenda for Baking (maltodextrin, sucralose)	8.1	-	-	-
Equal for Baking (maltodextrin, aspartame, acesulfame potassium)	-	7.6	-	-
Truvia (erythritol, stevia leaf extract, natural flavors)	-	-	30	-
Sweet'N Low (nutritive dextrose, saccharin, cream of tartar, calcium silicate)	-	-	-	8.0
Iodized salt (salt, calcium silicate, dextrose, potassium iodide)	2.1	2.1	2.1	2.1
Sodium bicarbonate	2.5	2.5	2.5	2.5
Dextrose solution[1]	33	33	33	33
Water	64	64	64	64
All-purpose flour (bleached wheat flour, malted barley flour, niacin, iron(reduced), thiamin mononitrate, riboflavin, folic acid)	225	225	225	225
Total	463.7	463.2	485.6	463.6

[1]Dextrose solution = 8.9 g dextrose in 150 mL water.

Laboratory Exercise

Laboratory handouts were provided on Canvas (Instructure, Inc., Salt Lake City, UT) for students to review prior to the laboratory. Canvas is an educational platform used by many universities to connect students and professors, and is a way for professors to post class information, assignments, and grades for students to access. The full laboratory exercise, including instructions, formulations, and rubrics, can be found in Appendix A. Prior to the beginning of laboratory, a five-point quiz was given to students to assess their pre-lab understanding of the laboratory exercise. Additionally, the instructor and TAs gave brief verbal instructions to the class before they began the exercise. Instructors discussed the role of the exercise as a thesis research project and emphasized the purpose of performing multiple replications of the exercise and the importance of following instructions during preparation and data collection methods to ensure accurate and precise results.

Each laboratory section was divided into four laboratory groups, and each group was assigned one sweetener. Students were responsible for preparing the batch with the full amount of their assigned alternative sweetener and with the alternative sweetener plus sucrose. All formulations and baking procedures were adapted from American Association of Cereal Chemists (AACC) Method 10-50.05: Baking Quality of Cookie Flour (AACC International, 1999).

Students were instructed to calculate the percent by weight and the baker's percent of each ingredient. They then were instructed that, throughout the experiment, they needed to record the weight of the empty mixing bowl, mixing bowl plus all ingredients before portioning, mixing bowl with unused dough after portioning, and all baked cookies (for use later in determining percent waste and yield). Ovens were preheated to 400ºF (204.4ºC) and ingredients

were gathered. Shortening, sugar, salt, and sodium bicarbonate were creamed in a stand mixer on Speed 2 for three min, scraping the bowl after each min. Dextrose solution and water were added and mixed for one min on Speed 2 and another min on Speed 4, scraping the bowl in between. Flour was added and mixed to a dough for two min on Speed 2, scraping the bowl every 30 s.

Dough was then placed between pieces of plastic wrap and rolled to a uniform thickness of 7 mm using dowel rods taped to a clean counter top 7" apart as guides. A round cookie cutter of 7.5 cm diameter was used to cut cookies. Students were instructed to cut as many cookies as they could from the dough, re-rolling the dough no more than two times to avoid overworking. Cookies were baked for 10 min on sheet trays lined with parchment paper. All cookies were removed from the oven after 10 min, regardless of appearance, to keep baking times between batches uniform. Cookies were allowed to cool for an additional 10 min before analyses were performed. Three cookies were set aside for texture analyses that was conducted by the GTA and data was provided to the students.

Physical Analyses

After all weights (as described above) were recorded, students calculated the percent waste and percent yield of each replication (Equations 1 and 2). Percent waste represents the amount of unused dough not made into cookies, and percent yield represents the weight of cookies prepared from the formulation.

$$\text{Percent waste} = \frac{\text{Wt. of bowl after portioning} - \text{Wt. of empty bowl}}{\text{Wt. of bowl plus ingredients} - \text{Wt. of empty bowl}} \times 100 \quad (1)$$

$$\text{Percent yield} = \frac{\text{Wt. of cookies after baking}}{\text{Wt. of bowl plus ingredients} - \text{Wt. of empty bowl}} \times 100 \quad (2)$$

Students used the following procedures to measure overall spread of cookies. Width-to-thickness (W/T) ratio of each batch was calculated using the AACC Method 10-50.05: Baking Quality of Cookie Flour (AACC International, 1999) with modification (three cookies instead of

six). Briefly, three cookies were laid side-by-side and their diameter was measured in mm with a ruler (Figure 3.1a). The cookies were turned 90º and the diameter was measured again. These two values were used to find the average diameter (width). The thickness was found by measuring the height in mm of three cookies (Figure 3.1b). The three cookies were shuffled and the height was measured again. These two values were used to find the average height (thickness).

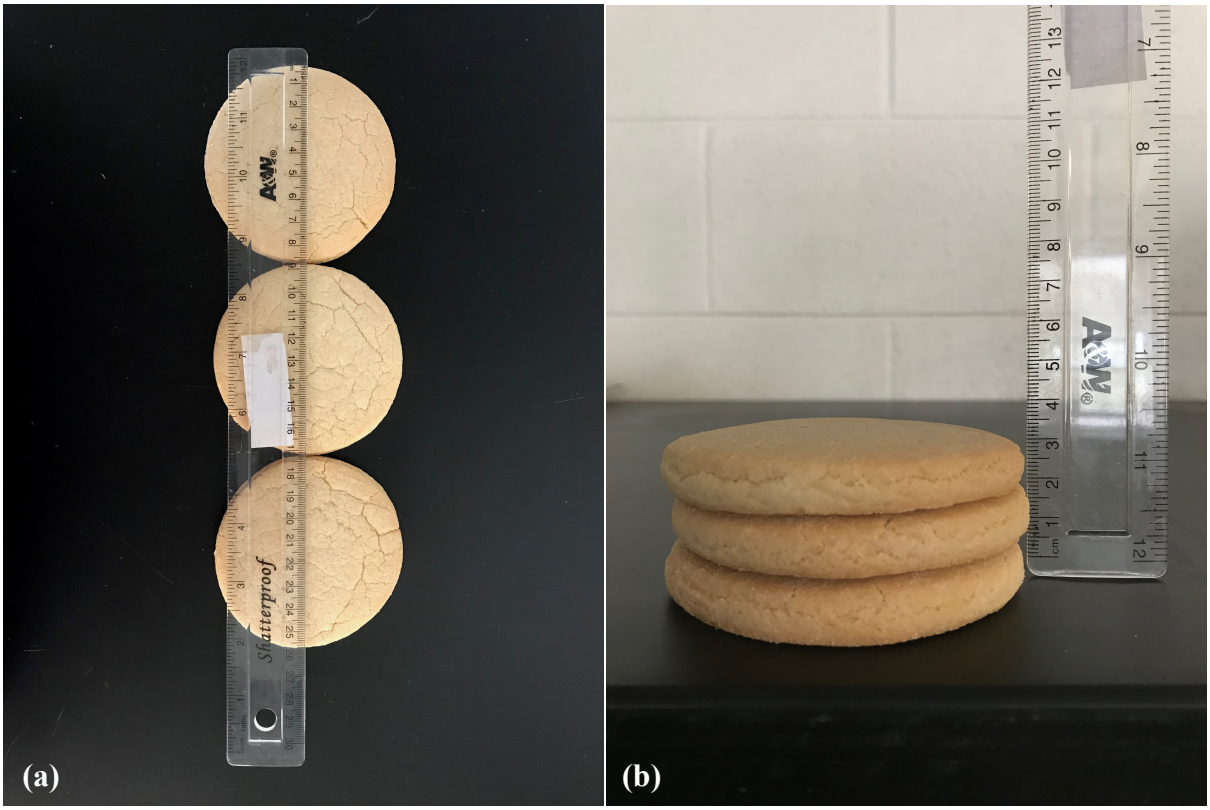

Figure 3.1–Images of control cookie showing width (a) and thickness (b) measurements to determine width-to-thickness ratio.

The W/T ratio was calculated by dividing the average width of the three cookies by the average thickness of the three cookies (Equation 3).

$$\mathrm{W/T} = \frac{\text{Average width of 3 cookies}}{\text{Average thickness of 3 cookies}} \quad (3)$$

The top color of one cookie per treatment was analyzed using a standardized HunterLab MiniScan EZ colorimeter. The colorimeter was standardized using the standard procedure provided by Hunter Associates Laboratory, Inc. (Reston, VA) calibrating against both a black glass port and a white tile. The L*, a*, and b* readings were recorded, and the total color change (ΔE) was calculated for each replication (Equation 4).

$$\Delta E = \sqrt{L^{*2} + a^{*2} + b^{*2}} \quad (4)$$

After the in-class analyses were complete, the GTA collected three cookies from each replication to use for texture profile analysis (TPA). TPA of cookies was performed for their hardness and snapping force using a calibrated Texture Technologies Corp texture analyzer by following the methods suggested by the manufacturer ("Texture Analysis Application Areas," n.d.). Snapping force was measured using a three-point snap test, where a blade attachment was used to fracture a cookie on a support with a separation of 20 cm. The probe was set to 25% strain and the load cell measured the force to fracture the cookie. The data from each compression was generated on Exponent Stable Micro Systems texture analysis software. Hardness was measured as maximum force at the first compression. The TPA analysis was performed in duplicate; two cookies from each replication were measured. Data was then distributed to students to include in their lab reports.

Sensory Analysis

One whole cookie from each treatment was placed on a plate and students observed the appearance of the cookie from each treatment. Students (n=60) then ingested a small portion of one cookie from each treatment and rated cookies on a hedonic scale (Appendix A) and wrote a short description of the appearance, texture, flavor, sweetness, and aftertaste. The ratings were numbered from one to nine (where 1=Dislike Extremely and 9=Like Extremely) to allow the

sensory data to be quantified. The sensory panel was not a blind study, which may contribute to a bias in results but exposed students to the different sensory profiles associated with the control and eight treatments.

Laboratory Report

After completion of the exercise, students were required to write a memorandum-style laboratory report over their findings from the exercise. The report was worth 75 points and students were given two weeks to complete the report. The full rubric and instructions can be found in Appendix A. Students were instructed to format their report with a memorandum heading and section headers (Overview, Materials and Methods, Results and Discussion, Conclusion) with all relevant information. They also were to include a minimum of four scientific, peer-reviewed references to support their findings in the report. Students were expected to write the laboratory report in a manner that would allow a reader to completely replicate the exercise from their written report alone. They also had to include a discussion of all results and their implications in terms of product quality and overall success of the exercise. Additionally, students were required to draw a flow diagram of a commercial rolled cookie operation, with correct arrows showing the flow of product through the processing system.

Statistical Analysis

All data from each lab section were collected in the form of laboratory reports, compiled and analyzed by the authors. The effects of treatments were analyzed for their significance ($p < 0.05$) using one-way ANOVA followed by a Tukey's multiple comparison test to elucidate the difference between samples. Prior to statistical analysis, class data was checked for outliers and those data points were removed. Student and controlled data also were analyzed for their interactions using a principal component analysis (PCA). PCA components are graphed for the

first two components to elucidate the effects of treatment on cookie quality parameters as well as preparation method (i.e., class versus controlled samples) All the statistical analyses were performed using Minitab 18© Software (State College, PA).

Results and Discussion

Appearance

Appearance of the cookies varied based on the sweetener that was added for each treatment. Control cookies had the typical cracked top, while cookies prepared with alternative sweeteners lacked this characteristic. Cookies from treatment T+S had a smooth surface similar to C, but lacked the cracked appearance. Cookies from the rest of the treatments had uneven, intact top surfaces after baking and greater thicknesses. Incorporation of sucrose into the alternative sweetener treatments was not enough to cause cookies to crack on top during baking.

Waste and Yield

The average percent wastes and yields varied greatly because replications were performed by different groups of students (Table 3.3). This may be due to the students performing these replications; certain groups could have been more careful to use as much of the dough as possible rather than making the minimum number of cookies needed and throwing the rest away. Large standard deviations for yield and waste were noted for all treatments (1.49-28.08%). Most waste was produced from the rolling step of preparing the treatments. Some groups chose not to use all the dough that was prepared and instead discarded dough. When rolling the cookies, the dough could only be rolled one to two times before becoming overworked and unusable, contributing to more waste. It was important for students to understand where waste was being generated and how much of each treatment was being thrown

away versus baked into the final product. On an industrial scale, waste must be kept to a minimum in order for companies to make a profit from their product. Students learned about minimizing waste and trying to achieve the highest possible percent yield from this benchtop example. In addition, the total waste (i.e., unused cookie dough for making baked cookies) considerably decreased (ca. 25%) from Week 1 (combined waste 57.4%) to Week 2 (combined waste 43.5%) when the exercise was first implemented, although the difference is not significant due to large standard errors. This observation indicates that students' skills can improve with practice and they can perform the task more effectively when they have previously experienced similar work. This exemplifies the importance of repetition of similar but distinct treatments in teaching.

Table 3.3–Means and standard deviations for percent waste and yield for each treatment.

Factor[1]	Waste (%)	Yield (%)
C	9.25±3.21	83.53±1.49
S	4.54±5.96	90.92±3.94
E	13.96±19.95	72.29±28.08
T	16.55±16.78	63.86±8.41
SNL	22.25±12.42	86.08±11.04
S+S	9.82±4.75	86.49±8.38
E+S	8.69±6.94	77.81±9.87
T+S	6.48±5.34	81.80±7.64
SNL+S	18.50±15.69	74.80±15.37

[1]C=Control; S=Splenda for baking; E=Equal for baking; T=Truvia; SNL=Sweet'N Low; S+S=Splenda for baking + sugar; E+S=Equal for baking + sugar; T+S=Truvia + sugar; SNL+S=Sweet'N Low + sugar

Spread

The W/T ratios for treatments fell into two Tukey comparison groups (Table 3.4). Treatments C, T, and T+S had much larger W/T ratios (7.2-7.8) and were significantly different ($p<0.05$) from all other treatments (4.5-5.6). This indicates these three treatments had smaller

thicknesses and larger diameters than the other treatments with alternative sweeteners. Figure 3.2 a-i shows the variations in thickness between each treatment.

Table 3.4–Means and standard deviations for W/T ratios of each treatment.

Factor[1]	Class Mean
C	7.8±0.4 [a]
S	4.6±0.6 [b]
E	4.6±0.9 [b]
T	7.2±1.0 [a]
SNL	4.5±0.1 [b]
S+S	4.8±0.3 [b]
E+S	5.6±0.8 [b]
T+S	7.4±0.8 [a]
SNL+S	4.8±0.3 [b]

[a-b]Tukey pairwise comparisons appear as superscripts by each mean. Means within a column that share a letter are not significantly different ($p>0.05$).

[1]C=Control; S=Splenda for baking; E=Equal for baking; T=Truvia; SNL=Sweet'N Low; S+S=Splenda for baking + sugar; E+S=Equal for baking + sugar; T+S=Truvia + sugar; SNL+S=Sweet'N Low + sugar

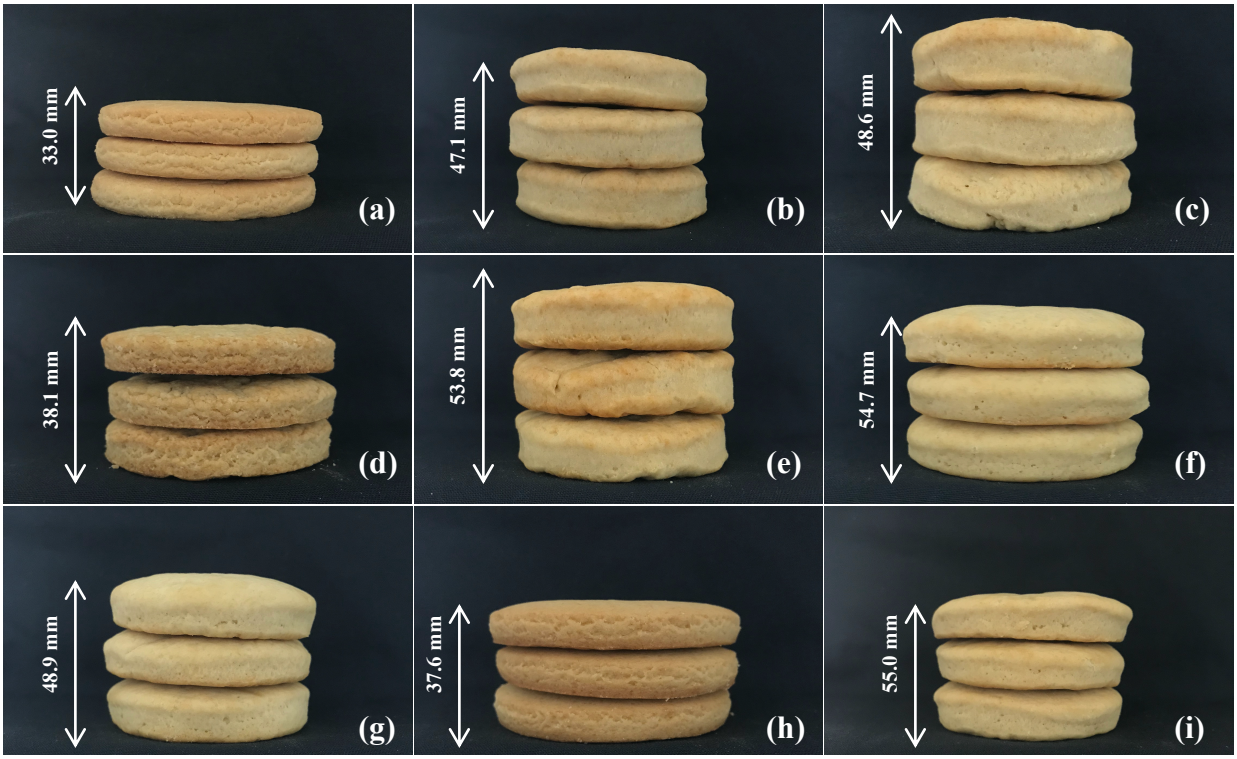

Figure 3.2–Side view of three cookies from each treatment: Control (a), Splenda for baking (b), Equal for baking (c), Truvia (d), Sweet'N Low (e), Splenda + sucrose (f), Equal + sucrose (g), Truvia + sucrose (h), Sweet'N Low + sucrose (i).

Color

Total color change (ΔE) between each treatment varied only slightly; no ΔE for any treatment was significantly different ($p>0.05$) from any other treatment (80.190-84.075) (Table 3.5). Mean L*, a*, and b* values varied very little though standard deviations were somewhat large.

Table 3.5–L*a*b*, ΔE, and standard deviations for each treatment.

Factor[1]	L*	a*	b*	ΔE
C	75.985 ±1.733	4.098 ±2.167	27.103 ±3.202	80.858 ±0.801 [a]
S	77.175 ±2.231	2.370 ±1.515	31.378 ±2.764	83.407 ±0.933 [a]
E	76.235 ±3.205	3.250 ±2.255	32.540 ±2.304	83.029 ±1.980 [a]
T	74.145 ±4.533	3.678 ±2.336	30.095 ±2.526	80.190 ±3.860 [a]
SNL	77.783 ±0.611	2.535 ±0.900	31.283 ±3.553	83.934 ±0.830 [a]
S+S	76.338 ±1.690	2.138 ±1.720	30.613 ±2.855	82.321 ±1.946 [a]
E+S	78.125 ±1.858	1.460 ±1.486	30.610 ±2.502	83.871 ±0.743 [a]
T+S	76.770 ±1.804	3.850 ±1.918	29.055 ±2.886	82.235 ±1.379 [a]
SNL+S	78.068 ±1.329	1.900 ±1.484	31.060 ±2.181	84.075 ±1.027 [a]

[a]Tukey pairwise comparisons appear as superscripts by each mean. Means within a column that share a letter are not significantly different ($p>0.05$).

[1]C=Control; S=Splenda for baking; E=Equal for baking; T=Truvia; SNL=Sweet'N Low; S+S=Splenda for baking + sugar; E+S=Equal for baking + sugar; T+S=Truvia + sugar; SNL+S=Sweet'N Low + sugar

Texture Profile Analysis

Values collected from TPA varied significantly with large standard deviations; however this is expected (Table 3.6). Food products are not homogenous, leading to variations in the values generated by TPA. Both hardness and fracturability values of cookies made with only alternative sweeteners were greater than treatments with the same sweeteners plus sucrose. This indicates cookies made with alternative sweeteners alone were harder and required more force to fracture than those made with both alternative sweetener and sucrose.

Table 3.6–Means and standard deviations for hardness and three-point fracturability of each treatment.

Factor[1]	Hardness (N)	3- Point Fracturability (N)
C	6369±1060 [a]	4460±687 [a]
S	2198±469 [c]	3844±783 [a,b]
E	2049±372 [c]	4622±1349 [a]
T	6878±1165 [a]	2914±1077 [a,b]
SNL	2004±610 [c]	3390.6±109.6 [a,b]
S+S	1518±508 [c]	1699±891 [b]
E+S	1603±280 [c]	1359±439 [b]
T+S	4224±1575 [b]	1635±1489 [b]
SNL+S	1776±417 [c]	1732±431 [b]

[a-c]Tukey pairwise comparisons appear as superscripts by each mean. Means within a column that share a letter are not significantly different ($p>0.05$).

[1]C=Control; S=Splenda for baking; E=Equal for baking; T=Truvia; SNL=Sweet'N Low; S+S=Splenda for baking + sugar; E+S=Equal for baking + sugar; T+S=Truvia + sugar; SNL+S=Sweet'N Low + sugar

Sensory Analysis

Students rated all treatments low on the hedonic scale. In terms of flavor and sweetness, treatment C rated the highest, followed closely by T+S meaning these two treatments were the most acceptable (Table 3.7). Treatment E rated the lowest in terms of flavor and sweetness. Overall, the low hedonic ratings were expected. The AACC cookie formulation used in this exercise was optimized for studying physical characteristics of rolled cookies rather than for taste.

Table 3.7–Means and standard deviations for hedonic ratings (out of nine) of sensory parameters for each treatment.

Factor[1]	Mean Appearance Rating	Mean Texture Rating	Mean Flavor Rating	Mean Sweetness Rating	Mean Aftertaste Rating
C	6.89±1.42 [a]	6.32±1.60 [a]	6.57±1.54 [a]	6.43±1.68 [a]	6.07±1.59 [a]
S	5.08±1.60 [c,d]	5.54±1.85 [a,b,c]	4.32±1.81 [b,c,d]	4.57±2.23 [c,d,e]	4.19±2.02 [b,c]
E	4.95±1.66 [c,d]	4.61±1.78 [c]	3.79±1.78 [d]	2.62±1.59 [f]	3.52±1.50 [c,d]
T	2.84±1.51 [e]	3.30±1.38 [d]	4.03±1.95 [d]	4.33±2.04 [d,e]	3.84±1.86 [b,c,d]
SNL	4.35±1.56 [d]	4.87±2.04 [c]	3.86±1.75 [d]	3.83±1.92 [e]	3.02±1.56 [d]
S+S	5.46±1.47 [b,c]	5.38±2.05 [a,b,c]	5.12±1.81 [b,c]	4.98±1.67 [c,d]	4.75±1.99 [b]
E+S	5.77±1.58 [b,c]	4.93±1.64 [b,c]	4.13±1.92 [c,d]	3.95±1.95 [e]	4.36±1.94 [b,c]
T+S	5.41±2.12 [c]	5.92±1.71 [a,b]	6.43±1.53 [a]	6.31±1.64 [a,b]	6.05±1.78 [a]
SNL+S	6.33±1.45 [a,b]	6.12±1.57 [a]	5.16±1.73 [b]	5.39±1.57 [b,c]	4.43±2.16 [b,c]

[a-e]Tukey pairwise comparisons appear as superscripts by each mean. Means within a column that share a letter are not significantly different ($p>0.05$).

[1]C=Control; S=Splenda for baking; E=Equal for baking; T=Truvia; SNL=Sweet'N Low; S+S=Splenda for baking + sugar; E+S=Equal for baking + sugar; T+S=Truvia + sugar; SNL+S=Sweet'N Low + sugar

Conclusion

Overall, researchers determined that the alternative sweeteners laboratory exercise was successfully implemented in the classroom. Student-generated data showed statistically significant differences between treatments in terms of physical and sensory parameters. These differences serve to illustrate functional differences between sucrose and alternative sweeteners in a rolled cookie application in an exercise that students can easily perform in a two-hour laboratory period. This exercise introduced students to official methods of sample preparation and standard methods of physical and sensory analysis.

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Chapter 4 - Assessing Functionality of Alternative Sweeteners in Rolled Cookies

Introduction

One important ingredient in rolled cookie formulations is sugar, and sucrose is commonly used (Kweon, Slade, Levine, Martin, & Souza, 2009). Sucrose is a highly functional ingredient and contributes to key physical and sensory characteristics of cookie dough and baked cookies. Sucrose acts as a plasticizer during baking as well, decreasing dough viscosity and dissolving into the dough during the mixing process. Any intact sucrose in cookie dough dissolves during baking (Pareyt et al., 2009). This fluidity causes the cookies to spread in the oven, with higher concentrations of sucrose correlating with greater spread (Pareyt et al., 2009). Cookies expand in the oven, followed by a structural collapse and recrystallization of dissolved sucrose. These phenomena are believed to give sugar snap cookies their characteristic cracked appearance on the top, but it is still debated whether structural collapse or sucrose recrystallization is the primary mechanism (Slade & Levine, 1994; Pareyt et al., 2009). Sucrose is a critical component of the Maillard browning reaction, giving sugar cookies a golden-brown color during baking (Ameur, Mathieu, Lalanne, Trystram, & Birlouez-Aragon, 2007). These characteristics contribute to expected final product quality of sugar-snap cookies, including crisp texture and storage stability (Slade & Levine, 1994).

Sugar reduction is one example of a current challenge being addressed in the food industry. Sugar provides empty calories and it is nutritionally poor. In addition, sugar consumption can lead to adverse health effects as it is considered to be a key factor to increased risk of obesity (Zoulias, Oreopoulou, & Kounalaki, 2002). Obesity, in turn, is an important risk factor for Type II diabetes, cardiovascular disease (CVD), some cancers, and other chronic

diseases. Indeed, the epidemic of obesity and its subsequent chronic diseases is a worldwide issue. By the year 2030, it is projected that 1.12 billion people around the world will be obese if current trends are sustained (Kelly, Yang, Chen, Reynolds, & He, 2008). Therefore, consumers are looking to lower the glycemic impact of the food they consume (Kweon, Slade, Levine, Martin, & Souza, 2009). However, sugar intake in the United States and many developed countries still remains higher than recommended, accounting for more than 20% of a person's total daily calories in some populations (Siervo et al., 2013). Studies have been done to assess both public health and economic benefits of imposing such a tax on sugary beverages in the United States because the current small sales tax on soft drinks has not deterred many consumers from continuing to purchase such beverages (Brownell et al., 2009).

There is, therefore, a large focus on replacing the sugar with healthier options. The use of alternative sweeteners has increased from 3% to 15% from 1960's to the new millennium for this reason (Gardner et al., 2012). Popular options for alternative sweeteners include sucralose, aspartame, acesulfame potassium (Ace-K), saccharine, plant-based sweeteners (such as Stevia), and sugar alcohols. Many of these options (i.e., except sugar alcohols) are considered "high-intensity" sweeteners, as their sweetness is much greater (i.e., 100 times). A much smaller amount of these alternative sweeteners can be added to foods to impart the same level of sweetness without adding calories. High-intensity sweeteners provide a good option for those consumers looking to cut calories. However, their functionality is limited when compared to sugar.

The objective of this study was to determine the effect of different sucrose alternatives on physiochemical and sensory properties of rolled cookies.

Materials and Methods

Experimental Design

The experiment consisted of nine treatments: sucrose control (C), Splenda for baking (S), Equal for baking (E), Truvia (T), Sweet N'Low (SNL), and mixtures of S and sucrose (S+S), E and sucrose (E+S), T and sucrose (T+S), and SNL and sucrose (SNL+S). Mixtures were calculated based on the relative sweetness of each alternative sweeteners compared to sucrose, so that the mixtures were 1:1 sweetness. The experiment was performed in triplicate (n=3).

Sweetener treatments were chosen based on popularity or to demonstrate lack of functional properties to food science students. Splenda for baking is made up of sucralose, a popular sugar alternative in baked goods, and maltodextrin, a bulking agent. Equal for baking includes aspartame, acesulfame potassium (Ace-K), and maltodextrin for bulking. Aspartame is a popular sugar-free sweetener for beverages, but is not heat-stable and therefore not useful in baked food applications. Truvia, composed of stevia and erythritol, is an all-natural sugar alternative with a sugar alcohol added for functional benefits. Sweet N'Low is made up of saccharin, but contains no bulking agents and therefore lacks functionality in baking applications.

Materials

All ingredients were purchased from a local store (Manhattan, KS). Suppliers and formulations can be found below in Tables 4.1 and 4.2. Equipment needed to prepare the cookies included scales (Ohaus, Parsippany, NJ), weigh boats, spoons, disposable pipettes, spatulas, stand mixer with flat paddle attachment (KitchenAid Artisan, Model No. KSM150PSWH, St. Joseph, MI), rolling pin, 7.5 cm circular cookie cutter, 7 mm diameter wooden dowel rods, parchment paper (Reynolds Consumer Products LLC, Lake Forest, IL), plastic wrap (Handi-

Film, Handi-foil of America Inc., Wheeling, IL), baking sheets (The Vollrath Co., L.L.C., Sheboygan, WI; USA PAN, Crescent, PA), ovens (Whirlpool Model RF367LXSB, Benton Harbor, MI), cooling racks, and low-density polyethylene (LDPE) bags (Ziploc, SC Johnson, Racine, WI).

Analytical equipment needed to collect data included digital calipers (Tool Shop, Eau Claire, WI), 12-inch rulers with cm/mm on one side, portable HunterLab MiniScan EZ colorimeter (Model No. 4500L, Reston, VA), Texture Technologies Corp texture analyzer with 30 kg load cell and flat blade attachment (TA-XT2, Scarsdale, NY), and Exponent Stable Micro Systems texture analysis software (Godalming, Surrey GU7 1YL, United Kingdom).

Table 4.1–Formulations for cookies made with 100% alternative sweeteners.

