

Journal of Foodservice Management & Education

Volume 20, Issue 2

Research Contributions:

Interdisciplinary Product Development Framework for Food Science Capstone Course and Undergraduate Research in Collaboration with a University Dining Center

Development and Scaling Soy Taco Crumble: A Study of University Students' Perceptions and Preferences for Soy-based Foods

Editor

Nathan Stokes, PhD,
Associate Professor
Brigham Young University

**Editorial Board
Members**

Yee Ming Lee, PhD, RD, CHE
Associate Professor
Auburn University

Joel Reynolds, PhD, CHE, CEC, CCE
Associate Professor
DePaul University

Pei Liu, PhD
Associate Professor
University of Missouri

Marcy Gaston, PhD, RD, CDN
Assistant Professor
SUNY Oneonta

Journal of Foodservice Management & Education

Published by the Foodservice Systems Management
Educational Council

Volume 20, Issue 2, 2026

Table of Contents

Abstracts iii

Research Manuscripts

Interdisciplinary Product Development Framework for Foo Science Capstone Course and Undergraduate Research in Collaboration with a University Dining Center 1

By: Aidan C. Cairns, MS; Kelly Whitehair, PhD, RD, LD; Kristi Baonga, RDN, LD; Katie Starzec, PhD; Kelly J.K. Getty, PhD

Development and Scaling Soy Taco Crumble: A Study of University Students' Perceptions and Preferences for Soy-based Foods 30

By: Sadaf Azhar; Jacqueline (Anelle) Wegley, PhD; Nellie Hill-Sullins, PhD; Kelly J. Whitehair, PhD, RD, LD; Kelly J.K. Getty, PhD



Abstracts

Research Manuscripts

Interdisciplinary Product Development Framework for Food Science Capstone Course and Undergraduate Research in Collaboration with a University Dining Center

A framework for two undergraduate food product development courses involving interdisciplinary work between food science and foodservice (university dining center) was implemented. We surveyed former students to determine the framework's impact. Students agreed that the framework gave them experience with larger-scale food production equipment, and taught them about foodservice perspectives (feasibility requirements, how dining centers operate) and the scale-up process. Students also developed research/laboratory skills, soft skills, and food production knowledge. In return, students developed new recipes for the dining center. This framework could be implemented at other universities to develop interdisciplinary relationships between dining centers and food science programs.

Development and Scaling Soy Taco Crumble: A Study of University Students' Perceptions and Preferences for Soy-based Foods

Our study explores the development and scaling of a soy taco crumble, a plant-based menu item, for university dining centers. Through a mixed-methods approach including focus groups, surveys, and sensory evaluations, our study assessed college students' perceptions and preferences regarding soy-based foods. Focus group participants indicated limited knowledge about soy and its nutritional benefits. To address this gap, educational infographics, visually designed materials highlighting the health and nutritional benefits of soy-based proteins, were developed and displayed alongside the soy taco crumble at dining centers. After viewing the infographics, 56% of students expressed increased willingness to try soy-based products. Sensory evaluation revealed strong consumer acceptance, with high ratings for flavor ($M = 7.41 \pm 1.35$), aroma ($M = 7.19 \pm 1.51$), and overall acceptability ($M = 7.54 \pm 1.17$) on a 9-point Hedonic Scale ($n = 208$). This research provides valuable insights for promoting sustainable plant-based food options in foodservice settings.

1

2 *Research Manuscript*

3 **Interdisciplinary Product Development Framework for**
4 **Food Science Capstone Course and Undergraduate**
5 **Research in Collaboration with a University Dining**
6 **Center**

7 Aidan C. Cairns¹, Sadaf Azhar², Kelly Whitehair³, Kristi Baonga⁴, Katie Starzec⁵, Missy Schrader⁵
8 Kelly J. K. Getty⁶

9 ¹ Department of Grain and Food Science, 1530 Mid Campus Dr North, Manhattan, KS 66506, Kansas State University; accairns@ksu.edu

10 ² Department of Grain and Food Science, 1530 Mid Campus Dr North, Manhattan, KS 66506, Kansas State University¹; sadafa@ksu.edu

11 ³ School of Health Sciences, 1324 Lovers Lane, Manhattan, KS 66506, Kansas State University; stirtz@ksu.edu

12 ⁴ Housing and Dining Services, 1835 Claflin Rd. Manhattan, KS 66506, Kansas State University; kristil@ksu.edu

13 ⁵ Department of Communications and Agricultural Education, 1612 Claflin Road, Manhattan, KS 66506, Kansas State University;
14 kstarzec@ksu.edu

15 ⁶ Department of Grain and Food Science, 1530 Mid Campus Dr North, Manhattan, KS 66506, Kansas State University; kgetty@ksu.edu

16

17 **ABSTRACT**

18 A framework for two undergraduate food product development courses involving interdisciplinary work
19 between food science and foodservice (university dining center) was implemented. We surveyed former
20 students to determine the framework's impact. Students agreed that the framework gave them experience
21 with larger-scale food production equipment, and taught them about foodservice perspectives (feasibility
22 requirements, how dining centers operate) and the scale-up process. Students also developed
23 research/laboratory skills, soft skills, and food production knowledge. In return, students developed new
24 recipes for the dining center. This framework could be implemented at other universities to develop
25 interdisciplinary relationships between dining centers and food science programs.