Ingredient	Supplier	Amount (g)				
		Control	Splenda for baking	Equal for baking	Truvia	Sweet' N Low
Shortening (soybean oil, hydrogenated palm oil, palm oil, mono and diglycerides, TBHQ, citric acid)	The Kroger Co., Cincinnati, OH	64	64	64	64	64
Sugar	Great Value, Wal-Mart Stores, Inc., Bentonville, AR	130	-	-	-	-
Splenda for Baking (maltodextrin, sucralose)	McNeil Nutritionals LLC, Fort Washington, PA	-	16.2	-	-	-
Equal for Baking (maltodextrin, aspartame, acesulfame potassium)	Merisant US, Inc., Chicago, IL	-	-	15.2	-	-
Truvia (erythritol, stevia leaf extract, natural flavors)	Cargill, Inc., Minneapolis, MN	-	-	-	60	-
Sweet'N Low (nutritive dextrose, saccharin, cream of tartar, calcium silicate)	Cumberland Packing Corp., Brooklyn, NY	-	-	-	-	16
Iodized salt (salt, calcium silicate, dextrose, potassium iodide)	The Kroger Co., Cincinnati, OH	2.1	2.1	2.1	2.1	2.1
Sodium bicarbonate	Arm & Hammer, Church & Dwight, Co., Inc., Ewing, NJ	2.5	2.5	2.5	2.5	2.5
Dextrose solution[1]	STALEYDEX 333, Tate & Lyle, Decatur, IL	33	33	33	33	33
Water		16	64	64	64	64
All-purpose flour (bleached wheat flour, malted barley flour, niacin, iron(reduced),	Great Value, Wal-Mart Stores, Inc., Bentonville, AR	225	225	225	225	225

thiamin mononitrate, riboflavin, folic acid)						
	Total	472.6	406.8	405.8	450.2	406.6

[1]Dextrose solution = 8.9g dextrose in 150 mL water.

Table 4.2–Formulations for cookies made with alternative sweeteners and sucrose blends.

Ingredient	Amount (g)			
	Splenda for baking + sugar	Equal for baking + sugar	Truvia + sugar	Sweet'N Low + sugar
Shortening (soybean oil, hydrogenated palm oil, palm oil, mono and diglycerides, TBHQ, citric acid)	64	64	64	64
Sugar	65	65	65	65
Splenda for Baking (maltodextrin, sucralose)	8.1	-	-	-
Equal for Baking (maltodextrin, aspartame, acesulfame potassium)	-	7.6	-	-
Truvia (erythritol, stevia leaf extract, natural flavors)	-	-	30	-
Sweet'N Low (nutritive dextrose, saccharin, cream of tartar, calcium silicate)	-	-	-	8.0
Iodized salt (salt, calcium silicate, dextrose, potassium iodide)	2.1	2.1	2.1	2.1
Sodium bicarbonate	2.5	2.5	2.5	2.5
Dextrose solution[1]	33	33	33	33
Water	64	64	64	64
All-purpose flour (bleached wheat flour, malted barley flour, niacin, iron(reduced), thiamin mononitrate, riboflavin, folic acid)	225	225	225	225
Total	463.7	463.2	485.6	463.6

[1]Dextrose solution = 8.9g dextrose in 150 mL water.

Procedures

Procedures and formulations were adapted from American Association of Cereal Chemists (AACC) Method 10-50.05: Baking Quality of Cookie Flour (AACC International, 1999). Ingredients were gathered and the oven was preheated to 400ºF (204.4ºC). Shortening, sweetener(s), salt, and sodium bicarbonate were creamed in a stand mixer for three min on Speed 2, pausing to scrape the sides of the bowl every one min. Dextrose solution and water were added and mixed on Speed 1 for one min and then one more min on Speed 4, stopping in between to scrape the bowl. Flour was then added and mixed for two min on Speed 2, scraping the bowl every 30 s.

Dough was removed from the bowl and placed between two pieces of plastic wrap. Two 7 mm diameter wooden dowel rods were taped to a clean countertop 7" apart, so that the entire width of the rolling pin rested on top of them. The dough was rolled to 7 mm thickness, using the dowel rods as guides. Cookies were cut using a 7.5 cm circular cookie cutter. Dough was rerolled up to two times to obtain as many cookies as possible from the dough to prevent overworking. Cookies were baked 10 min at 400ºF (204.4ºC), then promptly removed from the oven and placed on a cooling rack. Cookies were allowed to cool approximately 30 min before they were placed in LDPE bags and frozen at 10ºF (-12.2ºC) overnight. They were allowed to thaw approximately 1 hr before analyzing.

Physical Analyses

Spread

Cookies spread was measured using a method adapted from AACC Method 10-50.05: Baking Quality of Cookie Flour (AACC International, 1999). Three cookies were placed edge-to-edge and the width was measured in mm. The cookies were then rotated 90º and the width

was measured again. The average width was calculated. The same three cookies were then stacked on top of one another and the thickness (height) of the stack was measured in mm. The stack of cookies was shuffled and the thickness was measured again. The average thickness was calculated from the two thickness values. Then, the average width and average thickness were used to calculate the width-to-thickness (W/T) ratio (Equation 1.)

$$\mathrm{W/T} = \frac{\text{Average width of 3 cookies}}{\text{Average thickness of 3 cookies}} \quad (1)$$

Moisture Loss

Moisture loss was determined for each treatment to ensure the amount of water added in the raw dough for all treatments did not significantly affect the final cooked dough product. The baking sheet was first tared on a scale (Ohaus I-20W Model B10AS, Parsippany, NJ). Cut cookies were placed on the baking sheet and their weight was recorded. After baking, the cookies were allowed to cool slightly before their final weight was recorded. These values were used to calculate percent moisture loss that occurred during baking (Equation 2).

$$\text{Percent moisture loss} = \frac{\text{Wt.of raw cookies} - \text{Wt.of baked cookies}}{\text{Wt.of raw cookies}} \times 100 \quad (2)$$

Color

A portable HunterLab MiniScan EZ colorimeter was calibrated using the standardized methods provided by Hunter Associates Laboratory, Inc. (Reston, VA) using a black glass and while tile. Using the colorimeter, the top L*a*b* color of one cookie from each replication was collected. Using the collected L*a*b* values, the total color change (ΔE) was calculated (Equation 3).

$$\Delta E = \sqrt{L^{*2} + a^{*2} + b^{*2}} \quad (3)$$

Texture Profile Analysis (TPA)

Texture profile analysis was performed on two cookies per treatment from each replication. Cookies were analyzed for their hardness and three-point fracturability with a calibrated Texture Technologies Corp texture analyzer, using methods suggested by the manufacturer ("Texture Analysis Application Areas," n.d.). A flat blade attachment was attached to the texture analyzer and probe was set to 25% strain. Cookies were placed on a support with a separation of 20 cm. Two compressions of the cookies were performed consecutively. Data was generated on Exponent Stable Micro Systems texture analysis software. Hardness was measured as maximum force at the first compression and snapping force was measured as the amount of force required to fracture the cookie.

Sensory Analysis

A group of students in a food science class evaluated cookies on appearance, texture, flavor, sweetness, and aftertaste using a nine-point hedonic scale. Whole cookies from each treatment were placed on white plates for students to observe the appearance of each treatment. Students (n=60) then consumed a small piece of one cookie from each treatment and rated each characteristic from one to nine (1=dislike extremely, 9=like extremely). The sensory panel was not blind, meaning students knew which treatments they were rating. Class instructors wanted students to understand differences in treatments. This may have contributed to some bias in results, but provides trends on consumer acceptability.

Statistical Analysis

Data was compiled and effects of treatments were analyzed for their significance ($p<0.05$) using one-way ANOVA followed by a Tukey's multiple comparison test to find

differences between samples. All the statistical analyses were performed using Minitab 18© Software (State College, PA).

Results and Discussion

Appearance

The appearance of the cookies varied based on the sweetener that was added for each treatment (Figure 4.1). Control cookies had a cracked top as observed in typical sugar-snap cookies. Cookies from treatment T+S had a smooth surface similar to C, but lacked the cracked appearance. The remaining treatments yielded cookies with uneven, uncracked top surfaces after baking and the cookies appeared thicker. The incorporation of 50% sucrose into the alternative sweetener treatments did not yield a typical cracked surface appearance. This is probably because during baking, moisture is lost from the surface of the cookie but is replaced by water that diffuses from the center of the cookie (Delcour & Hoseney, 2010). However, sucrose is able to recrystallize at the cookie's surface; when this happens, the sucrose no longer holds moisture at the cookie's surface. The crystallized sucrose then causes the cookie's surface to dry and break as the cookie continues to expand during baking. This phenomenon causes the typical, cracked appearance of sugar cookies after baking (Delcour & Hoseney, 2010). Cookies made without sucrose do not have this expected appearance because alternative sweeteners are not able to recrystallize and crack on the cookie's surface.

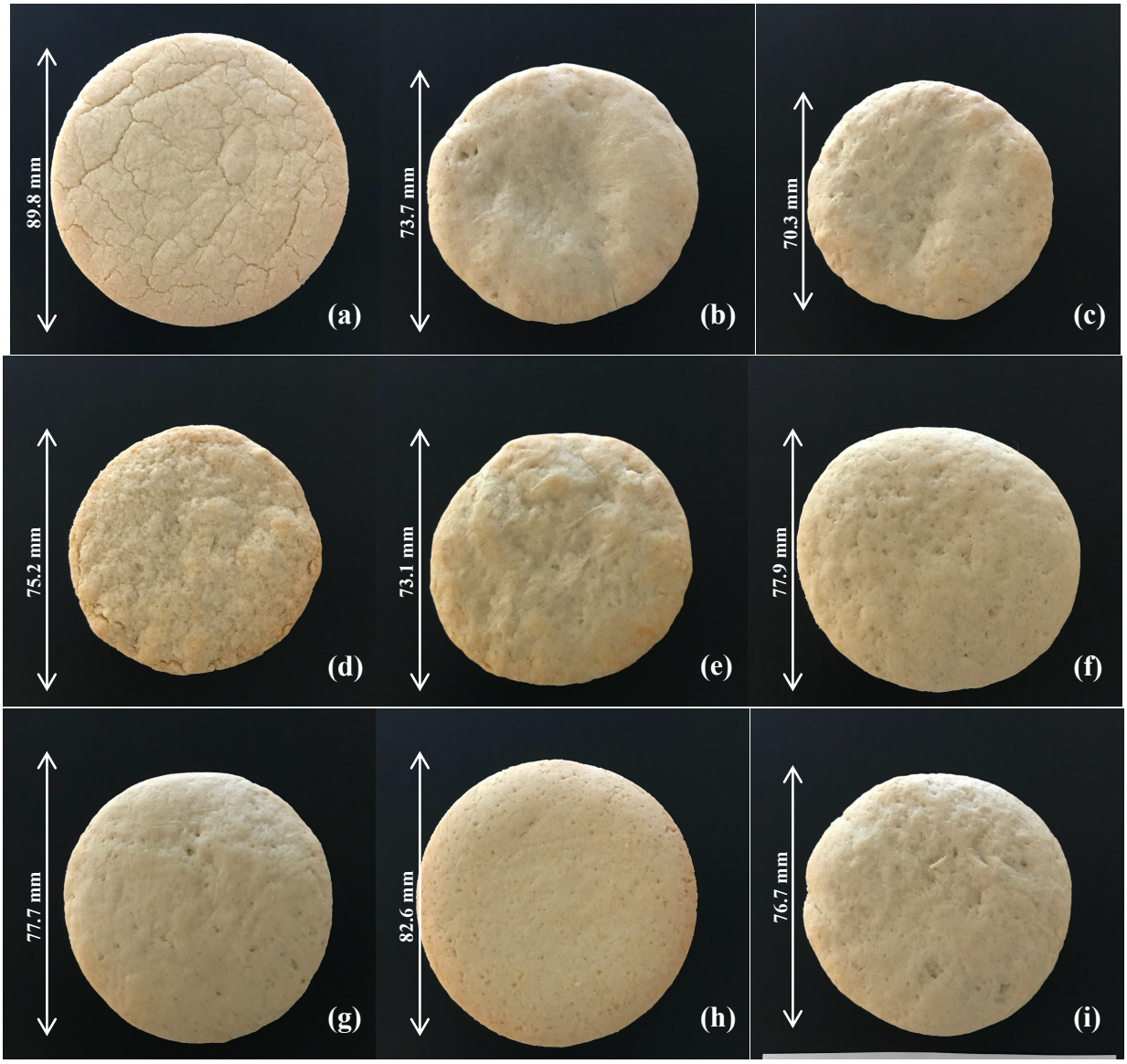

Figure 4.1–Top images of cookies from each treatment: Control (a), Splenda for baking (b), Equal for baking (c), Truvia (d), Sweet'N Low (e), Splenda + sucrose (f), Equal + sucrose (g), Truvia + sucrose (h), Sweet'N Low + sucrose (i).

Spread

The treatment with the largest W/T ratio was C (7.7), followed by T+S (6.6) and T (5.7) (Table 4.3, Figure 4.2). C was different ($p<0.05$) from all other treatments, and T and T+S were statistically similar but significantly different from all other treatments. Smaller widths indicate

that cookies did not spread, and thus have greater thicknesses. Smaller W/T ratios result when widths are small and thicknesses are large.

Sugar-snap cookies made with sucrose had greater diameters and lower thicknesses than cookies prepared with other sugars or sweeteners. As sucrose content in cookies increases, so does the diameter (Kweon et al., 2009; Doescher, Hoseney, Milliken, & Rubenthaler, 1987; Pareyt et al., 2009). Sucrose slowly dissolves throughout the baking time, leading to an improved spread over sweeteners that are fully dissolved prior to baking (Pareyt et al., 2009). The crystals of some alternative sweeteners do not share sucrose's ability to spread cookies during the baking process (Laguna, Vallons, Jurgens, & Sanz, 2013). As the amount of dietetic sweeteners (mannitol and sorbitol) in cookies increases, the width of the cookies decreases (Pasha, Butt, Anjum, & Shehzadi, 2002).

Table 4.3–Means and standard deviations for width-to-thickness ratios of each treatment.

Factor[1]	Controlled Mean
C	7.7±0.5 [a]
S	4.5±0.3 [c]
E	4.3±0.4 [c]
T	5.7±0.4 [b]
SNL	4.2±0.2 [c]
S+S	4.5±0.4 [c]
E+S	4.5±0.2 [c]
T+S	6.6±0.2 [b]
SNL+S	4.4±0.2 [c]

[a-c]Tukey pairwise comparisons appear as superscripts by each mean. Means within a column that share a letter are not significantly different ($p>0.05$).
[1]C=Control; S=Splenda for baking; E=Equal for baking; T=Truvia; SNL=Sweet'N Low; S+S=Splenda for baking + sugar; E+S=Equal for baking + sugar; T+S=Truvia + sugar; SNL+S=Sweet'N Low + sugar

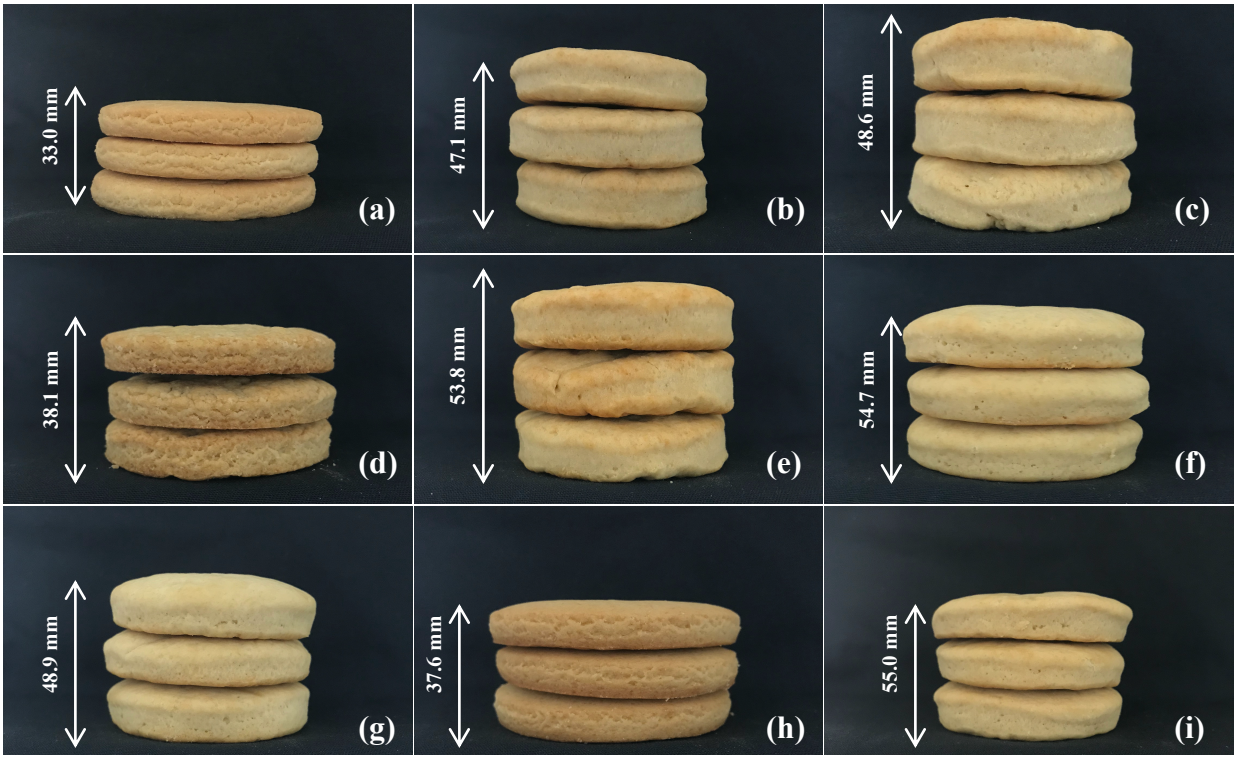

Figure 4.2–Side view of three cookies from each treatment: Control (a), Splenda for baking (b), Equal for baking (c), Truvia (d), Sweet'N Low (e), Splenda + sucrose (f), Equal + sucrose (g), Truvia + sucrose (h), Sweet'N Low + sucrose (i).

Moisture Loss

Moisture loss among all controlled setting treatments was not significant ($p>0.05$) (data not shown). Moisture loss ranged from 5.34 to 6.58%. Samples with both alternative sweetener and sugar had greater percent moisture losses than the formulations that did not contain sugar. Sucrose typically has a greater water-holding capacity than other sweeteners. As sucrose content in cookie dough decreases, so does the final moisture content (Pareyt et al 2009). Differences in moisture content stem back to the initial moisture content of the dough. Doughs made from the alternative sweeteners would have had lower initial moisture contents than the control (Pareyt et al 2009). A consistent oven temperature regulated the rate of moisture removal and percent moisture loss would have been similar for all treatments.

Color

C had the lowest L* value (76.160) and highest a* value (4.383) (Table 4.4). T+S had the highest b* value (28.770), followed by SNL+S (27.170) and then C (26.607). Treatments C (80.842) and SNL+S (83.208) were the only samples that had a difference in ΔE that was statistically significant ($p<0.05$). Sucrose participates in the Maillard browning reaction by breaking down into reducing sugars fructose and glucose and reacting with amino acids present (Ameur, Mathieu, Lalanne, Trystram, & Birlouez-Aragon, 2007; Davis, 1995). Maillard reactions produce brown pigments that give cookies (and other baked goods) their typical golden-brown, baked appearance. In the absence of sugar, other types of polysaccharides are needed in order for this reaction to proceed (Davis, 1995).

Other sugars and sweeteners react in a different way than sucrose during baking (Davis, 1995). Alternative sweeteners are not composed of fructose and glucose monosaccharides, so they do not break down into reducing sugars. Therefore, they cannot participate in the Maillard browning reaction that would normally occur during baking, leading to pale cookies with little browning. The standard deviations were low and L*, a*, and b* values were precise. These precise color values are likely attributed to the use of a single oven with a constant temperature.

Table 4.4–L*a*b*, ΔE, and standard deviations for each treatment.

Factor[1]	L*	a*	b*	ΔE
C	76.160±1.690	4.383±1.865	26.607±1.188	80.842±0.854 [b]
S	77.927±0.567	0.080±0.525	24.623±1.919	81.738±1.022[a,b]
E	78.283±0.045	0.257±0.297	24.817±0.641	82.125±0.165[a,b]
T	77.757±2.134	1.757±0.272	25.737±1.831	81.948 ±1.449[a,b]
SNL	77.773±0.665	1.353±0.140	25.340±1.140	81.815±0.531[a,b]
S+S	78.440±0.857	0.150±0.464	26.380±0.427	82.759±0.905[a,b]
E+S	78.930±0.860	0.113±0.356	25.360±0.646	82.907±0.766[a,b]
T+S	76.470±1.469	4.080±0.870	28.770±0.944	81.816±1.001[a,b]
SNL+S	78.627±0.788	0.837±0.605	27.170±1.943	83.208±0.939 [a]

[a-b]Tukey pairwise comparisons appear as superscripts by each mean. Means within a column that share a letter are not significantly different ($p>0.05$).
[1]C=Control; S=Splenda for baking; E=Equal for baking; T=Truvia; SNL=Sweet'N Low; S+S=Splenda for baking + sugar; E+S=Equal for baking + sugar; T+S=Truvia + sugar; SNL+S=Sweet'N Low + sugar

Texture Profile Analysis

Only C had a hardness value (5268 N) significantly different ($p<0.05$) from the other treatments (1055-3140 N). Overall, the hardness of cookies significantly decreased when sucrose was replaced with sugar alternatives, except for Truvia (Table 4.5). Traditional sugar-snap cookies made with sucrose have a characteristic snap when broken rather than bending. This snap occurs because of recrystallization of sucrose during and after baking (Delcour & Hoseney, 2010). Additionally, the inclusion of erythritol in Truvia aided in giving treatment T a harder texture most similar to C. Erythritol tends to crystallize, creating a harder texture for the final product (Lin, Lee, Mau, Lin, & Chiou, 2010). Alternative sweeteners disrupt the recrystallization of sucrose, making softer cookies that are more difficult to fracture (Delcour & Hoseney, 2010). Additionally, the dough made for the replications of T had the least amount of water added to create a dough, leading to cookies with a lower moisture content. Less moisture was initially

available so the final moisture content after baking was lower. This phenomenon may have created a harder texture in the final cookies for Treatment T.

SNL had the greatest fracturability value (8667 N) and T+S had the lowest fracturability value (2558 N) (Table 4.5). Treatments made with only alternative sweeteners (S, E, T, and SNL) were not significantly different from C ($p>0.05$). All treatments made with both sugar and alternative sweeteners (S+S, E+S, T+S, SNL+S) were statistically similar to C and S. Harder textured cookies allow for an easier fracture because they do not have the resistance to breakage that soft cookies have.

Table 4.5–Means and standard deviations for hardness and three-point fracturability of each treatment.

Factor[1]	Hardness (N)	3-Point Fracturability (N)
C	5268±1892 [a]	3561±1351 [c]
S	1649±226 [b]	5342±1099 [b,c]
E	1665±208 [b]	7802±441 [a,b]
T	3140±525 [a,b]	2699±524 [c]
SNL	2058±186 [b]	8667±2345 [a]
S+S	1093.6±89.6 [b]	3022±819 [c]
E+S	1055±175 [b]	3193±980 [c]
T+S	2800±621 [b]	2558±272 [c]
SNL+S	1296.6±79.8 [b]	4429±639 [c]

[a-c]Tukey pairwise comparisons appear as superscripts by each mean. Means within a column that share a letter are not significantly different ($p>0.05$).
[1]C=Control; S=Splenda for baking; E=Equal for baking; T=Truvia; SNL=Sweet'N Low; S+S=Splenda for baking + sugar; E+S=Equal for baking + sugar; T+S=Truvia + sugar; SNL+S=Sweet'N Low + sugar

Sensory Analysis

Cookies from treatment C had the overall highest rating for each category: appearance, texture, flavor, sweetness, and aftertaste (6.89, 6.32, 6.57, 6.43, and 6.07, respectively) (Table 4.6). Treatment T was rated the lowest of all treatments for appearance (2.84) and texture (3.30).

Treatment E was rated the lowest for all treatments for flavor (3.79) and sweetness (2.62). C and T+S had similar aftertastes ($p>0.05$) and SNL was rated the lowest for aftertaste (3.02). No treatment was rated above a seven in any category on the hedonic scale. However, AACC Method 10-50.05 is optimized for physical and chemical analysis of cookies, not for flavor or sensory acceptability. A different formulation should be considered to yield greater sensory ratings. However, trends in acceptability of alternative sugars can still be analyzed using this formulation.

Appearance of T+S was not significantly different from S+S and E+S ($p>0.05$) (Table 4.6). Treatment C was not significantly different from S, S+S, E+S, T+S, and SNL+S in terms of texture. Only C and T+S were had significantly similar flavor, sweetness, and aftertaste ratings. Treatment E had a significantly different sweetness rating from all other treatments. Equal for baking is made of maltodextrin, aspartame, and acesulfame potassium (Ace-K) ("Equal Original Granular," n.d.). Aspartame is not a heat-stable sweetener (Chattopadhyay, Raychaudhuri, & Chakraborty, 2014). While maltodextrin (bulking agent) and Ace-K are heat-stable, they are not present in great enough amounts to impart sweetness to cookies baked with them. Maltodextrin has very low sweetness, so a greater amount is required to impart noticeable sweetness. Ace-K is only included in Equal for baking at a 1:4 ratio with aspartame ("Equal Original Granular," n.d.). This ratio indicates that Equal for baking does not impart an acceptable sweetness level for cookies.

Table 4.6–Means and standard deviations for hedonic ratings (out of nine) of sensory parameters for each treatment.

Factor[1]	Mean Appearance Rating	Mean Texture Rating	Mean Flavor Rating	Mean Sweetness Rating	Mean Aftertaste Rating
C	6.89±1.42 [a]	6.32±1.60 [a]	6.57±1.54 [a]	6.43±1.68 [a]	6.07±1.59 [a]
S	5.08±1.60 [c,d]	5.54±1.85 [a,b,c]	4.32±1.81 [b,c,d]	4.57±2.23 [c,d,e]	4.19±2.02 [b,c]
E	4.95±1.66 [c,d]	4.61±1.78 [c]	3.79±1.78 [d]	2.62±1.59 [f]	3.52±1.50 [c,d]
T	2.84±1.51 [e]	3.30±1.38 [d]	4.03±1.95 [d]	4.33±2.04 [d,e]	3.84±1.86 [b,c,d]
SNL	4.35±1.56 [d]	4.87±2.04 [c]	3.86±1.75 [d]	3.83±1.92 [e]	3.02±1.56 [d]
S+S	5.46±1.47 [b,c]	5.38±2.05 [a,b,c]	5.12±1.81 [b,c]	4.98±1.67 [c,d]	4.75±1.99 [b]
E+S	5.77±1.58 [b,c]	4.93±1.64 [b,c]	4.13±1.92 [c,d]	3.95±1.95 [e]	4.36±1.94 [b,c]
T+S	5.41±2.12 [c]	5.92±1.71 [a,b]	6.43±1.53 [a]	6.31±1.64 [a,b]	6.05±1.78 [a]
SNL+S	6.33±1.45 [a,b]	6.12±1.57 [a]	5.16±1.73 [b]	5.39±1.57 [b,c]	4.43±2.16 [b,c]

[a-e]Tukey pairwise comparisons appear as superscripts by each mean. Means within a column that share a letter are not significantly different ($p>0.05$).

[1]C=Control; S=Splenda for baking; E=Equal for baking; T=Truvia; SNL=Sweet'N Low; S+S=Splenda for baking + sugar; E+S=Equal for baking + sugar; T+S=Truvia + sugar; SNL+S=Sweet'N Low + sugar

The effect of each sensory parameter on the overall acceptability (flavor) of the cookies was statistically analyzed (Table 4.7). Appearance ($p=0.198$) and Appearance*Sweetness ($p=0.085$) ratings had no significant effect on the flavor of the cookies ($p>0.05$). In addition, the appearance of the cookies did not have a significant effect on the perceived sweetness of the cookies, but did have an effect on how the texture of the cookies was perceived. Texture ($p=0.000$), Sweetness ($p=0.000$), and Appearance*Texture ($p=0.002$) contributed to the overall acceptability of the flavor of the cookies ($p<0.05$).

Table 4.7–Parameter effects on overall acceptability (flavor) of treatments using stepwise regression.

	Step 1		Step 2[3]	
	Coefficient	p[1]	Coefficient	p[1]
Constant	0.175		0.282	
Factors	-0.501	0.000	-0.506	0.000
Appearance	0.0443	0.635	0.1051	0.198
Texture	0.5056	0.000	0.4434	0.000
Sweetness	0.5722	0.000	0.5169	0.000
Appearance*Texture[2]	-0.0418	0.005	-0.0459	0.002
Appearance*Sweetness[2]	0.0312	0.033	0.0224	0.085
Texture*Sweetness[2]	-0.0191	0.184		

[1]$p \leq 0.05$ is interpreted as having an effect on the overall acceptability (flavor) of a cookie.

[2]Parameters linked by a '*' show the combined effect of both factors on flavor.

[3]Stepwise selection only required two steps ($\alpha = 0.15$).

In this experiment, treatments that included sugar in the formulation were rated higher on the hedonic scale than cookies prepared using only alternative sweeteners. Sugar has better functional properties in baked goods compared to alternative sweeteners, including rheology, dough viscosity, and Maillard browning (Davis, 1995). These improved functions contribute to better texture, mouthfeel, flavor, and color of the final product compared to cookies made with alternative sweeteners. Specifically, alternative sweeteners alone lack the bulking ability of sugar and require additional ingredients to form dough with favorable rheological properties and texture (Davis, 1995). To compensate, alternative sweeteners that are used for baking often are combined with maltodextrin. Maltodextrin is a bulking agent that does not impart a great amount of sweetness. Additionally, alternative sweeteners have different flavor and sweetness profiles than sucrose. Splenda for baking is made of maltodextrin and sucralose; Equal for baking is

made of maltodextrin, aspartame, and Ace-K; Truvia is derived from the plant *Stevia rebaudiana*; and Sweet'N Low is made of saccharin (Chattopadhyay et al., 2014). These sweeteners are significantly sweeter than sucrose alone but have potentially unpleasant or bitter aftertastes (Chattopadhyay et al., 2014). Overall, treatment T+S was the best reduced-sugar alternative, yielding cookies most similar to C is all sensory properties except appearance.

Conclusion

Results of this study show that sucrose plays a critical functional role in sugar-snap cookies. Replacement of sucrose with alternative sweeteners produced cookies with decreased spread, color change, hardness, and increased fracturability. Additionally, cookies with alternative sweeteners were rated lower on a nine-point hedonic scale by students compared to sugar-snap cookies made with sucrose. Reduced sugar cookies have the best characteristics when alternative sweeteners are substituted for only part of the sucrose in a formulation. The data in this experiment indicated that T+S yielded cookies most similar to sucrose control in terms of physiochemical and sensory properties. In a commercial reduced-sugar cookie application, using a combination of sucrose and Truvia would produce cookies most similar to cookies made with 100% sucrose.

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Chapter 5 - Development of a laboratory exercise to investigate the functionality of waxy sorghum inclusions in gluten-free sorghum bread

Introduction

Gluten is a highly functional ingredient that is extremely difficult to replace in bread formulations (Delcour & Hoseney, 2010). Gluten is a protein found in wheat and some other cereal grains and is composed of gliadin and glutenin fractions. Gliadin provides sticky and viscous properties and glutenin contributes elastic properties to gluten. Together, gliadin and glutenin form viscoelastic dough that can be stretched and molded (Capriles & Arêas, 2014; Delcour & Hoseney, 2010). The cross-linking of these fractions via disulfide bonds allows the dough to continue to cover the expanding air cells and create stable pockets of air in the final baked product (Delcour & Hoseney, 2010).

Because gluten is such a critical ingredient in bread formulations in terms of structure, gluten-free breads with acceptable qualities are challenging to produce. Gluten-free bread batter does not retain gases well, leading to impaired rise during baking. Therefore, gluten-free breads require additional ingredients or processing steps that contribute some of the same functional properties of gluten (Delcour & Hoseney, 2010; Capriles & Arêas, 2014). More water is added to gluten-free bread formulations than regular bread dough to form a batter that traps limited air during mixing. However, this suspension (batter) is not viscoelastic and cannot retain any gases that are produced during leavening. Only a few, unstable air pockets are formed during mixing. A number of quality defects are associated with gluten-free breads, including low loaf volume,

weak crumb structure, dry and crumbly texture, excessive cracking of the crust, poor mouthfeel, off flavors, and increased rate of staling (Capriles & Arêas, 2014).

Sorghum is a gluten-free cereal grain used in gluten-free breadmaking. Both regular and waxy varieties of sorghum can be used to produce gluten-free bread. Regular and waxy sorghum differ in their amylose-to-amylopectin ratio in the starch present in the grain. Carbohydrates in most regular starches are composed of 20-30% amylose and 70-80% amylopectin. Waxy starches are composed almost 100% of amylopectin (Delcour & Hoseney, 2010). Regular sorghum starch has been found to have an amylose content of 30.43%, similar to corn (30.91%) and wheat (30.57%) starches. Waxy sorghum, on the other hand, has amylose content below detectable levels (Han et al., 2008). Studies have shown that using waxy sorghum in bread formulations produces softer and less sticky starch pastes. Combining waxy genetic traits with high protein-digestibility traits decreases the paste stickiness (0.038-0.045 N) compared to regular sorghum (0.136-0.300 N) (Elhassan, Emmambux, Hays, Peterson, & Taylor, 2015). However, little information is available regarding how these properties affect the final baked products from the improved dough.

Despite quality defects and production challenges, gluten-free diets have been gaining popularity in recent years. More than $15.5 billion was spent on retail sales of gluten-free products in 2016, a 26% increase from sales in 2015 and a more than 50% increase from 2011 (Niland & Cash, 2018; Parker, 2017). Increasing awareness of gluten allergies, celiac disease, and perceived health benefits of gluten-free diets are some of the driving factors behind the increasing popularity of gluten-free foods. Social media and aggressive, consumer-oriented marketing have played a large role in making gluten-free foods so popular among many consumers. These marketing strategies convince many consumers that they need to follow a

gluten-free diet for perceived health benefits, rather than because of diagnosed health conditions. Up to 50% of certain populations (i.e., athletes) reportedly follow gluten-free diets, yet less than 1% of the United States population is diagnosed with celiac disease or wheat allergy (Niland & Cash, 2018). A survey conducted by Vitacost.com in 2012 found that 31% of respondents said they purchased gluten-free products because they perceived them to be healthier than traditional alternatives. Only 13% of respondents mentioned celiac disease in the survey (Pszczola, 2012).

As the popularity of gluten-free food products increases, food companies must meet consumer demands for such products. This sector of the food industry is predicted to grow, so it is important for food scientists to understand the properties and challenges of producing gluten-free foods to make the best products possible (Parker, 2017). Our research objective was to introduce students to the challenges and techniques used in gluten-free bread production. A secondary objective was to determine how different inclusions of waxy sorghum affected physical and sensory properties of gluten-free sorghum bread.

Materials and Methods

Experimental Design

The gluten-free bread laboratory exercise was first implemented in the spring of 2019 in a classroom setting. Students were given one two-hour laboratory period to prepare four treatments. The exercise consisted of four treatments: control (C), 15% waxy sorghum (15W), 25% waxy sorghum (25W), and 35% waxy sorghum (35W).

Undergraduate students completed four replications of the four treatments (n=4). Four laboratory sections of the Fundamentals of Food Processing course at Kansas State University

represented each of the replications. Eight laboratory groups containing two to three students were formed in each section.

Materials

Table 5.1 contains all formulations and supplier information for each treatment. Sorghum flours (White: Product # NLSC-WSWG-0010C; Burgundy waxy: Product # NLSC-WBSWF-0014I) were donated by NuLife Market (Scott City, KS) for this research. Sorghum flour used in this research was whole grain, with the bran milled along with the rest of the sorghum kernel. Hydroxypropyl methylcellulose (HPMC) was donated by The Dow Chemical Company (Midland, MI). Other ingredients for the experiment were purchased at a local grocery store (Hy-Vee, Manhattan, KS). Equipment needed to complete the exercise included scales (Ohaus, Parsippany, NJ), disposable pipettes and weigh boats, stand mixers with flat paddle attachment (KitchenAid Artisan, Model No. KSM150PSWH, St. Joseph, MI), spoons and butter knives, rubber spatulas, non-stick cooking spray (PAM, ConAgra Brands, Chicago, IL), pup loaf pans, masking tape, plastic wrap (Handi-Film, Handi-foil of America Inc., Wheeling, IL), proofing cabinet (Wilder, Winholt Equipment Group, Woodbury, NY), data logger (Dickson, Addison, IL), baking ovens (Whirlpool Model RF367LXSB, Benton Harbor, MI), cooling racks, and low density polyethylene (LDPE) bags (Ziploc, SC Johnson, Racine, WI).

Analytical equipment needed to collect data included digital calipers (Tool Shop, Eau Claire, WI), portable HunterLab MiniScan EZ colorimeter (Model No. 4500L, Reston, VA), water activity meter (AQUALAB, METER Group, Inc., Pullman, WA), Texture Technologies Corp texture analyzer with 30 kg load cell and cylindrical attachment (TA-XT2, Scarsdale, NY), and Exponent Stable Micro Systems texture analysis software (Godalming, Surrey GU7 1YL, United Kingdom).

Table 5.1–Formulations for gluten-free breads.

Ingredient	Supplier	Amount (g)			
		0% waxy sorghum	15% waxy sorghum	25% waxy sorghum	35% waxy sorghum
White whole-grain sorghum flour (Product # NLSC-WSWG-0010C)	NuLife Market, LLC, Scott City, KS	70	59.5	52.5	45.5
Waxy burgundy whole-grain sorghum flour (Product # NLSC-WBSWF-0014I)	NuLife Market, LLC, Scott City, KS	-	10.5	17.5	24.5
Potato starch	Bob's Red Mill Natural Foods, Inc., Milwaukie, OR	30	30	30	30
Iodized salt (salt, sodium silicoaluminate, dextrose, potassium iodide, sodium bicarbonate)	Great Value, Wal-Mart Stores, Inc., Bentonville, AR	1.75	1.75	1.75	1.75
Sugar	Great Value, Wal-Mart Stores, Inc., Bentonville, AR	1	1	1	1
HPMC (Methocel K4M Food Grade Modified Cellulose)	The Dow Chemical Company, Midland, MI	1.5	1.5	1.5	1.5
Warm water		100	100	100	100
Yeast (yeast, sorbitan monostearate)	Fleischmann's, ACH Food Companies, Inc., Memphis, TN	2	2	2	2
Egg	Kansas State University, Manhattan, KS	30	30	30	30
	Total	236.25	236.25	236.25	236.25

Laboratory Exercise

Laboratory exercise handouts were made available to students on Canvas (Instructure, Inc., Salt Lake City, UT) for them to read prior to the beginning of their respective laboratory section (Tuesday or Thursday). Canvas is an educational platform used at many universities that allows instructors to share class information, assignments, notes, and grades with students. The full laboratory handout including instructions, formulations, and rubrics can be found in Appendix B. Before beginning the exercise, students were given a short, five-point quiz in order to assess their pre-laboratory comprehension of the material and exercise. The instructor and graduate teaching assistant (GTA) gave brief verbal instructions throughout the laboratory period when students had breaks while the bread was proofing and baking. Instructors explained the use of students' data in a thesis research project, discussed the reason for performing multiple replications of the exercise, and emphasized the importance of following instructions closely while performing the exercise in order to obtain accurate and precise results.

Each of the four laboratory sections was further divided into four groups; each group was assigned one waxy sorghum treatment to prepare. Formulations and baking procedures were adapted from an optimized gluten-free sorghum bread formulation studied in the thesis "An evaluation of the role of eggs and DATEM on the quality of gluten-free sorghum bread" (Bize, 2012). An optimized gluten-free sorghum bread formulation was chosen to provide the best gluten-free bread experience for students, many of whom had never made or tasted gluten-free bread.

Before students arrived for their laboratory period, the proofing cabinet was turned on and set to 89.6ºF at 95% humidity. Pans containing 3.7 L of warm water were placed in the bottom to increase humidity. The data logger was set up and monitored the temperature and

humidity throughout the proofing processing (Figures 5.1, 5.2). Actual temperature readings of the proofing cabinet ranged from 74.2-133ºF with an average of 117.7ºF for data collected from both the Tuesday and Thursday labs. Relative humidity ranged from 7.4-72.5% with an average of 27.0%. The large range of values is attributed to the spike in relative humidity at the very beginning of the exercise. At this time, the water pans were full and contributing the most to the relative humidity, but the relative humidity gradually decreased over time. Each time the door to the proofing cabinet was opened to place loaf pans in or take them out, the relative humidity dipped, as seen in Figures 5.1 and 5.2. The real-time temperature and relative humidity inside the proofing cabinet created non-optimal proofing conditions.

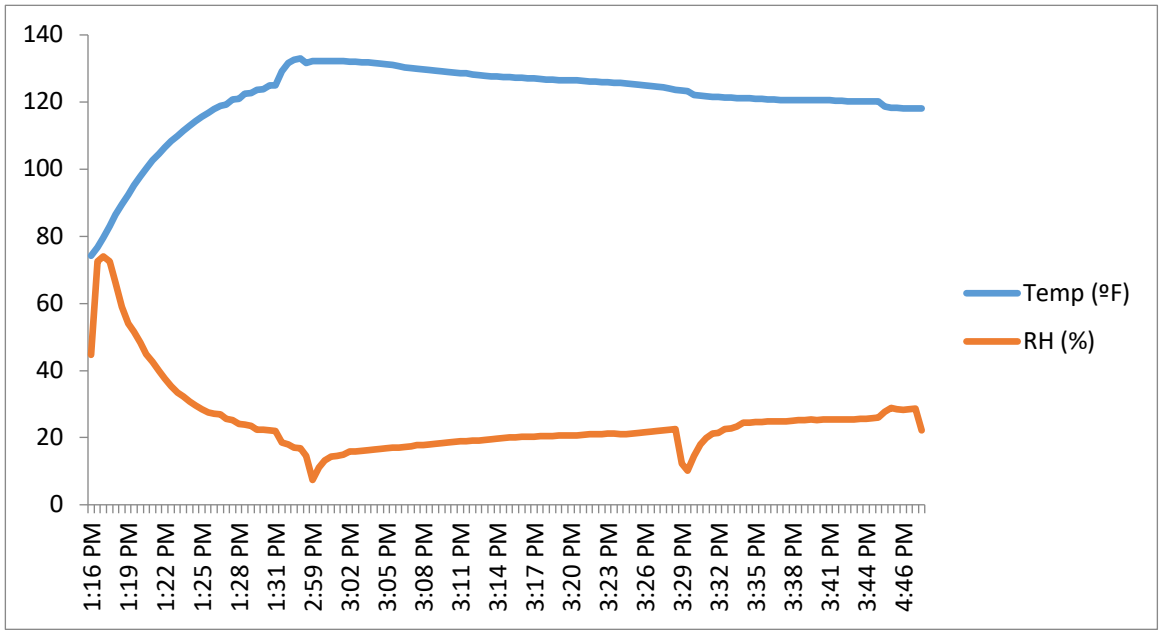

Figure 5.1–Real-time temperature (ºF) and relative humidity (RH%) recorded during student exercise on Tuesday.

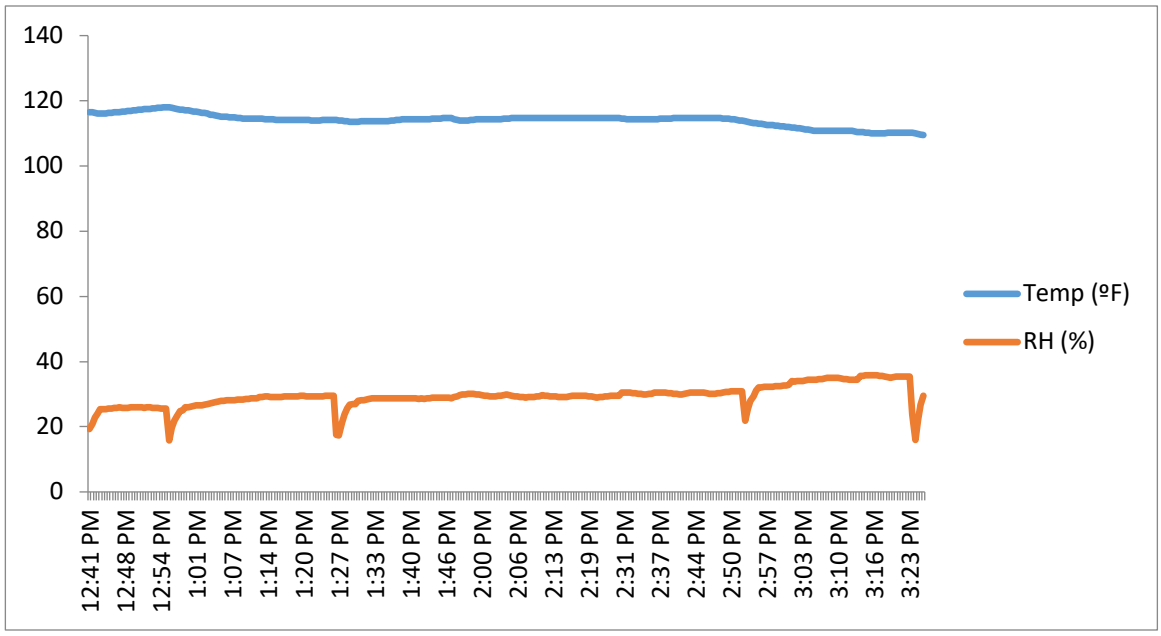

Figure 5.2–Real-time temperature (ºF) and relative humidity (RH%) recorded during student exercise on Thursday.

Throughout the experiment, students were asked to record the weight of the empty mixing bowl, empty pup loaf pan, mixing bowl plus all ingredients before portioning, mixing bowl with unused batter after portioning, and the baked pup loaf (for use later in determining percent waste and yield). On average, 3.73% ± 0.68% of the batter produced was discarded as waste (not used in the loaves). Ovens were preheated to 375ºF (190.6ºC). Yeast and warm water were combined in the stand mixer, gently combined, and allowed to bloom for five min. Then, white and waxy sorghum flours, potato starch, salt, sugar, hydroxypropyl methylcellulose (HPMC), and beaten egg were added and mixed for 90 s on Speed 1. Then, the sides of the bowl were scraped with a rubber spatula. The batter was mixed for another three min on Speed 2.

The bottom and sides of a pup loaf pan were sprayed with non-stick cooking spray. Batter was gently transferred from the mixing bowl to the pup loaf pan using a rubber spatula, making sure not to hit the spatula on the loaf pan and lose incorporated air. Pans were covered with plastic wrap and placed in the proofing cabinet for 30 min. After proofing, pans were removed

and the plastic wrap was carefully peeled away, being sure not to bump the pan which could result in the loss of gas from the batter. Pans were placed in the preheated ovens and baked for 30 min. Pans were then promptly removed from the oven, transferred to a cooling rack, and allowed to cool approximately 10-15 min before removing from the pan and analyzing.

Physical Analyses

All recorded weights (as previously described) were used to calculate the percent waste and percent yield (Equations 1 and 2). Percent waste is represented by the amount of batter that was unused to produce the loaf of bread. Percent yield is represented by the final weight of the loaf of bread produced from the raw materials.

$$\text{Percent waste} = \frac{\text{Wt. of bowl after portioning} - \text{Wt. of empty bowl}}{\text{Wt. of bowl plus ingredients} - \text{Wt. of empty bowl}} \times 100 \quad (1)$$

$$\text{Percent yield} = \frac{\text{Wt. of bread loaf after baking}}{\text{Wt. of bowl plus ingredients} - \text{Wt. of empty bowl}} \times 100 \quad (2)$$

TAs collected color data for students using a standardized HunterLab MiniScan EZ portable colorimeter. The colorimeter was calibrated using a black glass and white tile as provided by Hunter Associates Laboratory, Inc. (Reston, VA). The colorimeter was used to measure the color of the top crust of the bread in two places to find the average crust color. Then, GTA sliced loaves into slices 25 mm thick using a bread slicing guide. After, the colorimeter was used to measure the color of the crumb in two places, again calculating the average crumb color from these two values. Using the average L*, a*, and b* values, the total color change (ΔE) for both the crust and crumb was calculated (Equation 3).

$$\Delta E = \sqrt{L^{*2} + a^{*2} + b^{*2}} \quad (3)$$

Loaf height was also measured. Students were instructed to measure the height of the two center slices of the loaf using digital calipers. These two values were used to calculate the average loaf height.

GTA collected the sliced loaves from students, put them in LDPE bags, and placed them in the freezer overnight. Loaves were allowed to thaw approximately one hour prior to analyses. Texture profile analysis (TPA) of bread was performed to measure hardness, cohesiveness, and springiness using a calibrated Texture Technologies Corp texture analyzer by following the methods suggested by the manufacturer ("Texture Analysis Application Areas," n.d.). One slice of bread was placed on a flat platform and compressed twice with a cylindrical attachment. The probe was set to 10 mm distance with 10 g trigger force and the load cell measured the force to compress the slice of bread. The data from the two compressions was generated on Exponent Stable Micro Systems texture analysis software. Hardness is measured as the maximum force of the 1st compression. Cohesiveness is calculated as the area of work during the second compression divided by the area of work during the first compression. Springiness is calculated as ratio of the distance of the detected height during the second compression divided by the original compression distance. TPA analysis was performed in duplicate; two slices from each treatment from each replication were measured (n=4). Data was then distributed to students to analyze and include in their lab reports.

Slices of bread were then broken into pieces and placed in plastic trays (METER Group, Inc., Pullman, WA) for water activity measurement. The water activity meter was turned on and allowed to warm up for approximately 10 min. Then, a dish of the broken pieces of bread was sealed inside the chamber. Water activity measurement took approximately five min per sample and readings were generated on the meter's screen. Water activity measurement was performed in duplicate and average water activity was calculated for each replication (n=4). This data was compiled by GTA and distributed to students to include in their report.

Sensory Analysis

Prior to performing sensory analysis of bread treatments prepared in the laboratory, students tasted gluten-free sorghum bread prepared from a commercial mix (Jovial, North Stonington, CT) available in the health foods section of a local grocery store (Hy-Vee, Manhattan, KS). This tasting was not included in the sensory analysis. Rather, its purpose was to expose students to sensory properties of gluten-free sorghum breads in order to prepare them for the sensory analysis of the treatments they prepared. Gluten-free breads have very different sensory properties from regular breads and instructors did not want students making mental comparisons between the experimental breads and the glutinous breads with which they are familiar. Students reported the commercial bread had a very grainy texture and strong off-flavors.

One slice of bread from each treatment was placed on a white paper plate for students to observe the appearance and color. Students (n=63) then ingested a small piece of bread from each treatment. After tasting, they wrote a short description of the appearance, color, texture, flavor, and overall acceptability and rated each on a nine-point hedonic scale (where 1=Dislike Extremely and 9=Like Extremely) in order to quantify the sensory data. The sensory panel was not blinded, meaning students knew which treatments they were sampling as they rated them. This may have contributed to some bias in results.

Laboratory Report

Students were required to write a memorandum-style laboratory report over the exercise performed. The report was worth 50 points and students had two full weeks to complete the report. Writing instructions, formatting tools, and a rubric can be found in Appendix B. Students were instructed to format their report with a memorandum heading and section headers

(Overview, Materials and Methods, Results and Discussion, Conclusion) with all relevant information. Students were also required to cite three to five peer-reviewed, scientific references in their report and use them to support the data they collected. Instructors expected students to compose their reports in a manner that would allow a reader to replicate the exercise from their report. In "Results and Discussion," students needed to compare and contrast data collected and determine from the data points which treatment provided the best loaf of bread. Students also needed to explain what food additives or processing techniques could be used to improve the treatments. Finally, students were required to create a flow diagram of a commercial gluten-free bread processing operation, with arrows connecting processing steps showing product flow through the system.

Controlled Trial by GTA

The exercise was repeated in triplicate by GTA for comparison to student data. Formulations, procedures, and physical analyses were followed as described above. A consistent weight of batter was dispensed into loaf pans for each replication. Each pan weighed 215 g ± 0.26 g. No sensory data was collected during the controlled trial; all sensory data presented was gathered from students. Exact temperature and relative humidity from the proofing cabinet was monitored throughout the controlled trial (Figure 5.3). Proofing temperature ranged from 70.9–123.1ºF with an average of 118.8ºF. Relative humidity ranged from 15.3–90% with an average of 34.7%. The initial increase in relative humidity can be attributed to the full pans of hot water placed in the cabinet beginning of the exercise. Over time, water in the pans cooled and evaporated and contributed less to the relative humidity inside the cabinet. Each time the door to the proofing cabinet was opened to either put loaves in or take them out, the relative humidity

inside the cabinet dipped slightly (see Figure 5.3). The same non-optimal proofing conditions were replicated from the classroom exercise to maintain equal preparation conditions.

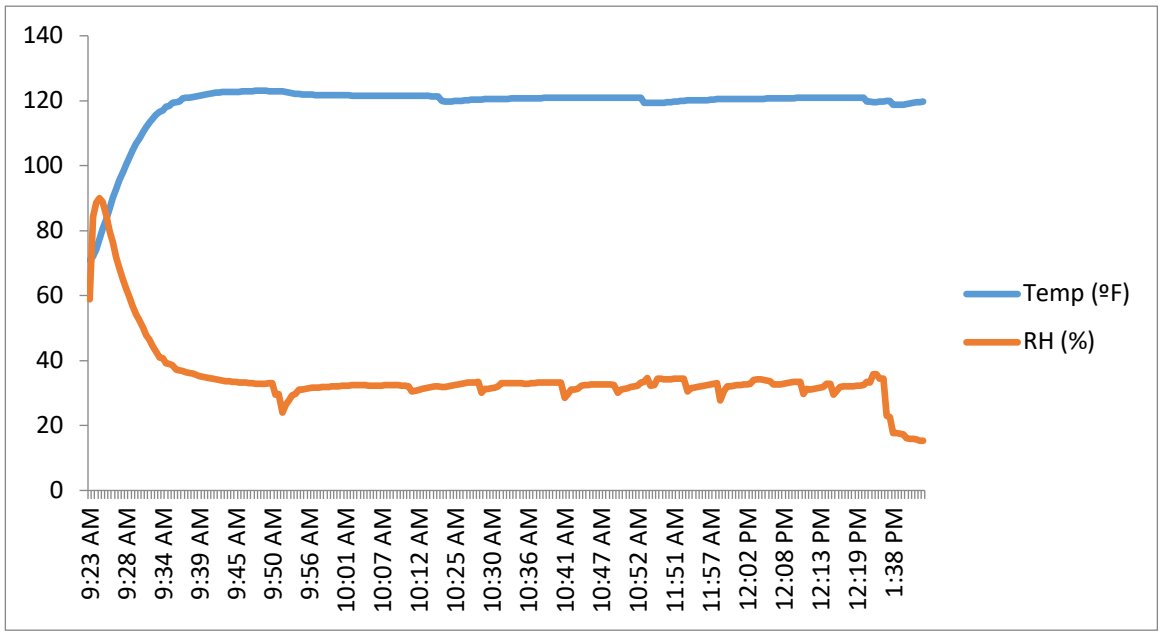

Figure 5.3–Real-time temperature (ºF) and relative humidity (RH%) recorded during controlled exercise.

Statistical Analysis

Data was collected from laboratory reports from each laboratory section and the controlled trial by GTA and analyzed by the authors. Effects of the treatments were analyzed for significance ($p<0.05$) using one-way ANOVA followed by a Tukey's multiple comparison test. This analysis determined differences between treatments. Outliers and missing data points were removed from the class data set prior to statistical analysis. Statistical analyses were performed using Minitab 18© Software (State College, PA).

Results and Discussion

Visual Appearance

Loaves from each treatment appeared similar in quality to other gluten-free sorghum breads. The top crusts of all treatments were excessively cracked (Figure 5.4). Tops were not rounded as expected from loaves of glutinous bread and rather had a large dip in the center. In bread, if the foam-to-sponge transition has been fully completed, the gases inside the air cells in the bread will be at equilibrium with its surrounding environment. If the transition is not fully completed, the gases can more easily escape from inside the loaf. Thus, the loaf will shrink after it is removed from the oven, causing collapse in the center (Casper & Atwell, 2014). Due to the shrink and collapse of the loaves from each treatment from our study, it is likely this transition was incomplete. A longer baking time may be necessary.

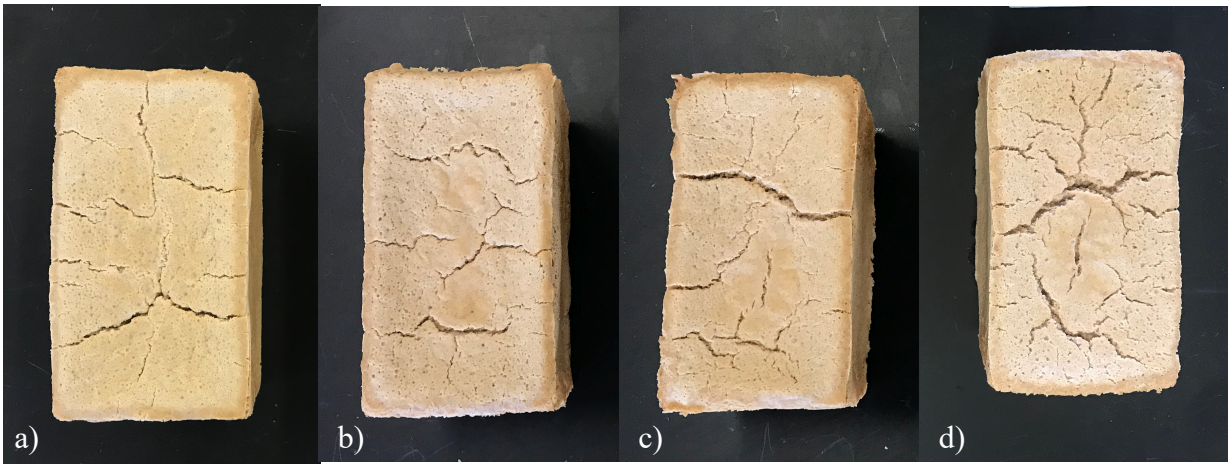

Figure 5.4–Top images of one loaf from treatment: a) Control; b) 15% waxy sorghum; c) 25%waxy sorghum; d) 35% waxy sorghum.

The internal crumb structures of all treatments were crumbly and dry, with a tight crumb structure and a few large air cells (Figure 5.5). The large number of small air cells is consistent with the sorghum bread produced in the study by Bize (2012), from which the formulation for our study was found. In the Bize (2012) study, the addition of eggs was found to have a positive

effect on the crumb structure by increasing the number of small air pockets and therefore the volume, and decreasing the density of the crumb. The formulation chosen for our study utilized the greatest amount of egg studied in the Bize (2012) formulation (30 g) and our loaves had similar visual crumb structure as the respective sample from the Bize (2012) study.

The dense bread crumbled with even a light touch and did not hold together well during slicing. Gluten-free breads lack the viscoelastic protein matrix that gluten provides in traditional breads. The gluten matrix is typically what helps set larger air cells inside the bread, giving it a more open structure and chewy texture. Gluten also helps bread hold together after baking and slicing. Without the structure of gluten, gluten-free breads do not hold together well without the addition of other ingredients, such as hydrocolloids or egg proteins (Casper & Atwell, 2014; Akin, 2017).

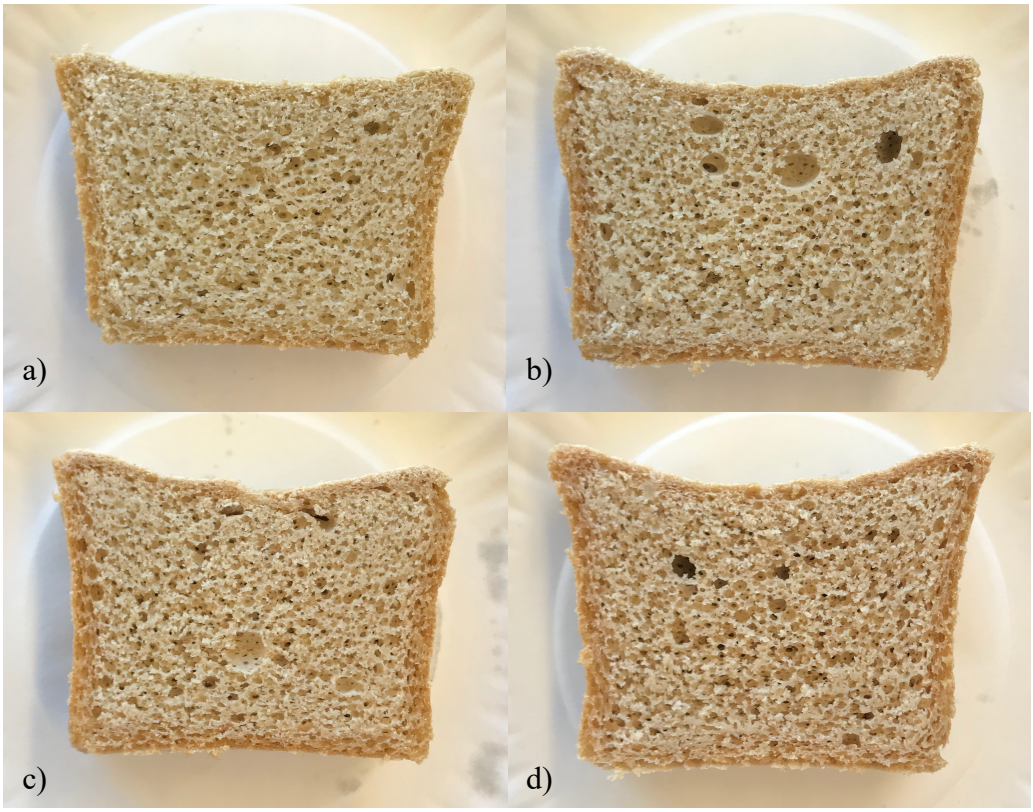

Figure 5.5**–Images of one slice of bread from each treatment: a) Control; b) 15% waxy sorghum; c) 25% waxy sorghum; d) 35% waxy sorghum.**

Loaf Height

Loaf height was measured for each treatment as an indicator of loaf volume. All treatments had loaf volumes (heights) that appeared similar to other gluten-free sorghum breads (Bize, 2012; Hager et al., 2012). In the in-class exercise, 35W had the greatest loaf height (56.23 mm) while C had the lowest loaf height (53.72) (Table 5.2). In the controlled trial, loaf heights ranged from 47.44 (25W) to 47.98 (C). Values collected during the controlled trial had smaller standard deviations than values collected by students in the classroom trial. No significant differences ($p>0.05$) were noted between any of the four treatments in either the classroom or controlled trial, indicating the varying waxy sorghum incorporations had no effect on the rise of the bread during baking.