26 **Keywords:** Foodservice; Interdisciplinary; Undergraduate research; Food product development

27

28 **Acknowledgment:** Assistance was provided by a USDA AMS Federal-State Marketing Improvement
29 Program Grant in collaboration with the Kansas Department of Agriculture and the Center for Sorghum
30 Improvement at KSU. The collaboration is called FarmUs. Thanks to Kansas State Housing and Dining
31 Services for the use of their facilities and equipment. Thanks to Anthony Mazzara for preparing and
32 conducting the physical parameter testing of the sweet potato muffin tops. This is contribution no. 24-090-
33 J of the Kansas Agricultural Experiment Station.

INTRODUCTION

Food science is focused on the chemical, microbiological, sensory, safety, regulatory, and quality assurance aspects of food, as well as the processing and engineering principles required to produce food on a large scale (IFT, 2018). Meanwhile, the field of foodservice focuses on the preparation and serving/distribution of food products for consumers to consume outside their homes (Edwards, 2013; USDA ERS - Food Service Industry, n.d.). Many universities have academic programs such as Hospitality Management, Dietetics, Culinary, and Business which focus on foodservice systems as part of their curriculum and often their areas of research. While food science education has emphasized experiential learning through industrial partnerships and case studies (Hollis & Eren, 2016; Bohn & Schmidt, 2008). The foodservice education has explored multi-professional collaboration in school meal settings (Janhonen & Elkjær, 2022). However, research examining how food science and campus foodservice operations can collaborate to create applied learning experiences for undergraduate students remains limited. Although campus dining services have been utilized as sites for nutrition education and sustainability initiatives (Malan et al., 2020; Caspi et al., 2021), these programs have primarily focused on consumer education and environmental outcomes rather than integrating food science curriculum with operational foodservice units. This represents a significant gap in understanding how interdisciplinary partnerships between academic food science programs and campus dining centers can enhance students' learning outcomes in product development, scale-up processes, and foodservice operational constraints.

Interdisciplinary collaboration brings diverse perspectives, which can improve not only the product being developed, but also the research process (Reinventing Undergraduate Education, 1998; Specht & Crowston, 2022; Struijk et al., 2022). Multi-professional collaboration in food education has been shown to create valuable learning outcomes when participants from different disciplines work together toward shared goals (Janhonen & Elkjær, 2022). Undergraduate research has been shown to be beneficial to students, providing them with scientific skills, soft skills, and experience (Adebisi, 2022; Linn et al., 2015; Petrella & Jung, 2008; Reinventing Undergraduate Education, 1998; Russell et al., 2007).

From a theoretical perspective, Kolb's Experiential Learning Theory (ELT) provides a strong foundation for understanding how interdisciplinary food product development experiences enhance student learning. According to Kolb (2014), experiential learning is "the process whereby knowledge is created through the transformation of experience." The ELT framework is built on a four-stage learning cycle: (1) concrete experience (CE), where learners engage in hands-on activities; (2) reflective observation (RO), where they reflect on their experiences; (3) abstract conceptualization (AC), where they develop theories and concepts from their reflections; and (4) active experimentation (AE), where they test their new understanding in practical applications (Kolb & Kolb, 2017). This cyclical process aligns exceptionally well with food product development activities, where students experience hands-on formulation work, reflect on formulation challenges and results, conceptualize solutions based on food science principles, and actively experiment with recipe modifications and scale-up procedures. Research in food science education has shown that students who participate in such hands-on, experiential activities demonstrate improved retention, application of course concepts, and enhanced collaboration skills (Bohn & Schmidt, 2008; Masdarina & Martsiti, 2024).

Integrating experiential learning with campus foodservice operations offers unique pedagogical benefits beyond traditional classroom instruction or external industry partnerships. Campus dining services represent readily accessible learning laboratories where students can apply theoretical knowledge to real operational constraints, including food safety regulations, cost limitations, equipment availability, and consumer acceptability requirements (Caspi et al., 2021). These partnerships bridge the gap between academic food science and foodservice practice, providing students with insight into feasibility

requirements, large-scale production considerations, developing foods for target audiences, and effectively communicating with foodservice professionals (Janhonen & Elkjær, 2022; Malan et al., 2020).