Table 5.2–Means and standard deviations of loaf height.

Factor[1]	Class (mm)	Controlled (mm)
C	53.72±2.94[a]	47.98±1.26[a]
15W	54.17±2.07[a]	47.69±0.82[a]
25W	54.40±3.11[a]	47.44±0.56[a]
35W	56.23±1.98[a]	47.96±0.47[a]

[a]Tukey pairwise comparisons appear as superscripts by each mean. Means within a column that share a letter are not significantly different ($p>0.05$).

[1]C=Control; 15W=15% waxy sorghum; 25W=25% waxy sorghum; 35W=35% waxy sorghum

Gluten-free breads typically exhibit lower loaf heights and volumes than breads containing gluten. The viscoelastic gluten structure developed in wheat bread during kneading helps retains gases produced during proofing that are critical for the leavening process. These gases fill and expand air cells in the dough during baking, thinning the cell walls separating the pockets of gas. This creates the porous texture typical of wheat bread. Gluten-free breads cannot develop this structure and therefore do not retain leavening gases well. This results in poor rise

during proofing and baking, leading to lower loaf heights and volumes (Delcour & Hoseney, 2010). Whole grain wheat breads also exhibit lower loaf volumes than wheat breads made with refined white flour. Whole grain flours contain bran, which disrupts the starch-gluten matrix and absorbs extra water that would normally be used for gluten development (Gan, Galliard, Ellis, Angold, & Vaughan, 1992; Lai, Hoseney, and Davis, 1989). Even inclusions as small as one to two percent can produce loaves of bread with decreased loaf volume and degraded crumb structure compared to bread produced with refined white flour (Gan, Galliard, Ellis, Angold, & Vaughan, 1992).

A study by Hager et al. (2012) found that gluten-free bread dough made using sorghum flour reached a lower dough development height ($p<0.05$) during proofing (28 mm) than wheat bread dough (49 mm). The gluten-free sorghum bread also had significantly lower loaf volume (1.85 ml/g) than wheat bread (2.62 ml/g) (Hager et al., 2012). The treatments in our study appeared to follow these trends of little rise during proofing and low loaf volume (height). The addition of hydrocolloids to gluten-free batters can increase batter viscosity in attempt to retain more gases during proofing (Casper & Atwell, 2014). HPMC was added to the bread in our study for this purpose. HPMC forms a heat-set gel network that increases batter viscosity and stabilizes expanding gas cells during proofing and baking. This ultimately leads to gluten-free bread loaves with greater volume (Houben, Hochstotter, & Becker, 2012). However, the amount of HPMC in the formulation was very minimal. A combination with other hydrocolloids that work synergistically could increase the viscosity further, leading to better gas retention and greater loaf volume (height) (Casper & Atwell, 2014). However, because no significant differences were noted between any of our treatments, it is unlikely that the use of waxy sorghum affects loaf volume (height).

Crust and Crumb Color

The color of the bread crust varied somewhat depending on the treatment. In both the classroom and controlled trials, 35W had the darkest (lowest L*), reddest (greatest a*), and bluest (lowest b*) color compared to the other three treatments (Table 5.3). C was the lightest (greatest L*) and greenest (lowest a*) in both trials. C also had the yellowest (greatest b*) color in the classroom trial, but 15W had the greatest b* in the controlled trial. The greatest total color change (ΔE) value was noted for treatment C in both trials (classroom=74.98; controlled=72.36). ΔE values were significant. In the classroom trial, C and 15W were similar ($p>0.05$), 15W and 35W were similar, and 35W and 25W were similar. In the controlled trial, C and 15W were similar ($p>0.05$) and 25W and 35W were similar ($p>0.05$), but each pair was significantly different ($p<0.05$) from the other two treatments.

Table 5.3–Means, standard deviations, and ΔE of bread crust color.

Factor[1]	Class				Controlled			
	L*	a*	b*	ΔE	L*	a*	b*	ΔE
C	65.93± 1.64	4.85± 0.56	33.96± 12.78	74.98±7.68[a]	67.02± 0.71	4.92± 0.39	26.82± 1.34	72.36±0.34[a]
15W	65.24± 2.53	6.41± 0.61	27.68± 0.50	71.16±2.31[a,b]	64.68± 0.35	7.22± 0.17	27.38± 0.32	70.61±0.38[a]
25W	62.62± 1.39	7.45± 0.40	26.98± 1.21	68.57±1.71[c]	63.07± 1.18	7.66± 0.46	26.21± 1.16	68.72±1.25[b]
35W	63.97± 1.62	7.36± 0.62	25.78± 1.11	69.36±1.46[b,c]	61.92± 0.64	8.27± 0.35	25.35± 0.86	67.42±0.25[b]

[a-c]Tukey pairwise comparisons appear as superscripts by each mean. Means within a column that share a letter are not significantly different ($p>0.05$).

[1]C=Control; 15W=15% waxy sorghum; 25W=25% waxy sorghum; 35W=35% waxy sorghum

Differences between treatments were also noted for the color of the crumb. Similar to crust color, the color of the crumb in C was lightest (greatest L*), greenest (lowest a*), and yellowest (greatest b*) of all treatments in both the classroom and controlled settings (Table 5.4). The darkest-colored crumb came from 25W in the classroom trial, but from 35W in the controlled trial. 35W had the reddest (greatest a*) and bluest (lowest b*) crumb color. C had the greatest ΔE in both the classroom (66.41) and controlled trials (67.98). In both trials, ΔE was significant ($p<0.05$). The ΔE values of C and 15W were similar ($p>0.05$) in the classroom trial. Additionally, 15W was similar to 25W and 25W was similar to 35W. In the controlled trial, ΔE of C was different from all other treatments.

Table 5.4–Means, standard deviations, and ΔE of bread crumb color.

Factor[1]	Class				Controlled			
	L*	a*	b*	ΔE	L*	a*	b*	ΔE
C	62.02± 1.97	3.59± 0.45	23.42± 0.90	66.41±1.52[a]	64.23± 0.33	3.09± 0.11	22.04± 0.28	67.98±0.29[a]
15W	59.64± 1.74	5.32± 0.58	22.83± 1.23	64.11±1.14[a,b]	62.31± 0.44	4.38± 0.07	21.02± 0.10	65.91±0.42[b]
25W	57.74± 1.05	6.23± 0.48	22.16± 0.70	62.17±0.79[b,c]	61.12± 0.55	5.15± 0.07	21.01± 0.08	64.83±0.53[c]
35W	58.23± 6.92	7.62± 0.63	22.06± 0.74	59.69±1.01[c]	60.31± 0.41	5.74± 0.04	20.18± 0.05	63.86±0.37[c]

[a-c]Tukey pairwise comparisons appear as superscripts by each mean. Means within a column that share a letter are not significantly different ($p>0.05$).

[1]C=Control; 15W=15% waxy sorghum; 25W=25% waxy sorghum; 35W=35% waxy sorghum

The waxy sorghum used in this study was whole grain burgundy waxy sorghum flour. Burgundy sorghum varieties have a dark red colored pericarp surrounding the kernel (Delcour & Hoseney, 2010). When whole grain flour is produced, the bran (pericarp) is milled along with the

rest of the kernel, producing flour that appears red as well (Delcour & Hoseney, 2010). This color is then imparted on the baked goods in which the flour is used and its subsequent products (Dykes, Rooney, Waniska, & Rooney, 2005). It is expected that as the concentration of red sorghum increases in the treatments, the darker the red color of the crust and crumb will be. The increase in color was more noticeable in the crumb color than the crust.

Water Activity

Water activity (a_w) of each treatment was very high with all treatments having a_w values ranging from 0.96-0.99 (Table 5.5). In the classroom trials, no significant differences were seen between any of the treatments. In the controlled setting, a_w of C differed ($p<0.05$) from all other treatments. However, it should be noted that the standard deviations for all of the treatments was low (0.001-0.003).

Table 5.5–Means and standard deviations of water activity (a_w).

Factor[1]	Class	Controlled
C	0.98±0.008[a]	0.96±0.003[a]
15W	0.98±0.010[a]	0.97±0.001[b]
25W	0.99±0.006[a]	0.97±0.002[b]
35W	0.98±0.008[a]	0.97±0.001[b]

[a-b]Tukey pairwise comparisons appear as superscripts by each mean. Means within a column that share a letter are not significantly different ($p>0.05$).

[1]C=Control; 15W=15% waxy sorghum; 25W=25% waxy sorghum; 35W=35% waxy sorghum

Gluten-free breads typically have greater water activities than wheat breads. In wheat bread, the gluten matrix absorbs and uses water to develop, binding it and making it unavailable for microbial and chemical reactions. Without gluten, gluten-free breads bind water poorly and end up with greater amounts of free water in the final products (Casper & Atwell, 2014; Hager et al., 2012).

Hager et al. (2012) found that a_w of sorghum bread was 0.980, similar to a_w values collected from the classroom trials of our study. The a_w values of sorghum bread from the Hager et al. (2012) study was significantly greater ($p<0.05$) than that of wheat bread (0.967). However, a_w values collected from our controlled trial were more similar to a_w value of wheat bread. HPMC was chosen as the hydrocolloid in our formulation due to its high water-binding capacity (Houben et al., 2012). Our study used a very small amount of HPMC (1.5%) in the formulation to bind water. Synergistic blends of hydrocolloids have been studied as methods of further improving characteristics of gluten-free breads. For example, the addition of a 1:1 ratio of guar gum and pectin increased bread quality without impacting moisture content. The guar gum and pectin hydrocolloid blend bound enough water in the crumb to prevent the chemical reactions that lead to spoiling without affecting the overall amount of moisture in the crumb (Gambus, Nowotna, Ziobro, Gumul, & Sikora, 2001). Similar hydrocolloid blends could be used to decrease the water activity. The addition of waxy sorghum did not make any statistical difference in a_w in the classroom trial. Though a statistical difference was noted in the controlled trial, the raw data numbers were very similar, suggesting it was just by chance that the difference in water activity between the waxy sorghum treatments and C was significant.

Texture Profile Analysis

No significant differences ($p<0.05$) in hardness, cohesiveness, or springiness between any treatments were found for either the classroom or controlled setting (Table 5.6). Hardness values ranged more and had greater standard deviations than cohesiveness and springiness values. 15W had the hardest texture and greatest cohesiveness, and C and 25W had the same springiness value in the classroom trial. In the controlled setting, C had the greatest hardness and springiness values, and 35W had the greatest cohesiveness value.

Table 5.6–Means and standard deviations of texture profile analysis (TPA).

Factor [1]	Hardness (N)		Cohesiveness		Springiness	
	Class	Controlled	Class	Controlled	Class	Controlled
C	798.27±182.78[a]	759.98±54.84[a]	0.70±0.13[a]	0.87±0.09[a]	0.69±0.01[a]	0.69±0.01[a]
15W	1060.98±357.82[a]	758.46±35.26[a]	0.91±0.13[a]	0.91±0.04[a]	0.68±0.02[a]	0.68±0.01[a]
25W	746.37±58.29[a]	700.60±61.59[a]	0.74±0.20[a]	0.88±0.08[a]	0.69±0.03[a]	0.68±0.02[a]
35W	855.21±122.09[a]	638.25±59.28[a]	0.68±0.22[a]	0.93±0.06[a]	0.68±0.01[a]	0.67±0.01[a]

[a]Tukey pairwise comparisons appear as superscripts by each mean. Means within a column that share a letter are not significantly different ($p>0.05$).

[1]C=Control; 15W=15% waxy sorghum; 25W=25% waxy sorghum; 35W=35% waxy sorghum

Gluten-free breads are often known to have denser, less chewy textures than wheat breads. The viscoelastic nature of the gluten network in wheat bread gives insight to why gluten-free breads typically have such poor texture. During kneading of bread dough, the visocoelastic properties of gluten are developed. The gluten network is strong and its elastic properties are retained through the proofing and baking processes. This provides the expected, chewy texture of wheat bread. It also strengthens air cells in the bread to give it its characteristic cohesive yet open texture (Casper & Atwell, 2014).

Hager et al. (2012) found that gluten-free sorghum bread had significantly greater ($p<0.05$) hardness (26.28 N), lower chewiness (5.26 N), and lower springiness (0.878) values than wheat bread (hardness=8.48 N; chewiness=7.74 N; springiness=1.004). The addition of hydrocolloids in gluten-free batters increases their viscosity, ultimately improving the texture of gluten-free breads. HPMC has the ability to act as an interface in gluten-free batter systems to prevent coalescence of air bubbles during proofing and baking, leading to improved crumb texture with a greater number of air cells in the crumb (Houben et al., 2012).

The lack of any significant differences in either the classroom or controlled setting indicate that waxy sorghum does not affect the final texture of gluten-free sorghum bread. Amylopectin, a component of starch, affects gelatinization of the starch during baking. Starch in waxy sorghum is composed almost completely of amylopectin while regular sorghum starch contains both amylose and amylopectin. However, because amylose makes up only about 30% of starch in regular sorghum, it is still primarily composed of amylopectin (Han et al., 2008). This phenomenon likely causes regular and waxy sorghum flours to behave similarly in baking systems, imparting insignificant differences between their respective final baked products.

Sensory Analysis

Students that performed sensory analysis gave all treatments average ratings on a hedonic scale. All values from each category ranged from 4.76 to 6.05 (out of 9) and had relatively low standard deviations (Table 5.7). Ratings in each category ranged without noticeable trends. 25W was rated highest for appearance (5.66), color (5.83), and flavor (5.46) and 15W was rated highest for texture (6.05). In terms of the overall acceptability of the treatments, 25W was rated the highest (6.00), while 35W was rated the lowest (5.38).

Table 5.7–Means and standard deviations for student sensory analysis.

Factor[1]	Appearance	Color	Texture	Flavor	Overall Acceptability
C	5.36±1.59	5.36±1.67	5.61±1.76	5.29±1.95	5.40±1.92
15W	5.56±1.61	5.63±1.50	6.05±1.60	5.31±2.02	5.75±1.78
25W	5.66±1.41	5.83±1.44	5.88±1.59	5.46±1.74	6.00±1.55
35W	5.41±1.42	5.46±1.43	5.66±1.66	4.76±1.87	5.38±1.56

[1]C=Control; 15W=15% waxy sorghum; 25W=25% waxy sorghum; 35W=35% waxy sorghum

Varying inclusions of waxy sorghum did not appear to affect student sensory ratings. The appearance and color improved as greater inclusions of waxy sorghum were added compared to the control. However, the flavor rating of 35W was reduced compared to the other three treatments. This is likely because the waxy sorghum was a burgundy variety. The burgundy sorghum's pericarp contains phenolic compounds that impart a dark red color and bitter taste. White sorghum does not have as high a concentration of phenolic compounds as burgundy sorghum, giving it a paler color and less bitter flavor (Dykes et al., 2005). Students likely preferred the darker red color from greater inclusions of waxy sorghum, but did not like the bitter flavor it imparted.

The regular and waxy sorghum flours obtained for this study was milled to very small particle size, making the flour very fine in texture. Student acceptance of the texture of the four treatments could be attributed to the fineness of the flour, which imparted a softer final texture on the breads. Because the two different flours were milled to similar particle size, little difference was noted in texture between the four treatments.

Conclusions

The incorporation of burgundy waxy sorghum did not affect the attributes of gluten-free sorghum greatly. Color and water activity were the only attributes that showed significant differences between treatments. Color differences can be attributed to the different colors of the waxy and regular sorghum. Gluten-free bread made only with regular sorghum was lighter in color with a significantly different ΔE value compared to the other three treatments with waxy sorghum incorporations. This is because the burgundy waxy sorghum imparted a dark red color on the bread compared to the color of the regular white sorghum. Additionally, this exercise

provided a good method of incorporating research methods into the classroom for students. Student data did not vary from data collected in the controlled setting. Student-generated data followed similar trends, indicating students were able to adequately perform the exercise and obtain useful research experience from this exercise.

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Chapter 6 - Application of food science laboratory exercises as a method of helping students gain undergraduate research experience

Introduction

Undergraduate research is an important student experience offered in many research laboratories. University and faculty members, especially in scientific disciplines, strongly recommended participation in undergraduate research projects as early as freshman and sophomore years in college (Taraban, 2008). The National Research Council (NRC), National Science Foundation (NSF), and Research Corporation recommend that all undergraduate students pursue research projects as early as they can (Taraban, Prensky, & Bowen, 2008). These research opportunities allow students to work closely with a faculty advisor and graduate students on a scientific research project in their field of study. Students gain hands-on experience in the laboratory and reinforce important information learned in classroom settings (Russell, 2008). The goal of undergraduate research is for students to develop "an understanding and appreciation of scientific methodology, the creation of new knowledge, and the role of science in society" (Taraban, 2008, p. 4).

These research opportunities provide highly valuable experiences to undergraduate students when properly implemented. Advisors and mentors must be willing and prepared to guide students; the most noted factor in student discontent with research experiences was ill-prepared mentors (Taraban, 2008). Research participation is a key factor in assisting students to build interest in scientific careers and discover research topics they are passionate about, according to the NSF (Taraban et al., 2008). Undergraduate research allows students to become more academically motivated, achieve greater technical skills, and increases their confidence in performing research projects. Additionally, creating a working relationship between the faculty

advisor and student further integrates students into scientific culture (Taraban et al., 2008). Many colleges and universities are putting more time and resources toward the goal of making undergraduate research projects more widely available to students (Taraban & Logue, 2012).

However, some challenges still exist that block students from being able to participate in these research opportunities. Faculty advisors and graduate students most often cite lack of funding as a reason why they do not offer more undergraduate research opportunities (Russell, 2008). Often there are more students interested in participating in these undergraduate research projects than there are funded positions with available. Another barrier noted was a lack of faculty advisors who are willing or able to take on students. This could be because these faculty members already have many students they are advising on research projects, lack sufficient funding, or may not be interested in advising undergraduate research (Russell, 2008). These issues leave many interested students without research opportunities to pursue.

Course-embedded research opportunities have been explored. It is believed that if research principles were effectively implemented in science laboratory classes, outcomes from undergraduate research projects would occur (Trosset, Lopatto, & Elgin, 2008). However, it can be difficult to include all the factors associated with an undergraduate research experience. There are many classroom factors that are beyond the control of the instructor, making it difficult to create a research-oriented environment. Large class sizes, class time constraints, university deadlines, and assessment and grading requirements make it difficult for students to get personal mentoring from instructors (Trosset et al., 2008).

The goal of our student survey research was to determine if specific laboratory exercises from a sophomore-level food science laboratory provided an effective method of replicating undergraduate research projects on a smaller scale. Students performed two laboratory exercises

in the Fundamentals of Food Processing (FDSCI 305) course at Kansas State University. One exercise focused on replacing or reducing sucrose in sugar snap cookies with alternative sweeteners. In the other exercise, students prepared gluten-free sorghum bread with varying inclusions of waxy sorghum. The objective of this study was to determine students' perceptions of the learning experience from each exercise regarding physical and sensory properties of each food product, research and writing skills, and food processing knowledge.

Materials and Methods

Overview of Laboratory Exercises

Two laboratory exercises were performed by undergraduate students enrolled in the Fundamentals of Food Processing course at Kansas State University. The class was divided into four separate laboratory sections. Within laboratory section, students were divided into lab groups of 3-6 students that worked together to complete each exercise. After completing the laboratory exercises, students were asked to write a laboratory report discussing their findings.

Alternative Sweeteners in Cookies

Students made rolled cookies using different alternative sweeteners and combinations of these sweeteners. Cookies were made with sucrose (control), Splenda for baking, Equal for baking, Truvia, Sweet'N Low, and combination of each of these sweeteners with sucrose. Students evaluated each treatment for spread (cookie width-to-thickness ratio), color, and sensory profile. Cookies were then collected by the graduate teaching assistant (GTA) and analyzed for texture profile analysis (TPA). Student data was compiled by the GTA and distributed to students.

After completing the exercise in class, students were required to compose a memorandum-style laboratory report about their exercise and the data they collected. Students needed to make observations, synthesize all student data collected from the laboratory exercise, and draw conclusions about the cookies produced. They needed to support their conclusions with peer-reviewed, scientific resources.

Gluten-Free Bread

Students prepared and analyzed pup loaves of gluten-free sorghum bread with varying levels of waxy and white sorghum. Gluten-free sorghum bread was made with a blend of 70% sorghum flour and 30% potato starch (baker's percent). Treatments included a control with no waxy sorghum, 15% waxy sorghum, 25% waxy sorghum, and 35% waxy sorghum. After baking, students evaluated loaves of bread on loaf height, crust and crumb color, and sensory profile in the laboratory. Samples were collected by the GTA, then analyzed for water activity and texture profile.

All data was compiled by the TA and given to students for analysis. Students then wrote a memorandum laboratory report, including an introduction, materials and methods, results, and discussion sections. Students were required to synthesize the data collected from the exercise and draw conclusions supported by scientific, peer-reviewed research.

Institutional Review Board

Prior to distributing surveys to students, permission was obtained from the Institutional Review Board (IRB) at Kansas State University in order to perform research involving human subjects. The two surveys, informed consent statement for each survey, and a debriefing statement for each survey were submitted. Researchers submitted the proposal (9631) to the IRB

and received approval prior to distributing surveys to students. All IRB documents submitted and provided to students can be found in Appendix C.

Surveys

Researchers used Qualtrics (Provo, UT; Seattle, WA) as the platform to compose and distribute surveys to students. Two surveys were distributed to students by researchers, each covering one of the two laboratory exercises described above and in previous chapters (see Chapters 3 and 5). The survey covering the rolled cookie exercise was distributed to two groups of students: students who performed the exercise in 2018 and in 2019. This survey was distributed to both groups of students at the same time in 2019. Students who performed the exercise in 2018 were being asked to reflect upon the exercise they performed a year ago. The gluten-free bread survey was only distributed to students in the 2019 class, as that was the first time that laboratory was used as part of the course.

Survey Questions

The goal of each survey was to assess student perceptions of learning outcomes and overall success of the rolled cookie and the gluten-free bread exercises. Questions in each survey were separated into four sections: 1) Demographics (year in school, major, and other food science courses taken), 2) Physical and Sensory Properties, 3) Research and Writing Skills, and 4) Food Processing Knowledge. The questions in these categories assessed student perceptions of how each exercise improved their data collection skills, writing and research abilities, and knowledge of food processing. Questions in the latter three categories were written for responses to be provided on a Likert scale. A Likert scale is a five-point scale in which respondents choose the option that matches how much they agree or disagree with a statement. Likert scale response options provided were as follows: Strongly Disagree, Somewhat Disagree, Neither Agree Nor

Disagree, Somewhat Agree, and Strongly Agree. The full surveys for both exercises can be found in Appendix C.

Students who completed the 2018 rolled cookie survey were incentivized to complete the survey by being entered into a drawing for one of two $25 Amazon gift cards. Students who completed the 2019 cookie and gluten-free bread surveys were incentivized to complete the survey by receiving five bonus points toward their laboratory grade for each survey (10 total bonus points for completing both surveys or 1.75% of their total laboratory grade).

Results and Discussion

Demographics

Cookie Exercise

A total of 31 students (approximately 50% of the class) completed the 2018 survey. A majority of students completing the 2018 survey were Food Science students (16), followed by Animal Sciences and Industry (10) (Figure 6.1). Thirteen of the 31 students who completed the survey were sophomores at the time when they performed the exercise. Nine students were juniors, seven were seniors, and only two were freshman.

In 2019, a total of 53 students (nearly 85% of the class) completed the survey. Almost half of the respondents (48) were Animal Science and Industry majors while only 22 students were Food Science majors (Figure 6.1). Fifty-four responses were recorded for the question regarding majors, indicating one student had two majors. Twenty-five of the 53 students who completed the 2019 survey were juniors when they performed the cookie exercise. Fifteen students were seniors, 13 were sophomores, and none were freshman.

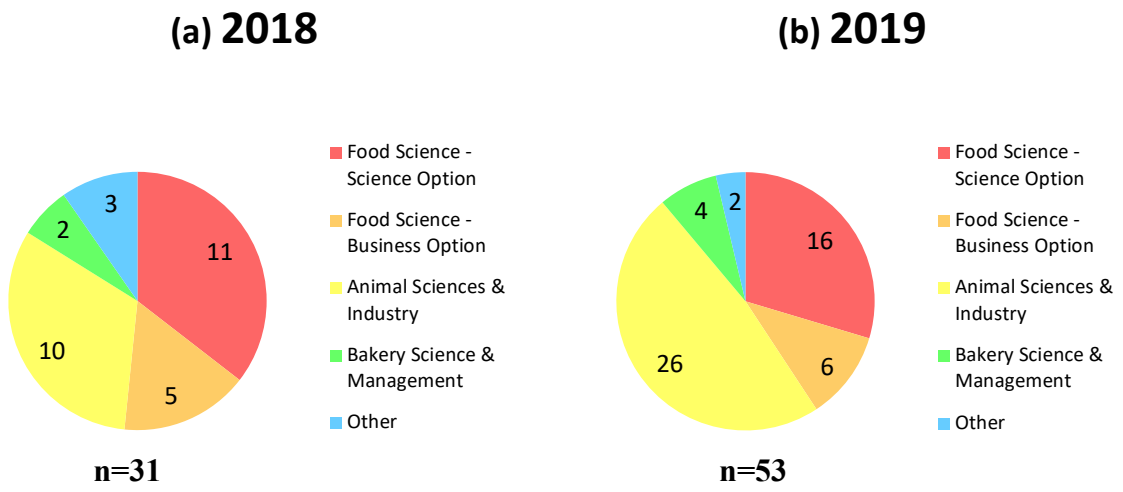

Figure 6.1–Majors of students completing the cookie survey in 2018 (a) and 2019 (b).

Students were asked whether they had previously taken specific food science courses prior to being enrolled in FDSCI 305. These courses included Introduction to Food Science (FDSCI 302), Food Products Evaluation (FDSCI 430), Food Chemistry (FDSCI 501), Food Microbiology (FDSCI 600), Fruit and Vegetable Processing (FDSCI 630), and Principles of HACCP and HARPC (FDSCI 690). A "none of the above" option was also provided.

Of the students completing the 2018 survey, 17 had taken FDSCI 302. A combined 13 students had taken all the other courses listed, with no students having taken FDSCI 430. Thirteen students had not taken any of the courses listed. In the 2019 survey, 30 of the respondents had taken FDSCI 302. Only 11 students total had taken any of the other listed courses. Twenty-two students had not taken any of the listed courses. It is likely that most of the students who had not taken any of the courses listed in the 2018-19 surveys were majoring in Animal Science and Industry or Bakery Science and Management. These students are part of separate curriculums on campus and therefore have different course requirement than Food Science students.

Gluten-Free Bread Exercise

Fifty-three students (approximately 85% of the class) completed the survey (Figure 6.2). Nearly half of the respondents (46%) were Animal Science and Industry, followed closely by Food Science students (40%). Fifty-four responses about student majors were recorded, indicating one student was a double major. Of the students who completed the survey, 22 were juniors, 14 were seniors, 12 were sophomores, and none were freshmen.

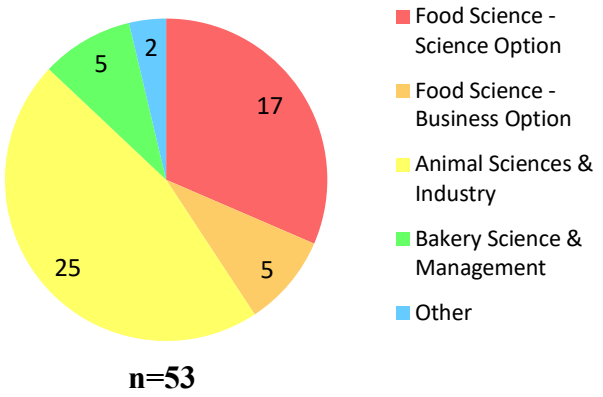

Figure 6.2– Majors of students completing the gluten-free bread survey.

Researchers also asked students about food science courses they had previously taken. The same courses were listed as those used in the survey about the cookie exercise (described above). Twenty-nine of the students who had completed the survey had previously taken FDSCI 302. Only 11 students total had taken any of the other five courses listed. Twenty-three students had never taken any of the listed courses. As in the survey regarding the cookie exercise, the respondents who said they had not taken any of the listed courses were likely students in Animal Science and Industry, Bakery Science and Management, or another major. These majors are in

separate departments from Food Science and therefore have different course requirements, so these students may never take other food science courses.

Physical and Sensory Properties

Cookie Exercise

Overall, student survey results were positive about the laboratory exercise. Seventy percent or more of students who completed the surveys answered “Strongly Agree” or “Somewhat Agree” for all questions in the “Physical and Sensory Properties” section of both the 2018 and 2019 surveys (Figure 6.3). Questions 1 (understanding of the effect of artificial sweeteners on sensory properties of cookies) and 2 (understanding of the effect of sugar on sensory properties of cookies) had the most positive responses in the 2018 survey. Only 11 responses of “Strongly Disagree” or “Somewhat Disagree” and no responses of “Neither Agree nor Disagree” were recorded across all questions in this section. More negative responses were recorded in the 2019 survey. Every question in the “Physical and Sensory Properties” of the 2019 survey reported up to 15% of the responses as “Strongly Disagree” or “Somewhat Disagree” and up to 13% as “Neither Agree nor Disagree” were recorded.

A majority of students indicated the laboratory exercise helped them gain a better understanding of sucrose functionality in a baked cookie application and the functional differences that alternative sweeteners presented. Students had mostly positive perceptions about how well performing the exercise improved their knowledge of alternative sweeteners. They believed their knowledge about the physical and sensory properties of rolled cookies was improved by performing this laboratory exercise.

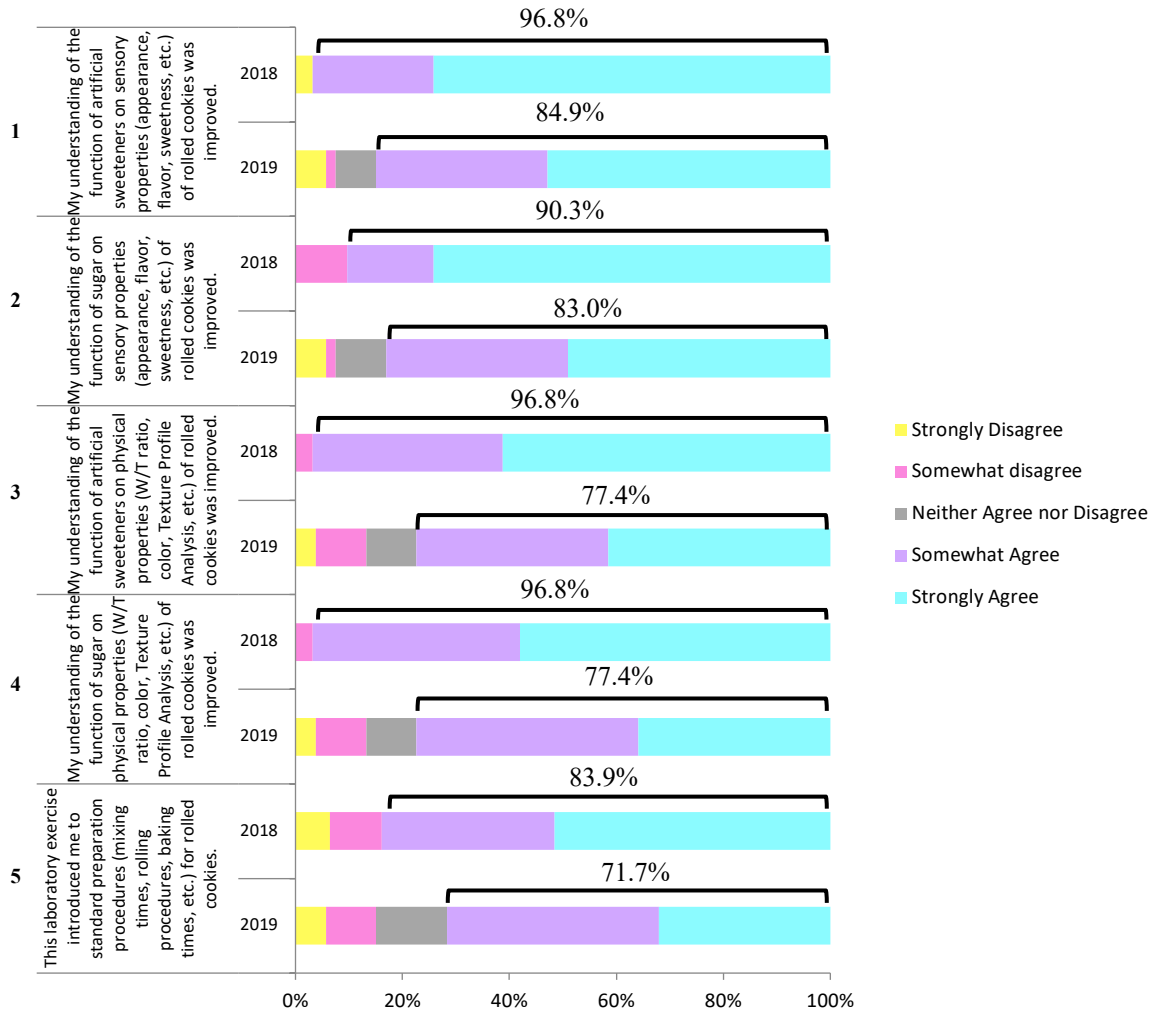

Figure 6.3–Survey results for "Physical and Sensory Properties" section of the 2018-19 cookie survey.

Gluten-Free Bread Exercise

Students gave mostly positive responses to all questions in the "Physical and Sensory Properties" section of the gluten-free bread survey. More than 65% of respondents gave positive answers to all questions in this section (Figure 6.4). Question 4 had the most negative responses, with eight students responding "Strongly Disagree" and another eight responding "Somewhat Disagree." This question was about whether or not this laboratory exercise was students' first experience with gluten-free bread. It is expected that students would give negative responses if

they had previously consumed gluten-free bread products. With the rising popularity of gluten-free, it is not unexpected that some students would be familiar with gluten-free products.

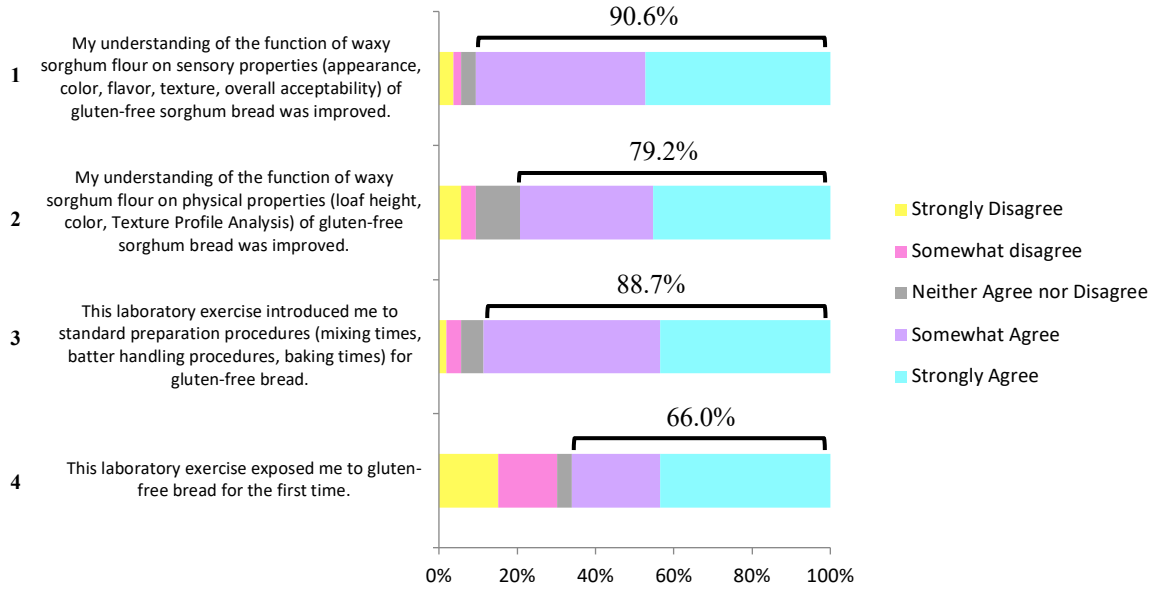

Figure 6.4–Survey results for "Physical and Sensory Properties" section of the 2019 gluten-free bread survey.

Implications

In research, data most often reflects the physical properties that can be measured. Understanding these parameters is key when attempting to draw conclusions from a research project. From the results collected from both surveys, students had mostly positive experiences collecting and interpreting the physical properties in both of these exercises. Student responses indicate performing each exercise facilitated learning about new topics in food science and assisted in gaining relevant knowledge about baked food products and ingredient functionality. Active, hands-on learning is proven to increase retention of information learned, compared to lecturing alone. Practical experience, including performing research and laboratory exercises,

leads to 75% retention of information compared to 5% retention from only lecture (Hollis & Eren, 2016).

A previous study conducted by Trosset et al. (2008) found that 81% of students who performed course-embedded research believe they learned a great deal about subject matter from the opportunity. Students volunteered information that supplemental laboratory activities played an important role in reinforcing information. These activities included writing lab reports, having the opportunity to ask questions, and participating in class discussions during oral presentations. This is similar to findings from the discussed student survey data.

Research and Writing Skills

Cookie Exercise

In the "Research and Writing Skills" section, more negative responses of "Strongly Disagree," "Somewhat Disagree," and "Neither Agree nor Disagree" were recorded for both the 2018 and 2019 surveys, compared to the previous section (Figures 6.5 and 6.6). In the 2018 survey, question 13 (familiarity with data collection strategies) recorded the most positive responses, with 100% of students who completed the survey answering either "Strongly Agree" or "Somewhat Agree." As in the previous section, more negative responses were recorded from students who completed the 2019 survey than the 2018 survey. Eleven out of the 12 questions in the "Research and Writing Skills" section of the 2019 survey had one or more responses of "Strongly Disagree." However, a majority of the responses for every question were positive, with 67% or more of responses in the "Somewhat Agree" or "Strongly Agree" categories.

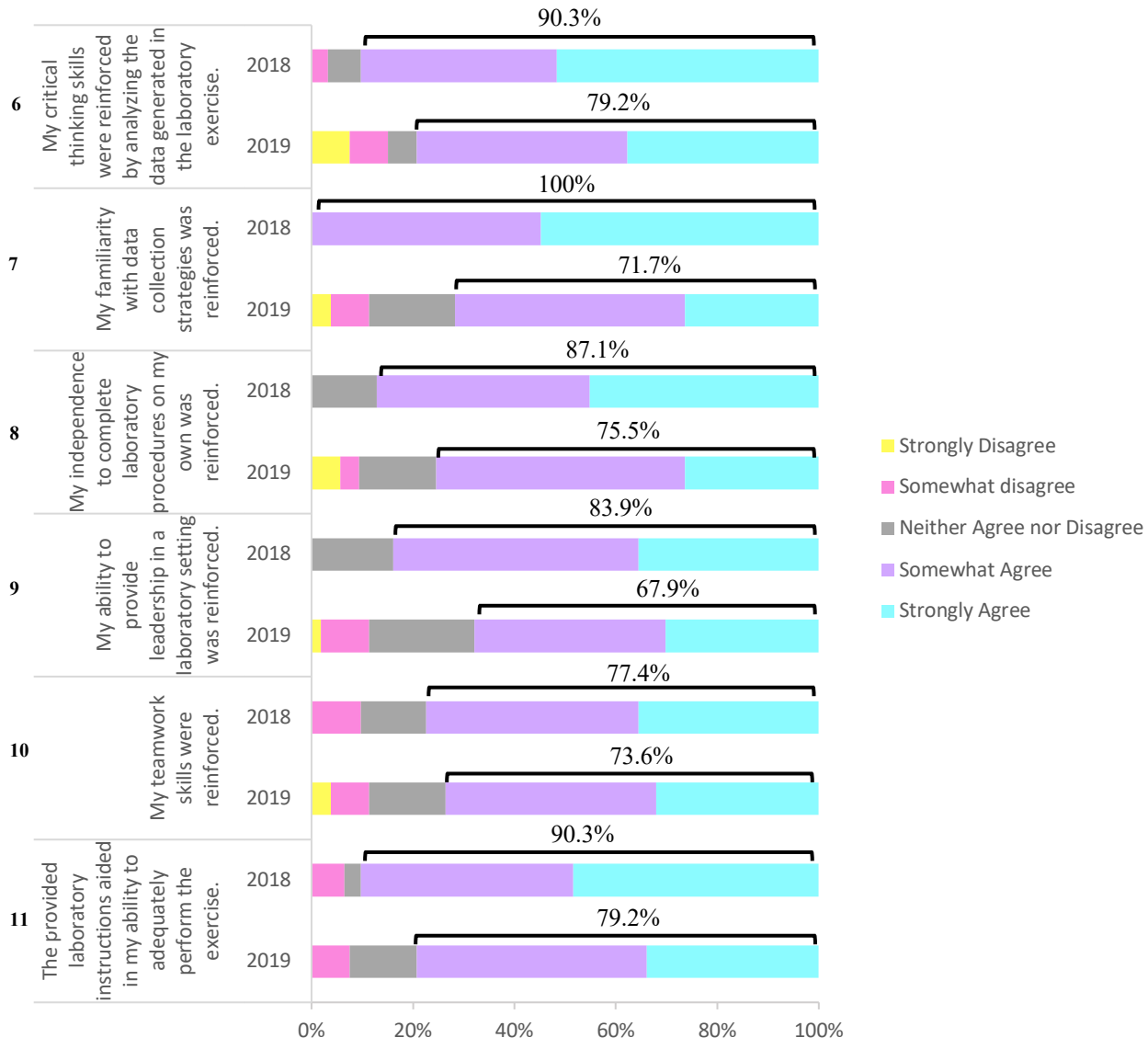

Figure 6.5–Survey results for "Research and Writing Skills" section of the 2018-19 cookie survey.

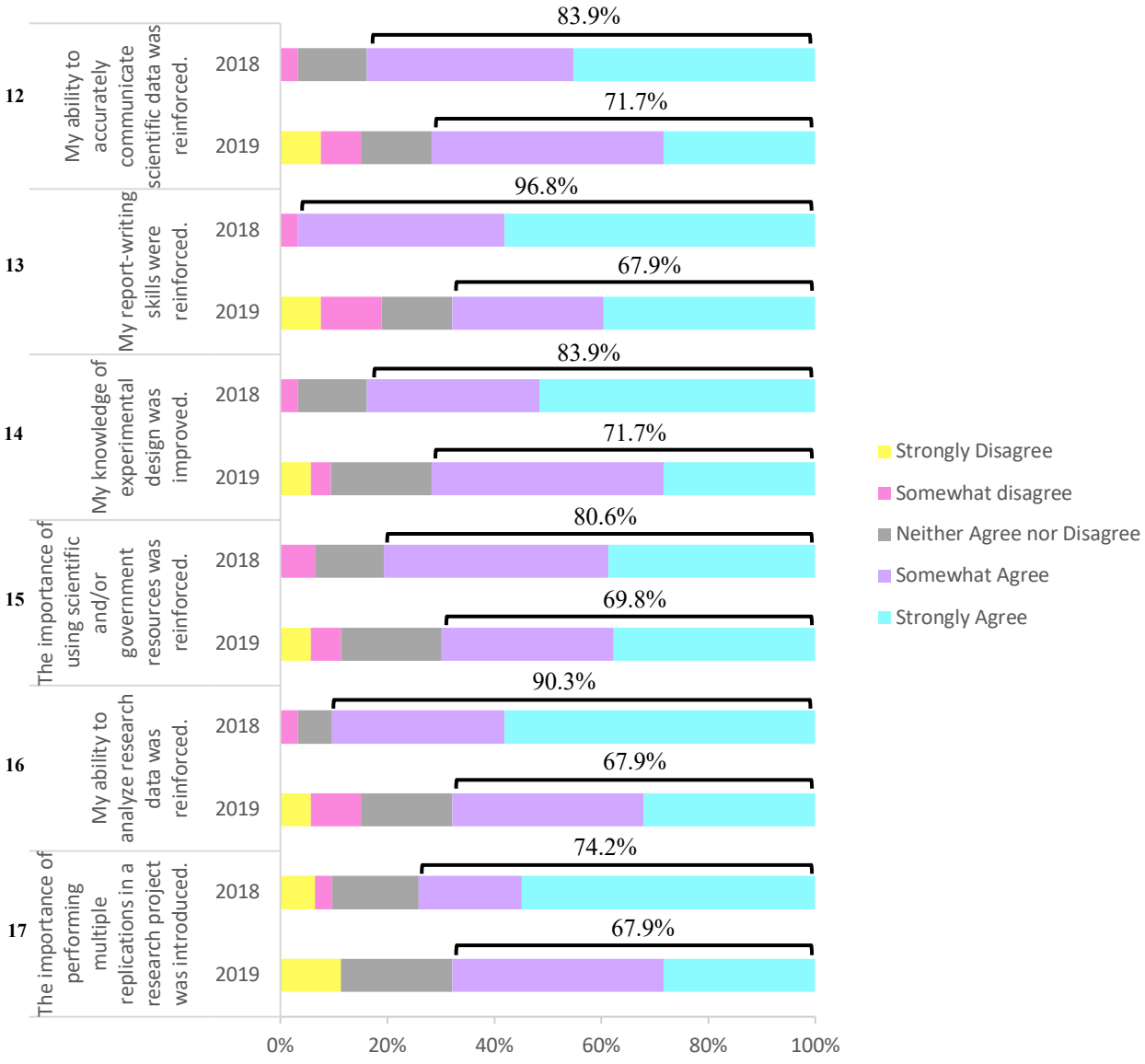

Figure 6.6–Survey results for "Research and Writing Skills" section of the 2018-19 cookie survey, continued.

Gluten-Free Bread Exercise

Responses from the "Research and Writing Skills" of the gluten-free bread survey had more negative responses, similar to the same section of the surveys regarding the cookie exercise (Figure 6.7). Questions 5 (ability to communicate data with peers), 8 (importance of using scientific resources), and 14 (ability to provide leadership) had the most negative or neutral

responses, each with 17 responses of "Strongly Disagree," "Somewhat Disagree," or "Neither Agree nor Disagree." However, 68% or more of responses for all questions were positive, indicating students believed the exercise had a positive impact on their knowledge of research techniques and writing skills. The question with the greatest number of positive responses was question 15, regarding teamwork skills. Most students believe the exercise was successful at helping them build teamwork skills.

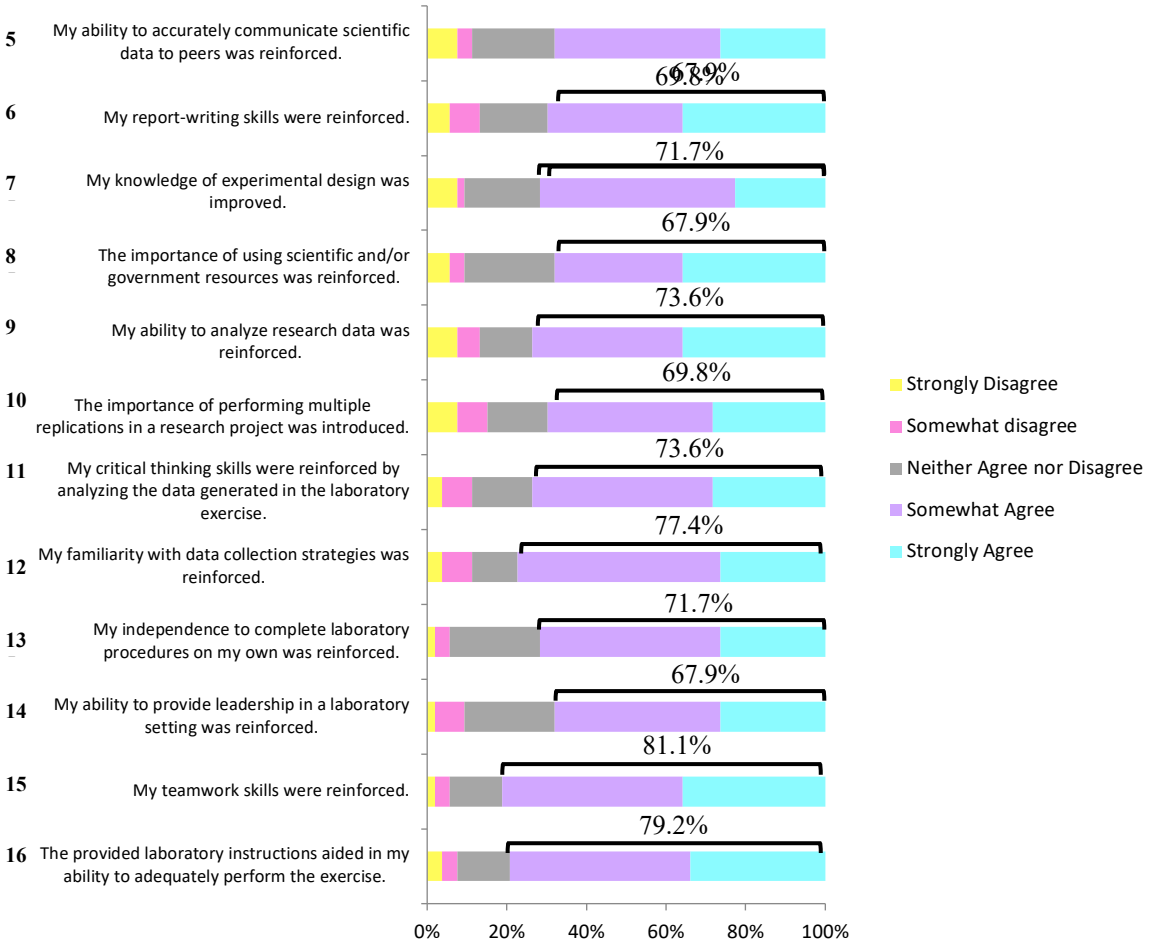

Figure 6.7–Survey results for "Research and Writing Skills" section of the 2019 gluten-free bread survey.

Implications

These responses indicate that students had overall positive perceptions about the soft skills they developed during these laboratory exercises. Most students believed these exercises helped introduce them to or reinforce their understanding of research principles and common scientific research techniques. They also believed that performing this exercise and having to write a laboratory report improved their scientific writing skills.

Building research skills is an integral part of undergraduate research projects. In-class activities, such as the ones studied by the authors, have a greater potential to teach real-world applications of scientific knowledge than lecturing alone (Arthurs & Kreager, 2017). Students are exposed first-hand to laboratory techniques, research design principles, and data collection strategies. These skills help students apply scientific knowledge in the decision-making process during research (Arthurs & Kreager, 2017). Advisors use these research opportunities to teach undergraduates about these research principles and how to apply them in a laboratory setting. Students who participate in undergraduate research also typically present their research in a professional setting, further helping them learn scientific writing and communication skills. These laboratory exercises appear to have taught students some of these critical research skills and principles as well as building their scientific communication skills.

The findings from this study mirror those from the study conducted by Trosset et al. (2008). Writing skills were the most noted student improvement from participating in course-embedded research opportunities. Students noted that the format of scientific writing is vastly different from writing taught in humanities courses. They noted writing reports based on their research was helpful in teaching them writing skills that would be useful in the future. Additionally, this same study found students also reacted positively to their experience learning

how to conduct research. The “Understanding the research process” section of their survey received the highest scores of any section on the survey. Instructors of the course rated 77% of students who participated in the research as excellent or good in their understanding of the research process (Trosset et al., 2008).

Food Processing Knowledge

Cookie Exercise

In the 2018 survey, question 18 (applying principle of food science to practical food processing issues) in the “Food Processing Knowledge” section had the fewest negative responses, with only one “Somewhat Disagree” and one “Neither Agree nor Disagree” responses (Figure 6.8). Question 20 (basic unit operations required to produce rolled cookies) had the most negative responses; four students answered “Strongly Disagree” and one answered “Somewhat Disagree.” In the 2019 survey, questions 19 (effects of processing parameters on cookie quality) and 20 (basic unit operations required to produce rolled cookies) had a smaller proportion of negative responses compared to the same questions from the 2018 survey. This could be attributed to improvements made on the overall explanation of the exercise and its big-picture implications between when the exercise was performed in 2018 to 2019.

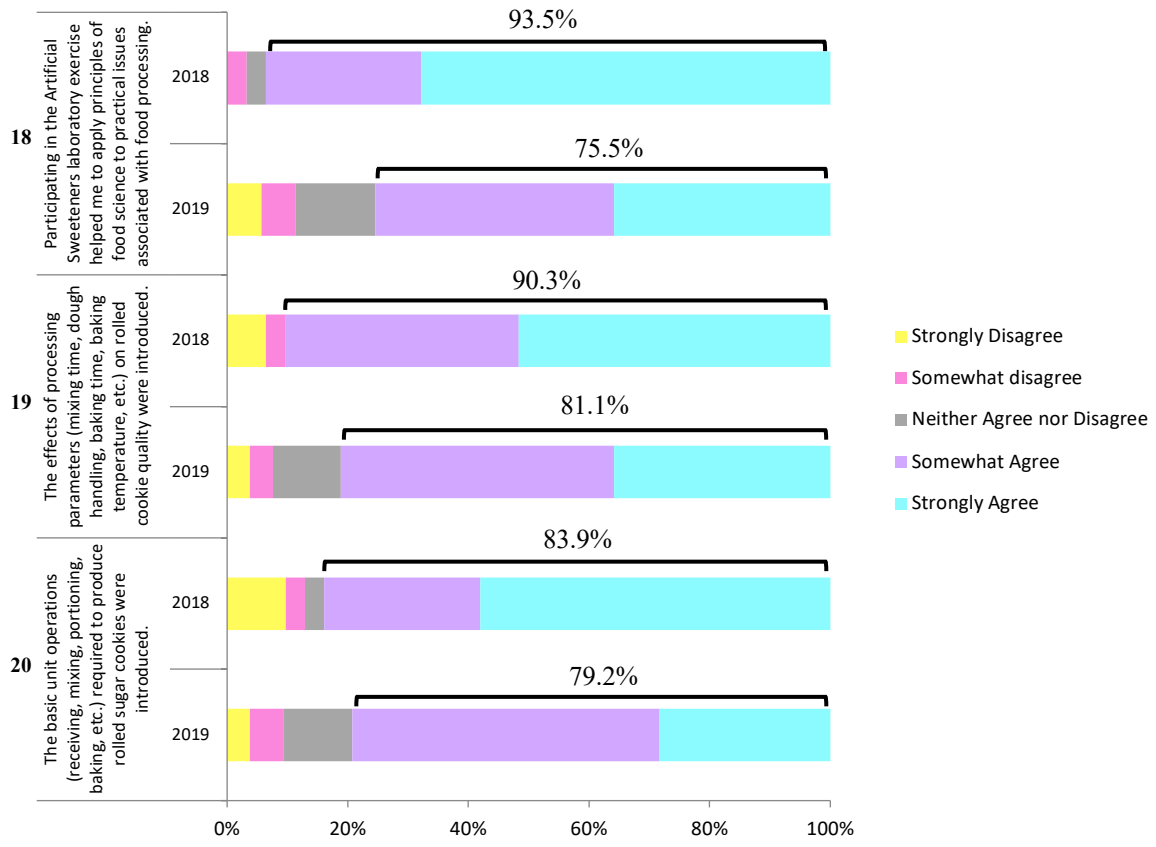

Figure 6.8–Survey results for "Food Processing Knowledge" section of the 2018-19 cookie survey.

Results show that a majority of students who completed the survey believed participating in this laboratory exercise aided in building their knowledge of food processing techniques required to produce rolled cookies and gluten-free bread. In terms of the cookie survey, more students completing the 2019 survey had positive or neutral responses than those who completed the 2018 survey. This is most noted in questions 19 and 20. These two questions are more short-term implications from the laboratory exercise, so students from the 2019 class may have had better recollection of these principles since less time had passed between their completion of the exercise and filling out the survey. However, more students from 2018 responded positively to question 18. This question was more focused on over-arching and long-term learning outcomes

from the exercise that may be developed after reflecting upon the exercises. Students from the 2018 class had more time to reflect upon the exercise and use this knowledge in other settings than the 2019 class, and this may have led to more positive responses to this question.

Gluten-Free Bread Exercise

A large percentage of the responses in the "Food Processing Knowledge" section were positive (Figure 6.9). Over 90% of responses on questions 18 (challenges associated with producing gluten-free bread), 19 (effects of processing parameters on gluten-free bread quality), and 20 (basic unit operations required to produce gluten-free bread) were either "Strongly Agree" or "Somewhat Agree." Question 17 (applying principles of food science to practical food processing issues) had slightly fewer positive responses, with 77% of responses being positive.

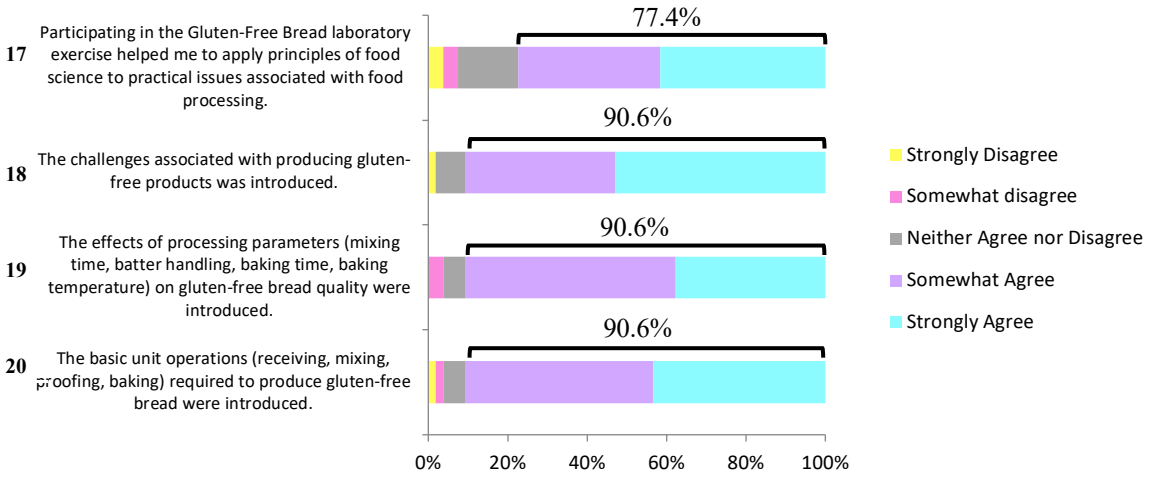

Figure 6.9–Survey results for "Food Processing Knowledge" section of the 2019 gluten-free bread survey.

Additionally, question 17 of the gluten-free bread survey was about long-term understanding of food processing principles applied to current issues. This question requires students to reflect upon the long-term learning outcomes from the exercise. However, they took the survey only a few weeks after completing the exercise and did not have time to reflect on the

exercise or fully understand how the exercise affects their perceptions. More time to reflect on the exercise may have increased the positive responses.

Implications

Perhaps one of the most important parts of an undergraduate research project is learning the principles behind the research topic. Students are exposed to new and innovative topics in their field of research during such projects. They learn everything from basic principles to new technology and research areas associated with their field. In the case of these exercises, students learned about the principles of food processing.