This framework has broader educational implications beyond food science programs. The model of integrating academic coursework with operational campus partners can be adapted for hospitality management, nutrition and dietetics, and culinary programs. By demonstrating how existing campus resources can serve as experiential learning laboratories, this approach offers a replicable model for institutions looking to enhance applied learning opportunities without requiring extensive external partnerships or additional resources. The framework also addresses calls from the food science profession for curricula that develop students' success skills—including communication, teamwork, and problem-solving—alongside technical competencies (IFT, 2011).

FarmUS: a farm-to-campus collaborative was a project funded by the United States Department of Agriculture's Federal State Market Improvement grant. The goal of the project was to allow students to see the connection from field to lab to kitchen to table. Three pillars of the project were to innovate, scale, and connect. The innovation began with students in a senior-level capstone research and development course developing new concepts for students eating in the dining center, then scale-up refinement by undergraduate students majoring in food science and lastly having students consuming new products that contained mostly wheat or sorghum. Grounded in Kolb's experiential learning cycle, this project exemplified how experiencing the complete product development cycle—from initial concept through consumer testing—enables students to gain practical skills that are difficult to develop through classroom instruction alone.

Learning Outcomes

Our project-based case study assessed the impact of a food science/foodservice interdisciplinary product development/undergraduate research experience framework, where food product formulations are created, scaled up, and developed into quantity recipes to be served in the dining centers. We assessed the framework's impact by interviewing and/or surveying students about their experiences while working on this project.