A study by Hollis & Eren (2016) found that hands-on laboratory activities had a positive impact on student perceptions of real-world issues associated with food science and food processing. Their study focused on a product development class; thus, students' understanding of food product development and all the steps involved in such a process were studied. Researchers found that, after participating in the course, students had improved knowledge of the product development process and specific interactions of ingredients. This allowed students to have improved abilities to critically think about food science problems with a real-world perception. This shows that hands-on and in-class research activities have an impact on student understanding of food science principles and assist them in learning pertinent information to think more critically about food science challenges (Hollis & Eren, 2016).

Conclusion

The overall student response to all three surveys was positive. Sixty-five percent or more of students who completed the surveys believed each exercise provided a valuable learning experience and introduced them to new topics in food science. These positive responses indicate

that each of the exercises gives a similar experience to an undergraduate research project in an abbreviated form. The exercises taught students real-world food processing techniques for different grain products. Students also learned about research and data collection techniques and scientific communication skills. These exercises and their learning outcomes provided a condensed version of undergraduate research projects for students and a means to integrate knowledge they learned in the classroom with real-world food science challenges.

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Chapter 7 - Summary and Implications

Overall, the two grain-based food processing laboratory exercises used in this study provided successful research experiences for students, based on data collected and student survey responses. Student data for both the alternative sweeteners and gluten-free sorghum bread exercises was similar to data collected in a controlled environment. Students generated and collected data accurately in the laboratory setting, indicating they were observing the correct results of each exercise.

In the classroom setting, the control cookies (7.8), Truvia cookies (7.2), and Truvia and sugar cookies (7) had similar W/T ratios but were different from all other treatments (4.5-5.6). All treatments were similar in terms of total color change (ΔE). Control (6369 N) and Truvia (6878 N) cookies had similar hardness values but differed from all other treatments. Sensory data varied greatly (2.62-6.89 out of 9), since it was subjectively based on individual opinions. Overall, sensory ratings were average on the 9-point scale with control cookies rating the best out of all treatments. In the alternative sweeteners exercise, student data only differed ($p<0.05$) from controlled data in terms of color. Student-generated data from all other data categories (width-to-thickness (W/T) ratios, color, and texture) was similar to values collected from the controlled setting. This exercise demonstrated that the control cookies were the best treatment in terms of physical parameters and sensory properties. However, cookies prepared using a blend of sugar and Truvia could provide an acceptable reduced-sugar alternative because these cookies were most similar to the control.

In the gluten-free bread exercise, minimal differences between treatments were noted for any physical or sensory properties. In both the controlled and classroom setting, no significant differences were noted between the four treatments in terms of loaf height (classroom: 53.72-

56.23; controlled: 47.44-47.98) and Texture Profile Analysis (TPA). The water activity (a_w) of the control in the controlled setting (0.96) differed from the a_w of all other treatments (0.97), but no differences were noted in the classroom setting (0.98-0.99). However, this difference is likely due to chance as the true values are close to one another. The most differences were noted in the crust and crumb color of the different treatments. Color differences can be attributed to the differences in the color of the regular white versus the waxy burgundy sorghum. The red color of the waxy burgundy sorghum contributed a darker color to the bread that deepened as the amount of burgundy sorghum increased. Bread made with 25% waxy sorghum was overall the most acceptable treatment in terms of sensory properties, rating the highest in the appearance (5.66), color (5.83), flavor (5.46), and overall acceptability (6.00) categories. The treatment using 35% waxy sorghum was rated the lowest for flavor (4.76) and overall acceptability (5.38), due to the bitter flavor that the burgundy sorghum imparted on the bread. These findings indicate that inclusions of up to 25% burgundy waxy sorghum may be added to gluten-free sorghum bread formulations without negatively impacting its quality. Changing of the levels of waxy sorghum did not provide students with a visualization of differences between treatments, but did show them that not all changes to formulations create changes in a final product.

Student survey responses were primarily positive for both classroom exercises. Questions were divided into three categories: “Physical and Sensory Properties”, “Research and Writing Skills”, and “Food Processing Knowledge”. In all categories, 65% or more of all respondents marked “Somewhat agree” or “Strongly agree” for all questions. Few responses to the questions were neutral or negative. One question in the “Food Processing Knowledge” section was designed to gauge the overall impact performing each exercise had on students’ ability to integrate the knowledge they gained during the hands-on laboratory exercise with knowledge

they learned in class ("Participating in the ___ laboratory exercise helped me to apply principles of food science to practical issues associated with food processing.") Responses to the question were mainly positive, however a greater number of positive responses were recorded from the class who performed the artificial sweeteners exercise in 2018. One year passed between the time this group of students performed the exercise and completed the survey. The greater number of positive responses is likely because this group had a longer period of time to use this knowledge in other settings and understand the real-world applications of the knowledge gained.

These exercises proved to be positive, hands-on learning experiences about food processing techniques. The great accuracy of student data and large number of positive survey responses indicate students understood the exercises and believed that participating in these exercises gave them the opportunity to learn important knowledge and skills. Undergraduate students are able to accurately generate, collect, and synthesize data in the context of a research experience when provided with sufficient written and verbal instructions.

Further research should be done in order to more fully understand how well students may perform in the laboratory setting. The gluten-free bread exercise could be edited to give more clear and direct instructions, as gluten-free bread is difficult to produce well. Additionally, since few significant differences were seen between treatments in the gluten-free bread exercise, different parameters (i.e. – egg, HPMC, starch) should be adjusted to provide students with an exercise that shows differences between treatments and demonstrates the importance of certain ingredients in gluten-free bread formulations.

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Appendix A – Alternative Sweeteners Laboratory Handout, Rubrics, and Controlled Data Set

Supplemental Material 1–Laboratory handout for students.

Objective: Determine the effect of different sweeteners on flavor, texture, and appearance of a rolled sugar cookie. Taste various products with different sweeteners or sweetness levels. Become familiar with the flavor profiles of various sweeteners.

Cookies:

1. Prepare cookies according the recipe, altering as assigned. (See recipes in table below.) Different sweeteners will replace part of the granulated sugar. Use the following formulations to prepare your batches.
   *TAs will prepare batches of control cookies for analysis and comparison.
   Treatment 1: Splenda for baking
   Treatment 2: Equal for baking
   Treatment 3: Truvia
   Treatment 4: Sweet'N Low
   Treatment 5: Splenda for baking + Sugar
   Treatment 6: Equal for baking + Sugar
   Treatment 7: Truvia + Sugar
   Treatment 8: Sweet'N Low + Sugar

Formulas for treatments with 100% alternative sweetener

Added by:	Ingredient	Supplier	Control	Splenda	Equal	Truvia	Sweet 'N Low
	Shortening		64 g	64 g	64 g	64 g	64 g
	Sugar		130 g	---	---	---	---
	Splenda		---	16.2 g	---	---	---
	Equal		---	---	15.2 g	---	---
	Truvia		---	---	---	60 g	---
	Sweet'N Low		---	---	---	---	16 g
	Salt		2.1 g	2.1 g	2.1 g	2.1 g	2.1 g
	Sodium Bicarbonate		2.5 g	2.5 g	2.5 g	2.5 g	2.5 g
	Dextrose solution (8.9 g in 150 mL water)		33 g	33 g	33 g	33 g	33 g
	Water		16 g	64 g	64 g	16 g	64 g

	Flour		225 g	225 g	225 g	225 g	225 g

Formulas for treatments with 50% alternative sweetener and 50% sugar

Added by:	Ingredient	Supplier	Splenda	Equal	Truvia	Sweet 'N Low
	Shortening		64 g	64 g	64 g	64 g
	Sugar		65 g	65 g	65 g	65 g
	Splenda		8.1 g	---	---	---
	Equal		---	7.6 g	---	---
	Truvia		---	---	30 g	---
	Sweet'N Low		---	---	---	8 g
	Salt		2.1 g	2.1 g	2.1 g	2.1 g
	Sodium Bicarbonate		2.5 g	2.5 g	2.5 g	2.5 g
	Dextrose solution (8.9 g in 150 mL water)		33 g	33 g	33 g	33 g
	Water		64 g	64 g	16 g	64 g
	Flour		225 g	225 g	225 g	225 g

2. **Tables 1a and 1b** includes both % by weight and bakers %. Using your recipes, calculate both the % and baker's % for each ingredient.
    a. Ingredient % by weight is (ingredient weight/total weight)
    b. Bakers % is (ingredient weight/flour weight)
3. Record weight of the dry bowl, bowl with ingredients before portioning, bowl after portioning, and the weight of the finished cookies in **Table 2** to determine percentage yields. This should be calculated for all batches.

<u>Baking instructions (adapted from AACC Method 10-50.05)</u>:

***Repeat the following instructions for BOTH formulations that your group is assigned!**

1. Preheat oven to 400°F.
2. Cream shortening, sugar, salt, and sodium bicarbonate in mixer with flat beater, using low speed for 3 min. Scrape down bowl after each min.
3. Add dextrose solution and distilled water. Mix 1 min on low speed. Scrape down bowl. Mix 1 min at medium speed. Add all the flour and mix 2 min at low speed, scraping down the bowl after each 30 sec.

4. Place dough between pieces of plastic wrap. Flatten dough slightly, then roll dough to proper thickness (7 mm or 0.275 in.) using rolling pin and guide dowels. Cut cookies using the cutter.
5. Re-roll the scrap dough to prepare as many cookies from batch as possible, so they can be shared with the other groups for sensory testing.
6. Bake cookies at 400°F for 10 min.
7. On removal from oven, transfer cookies to cooling rack using a spatula. Allow cookies to cool.
8. Cool cookies and place a group number on your cookies for tasting. Set aside 3 cookies for analysis, and the others for sensory testing.

Analysis (adapted from AACC Method 10-50.05):

1. Lay 3 cookies edge to edge and measure width in mm. Rotate cookies 90° and re-measure to obtain the average width (W) in mm. Record in **Table 3.**
2. Stack 3 cookies on top of one another and measure thickness. Restack in different order and re-measure to get an average thickness (T) in mm. Record in **Table 3.**
3. Calculate the W/T ratio as a measure of the cookie spread, and compare cookies baked with different sweeteners. Record in **Table 3.**
4. Use the portable spectrophotometer to analyze the L*a*b* color of one cookie from your batch. Record in **Table 4**. Using the L*a*b* values, calculate the ΔE using the following equation and record in **Table 4**.

$$\Delta E = \sqrt{L^{*2} a^{*2} b^{*2}}$$

5. The TAs will collect 3 cookies from each batch and run a Texture Profile Analysis (TPA). This data will be sent to you in a spreadsheet. From this data, determine the average Hardness and Fracturability of the cookies from each batch. Record this data in **Table 5**.
    a. Hardness is measured as the maximum force of the 1st compression
    b. Fracturability is measured as the force at the first peak.
6. Taste and score all products compared to the provided control cookies. Compare the flavor, appearance, texture, sweetness, and aftertaste of the cookies baked with different sweeteners. Record in **Tables 6a and 6b.**

Tables

Table 1a: Ingredients for Treatment #_____.

Ingredient	Mass (g)	%	Baker's %
Shortening			
Salt			
Sodium bicarbonate			
Dextrose solution			
Distilled water			
Flour			
Sweetener:			
Sugar			

Table 1b: Ingredients for Treatment #_____.

Ingredient	Mass (g)	%	Baker's %
Shortening			
Salt			
Sodium bicarbonate			
Dextrose solution			
Distilled water			
Flour			
Sweetener:			
Sugar			

Table 2: Yield Measurements

Treatment	Empty Bowl (g)	Bowl + Ingredients (g)	Bowl after portioning (g)	Cookies after baking (g)	% Waste	% Yield
Control						
Splenda for baking						
Equal for baking						
Truvia						
Sweet'N Low						
Splenda for baking + sugar						
Equal for baking + sugar						
Truvia + sugar						
Sweet'N Low + sugar						

Table 3: W/T Ratios of cookies.

Treatment	Width (mm)			Thickness (mm)			W/T Ratio
Control	1:	2:	Avg:	1:	2:	Avg:	
Splenda for baking	1:	2:	Avg:	1:	2:	Avg:	
Equal for baking	1:	2:	Avg:	1:	2:	Avg:	
Truvia	1:	2:	Avg:	1:	2:	Avg:	
Sweet'N Low	1:	2:	Avg:	1:	2:	Avg:	
Splenda for baking + sugar	1:	2:	Avg:	1:	2:	Avg:	
Equal for baking + sugar	1:	2:	Avg:	1:	2:	Avg:	
Truvia + sugar	1:	2:	Avg:	1:	2:	Avg:	
Sweet'N Low + sugar	1:	2:	Avg:	1:	2:	Avg:	

Table 4: L*a*b* colorimetry data for cookies.

Treatment	L*	a*	b*	ΔE
Control				
Splenda for baking				
Equal for baking				
Truvia				
Sweet'N Low				
Splenda for baking + sugar				
Equal for baking + sugar				
Truvia + sugar				
Sweet'N Low + sugar				

Table 5: TPA for cookies.

Treatment	Hardness	Fracturability
Control		
Splenda for baking		
Equal for baking		
Truvia		
Sweet'N Low		
Splenda for baking + sugar		
Equal for baking + sugar		
Truvia + sugar		
Sweet'N Low + sugar		

Supplemental Material 2–Hedonic scale handouts given to students for sensory evaluation.

Table 1a–Sensory evaluation ballots given to students for cookies made with alternative sweeteners.

	Treatment	Control	Splenda for baking	Equal for baking	Truvia	Sweet'N Low
Appearance	Description					
	Hedonic ranking					
Texture	Description					
	Hedonic ranking					
Flavor	Description					
	Hedonic ranking					
Sweetness	Description					
	Hedonic ranking					
Aftertaste	Description					
	Hedonic ranking					

Table 1b–Sensory evaluation ballots given to students for cookies made with alternative sweeteners and sucrose.

	Treatment	Splenda for baking + sugar	Equal for baking + sugar	Truvia + sugar	Sweet'N Low + sugar
Appearance	Description				
	Hedonic ranking				
Texture	Description				
	Hedonic ranking				
Flavor	Description				
	Hedonic ranking				
Sweetness	Description				
	Hedonic ranking				
Aftertaste	Description				
	Hedonic ranking				

Table 2–Hedonic scale format:

Dislike extremely	Dislike very much	Dislike moderately	Dislike slightly	Neither like nor dislike	Like slightly	Like moderately	Like very much	Like extremely

Supplemental Material 3–Rubric given to students for report writing.

	Exceeds Expectations	Meets Expectations	Below Expectations	Little to No Expectations Met
Professional Writing & Grammar	(5.0 to >4.5 pts) Used language that skillfully communicated meaning with clarity and fluency. Contained virtually no grammatical/ mechanical errors. All writing is in 3rd person.	(4.5 to >3.0 pts) Used straightforward language that generally conveyed meaning with clarity. Contained minimal grammatical/ mechanical errors. Minimal use of 1st, 2nd person writing.	(3.0 to >2.0 pts) Used language that sometimes conveyed meaning with clarity. Contained some/several grammatical/ mechanical errors. Multiple uses of 1st, 2nd person writing.	(2.0 to 0 pts) Used language that impeded the meaning. Difficult to read or understand because of extensive grammatical/ mechanical errors. Consistent use of 1st, 2nd person writing.
Introduction & Overview	(10.0 to >9.0 pts) Used appropriate, relevant, and compelling content to introduce and summarize the topic with relevant cited references. Objectives are clearly stated.	(9.0 to >6.0 pts) Used adequate and relevant content to introduce and summarize the topic with relevant cited references. Objectives are stated.	(6.0 to >4.0 pts) Used somewhat adequate and relevant content to introduce and summarize the topic with some cited references. Objectives are incomplete or difficult to understand.	(4.0 to 0 pts) Lacked sufficient or relevant content to introduce the topic. No cited references used. Objectives are not stated.
Material & Methods	(15.0 to >13.5 pts) Successfully described experimental procedure and materials used in the experiment, including equipment, ingredients, scale-up. Reader would be able to successfully replicate the	(13.5 to >9.0 pts) Described the experimental procedure and materials used, but with some details missing. Reader should still be able to replicate the experiment, but may have some difficulty. Formulation is included.	(9.0 to >6.0 pts) Somewhat described the experimental procedure and materials used, but with several details or pieces of information missing. Reader would have difficulty replicating the experiment. Formulation	(6.0 to 0 pts) Unsuccessfully described the experimental procedure and materials used. Reader would have no way to replicate the experiment. Formulation not included.

	experiment based on the writing. Formulation is included.		included, but may be incomplete.	
Results & Discussion	(15.0 to >13.5 pts) Used appropriate, relevant, and compelling content to illustrate writer's understanding of the subject. Science-based findings were correctly interpreted and well supported with relevant references. Addressed all points listed in the report instructions completely. All tables are clearly referenced in the text. References are clearly and appropriately cited in-text.	(13.5 to >9.0 pts) Used appropriate, relevant, and compelling content to illustrate writer's understanding of the subject. Adequately used science-based findings and generally interpreted them correctly with relevant references. Addressed main points listed in report instructions, but some important details missing. Some tables referenced in text. Some correct in-text citations are used.	(9.0 to >6.0 pts) Used somewhat adequate and relevant content to illustrate writer's understanding of the subject. Included some science-based findings, but not always interpreted or supported correctly with few or some relevant references. Addressed some important points listed in report instructions, but provided few details. Tables are incorrectly referenced in text. Very few in-text citations are used, perhaps with incorrect formatting.	(6.0 to 0 pts) Lacked sufficient or relevant content to illustrate writer's understanding of the subject. Science-based findings were either not included or incorrectly interpreted with few to no references. Several important points listed in report instructions are not addressed. Tables are not referenced in text. No in-text citations.
Conclusion & References	(10.0 to >9.0 pts) Thoroughly developed conclusions based on findings and significance to Food Science. A minimum of 4 scientific and peer-reviewed	(9.0 to >6.0 pts) Adequately developed conclusions based on findings and significance to Food Science. A minimum of 3 scientific and peer-reviewed	(6.0 to >4.0 pts) Developed conclusions based on some findings and demonstrated some relevance to Food Science. 1-2 scientific and peer-reviewed	(4.0 to 0 pts) Insufficient conclusions based on findings and relevance to Food Science. No references were included, or references were of poor credibility

	references were included with proper Journal of Food Science citations. Demonstrated skillful use of high-quality, credible, and relevant sources to develop or support ideas. Clearly stated which formulation was best and stated why. Clear future research steps are laid out.	references were included with proper Journal of Food Science citations. Mostly demonstrated skillful use of high-quality, credible sources to develop or support ideas. States which formulation was best, but lacks reasoning. Future research steps listed.	reference included. Significant citation errors may exist. Quality or credibility of references should be improved to better develop and support ideas. Best formulation statement is unclear or incomplete. Future research steps unclear.	and incorrectly cited. Missing information about best formulation and future research steps.
Appendix	(15.0 to >13.5 pts) All necessary tables, figures, and formulations have been included. Tables and figures are correctly labeled with table number and title. Flow diagram includes all commercial steps and is referenced in text.	(13.5 to >9.0 pts) All necessary tables, figures, and formulations have been included, but may be incorrectly labeled. Flow diagram may be missing a couple commercial steps.	(9.0 to >6.0 pts) Some necessary tables, figures, and formulations are missing. Tables and figures may be incorrectly labeled. Flow diagram is missing many commercial steps and may not be referenced in text.	(6.0 to 0 pts) Several or all necessary tables, figures, and formulations are missing. Or Appendix section is not included at all. Flow diagram is missing.
Style & Formatting	(5.0 to >4.5 pts) Main points are easily followed. Effective transitions are used. All main headings for memorandum format are included. Formatting is	(4.5 to >3.0 pts) Main points can generally be followed. Basic transitions are used. Most main headings for the memorandum are included. Formatting is somewhat simple	(3.0 to >2.0 pts) Some main points are hard to follow due to inadequate transitions or lack of effective format and stylistic choices. Several headings for the	(2.0 to 0 pts) Difficult to follow, lacks effective organization, and uses unsuccessful transitions, structure, or stylistic choices. Does not resemble the

	simple and easy to follow. Correct memo heading at the beginning is included with italicized initials.	and easy to follow. Correct memo heading at the beginning but may be missing certain parts, like italicized initials.	memorandum are either missing or incorrect. Formatting may be slightly confusing. Heading at beginning is improperly formatted.	memorandum format. Formatting is confusing and hard to follow. Heading at beginning is improperly formatted or missing.

Supplemental Material 4–Writing instructions given to students.

Lab report:

- Format will be the same as for the Memorandum, but will be longer than previous reports.
- Your lab report should be 4+ pages and is worth 75 points.
- Make sure to include a minimum of 4 scientific references in your report.
- You will take the information you gained in class and focus on how to produce a sugar-free, reduced sugar, or "diet" sugar cookie for your company.
- In the Materials and Method section, you will need to explain how to move the product from bench-top all the way through to commercial production and develop a process flow diagram (located in the Appendix) using basic units of operation for a commercial cookie process. The materials and methods section should focus on the cookies you made and also list the other variations made in the lab. It should also include the information about how the product would be made commercially in a paragraph form. You would need to include the equipment and ingredient information in this section. Be sure to include the formulation in the Appendix.
- You must include a flow diagram of the commercial process. Be sure that you start from receiving of ingredients to distribution of finished products. (It can be referenced in writing, but should be located in the Appendix.)
- You will also need to identify pieces of equipment needed for commercial processing and include the suppliers' names and addresses. You also can put this information in a table.
- In the Results and Discussion section, you first need to focus on what alternative sweeteners or combo of sweeteners worked the best in the experiment and which did not. You need to reference all tables in the text. You must address all data and discuss the implications of it (meaning tell us what the data mean and how it affects cookie quality). Discuss some of the functional properties of sugar that many alternative sweeteners lack. You also need to identify some additional ingredients/flavors that could improve your product. You should think about what ingredients are needed to improve binding, color, flavor, texture, etc. I am looking for your thoughts and research on processing cookies on a large production basis. Think about the various videos and the equipment you have seen.
- In the Conclusion section, determine what direction your company would like to move with making sugar-free or reduced sugar cookies. You CANNOT state you will not make these cookies and stay with the control formula. You need to discuss next steps for testing and production.

Supplemental Material 5–Memo formatting guide given to students.

Guide to Writing a Memo Style Report

Memorandum

To: Dr. Kelly Getty
From: your name (initial after printing)
Date: Month/Day/Year
Re: Title of Lab

Note the headings may or may not be used when formatting your memorandum.

Overview

This section should state the purpose/objective of the lab. Be sure to briefly describe the materials and processes that are unique to this laboratory. Tell how the laboratory procedure might apply to the commercial market. Relevant background material should be placed in this section.

Materials and Methods (Lab Procedures)

Describe the materials used and the methods/procedure(s) you followed. Include formulations, general specifications, the basic processing procedures, and any other information relevant to the procedure. For example, if you made two batches of chili and had all the class members taste it, you would include the following: "A team of 25 panelists tasted approximately one tablespoon of each chili and were asked to rank each for overall flavor and overall heat on the scale of 1-dislike extremely to 7-like extremely. The scores were then combined and the average of overall flavor and average of overall heat was calculated for each batch."

You also will need to note when samples were taken and how many samples were analyzed. For example, two samples were taken from each batch prior to cooking and at the end of the cooking cycle. Samples were analyzed for pH and water activity levels with pH and water activity meters. Make sure to note any deviations from the lab manual procedure and why these deviations occurred.

Results and Discussion

Be sure to take precise data during lab. A few things to include in your data taken during lab: (1) descriptions of what occurred – i.e. solubility, consistency, viscosity, changes in various properties including color, smells, liquid absorption; and (2) descriptions of properties such as color, flavor, and texture – i.e., salty, sweet, slimy, dry, dark brown, bright pink.

The results and discussion section needs to include numerical data when possible and explain the data – acceptable levels, rankings of treatments (high to low), comparison of data, etc. Beneficial data may also be descriptions/observations of product evaluated. Remember, you may use simple graphs or tables to report the data. Make sure all data has acceptable units (g, cm, ml, etc.).

Look for questions and key words such as, "compare," "evaluate," and "observe" within the lab procedure. Use concepts from lecture to explain your results. Describe possible sources of error and ways to improve your techniques and results.

Conclusions/Implications
In this section, explain what your results mean and why they are relevant and how the information used applies to your company. A statement of future research needs or a direction your company should take needs to be included.

Appendix
In this section you will include all collected data in tables. Recreate the tables and insert the data.

Resources
Be sure to include any resources you use. Follow the Institute of Food Technologists (IFT) formatting using APA citation style. Link to IFT: http://www.ift.org/knowledge-center/read-ift-publications/journal-of-food-science/authors-corner/jfs-author-guidelines.aspx#FormattingReferences. Remember to abbreviate the journal articles correctly. Journal articles should not be italicized. Publication years should be in parentheses. Article titles should have the first word with an initial capital such as Recovery and the rest should be in lowercase unless it is a state or name of a microorganism. Journal title and volume number should be italicized.

Some examples are:

Khiari, Z., Markis, D., & Kefalas, P. (2008). Recovery of bioactive flavonols from onion solid wastesemploying water/ethanol-based solvent system. *Food Science and Technology International, 14*, 497–502. doi: 10.1177/1082013208100707

Knoerzer, K., Juliano, P., Roupas, P., & Versteeg, C. (2011). *Innovative food processing technologies: Advances in multiphysics simulation.* West Sussex, UK: John Wiley and Sons, Ltd. And Institute of Food Technologists.

Kumar, H. & Salminen, S. (2016). Probiotics. In: *Encyclopedia of food and health* (pp. 510–515). Oxford, UK: AcademicPress.

Lefebvre, V.M., De Steur, H., & Gellynck, X. (2015). External sources for innovation in food SMEs. *British Food Journal, 117*(1), 412–430. doi: 10.1108/BFJ-09-2013-0276

Ministry of Health Labour and Welfare. (2015). Food for Special Dietary Uses (FOSDU). Available from: http://www.mhlw.go.jp/english/topics/foodsafety/fhc/03.html. Accessed 2016 May 11.

Formatting Notes
Keep lab reports to two to three pages. Use Times New Roman or Arial, 12-point font and 1" margins. This report should be written in third-person. Points will be deducted for reports written in first person (ie – using terms like "I", "we", etc.)

Grading and Points for Lab Reports
Please refer to the course syllabus for more information on grading of labs. Two points may be deducted from each lab report for failing to participate. The instructor will deduct one point from each lab report for failure to follow GMPs. Participation includes attendance, performing the

experiment, and making sure your workstation and the lab are clean before you leave. Failure to meet the cleaning requirement will result in a one-point deduction.
Lab reports will be graded based on professional writing (clear and concise explanation), content and coverage of the topics, grammar, and style and formatting.

Websites you might find helpful:

- Code of Federal Regulations: https://www.gpo.gov/fdsys/browse/collectionCfr.action?collectionCode=CFR
- USDA/FSIS: http://www.fsis.usda.gov/
- FDA: http://www.fda.gov/
- Google Scholar: http://scholar.google.com
- Please do not use Wikipedia or ".com" websites as references. Only scientific, peer-reviewed resources may be used.

Appendix B – Gluten-Free Bread Laboratory Handout, Rubrics, and Survey

Supplemental Material 1–Gluten-free bread laboratory handout for students.

Objectives: Determine the properties of bread made with gluten-free flour versus wheat flour. Analyze the effects of waxy flour versus regular flour on the loaf volume, texture, flavor, color, and water activity of gluten-free bread.

Formulations: Each lab bench will be responsible for preparing two (2) pup loaves of one of the following formulas. Use Formulas 1-4 below to prepare your assigned loaves.
Bench 1: Control (Formula 1)
Bench 2: 15% Waxy Sorghum (Formula 2)
Bench 3: 25% Waxy Sorghum (Formula 3)
Bench 4: 35% Waxy Sorghum (Formula 4)

Formula 1: Control

Added by:	Ingredient	Supplier	% Flour Basis (Baker's %)	Amount (g)
	White sorghum flour		70	70
	Potato starch		30	30
	Salt		1.75	1.75
	Sugar		1	1
	HPMC (Hydroxypropyl methylcellulose)		1.5	1.5
	Warm water		100	100
	Yeast		2	2
	Egg		30	30

Formula 2: 15% Waxy Sorghum

Added by:	Ingredient	Supplier	% Flour Basis (Baker's %)	Amount (g)
	White sorghum flour		59.5	59.5
	Waxy sorghum flour		10.5	10.5
	Potato starch		30	30
	Salt		1.75	1.75
	Sugar		1	1
	HPMC (Hydroxypropyl methylcellulose)		1.5	1.5
	Warm water		100	100
	Yeast		2	2
	Egg		30	30

Formula 3: 25% Waxy Sorghum

Added by:	Ingredient	Supplier	% Flour Basis (Baker's %)	Amount (g)
	White sorghum flour		52.5	52.5
	Waxy sorghum flour		17.5	17.5
	Potato starch		30	30
	Salt		1.75	1.75
	Sugar		1	1
	HPMC (Hydroxypropyl methylcellulose)		1.5	1.5
	Warm water		100	100

	Yeast		2	2
	Egg		30	30

Formula 4: 35% Waxy Sorghum

Added by:	Ingredient	Supplier	% Flour Basis (Baker's %)	Amount (g)
	White sorghum flour		45.5	45.5
	Waxy sorghum flour		24.5	24.5
	Potato starch		30	30
	Salt		1.75	1.75
	Sugar		1	1
	HPMC (Hydroxypropyl methylcellulose)		1.5	1.5
	Warm water		100	100
	Yeast		2	2
	Egg		30	30

Baking Instructions:

1. Turn the proofer on and set to 89.6˚F at 95% humidity.
   *NOTE: Make sure the water pan is full of boiling water.
2. Preheat oven to 375˚F.
3. Gather all ingredients and weigh them out according to your assigned formula (Formulas 1-4 above). Be sure to weight out the amounts listed in the "Amount (g)" column. Record the supplier of each ingredient in your assigned formula table above.
4. Record the weights of the empty KitchenAid mixing bowl and pup loaf pan you will use (Table 1).
5. Put yeast and warm water in the bowl of a KitchenAid mixer. Record the initials of the person who added each ingredient in your assigned formula table above. Stir gently to combine and allow yeast to pre-hydrate for 5 minutes.
6. After 5 minutes, add the dry ingredients and egg to the mixing bowl. Record the initials of the person who added each ingredient in your assigned formula table above.
7. With the flat beater attachment, mix on Speed 1 for 90 seconds. Then scrape down the sides of the bowl.

8. Mix for another 3 minutes on Speed 2.
9. Spray the bottom and sides of a pup loaf pans with cooking spray.
10. Record the weight the KitchenAid mixing bowl with the mixture in it (Table 1).
11. Record the weights of each full loaf pan and the empty bowl with any residual batter in it (Table 1).
12. Cover the pans with plastic wrap. Place in the proofer and proof for 30 minutes.
13. After proofing, remove pans from the proofer and remove plastic wrap.
14. Bake at 375˚F for 30 minutes.
    *NOTE: DO NOT under- or over-bake the loaves. Immediately remove from the oven after 30 minutes, do not bake longer or shorter than 30 minutes.
15. Remove pans from the oven carefully. Allow to cool for a couple minutes in the pan, then remove the loaves from the pans and allow to cool on a cooling rack.
    *NOTE: If the loaves does not come out of the pan easily, run a butter knife around the sides to loosen from the pan.
16. Cool for 15 minutes then record the weights of the baked loaves of bread (Table 1).

Analysis:

1. Using the following equations, calculated and record the percent waste and percent yield of your loaf using values in Table 1. Record in Table 1.

$$\text{Equation 1: \% waste} = \frac{\boldsymbol{Wt.of\ bowl\ after\ portioning - Wt.of\ empty\ bowl}}{\boldsymbol{Wt.of\ bowl\ plus\ ingredients - Wt.of\ empty\ bowl}} \times 100$$

$$\text{Equation 2: \% yield} = \frac{\boldsymbol{Wt.of\ loaf\ after\ baking}}{\boldsymbol{Wt.of\ bowl\ plus\ ingredients - Wt.of\ empty\ bowl}} \times 100$$

2. Weight your loaf on the scale and record in Table 2.
3. With TAs' help, use the portable spectrophotometer to find the L*a*b* color value of the top of the crust in 2 places. Record in Table 4 and find the average.
4. Using the bread slicing guide, cut your loaf into as many slices as possible. Take the 2 center slices and set aside in a ziplock bag. (These will be used for texture profile analysis by Tas.) Using calipers, measure the loaf height in the middle of each loaf. Record in Table 2.
5. With TAs' help, use the water activity meter to find the water activity (a_w) of your loaf. Record in Table 3.
   *Water activity meter instructions:
   - Turn on the water activity meter and allow to warm up for ~10 minutes.
   - Cut a thin slice of bread and break the slice into smaller pieces.
   - With the broken pieces, cover the bottom of the provided cup for the water activity meter. Be sure to cover the bottom of the cup completely but do not fill the sample above the marked line in the cup.
   - Place the cup in the sample holder of the water activity meter.
   - Close the sample holder and turn the knob to begin reading the sample. Reading will take ~5-10 minutes, depending on the water activity.
   - Record the water activity value displayed.
6. With TAs' help, use the portable spectrophotometer to find the L*a*b* color values the inside crumb of your loaf in 2 places. Record in Table 4 and find the average. Using the following equation, use the recorded average L*a*b* values to calculate ΔE of both crust and crumb color. Record in Table 4.

$$\text{Equation 3: } \Delta E = \sqrt{\boldsymbol{L^{*2} + a^{*2} + b^{*2}}}$$

7. TAs will collect the 2 center slices of each formula from each group and run a Texture Profile Analysis (TPA) in duplicate (2 readings for each formula). This data will be sent to you in a spreadsheet. From this data, determine the average Hardness, Cohesiveness, and Springiness of each bread. Record this data in Table 5.
   *TPA values:
   - Hardness is measured as the maximum force of the 1st compression.
   - Cohesiveness is the area of work during the second compression divided by the area of work during the first compression.
   - Springiness is a ratio of the distance of the detected height during the second compression divided by the original compression distance.
8. Groups will be provided with a sample of commercial gluten-free bread to taste prior to doing sensory of the loaves made in class. DO NOT taste any of the class loaves before the commercial bread.
9. Taste and score all products using the provided hedonic scale. Score the loaves based on Appearance, Color, Texture, Flavor, and Overall acceptibility. Record ratings and descriptions in Table 7.

Sources:

Alvarez-Jubete, L., Auty, M., Arendt, E.K., and Gallagher, E. (2009). Baking properties and microstructure of pseudocereal flours in gluten-free bread formulations. European Food Research and Technology 230:437–445. doi: 10.1007/s00217-009-1184-z

Bize, M. (2012). An evaluation of the role of eggs and DATEM on the quality of gluten-free sorghum bread. Thesis.

Overview of Texture Profile Analysis (TPA). In: Texture Technologies. http://texturetechnologies.com/resources/texture-profile-analysis

Tables

Table 1–Weights, waste, and yield

Formula	Control	15% Waxy Sorghum	25% Waxy Sorghum	35% Waxy Sorghum
Empty bowl (g)				
Empty loaf pan (g)				
Bowl + ingredients (g)				
Loaf pan + batter (g)				
Bowl after portioning (g)				
Baked loaf (g)				
% Waste				
% Yield				

Table 2–Loaf volume and height

Formula	Loaf Weight (g)	Loaf Height (mm)
Control		1: 2: Avg:
15% Waxy Sorghum		1: 2: Avg:
25% Waxy Sorghum		1: 2: Avg:
35% Waxy Sorghum		1: 2: Avg:

Table 3–Water activity

Formula	a_w
Control	
15% Waxy Sorghum	
25% Waxy Sorghum	
35% Waxy Sorghum	

Table 4–Loaf color

	Crust Color				Crumb Color			
Formula	L*	a*	b*	ΔE	L*	a*	b*	ΔE
Control	1: 2: Avg:	1: 2: Avg:	1: 2: Avg:	1: 2: Avg:	1: 2: Avg:	1: 2: Avg:	1: 2: Avg:	1: 2: Avg:
15% Waxy Sorghum	1: 2: Avg:	1: 2: Avg:	1: 2: Avg:	1: 2: Avg:	1: 2: Avg:	1: 2: Avg:	1: 2: Avg:	1: 2: Avg:
25% Waxy Sorghum	1: 2: Avg:	1: 2: Avg:	1: 2: Avg:	1: 2: Avg:	1: 2: Avg:	1: 2: Avg:	1: 2: Avg:	1: 2: Avg:
35% Waxy Sorghum	1: 2: Avg:	1: 2: Avg:	1: 2: Avg:	1: 2: Avg:	1: 2: Avg:	1: 2: Avg:	1: 2: Avg:	1: 2: Avg:

Table 5–Crumb texture profile analysis (TPA)

Formula	Hardness	Cohesiveness	Springiness
Control			
15% Waxy Sorghum			
25% Waxy Sorghum			
35% Waxy Sorghum			

Supplemental Material 2–Hedonic scale handouts given to students for sensory evaluation.

Table 1–Sensory analysis of gluten free bread (made in class)

Formula		Appearance	Color	Texture	Flavor	Overall Acceptibility
Control	Description					
	Hedonic rating					
15% waxy sorghum	Description					
	Hedonic rating					
25% waxy sorghum	Description					
	Hedonic rating					
35% waxy sorghum	Description					
	Hedonic rating					

Table 2–Hedonic scale format

Dislike extremely	Dislike very much	Dislike moderately	Dislike slightly	Neither like nor dislike	Like slightly	Like moderately	Like very much	Like extremely

Supplemental Material 3–Rubric given to students for report writing.

	Exceeds Expectations	Meets Expectations	Below Expectations	Little to No Expectations Met
Professional Writing & Grammar	(5.0 to >4.5 pts) Used language that skillfully communicated meaning with clarity and fluency. Contained virtually no grammatical/ mechanical errors. All writing is in 3rd person.	(4.5 to >3.0 pts) Used straightforward language that generally conveyed meaning with clarity. Contained minimal grammatical/ mechanical errors. Minimal use of 1st, 2nd person writing.	(3.0 to >2.0 pts) Used language that sometimes conveyed meaning with clarity. Contained some/several grammatical/ mechanical errors. Multiple uses of 1st, 2nd person writing.	(2.0 to 0 pts) Used language that impeded the meaning. Difficult to read or understand because of extensive grammatical/ mechanical errors. Consistent use of 1st, 2nd person writing.
Introduction & Overview	(5.0 to >4.5 pts) Used appropriate, relevant, and compelling content to introduce and summarize the topic with relevant cited references. Objectives are clearly stated.	(4.5 to >3.0 pts) Used adequate and relevant content to introduce and summarize the topic with relevant cited references. Objectives are stated.	(3.0 to >2.0 pts) Used somewhat adequate and relevant content to introduce and summarize the topic with some cited references. Objectives are incomplete or difficult to understand.	(2.0 to 0 pts) Lacked sufficient or relevant content to introduce the topic. No cited references used. Objectives are not stated.
Material & Methods	(5.0 to >4.5 pts) Successfully described experimental procedure and materials used in the experiment, including equipment, ingredients, scale-up. Reader would be able to successfully replicate the experiment based	(4.5 to >3.0 pts) Described the experimental procedure and materials used, but with some details missing. Reader should still be able to replicate the experiment, but may have some difficulty. Formulation is included.	(3.0 to >2.0 pts) Somewhat described the experimental procedure and materials used, but with several details or pieces of information missing. Reader would have difficulty replicating the experiment. Formulation	(2.0 to 0 pts) Unsuccessfully described the experimental procedure and materials used. Reader would have no way to replicate the experiment. Formulation not included.

	on the writing. Formulation is included.		included, but may be incomplete.	
Results & Discussion	(10.0 to >9.0 pts) Used appropriate, relevant, and compelling content to illustrate writer's understanding of the subject. Science-based findings were correctly interpreted and well supported with relevant references. Addressed all points listed in the report instructions completely. All tables are clearly referenced in the text. References are clearly and appropriately cited in-text.	(9.0 to >6.0 pts) Used appropriate, relevant, and compelling content to illustrate writer's understanding of the subject. Adequately used science-based findings and generally interpreted them correctly with relevant references. Addressed main points listed in report instructions, but some important details missing. Some tables referenced in text. Some correct in-text citations are used.	(6.0 to >4.0 pts) Used somewhat adequate and relevant content to illustrate writer's understanding of the subject. Included some science-based findings, but not always interpreted or supported correctly with few or some relevant references. Addressed some important points listed in report instructions, but provided few details. Tables are incorrectly referenced in text. Very few in-text citations are used, perhaps with incorrect formatting.	(4.0 to 0 pts) Lacked sufficient or relevant content to illustrate writer's understanding of the subject. Science-based findings were either not included or incorrectly interpreted with few to no references. Several important points listed in report instructions are not addressed. Tables are not referenced in text. No in-text citations.
Conclusion & References	(5.0 to >4.5 pts) Thoroughly developed conclusions based on findings and significance to Food Science. A minimum of 3-5 scientific and peer-reviewed references were	(4.5 to >3.0 pts) Adequately developed conclusions based on findings and significance to Food Science. A minimum of 2 scientific and peer-reviewed references were	(3.0 to >2.0 pts) Developed conclusions based on some findings and demonstrated some relevance to Food Science. 1 scientific and peer-reviewed reference	(2.0 to 0 pts) Insufficient conclusions based on findings and relevance to Food Science. No references were included, or references were of poor credibility and incorrectly

	included with proper Journal of Food Science citations. Demonstrated skillful use of high-quality, credible, and relevant sources to develop or support ideas. Clearly stated which formulation was best and stated why. Clear future research steps are laid out.	included with proper Journal of Food Science citations. Mostly demonstrated skillful use of high-quality, credible sources to develop or support ideas. States which formulation was best, but lacks reasoning. Future research steps listed.	included. Significant citation errors may exist. Quality or credibility of references should be improved to better develop and support ideas. Best formulation statement is unclear or incomplete. Future research steps unclear.	cited. Missing information about best formulation and future research steps.
Appendix	(15.0 to >13.5 pts) All necessary tables, figures, and formulations have been included. Tables and figures are correctly labeled with table number and title. Flow diagram includes all commercial steps and is referenced in text.	(13.5 to >9.0 pts) All necessary tables, figures, and formulations have been included, but may be incorrectly labeled. Flow diagram may be missing a couple commercial steps.	(9.0 to >6.0 pts) Some necessary tables, figures, and formulations are missing. Tables and figures may be incorrectly labeled. Flow diagram is missing many commercial steps and may not be referenced in text.	(6.0 to 0 pts) Several or all necessary tables, figures, and formulations are missing. Or Appendix section is not included at all. Flow diagram is missing.
Style & Formatting	(5.0 to >4.5 pts) Main points are easily followed. Effective transitions are used. All main headings for memorandum format are included. Formatting is simple and easy	(4.5 to >3.0 pts) Main points can generally be followed. Basic transitions are used. Most main headings for the memorandum are included. Formatting is somewhat simple and easy to	(3.0 to >2.0 pts) Some main points are hard to follow due to inadequate transitions or lack of effective format and stylistic choices. Several headings for the memorandum	(2.0 to 0 pts) Difficult to follow, lacks effective organization, and uses unsuccessful transitions, structure, or stylistic choices. Does not resemble the

	to follow. Correct memo heading at the beginning is included with italicized initials.	follow. Correct memo heading at the beginning but may be missing certain parts, like italicized initials.	are either missing or incorrect. Formatting may be slightly confusing. Heading at beginning is improperly formatted.	memorandum format. Formatting is confusing and hard to follow. Heading at beginning is improperly formatted or missing.

Supplemental Material 4–Writing instructions given to students.

LAB REPORT GUIDELINES

Prepare a full lab report in memo format (3-4 pages) addressed to Dr. Getty, the product development executive for your company. You will be writing as a product developer for a gluten-free bread for a company with the name of your choosing. Your goal is to tell the product development executive (Dr. Getty) how your initial trials of gluten-free sorghum bread went, and what needs to be improved to make better gluten-free bread. **Make sure to include 3-5 scientific references in your report.**

Please followed the memo formatting handout and rubric carefully to ensure you include all the necessary components! All sections listed in the memo handout must be present and clearly labled.

In addition to the requirements in the memo formatting handout, your memo needs to address the following:

- Describe the different treatments that were performed and briefly explain what parameters were used while testing the variations of the bread.
    - What parameters were held constant between batches? Which were changed? Be sure to identify the batch your group made.
- In the Results and Discussion section, compare and contrast all data collected (loaf height, water activity, color, and texture). From the data collected from all bread samples, discuss why each result occured.
    - Discuss how the loaf height correlates to loaf volume. Which loaf had the best "volume"?
    - Is the water activity at an acceptable level? What quality or safety issues could arise if the water activity is too high?
    - What factors affect the color of the bread? How is the color of each loaf affected by the waxy sorghum content?
- Then you need to focus on what level of waxy sorghum worked the best in the experiment and which did not. Discuss some of the functional properties of wheat flour that gluten-free flours/starches lack. You also need to identify some additional ingredients that could improve your product. You may want to think about what ingredients are needed to improve binding, color, flavor, texture, etc.
    - Explain how the different gluten-free flours or starches and might affect your bread. How would the texture of the flour/starch affect the gluten-free bread?
    - Are there other gluten-free flours/staches that would improve the quality?
- In the Conclusion section, summarize the experiment and talk about its importance in food science research. Determine what direction your company would like to move with making gluten-free sorghum bread. You CANNOT state you will not make the control formula, you need to choose an experiment formulation and improvements to make upon it. You need to discuss next steps for testing.
- Finally, you will need to make a flow diagram of a commercial gluten-free bread making process and include it in the Appendix section of your report.

Supplemental Material 5–Memo formatting guide given to students.

Guide to Writing a Memo Style Report

Memorandum

To: Dr. Kelly Getty
From: your name (initial after printing)
Date: Month/Day/Year
Re: Title of Lab

Note the headings may or may not be used when formatting your memorandum.

Overview

This section should state the purpose/objective of the lab. Be sure to briefly describe the materials and processes that are unique to this laboratory. Tell how the laboratory procedure might apply to the commercial market. Relevant background material should be placed in this section.

Materials and Methods (Lab Procedures)

Describe the materials used and the methods/procedure(s) you followed. Include formulations, general specifications, the basic processing procedures, and any other information relevant to the procedure. For example, if you made two batches of chili and had all the class members taste it, you would include the following: "A team of 25 panelists tasted approximately one tablespoon of each chili and were asked to rank each for overall flavor and overall heat on the scale of 1-dislike extremely to 7-like extremely. The scores were then combined and the average of overall flavor and average of overall heat was calculated for each batch."

You also will need to note when samples were taken and how many samples were analyzed. For example, two samples were taken from each batch prior to cooking and at the end of the cooking cycle. Samples were analyzed for pH and water activity levels with pH and water activity meters. Make sure to note any deviations from the lab manual procedure and why these deviations occurred.

Results and Discussion

Be sure to take precise data during lab. A few things to include in your data taken during lab: (1) descriptions of what occurred – i.e. solubility, consistency, viscosity, changes in various properties including color, smells, liquid absorption; and (2) descriptions of properties such as color, flavor, and texture – i.e., salty, sweet, slimy, dry, dark brown, bright pink.

The results and discussion section needs to include numerical data when possible and explain the data – acceptable levels, rankings of treatments (high to low), comparison of data, etc. Beneficial data may also be descriptions/observations of product evaluated. Remember, you may use simple graphs or tables to report the data. Make sure all data has acceptable units (g, cm, ml, etc.).

Look for questions and key words such as, "compare," "evaluate," and "observe" within the lab procedure. Use concepts from lecture to explain your results. Describe possible sources of error and ways to improve your techniques and results.

Conclusions/Implications
In this section, explain what your results mean and why they are relevant and how the information used applies to your company. A statement of future research needs or a direction your company should take needs to be included.

Appendix
In this section you will include all collected data in tables. Recreate the tables and insert the data.

Resources
Be sure to include any resources you use. Follow the Institute of Food Technologists (IFT) formatting using APA citation style. Link to IFT: http://www.ift.org/knowledge-center/read-ift-publications/journal-of-food-science/authors-corner/jfs-author-guidelines.aspx#FormattingReferences. Remember to abbreviate the journal articles correctly. Journal articles should not be italicized. Publication years should be in parentheses. Article titles should have the first word with an initial capital such as Recovery and the rest should be in lowercase unless it is a state or name of a microorganism. Journal title and volume number should be italicized.

Some examples are:

Khiari, Z., Markis, D., & Kefalas, P. (2008). Recovery of bioactive flavonols from onion solid wastesemploying water/ethanol-based solvent system. *Food Science and Technology International, 14*, 497–502. doi: 10.1177/1082013208100707

Knoerzer, K., Juliano, P., Roupas, P., & Versteeg, C. (2011). *Innovative food processing technologies: Advances in multiphysics simulation.* West Sussex, UK: John Wiley and Sons, Ltd. And Institute of Food Technologists.

Kumar, H. & Salminen, S. (2016). Probiotics. In: *Encyclopedia of food and health* (pp. 510–515). Oxford, UK: AcademicPress.

Lefebvre, V.M., De Steur, H., & Gellynck, X. (2015). External sources for innovation in food SMEs. *British Food Journal, 117*(1), 412–430. doi: 10.1108/BFJ-09-2013-0276

Ministry of Health Labour and Welfare. (2015). Food for Special Dietary Uses (FOSDU). Available from: http://www.mhlw.go.jp/english/topics/foodsafety/fhc/03.html. Accessed 2016 May 11.

Formatting Notes
Keep lab reports to two to three pages. Use Times New Roman or Arial, 12-point font and 1" margins. This report should be written in third-person. Points will be deducted for reports written in first person (ie – using terms like "I", "we", etc.)

Grading and Points for Lab Reports
Please refer to the course syllabus for more information on grading of labs. Two points may be deducted from each lab report for failing to participate. The instructor will deduct one point from each lab report for failure to follow GMPs. Participation includes attendance, performing the

experiment, and making sure your workstation and the lab are clean before you leave. Failure to meet the cleaning requirement will result in a one-point deduction.
Lab reports will be graded based on professional writing (clear and concise explanation), content and coverage of the topics, grammar, and style and formatting.

Websites you might find helpful:

- Code of Federal Regulations: https://www.gpo.gov/fdsys/browse/collectionCfr.action?collectionCode=CFR
- USDA/FSIS: http://www.fsis.usda.gov/
- FDA: http://www.fda.gov/
- Google Scholar: http://scholar.google.com

Please do not use Wikipedia or ".com" websites as references. Only scientific, peer-reviewed resources may be used.

Appendix C – Student Surveys

Supplemental Material 1–IRB Application

IRB Application Page 2

ADMINISTRATIVE INFORMATION:

Title of Project/Course: Evaluation of Grain Products and Student Learning Experiences

Type of Application: (check one box)
☑ New / Renewal ☐ Revision (to a pending new application)
☐ Modification to an existing approved application #:

Principal Investigator Details: (must be a KSU faculty member):

Name: Kelly Getty Degree/Title: Ph.D., Associate Professor

Department: Food Science Institute Campus Phone: (785)532-2203

Campus Address: 216 Call Hall, 1530 Mid-Campus Drive North, Manhattan, KS 66506

E-mail: kgetty@ksu.edu Fax #: 5861

Responsible Graduate Student: (Person to contact for questions/problems with the form):

Name: Melanie Heermann Campus Phone: (402)875-0053

E-mail: melanieheermann@ksu.edu

Does this project involve any collaborators not part of the faculty/staff at KSU? (projects with non-KSU collaborators may require additional coordination and approvals):

☑ No ☐ Yes

Project Classification (Is this project part of one of the following?):

☑ Thesis ☐ Dissertation ☐ Faculty Research
☐ Other:

Note: Class Projects should use the short form application for class projects.

Copy of the Consent Form: ☑ Copy will be submitted to comply@ksu.edu with this application ☐ Consent form not used

Funding Source: ☐ Federal ☑ State ☐ Internal ☐ Other

Funding Agency: Please give name of Funding Agency. (You will also need to provide a copy of the sponsor's grant application or contract as submitted to the funding agency. Submit documents to comply@ksu.edu with your application.)

Based upon criteria found in 45 CFR 46 – and the overview of projects that may qualify for exemption explained at http://www.hhs.gov/ohrp/policy/checklists/decisioncharts.html, I believe that my project using human subjects should be determined by the IRB to be exempt from IRB review:

☐ No ☑ Yes (If yes, please provide the category of "Exemption" in the space below)

Exempt Projects: 45 CFR 46 identifies six categories of research involving human subjects that may be exempt from IRB review. The categories for exemption are listed here: **http://www.hhs.gov/ohrp/policy/checklists/decisioncharts.html#c2** If you believe that your project qualifies for exemption, please indicate which exemption category applies (1-6). Please remember that only the IRB can make the final determination whether a project is exempt from IRB review, or not.

Exemption Category: 45 CFR 46.101(b)(2)

MODIFICATION:

Is this a modification of an approved protocol? ☑ **No** ☐ **Yes** **If yes, please comply with the following:**

If you are requesting a modification or a change to an IRB approved protocol, please provide a concise description of all of the changes that you are proposing in the following block. Additionally, please highlight or bold the proposed changes in the body of the protocol where appropriate, so that it is clearly discernible to the IRB reviewers what and where the proposed changes are. This will greatly help the committee and facilitate the review.

I. NON-TECHNICAL SYNOPSIS (Please provide a brief narrative description of proposal. This should typically be less than 75 words and be easily understood by nonscientists):

Students in a food processing laboratory will participate in laboratory exercises preparing grain products. A graduate student will perform the same experiments in a controlled setting to compare accuracy of student-generated data. Students will perform sensory analysis over the products prepared. Surveys will be sent out to these participants to assess their learning experience.

II. BACKGROUND (concise narrative review of the literature and basis for the study):

Student-generated and -collected data is used to facilitate learning in science classrooms and laboratories when students perform experiments. Little existing research was found comparing the accuracy of student data versus data generated and collected by a trained researching under controlled conditions.

III. PROJECT/STUDY DESCRIPTION

(Please provide a concise narrative description of the proposed activity in terms that will allow the IRB or other interested parties to clearly understand what it is that you propose to do that involves human subjects. This description must be in enough detail so that IRB members can make an informed decision about the proposal).

Undergraduate students enrolled in a Fundamentals of Food Processing laboratory will prepare grain products as part of different laboratory exercises. The graduate student will perform the same experiments in a controlled setting to compare accuracy of student-generated and -collected data versus data generated and collected by a trained researcher. Products will be tasted and evaluated by students using sensory analysis on a hedonic scale and anonymous sensory ballots will be collected for data analysis by graduate student. Students will be provided with an informed consent form to sign so they are informed of all ingredients and potential allergens that are in the products. An online survey will be sent out to students to collect their feedback about the learning experiences. Survey questions will address levels of participants' knowledge and success skills before and after their involvement in the project.

IV. OBJECTIVE

(Briefly state the objective of the research – what you hope to learn from the study).

In addition, the focus of this research was to determine how accurate student data generated and collected in a classroom setting was compared to data collected under controlled conditions.

V. DESIGN AND PROCEDURES (succinctly outline formal plan for study)

A. List all sites where this research will be conducted:

On campus at Kansas State University and online

B. Variables to be studied: Appearance, texture, flavor, aftertaste of food product
Level of mastery on communications, critical thinking, professionalism, interaction, information acquisition, and organizational skills prior and after participation in the laboratory exercises

C. Data collection methods: (surveys, instruments, etc **- copies must submitted to comply@k-state.edu**).

Surveys and sensory ballots

D. List any factors that might lead to a subject dropping out or withdrawing from a study. These might include, but are not limited to emotional or physical stress, pain, inconvenience, etc.

Lack of time to complete the survey. Have allergies to wheat, eggs, or other allergenic ingredients in products that would

prevent them from participating in sensory analysis.

E. List all biological samples taken: (if any)

N/A

Describe storage and disposition of biological samples: (How long will samples be kept, will samples be used for other purposes, how will samples be destroyed)

N/A

Will whole genome sequencing be used:

☑ **No**

☐ **Yes**

F. Debriefing procedures for participants:

Participants will be notified that participation in the survey is voluntary and that they can choose to withdraw their participation at anytime without repercussion.

VI. RESEARCH SUBJECTS:

A. Source:

Human subjects will be recruited through enrollment in the Fundamentals of Food Processing laboratory.

B. Number: (provide a brief rationale for your sample size)

60, depending on number of students enrolled in the Fundamentals of Food Processing laboratory.

C. Inclusion criteria: (List any unique qualifiers desirable for research subject participation)

Student enrolled in Fundamentals of Food Processing laboratory.

D. Exclusion criteria: (list any unique disqualifiers for research subject participation)

Have allergies to wheat, eggs, or other allergenic ingredients in products that would prevent them from participating in sensory analysis.

E. Recruitment procedures:
How will subjects be identified?

Enrolled students in the Fundamentals of Food Processing laboratory.

How will subjects be recruited (advertisement, associates, etc.) ?

Recommendation to enroll in class by advisors, peers, etc.

How will subjects be enrolled?

Subjects will be officially enrolled in the class through Kansas State University.

Describe any follow-up recruitment procedures: (reminder emails, mailings, etc.)

Reminder emails will be sent to remind students to complete online surveys.

VII. RISK - PROTECTION - BENEFITS:

The answers for the three questions below are central to human subjects research. You must demonstrate a reasonable balance between anticipated risks to research participants, protection strategies, and anticipated benefits to participants or others.

A. Risk for Subjects: (check all that apply)

- ☐ Exposure to infectious diseases
- ☐ Use of confidential records
- ☐ Exposure to radiation
- ☐ Manipulation of psychological or social variables such as sensory deprivation, social isolation, psychological stressors
- ☐ Examining for personal or sensitive information in surveys or interviews
- ☐ Presentation of materials which subjects might consider sensitive, offensive, threatening, or degrading
- ☐ Invasion of privacy of subject or family
- ☐ Social or economic risk
- ☐ Risk associated with exercise or physical exertion
- ☐ Legal risk
- ☐ Review of medical records
- ☐ Review of criminal records
- ☐ HIV/AIDS or other STD's
- ☐ Employment/occupational risk
- ☑ Others – Please explain below (Indirect risks, risk to individuals who are not the primary subjects):

Potential allergenic food ingredients

B. **Minimizing Risk**: (Describe specific measures used to minimize or protect subjects from anticipated risks.)

Subjects will provide written consent to participate in sensory analysis. Quantitative responses will be aggregated.

C. **Benefits**: (Describe any reasonably expected benefits for research participants, a class of participants, or to society as a whole.)

Current students will be offered extra credit toward their class grade for completing the online survey.
Students from previous years will be entered into a drawing for a gift card.

D. **More than Minimal Risk?** In your opinion, does the research involve more than minimal risk to subjects? ("Minimal risk" means that "the risks of harm anticipated in the proposed research are not greater, considering probability and magnitude, than those ordinarily encountered in daily life or during the performance of routine physical or psychological examinations or tests.")

☐ Yes ☑ No

VIII. **CONFIDENTIALITY:** Confidentiality is the formal treatment of information that an individual has disclosed to you in a relationship of trust and with the expectation that it will not be divulged to others without permission in ways that are inconsistent with the understanding of the original disclosure. Consequently, it is your responsibility to protect information that you gather from human research subjects in a way that is consistent with your agreement with the volunteer and with their expectations.

A) Explain the type of data that will be collected (electronic, hard copy, video, specimens, etc.):

Quantitative responses will be aggregated. Sensory analysis ballots will be collected as hard copies without names. Subjects will provide written consent to participate in sensory analysis. Consent forms will be maintained internally for 3 years after the study completion.

B) Explain where the data will be stores:

Graduate student will keep all forms in a locked desk. Upon graduation, graduate student will give all copies to Principle

investigator for storage. Online survey responses will be protected online through Qualtrics.

C) Explain the time frame of the data storage, to include how data will be distroyed:

Data will be maintained for 3 years and then shredded to destroy.

D) Explain who will have access to the data, and privacy/security provisions (password protection, encryption, etc.):

Graduate Student and Principle Investigator
Hard copies will be kept in a lock desk, online survey responses will be encrypted by Qualtrics.

IX. INFORMED CONSENT: Informed consent is a critical component of human subjects research - it is your responsibility to make sure that any potential subject knows exactly what the project that you are planning is about, and what his/her potential role is. (There may be projects where some forms of "deception" of the subject is necessary for the execution of the study, but it must be carefully justified to and approved by the IRB). A schematic for determining when a waiver or alteration of informed consent may be considered by the IRB is found at **http://www.hhs.gov/ohrp/policy/checklists/decisioncharts.html#c10**

Even if your proposed activity does qualify for a waiver of informed consent, you must still provide potential participants with basic information that informs them of their rights as subjects, i.e. explanation that the project is research and the purpose of the research, length of study, study procedures, debriefing issues to include anticipated benefits, study and administrative contact information, confidentiality strategy, and the fact that participation is entirely voluntary and can be terminated at any time without penalty, etc. Even if your potential subjects are completely anonymous, you are obliged to provide them (and the IRB) with basic information about your project. See informed consent example on the URCO website. It is a federal requirement to maintain informed consent forms for 3 years after the study completion.

Answer the following questions about the informed consent procedures.

☑ Yes ☐ No **A.** Are you using a written informed consent form? If "yes," include a copy with this application. If "no" see B.

☐ Yes ☑ No **B.** In accordance with guidance in 45 CFR 46, I am requesting a waiver or alteration of informed consent elements (see section VIII above). If "yes," provide a basis and/or justification for your request.

☑ Yes ☐ No **C.** Are you using the online Consent Form Template provided by the URCO? If "no," does your Informed Consent document have all the minimum required elements of informed consent found in the Consent Form Template? (Please explain)

☐ Yes ☑ No **D.** Are your research subjects anonymous? If they are anonymous, you will not have access to any information that will allow you to determine the identity of the research subjects in your study, or to link research data to a specific individual in any way. Anonymity is a powerful protection for potential research subjects. (An anonymous subject is one whose identity is unknown even to the researcher, or the data or information collected cannot be linked in any way to a specific person).

☑ Yes ☐ No **E.** Are subjects debriefed about the purposes, consequences, and benefits of the research? Debriefing refers to a mechanism for informing the research subjects of the results or conclusions, after the data is collected and analyzed, and the study is over. (If "no" explain why.) **Copy of debriefing statement to be utilized should be submitted to comply@k-state.edu with your application.**

F. **Describe the Informed Consent Process:**

Who is obtaining the consent? (i.e. Principle Investigator, Graduate Student, etc.)

Principle Investigator and Graduate Student

When and where will consent be obtained?

Prior to participating in sensory analysis and completion of survey

If assent (for minors) is required, please describe who will obtain the assent? (Assent means a child's affirmative agreement to participate in research)

N/A

If assent (for minors) is required, when and where will assent be obtained?

N/A

How will consent be obtained from non-English speaking participants? (a translated written form, orally, identify the name and qualifications of the individual providing the translation)

No non-English speaking participants participate in this experiment.

Informed Consent Checklist

Items	YES	NO	N/A
Does the title appear at the top of the consent/assent form?	☑	☐	☐
Is the consent/assent form written toward the subject?	☑	☐	☐
Is there a statement that explains that the study is *research*?	☑	☐	☐
Is there a statement that explains the *purpose* of the research?	☑	☐	☐
Are the procedures to be followed explained clearly and adequately?	☑	☐	☐
Does the consent document describe *risks or discomforts* to subjects as a result of participating in the research?	☑	☐	☐
Is the consent/assent form written in the *native language* of the potential subject?	☑	☐	☐
Are participants compensated?	☑	☐	☐
If the subjects' identity is known to the PI, does the form detail how confidentiality of records will be maintained?	☑	☐	☐
Is contact information for both the PI and the URCO/IRB office included?	☑	☐	☐
Does the consent document indicate to the participant that he/she can withdraw at any time from the project without penalty or loss of benefit?	☑	☐	☐
Are there probable circumstances which would require the PI to terminate a subject's participation regardless of his or her consent?	☐	☑	☐

A statement that identifiers might be removed from the identifiable private information or identifiable biospecimens and that, after such removal, the information or biospecimens could be used for future research studies or distributed to another investigator for future research studies without additional informed consent	☐	☐	☑
A statement that the subject's information or biospecimens collected as part of the research, even if identifiers are removed, will not be used or distributed for future research studies.	☐	☐	☑
A statement that biospecimens (even after identifiers are removed) may (or may not) be used for commercial profit.and whether subjects will or will not share in the profit.	☐	☐	☑
A statement that clinically relevant research results will or will not be provided to subjects. .	☐	☐	☑
A statement indicating whether or not the research project will or will not include whole genome sequencing. .	☐	☐	☑
Is the consent document written in lay language (Recommended 8th grade level)?	☑	☐	☐

X. PROJECT INFORMATION: (If you answer Yes to any of the questions below, you should explain them in one of the paragraphs above)

☐ Yes	☑ No	A.	Deception of subjects? If "YES" explain why this is necessary.
☐ Yes	☑ No	B.	Shock or other forms of punishment
☐ Yes	☑ No	C.	Sexually explicit materials or sexual experience
☐ Yes	☑ No	D.	Sexual orientation
☐ Yes	☑ No	E.	Sexual abuse
☐ Yes	☑ No	F.	Handling of money or other valuable commodities
☐ Yes	☑ No	G.	Extraction or use of blood, other bodily fluids, or tissues (if "yes', you must comply with facility and handling protections detailed in the 5th Edition of the Biosafety in Biomedical Laboratories (BMBL))
☐ Yes	☑ No	H.	Questions about any kind of illegal or illicit activity
☐ Yes	☑ No	I.	Questions about protected health information as defined by HIPAA
☐ Yes	☑ No	J.	Purposeful creation of anxiety
☐ Yes	☑ No	K.	Any procedure that might be viewed as invasion of privacy
☐ Yes	☑ No	L.	Physical exercise or stress
☑ Yes	☐ No	M.	Administration of substances (food, drugs, etc.) to subjects
☐ Yes	☑ No	N.	Any procedure that might place subjects at risk
☐ Yes	☑ No	O.	Will there be any use of Radioactive materials and/or use of Radioactive producing machines
☐ Yes	☑ No	P.	Any form of potential abuse; i.e., psychological, physical, sexual
☑ Yes	☐ No	Q.	Is there potential for the data from this project to be published in a journal, presented at a conference, etc?
☑ Yes	☐ No	R.	Use of surveys or questionnaires for data collection. **Copies should be submitted to comply@k-state.edu with your application.**
☐ Yes	☑ No	S.	Is this a Clinical Trial? (one or more human subjects are prospectively assigned to one or more interventions (which may include placebo or other control) to evaluate the effects of the interventions on biomedical or behavioral health-related outcomes.)

XI. SUBJECT INFORMATION: (If you answer yes to any of the questions below, you should explain them in one of the paragraphs above)

☐ Yes	☑ No	a.	Under 18 years of age (these subjects require parental or guardian consent)
☐ Yes	☑ No	b.	Over 65 years of age
☐ Yes	☑ No	c.	Minorities as target population
☐ Yes	☑ No	d.	Physically or mentally disabled
☐ Yes	☑ No	e.	Economically or educationally disadvantaged
☐ Yes	☑ No	f.	Unable to provide their own legal informed consent
☐ Yes	☑ No	g.	Pregnant females as target population
☐ Yes	☑ No	h.	Victims
☐ Yes	☑ No	i.	Subjects in institutions (e.g., prisons, nursing homes, halfway houses)
☐ Yes	☑ No	j.	Are subjects likely to be vulnerable to coercion or undue influence
☐ Yes	☑ No	k.	Is this international research? If yes, provide details as to if OHRP regulations apply in or near the area you intend to conduct research or if you have contacted individuals for applicable regulations to human subject research.
☑ Yes	☐ No	l.	Are research subjects in this activity students recruited from university classes or volunteer pools? If so, do you have a reasonable alternative(s) to participation as a research subject in your project, i.e., another activity such as writing or reading that would serve to protect students from unfair pressure or coercion to participate in this project? If you answered this question "Yes," explain any alternatives options for class credit for potential human subject volunteers in your study. (It is also important to remember that: Students must be free to choose not to participate in research that they have signed up for at any time without penalty. Communication of their decision can be conveyed in any manner, to include simply not showing up for the research.)

Students will not lose points in class for not participating in the sensory analysis or survey.

☐ Yes	☑ No	m.	Is audio from the subjects recorded? If yes, how do you plan to protect the recorded information and mitigate any additional risks?
☐ Yes	☑ No	n.	Are research subjects' images being recorded (video taped, digitally recorded, photographed)? If yes, how do you plan to protect the recorded information and mitigate any additional risks?

XII. FDA ACTIVITIES: Answer the following questions about potential FDA regulated activities:

☐ Yes	☑ No	a.	Is this a Clinical Trial?
☐ Yes	☑ No	b.	Are you using an FDA approved drug/device/diagnostic test?
☐ Yes	☑ No	c.	Does this activity involve the use of FDA-Regulated products? (biological products, color additives, food additives, human drugs, etc.)
☐ Yes	☑ No	d.	Has the protocol been submitted to the FDA, or are there plans to submit it to the FDA?
☐ Yes	☑ No	e.	Have you submitted an FDA form 3454 or 3455 (conflict of interest)?

XIII. CONFLICT OF INTEREST: Concerns have been growing that financial interests in research may threaten the safety and rights of human research subjects. Financial interests are not in them selves prohibited and may well be appropriate and legitimate. Not all financial interests cause Conflict of Interest (COI) or harm to human subjects. However, to the extent that financial interests may affect the welfare of human subjects in research, IRB's, institutions, and investigators must consider what actions regarding financial interests may be necessary to protect human subjects. Please answer the following questions:

☐ Yes	☑ No	a.	Do you or the institution have any proprietary interest in a potential product of this research, including patents, trademarks, copyrights, or licensing agreements?
☐ Yes	☑ No	b.	Do you have an equity interest in the research sponsor (publicly held or a non-publicly held company)?

☐ Yes ☑ No c. Do you receive significant payments of other sorts, eg., grants, equipment, retainers for consultation and/or honoraria from the sponsor of this research?

☐ Yes ☑ No d. Do you receive payment per participant or incentive payments?

e. If you answered **yes** to any of the above questions, please provide adequate explanatory information so the IRB can assess any potential COI indicated above.

XIV. PROJECT COLLABORATORS:

A. KSU Collaborators: List anyone affiliated with KSU who is collecting or analyzing data: (list all collaborators on the project, including co-principal investigators, undergraduate and graduate students).

Name:	Department:	Campus Phone:	Campus E-mail:
Melanie Heermann	Food Science Institute	(402)875-0053	melanieheermann@ksu.edu
Kelly Getty	Food Science Institute	(785)532-2203	kgetty@ksu.edu
Umut Yucel	Food Science Institute	(785)532-1208	yucel@ksu.edu

Add Row Delete Row

B. Non-KSU Collaborators: List all collaborators on your human subjects research project not affiliated with KSU in the spaces below. KSU has negotiated an Assurance with the Office for Human Research Protections (OHRP), the federal office responsible for oversight of research involving human subjects.

Name:	Organization:	Phone:	Institutional E-mail:

Add Row Delete Row

C. Does your non-KSU collaborator's organization have an Assurance with OHRP? (for Federalwide Assurance listings of other institutions, please reference the OHRP website under Assurance Information at: **http://ohrp.cit.nih.gov/search**).

☐ Yes ☑ No If yes, Collaborator's FWA #

Is your non-KSU collaborator's IRB reviewing this proposal?

☐ Yes ☑ No If yes, IRB approval #

Describe the non-KSU collaborator's role in the research activity.

XV. IRB Training:

A. The URCO must have a copy of the Unaffiliated Investigator Agreement on file for each non-KSU collaborator who is not covered by their own IRB and assurance with OHRP. When research involving human subjects includes collaborators who are not employees or agents of KSU the activities of those unaffiliated individuals may be covered under the KSU Assurance only in accordance with a formal, written agreement of commitment to relevant human subject protection policies and IRB oversight. The Unaffiliated Investigators Agreement can be found and downloaded at **http://www.k-state.edu/research/comply/irb/forms**

Online Training

TRAINING REQUIREMENTS HAVE RECENTLY CHANGED

The IRB has mandatory training requirements prior to protocol approval. Training is now offered through the Collaborative Institutional Training Initiative (CITI) Program. Instructions for registration and access to training are on the URCO website http://www.k-state.edu/research/comply/.

Use the check boxes below to select the training courses that apply to this application. If you have any questions about training, contact URCO at comply@ksu.edu, or (785) 532-3224.

Mandatory Training

Required for all Principal Investigators, research staff and students

☒ Responsible Conduct of Research

☒ IRB core modules (IRB Researchers and personnel on IRB protocols)

Required (Provost-mandated) for all full-time K-State employees

☐ Export Compliance

Required procedure-specific training (check all that apply to this protocol):

☐ International Research ☐ Research in Public Elementary and Secondary Schools ☐ Research with Children

☐ Research with Prisoners ☒ Internet Research ☐ Vulnerable Subjects - Research Involving Workers/Employees

☐ Research with Subjects with Physical Disabilities and Impairments ☐ Illegal Activities or Undocument Status in Human Research

☐ Gender and Sexuality Diversity in Human Research ☐ Research with human blood, body fluids, or tissues

☐ Research with Older Adults

All new personnel or personnel with expired training are required to register for CITI and take the new training requirements. If you previously completed online IRB modules, your training status will remain current until it expires. URCO will verify training from the previous system as well as the new system prior to approval of any protocol.

INVESTIGATOR ASSURANCE FOR RESEARCH INVOLVING HUMAN SUBJECTS

(Print this page separately because it requires a signature by the PI.)

P.I. Name: Kelly Getty

Title of Project: Evaluation of Grain Products and Student Learning Experiences

XVI. ASSURANCES: As the Principal Investigator on this protocol, I provide assurances for the following:

A. Research Involving Human Subjects: This project will be performed in the manner described in this proposal, and in accordance with the Federalwide Assurance FWA00000865 approved for Kansas State University available at http://www.hhs.gov/ohrp/assurances/forms/filasurt.html, applicable laws, regulations, and guidelines. Any proposed deviation or modification from the procedures detailed herein must be submitted to the IRB, and be approved by the Committee for Research Involving Human Subjects (IRB) prior to implementation.

B. Training: I assure that all personnel working with human subjects described in this protocol are technically competent for the role described for them, and have completed the required IRB training accessed via the URCO website at: http://www.k-state.edu/research/comply/irb/training. I understand that no proposals will receive final IRB approval until the URCO has documentation of completion of training by all appropriate personnel.

C. Extramural Funding: If funded by an extramural source, I assure that this application accurately reflects all procedures involving human subjects as described in the grant/contract proposal to the funding agency. I also assure that I will notify the IRB/URCO, the KSU PreAward Services, and the funding/contract entity if there are modifications or changes made to the protocol after the initial submission to the funding agency.

D. Study Duration: I understand that it is the responsibility of the Committee for Research Involving Human Subjects (IRB) to perform continuing reviews of human subjects research as necessary. I also understand that as continuing reviews are conducted, it is my responsibility to provide timely and accurate review or update information when requested, to include notification of the IRB/URCO when my study is changed or completed.

E. Conflict of Interest: I assure that I have accurately described (in this application) any potential Conflict of Interest that my collaborators, the University, or I may have in association with this proposed research activity.

F. Adverse Event Reporting: I assure that I will promptly report to the IRB / URCO any unanticipated problems involving risks to subjects or others that involve the protocol as approved. Unanticipated or Adverse Event Form is located on the URCO website at: http://www.k-state.edu/research/comply/irb/forms. In the case of a serious event, the Unanticipated or Adverse Events Form may follow a phone call or email contact with the URCO.

G. Accuracy: I assure that the information herein provided to the Committee for Human Subjects Research is to the best of my knowledge complete and accurate.

You may sign this form using a digital signature. DO NOT sign the form until it has been completed.
You cannot edit the form entries once the form has been digitally signed. If you are making revisions to a previously signed form, right-click the digital signature and select Clear to remove the signature (this can only be done by the person who originally digitally signed the form). Forms that have not been signed will not be accepted.

P.I. Signature: Date:

Supplemental Material 2– IRB Informed Consent for Cookie Exercise Survey

PROJECT TITLE: Assessing Functionality of Artificial Sweeteners in Rolled Sugar Cookies in a Food Science Classroom

PROJECT APPROVAL DATE/ EXPIRATION DATE: 2/14/2019

LENGTH OF STUDY: 15 minutes

PRINCIPAL INVESTIGATOR/CO-INVESTIGATOR(S): Dr. Kelly Getty, (785) 532-2203, kgetty@ksu.edu; Melanie Heermann, (402)875-0053, melanieheermann@ksu.edu

IRB CHAIR CONTACT INFORMATION: For the subject should he/she have questions or wish to discuss on any aspect of the research with an official of the university or the IRB. These are: Rick Scheidt, Chair, Committee on Research Involving Human Subjects, 203 Fairchild Hall, Kansas State University, Manhattan, KS 66506, (785) 532-3224; Cheryl Doerr, Associate Vice President for Research Compliance, 203 Fairchild Hall, Kansas State University, Manhattan, KS 66506, (785) 532-3224.

PROJECT SPONSOR: N/A

PURPOSE OF THE RESEARCH: Undergraduate students enrolled in the Fundaments of Food Processing laboratory participated in a two-week laboratory exercise about the functionality of artificial sweeteners in rolled sugar cookies. This study is part of a thesis research project. The main objective of this study is to understand how accurate the data collected in a science classroom setting is compared to data collected by a trained researching in a controlled setting, and how the laboratory exercise helps to facilitate students' development in learning outcomes as identified by the principle investigator.

PROCEDURES OR METHODS TO BE USED: Participants of the laboratory exercise will receive an online message asking for their willingness to participate in this study. If they choose to participate, they will be asked to answer survey questions online.

ALTERNATIVE PROCEDURES OR TREATMENTS, IF ANY, THAT MIGHT BE ADVANTAGEOUS TO SUBJECT: N/A

RISKS OR DISCOMFORTS ANTICIPATED: There are no known risks of participation.

BENEFITS ANTICIPATED: Participants will be acknowledged of their time via an online message at the conclusion of the survey. Participants who complete the survey will be put in a drawing for a $25 Amazon gift card.

EXTENT OF CONFIDENTIALITY: Quantitative responses will be aggregated. Subjects will provide written consent if direct quotes are to be included in project outcome.

IS COMPENSATION OR MEDICAL TREATMENT AVAILABLE IF INJURY OCCURS: N/A

Terms of participation: I understand this project is research, and that my participation is voluntary. I also understand that if I decide to participate in this study, I may withdraw my consent at any time, and stop participating at any time without explanation, penalty, or loss of benefits, or academic standing to which I may otherwise be entitled.

By clicking the button below, you acknowledge that your participate is voluntary, you are 18 years of age, and that you are aware that you may choose to terminate your participation in the study at any time and for any reason.

□ I consent, begin the study

□ I do not consent, I do not wish to participate

Supplemental Material 3–IRB Informed Consent for Gluten-Free Bread Exercise

Survey

PROJECT TITLE: Assessing Functionality of Waxy Sorghum in Gluten-Free Sorghum Bread in a Food Science Classroom

PROJECT APPROVAL DATE: 2/14/2019

LENGTH OF STUDY: 15 minutes

PRINCIPAL INVESTIGATOR/CO-INVESTIGATOR(S): Dr. Kelly Getty, (785) 532-2203, kgetty@ksu.edu; Melanie Heermann, (402)875-0053, melanieheermann@ksu.edu

IRB CHAIR CONTACT INFORMATION: For the subject should he/she have questions or wish to discuss on any aspect of the research with an official of the university or the IRB. These are: Rick Scheidt, Chair, Committee on Research Involving Human Subjects, 203 Fairchild Hall, Kansas State University, Manhattan, KS 66506, (785) 532-3224; Cheryl Doerr, Associate Vice President for Research Compliance, 203 Fairchild Hall, Kansas State University, Manhattan, KS 66506, (785) 532-3224.

PROJECT SPONSOR: N/A

PURPOSE OF THE RESEARCH: Undergraduate students enrolled in the Fundaments of Food Processing laboratory participated in a laboratory exercise about the functionality of waxy sorghum in gluten-free sorghum bread. This study is part of a thesis research project. The main objective of this study is to understand how accurate the data collected in a science classroom setting is compared to data collected by a trained researcher in a controlled setting, and how the laboratory exercise helps to facilitate students' development in learning outcomes as identified by the principle investigator.

PROCEDURES OR METHODS TO BE USED: Participants of the laboratory exercise will receive an online message asking for their willingness to participate in this study. If they choose to participate, they will be asked to answer survey questions online.

ALTERNATIVE PROCEDURES OR TREATMENTS, IF ANY, THAT MIGHT BE ADVANTAGEOUS TO SUBJECT: N/A

RISKS OR DISCOMFORTS ANTICIPATED: There are no known risks of participation.

BENEFITS ANTICIPATED: Participants will be acknowledged of their time via an online message at the conclusion of the survey. Participants who complete the survey will be eligible to receive 5 bonus points toward their laboratory grade.

EXTENT OF CONFIDENTIALITY: Quantitative responses will be aggregated. Subjects will provide written consent if direct quotes are to be included in project outcome.

IS COMPENSATION OR MEDICAL TREATMENT AVAILABLE IF INJURY OCCURS: N/A

Terms of participation: I understand this project is research, and that my participation is voluntary. I also understand that if I decide to participate in this study, I may withdraw my consent at any time, and stop participating at any time without explanation, penalty, or loss of benefits, or academic standing to which I may otherwise be entitled.

By clicking the button below, you acknowledge that your participate is voluntary, you are 18 years of age, and that you are aware that you may choose to terminate your participation in the study at any time and for any reason.

□ I consent, begin the study

□ I do not consent, I do not wish to participate

Supplemental Material 4–IRB Debriefing Statement

Thank you for participating in our survey. Your responses are critical to improving this laboratory exercise and learning experience for future students enrolled in FDSCI 305: Fundamentals of Food Processing. All data collected in this survey will remain confidential and anonymous when discussed in peer reviewed journal publications.

If you are interested in receiving a short report of the results, please email melanieheermann@ksu.edu and provide an email address where the report may be sent. Again, thank you for your time and assistance in completing this research.

Sincerely,

Melanie Heermann	Kelly Getty, Ph.D.
M.S. Graduate Student	Associate Professor
Food Science Institute	Food Science Institute
Kansas State University	Kansas State University
melanieheermann@ksu.edu	kgetty@ksu.edu

□ Yes, I would like to receive a short report of the results collected from this survey.

Email address: _____

Supplemental Material 5–Cookie Survey Questions

Physical and Sensory Properties

1. My understanding of the function of artificial sweeteners on sensory properties (appearance, flavor, sweetness, etc.) of rolled cookies was improved.

   □ Strongly Disagree □ Somewhat Disagree □ Neither Agree nor Disagree

   □ Somewhat Agree □ Strongly Agree

2. My understanding of the function of sugar on sensory properties (appearance, flavor, sweetness, etc.) of rolled cookies was improved.

   □ Strongly Disagree □ Somewhat Disagree □ Neither Agree nor Disagree

   □ Somewhat Agree □ Strongly Agree

3. My understanding of the function of artificial sweeteners on physical properties (W/T ratio, color, Texture Profile Analysis, etc.) of rolled cookies was improved.

   □ Strongly Disagree □ Somewhat Disagree □ Neither Agree nor Disagree

   □ Somewhat Agree □ Strongly Agree

4. My understanding of the function of sugar on physical properties (W/T ratio, color, Texture Profile Analysis, etc.) of rolled cookies was improved.

   □ Strongly Disagree □ Somewhat Disagree □ Neither Agree nor Disagree

   □ Somewhat Agree □ Strongly Agree

5. This laboratory exercise introduced me to standard preparation procedures (mixing times, rolling procedures, baking times, etc.) for rolled cookies.

   □ Strongly Disagree □ Somewhat Disagree □ Neither Agree nor Disagree

   □ Somewhat Agree □ Strongly Agree

Research and Writing Skills

6. My ability to accurately communicate scientific data was reinforced.

   □ Strongly Disagree □ Somewhat Disagree □ Neither Agree nor Disagree

   □ Somewhat Agree □ Strongly Agree

7. My report-writing skills were reinforced.

   □ Strongly Disagree □ Somewhat Disagree □ Neither Agree nor Disagree

   □ Somewhat Agree □ Strongly Agree

8. My knowledge of experimental design was improved.

   □ Strongly Disagree □ Somewhat Disagree □ Neither Agree nor Disagree

   □ Somewhat Agree □ Strongly Agree

9. The importance of using scientific and/or government resources was reinforced.

   □ Strongly Disagree □ Somewhat Disagree □ Neither Agree nor Disagree

   □ Somewhat Agree □ Strongly Agree

10. My ability to analyze research data was reinforced.

    □ Strongly Disagree □ Somewhat Disagree □ Neither Agree nor Disagree

    □ Somewhat Agree □ Strongly Agree

11. The importance of performing multiple replications in a research project was introduced.

    □ Strongly Disagree □ Somewhat Disagree □ Neither Agree nor Disagree

    □ Somewhat Agree □ Strongly Agree

12. My critical thinking skills were reinforced by analyzing the data generated in the laboratory exercise.

    □ Strongly Disagree □ Somewhat Disagree □ Neither Agree nor Disagree

    □ Somewhat Agree □ Strongly Agree

13. My familiarity with data collection strategies was reinforced.

□ Strongly Disagree □ Somewhat Disagree □ Neither Agree nor Disagree

□ Somewhat Agree □ Strongly Agree

14. My independence to complete laboratory procedures on my own was reinforced.

□ Strongly Disagree □ Somewhat Disagree □ Neither Agree nor Disagree

□ Somewhat Agree □ Strongly Agree

15. My ability to provide leadership in a laboratory setting was reinforced.

□ Strongly Disagree □ Somewhat Disagree □ Neither Agree nor Disagree

□ Somewhat Agree □ Strongly Agree

16. My teamwork skills were reinforced.

□ Strongly Disagree □ Somewhat Disagree □ Neither Agree nor Disagree

□ Somewhat Agree □ Strongly Agree

17. The provided laboratory instructions aided in my ability to adequately perform the exercise.

□ Strongly Disagree □ Somewhat Disagree □ Neither Agree nor Disagree

□ Somewhat Agree □ Strongly Agree

Food Processing Knowledge

18. Participating in the Artificial Sweeteners laboratory exercise helped me to apply principles of food science to practical issues associated with food processing.

□ Strongly Disagree □ Somewhat Disagree □ Neither Agree nor Disagree

□ Somewhat Agree □ Strongly Agree

19. The effects of processing parameters (mixing time, dough handling, baking time, baking temperature, etc.) on rolled cookie quality were introduced.

□ Strongly Disagree □ Somewhat Disagree □ Neither Agree nor Disagree

□ Somewhat Agree □ Strongly Agree

20. The basic unit operations (receiving, mixing, portioning, baking, etc.) required to produce rolled sugar cookies were introduced.

□ Strongly Disagree □ Somewhat Disagree □ Neither Agree nor Disagree

□ Somewhat Agree □ Strongly Agree

Supplemental Material 6–Gluten-Free Bread Survey Questions

Physical and Sensory Properties

1. My understanding of the function of waxy sorghum flour on sensory properties (appearance, color, flavor, texture, overall acceptability) of gluten-free sorghum bread was improved.

   □ Strongly Disagree □ Somewhat Disagree □ Neither Agree nor Disagree

   □ Somewhat Agree □ Strongly Agree

2. My understanding of the function of waxy sorghum flour on physical properties (loaf height, color, Texture Profile Analysis) of gluten-free sorghum bread was improved.

   □ Strongly Disagree □ Somewhat Disagree □ Neither Agree nor Disagree

   □ Somewhat Agree □ Strongly Agree

3. This laboratory exercise introduced me to standard preparation procedures (mixing times, batter handling procedures, baking times) for gluten-free bread.

   □ Strongly Disagree □ Somewhat Disagree □ Neither Agree nor Disagree

   □ Somewhat Agree □ Strongly Agree

4. This laboratory exercise exposed me to gluten-free bread for the first time.

   □ Strongly Disagree □ Somewhat Disagree □ Neither Agree nor Disagree

   □ Somewhat Agree □ Strongly Agree

Research and Writing Skills

5. My ability to accurately communicate scientific data to peers was reinforced.

   □ Strongly Disagree □ Somewhat Disagree □ Neither Agree nor Disagree

   □ Somewhat Agree □ Strongly Agree

6. My report-writing skills were reinforced.

   □ Strongly Disagree □ Somewhat Disagree □ Neither Agree nor Disagree

   □ Somewhat Agree □ Strongly Agree

7. My knowledge of experimental design was improved.

   □ Strongly Disagree □ Somewhat Disagree □ Neither Agree nor Disagree

   □ Somewhat Agree □ Strongly Agree

8. The importance of using scientific and/or government resources was reinforced.

   □ Strongly Disagree □ Somewhat Disagree □ Neither Agree nor Disagree

   □ Somewhat Agree □ Strongly Agree

9. My ability to analyze research data was reinforced.

   □ Strongly Disagree □ Somewhat Disagree □ Neither Agree nor Disagree

   □ Somewhat Agree □ Strongly Agree

10. The importance of performing multiple replications in a research project was introduced.

    □ Strongly Disagree □ Somewhat Disagree □ Neither Agree nor Disagree

    □ Somewhat Agree □ Strongly Agree

11. My critical thinking skills were reinforced by analyzing the data generated in the laboratory exercise.

    □ Strongly Disagree □ Somewhat Disagree □ Neither Agree nor Disagree

    □ Somewhat Agree □ Strongly Agree

12. My familiarity with data collection strategies was reinforced.

    □ Strongly Disagree □ Somewhat Disagree □ Neither Agree nor Disagree

    □ Somewhat Agree □ Strongly Agree

13. My independence to complete laboratory procedures on my own was reinforced.

□ Strongly Disagree □ Somewhat Disagree □ Neither Agree nor Disagree

□ Somewhat Agree □ Strongly Agree

14. My ability to provide leadership in a laboratory setting was reinforced.

□ Strongly Disagree □ Somewhat Disagree □ Neither Agree nor Disagree

□ Somewhat Agree □ Strongly Agree

15. My teamwork skills were reinforced.

□ Strongly Disagree □ Somewhat Disagree □ Neither Agree nor Disagree

□ Somewhat Agree □ Strongly Agree

16. The provided laboratory instructions aided in my ability to adequately perform the exercise.

□ Strongly Disagree □ Somewhat Disagree □ Neither Agree nor Disagree

□ Somewhat Agree □ Strongly Agree

Food Processing Knowledge

17. Participating in the Gluten-Free Bread laboratory exercise helped me to apply principles of food science to practical issues associated with food processing.

□ Strongly Disagree □ Somewhat Disagree □ Neither Agree nor Disagree

□ Somewhat Agree □ Strongly Agree

18. The challenges associated with producing gluten-free products was introduced.

□ Strongly Disagree □ Somewhat Disagree □ Neither Agree nor Disagree

□ Somewhat Agree □ Strongly Agree

19. The effects of processing parameters (mixing time, batter handling, baking time, baking temperature) on gluten-free bread quality were introduced.

□ Strongly Disagree □ Somewhat Disagree □ Neither Agree nor Disagree

□ Somewhat Agree □ Strongly Agree

20. The basic unit operations (receiving, mixing, proofing, baking) required to produce gluten-free bread were introduced.

□ Strongly Disagree □ Somewhat Disagree □ Neither Agree nor Disagree

□ Somewhat Agree □ Strongly Agree