METHODS

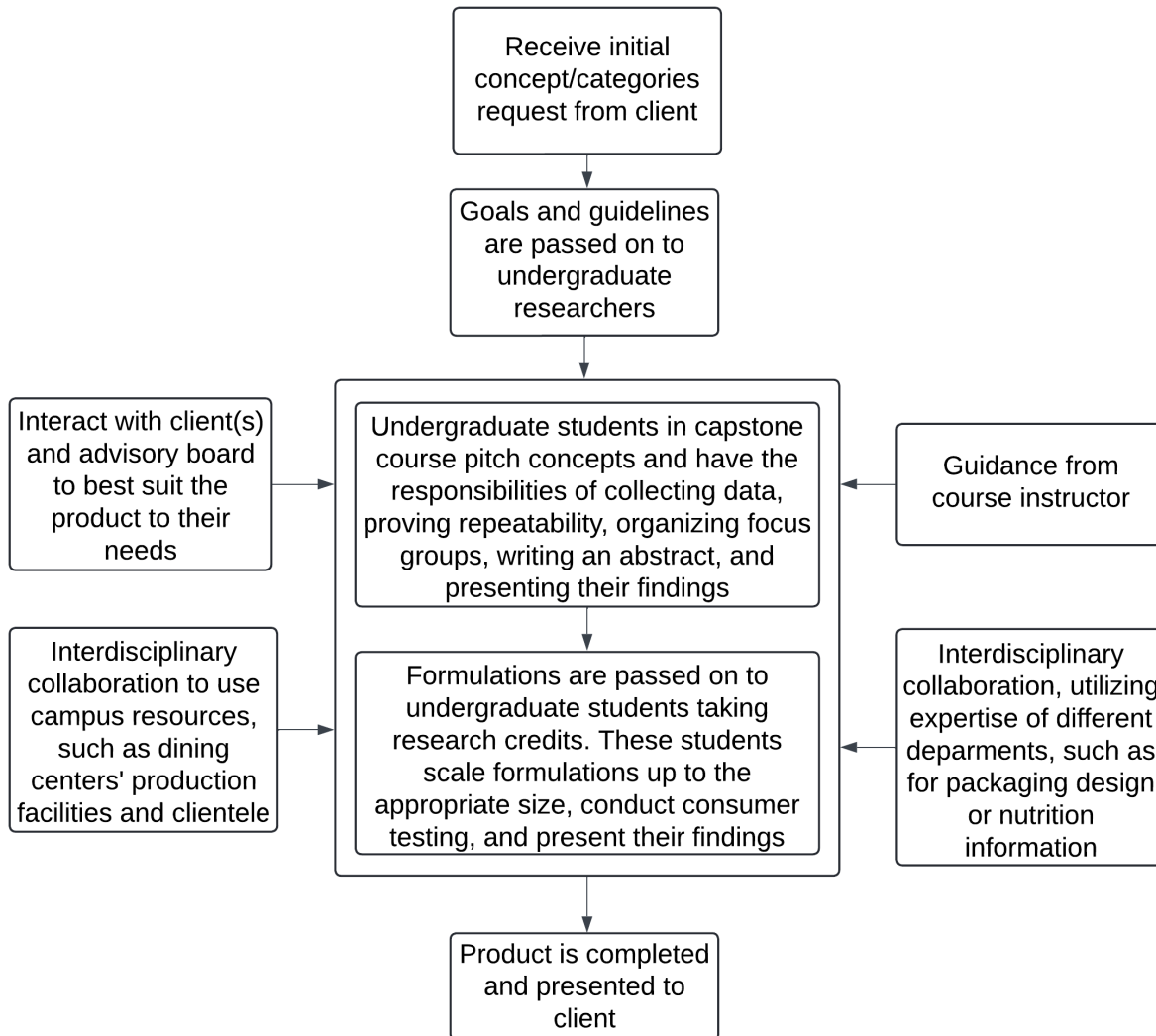
Subject of this Case Study

The Kansas Department of Agriculture (KDA) and the Center for Sorghum Improvement (CSI) sought to increase the consumption of Kansas sorghum and wheat in college students' diets by developing products to be served in campus dining centers. The goal of this project (FarmUS) was to increase students' knowledge of whole grain and gluten-free food product options. To carry out this project, we decided to have "University" food science students in a senior-level capstone research and development of food products course and/or undergraduate research credits develop food products while collaborating with "University" Housing and Dining Services for scaling up those food products.

The FarmUS project was a three-year project that was continued for a fourth year in a slightly different framework. Each year had a different category of sorghum and wheat products, determined by the Center for Sorghum Improvement (CSI), the Kansas Department of Agriculture (KDA), and Dining Center representatives. The three categories were entrées, snacks, and baked goods. For each of these categories, Dining Services was specifically looking for items that could be sold at the recreational complex, on-the-go baked products, par-baked/frozen buns, and "on trend" baked items. As an enhancement of this framework, the 2024 food science senior-level capstone course students worked directly with Dining Services to experience the process of developing products from an initial concept to

a finished scaled-up quantity recipe and conducting a consumer acceptability study within one semester. Students in the undergraduate research course were involved in the course for all four years.

Figure 1. Course Framework (senior-level capstone course in product development and undergraduate research course for further development of products in a dining center).



Framework of Case Study

The goal of the framework was to give undergraduate students an experience similar to product development in industry. Throughout product development, students interacted with the clients and an advisory board to ensure they met the client's needs. They also communicated and collaborated to use additional resources on campus such as dining center production facilities. The framework (Figure 1) includes two parts: a senior-level capstone course in food product development and an undergraduate food science research course.

FarmUS Capstone Course Previous Years (PY)

In the senior-level capstone course in food product development, students were given basic guidelines in the form of categories or concepts from the dining center staff. Students then conducted market screenings and pitched product concepts that fit within those guidelines. The professor and dining center representatives selected the best concepts (determined by feasibility, creativity, and market potential) to move forward to development. Students began to develop formulations during the lab section of the course [either alone or in groups, and either at home (due to COVID) or in a food science lab on campus] and collected data throughout development. The course instructor(s) guided students during the lab period and provided feedback.

There was an additional interdisciplinary project-based learning approach for students to collaborate with undergraduate agricultural and natural resources communications students in a layout and design course. Food science students provided content (product name, photos, net content, nutritional facts panel, ingredient statement and a company name/address) for a packaging label. Undergraduate agricultural communications students enrolled in a layout and design course (AGCOM 345) submitted draft packaging designs that were reviewed by the course instructor and edited. The labels were then provided to the food science students to respond with additional feedback and suggested revisions for students in the layout and design course. This allowed food science students to learn about the creative process and agricultural communications students to learn about labeling requirements while gaining experience in making an appealing packaging design. Students completed a reflective survey on their assessment of working with an undergraduate agricultural communication student. In addition, the capstone instructor graded the final packaging project using a rubric to determine if all required labeling elements were included.

Food science students then organized and conducted a focus group to sample their products. Students prepared a focus summary report that was graded by the instructor using a rubric. Sensory aspects of products were also evaluated by the KDA, CSI consortium, and dining center students and management staff. Once all data was collected, students prepared a final report and presentation in an industry-style format. The final report was written using work from the entire semester and included an executive summary, market screening, project description, a formulation in percentages, description of each ingredient's function, process description (including a process flow diagram and specific equipment to be used), quality and safety parameters, package prototype, regulatory requirements, and a production cost analysis. They also gave a final presentation on their findings. A rubric was also used to evaluate learning outcomes for the final report.

A senior-level capstone course in food product development requires skills and knowledge students have accumulated throughout their degree program. Students used good manufacturing practices and food safety principles as they prepared product prototypes in the laboratory. Students also used their knowledge of physical, chemical, and sensory properties of ingredients to guide them on how to adjust formulations to create a better product. When writing the process flow diagram and calculating the scaled-up formulation, students used the skills they learned in their food processing and process calculations courses. Their knowledge of regulations was used when writing the quality and safety section of the report, which includes creating critical control points. The capstone course gives students the opportunity to combine and apply skills and knowledge learned throughout their degree, which further prepares them for careers in food science. The experience of interdisciplinary work and research in this course prepares them for a typical collaborative industry experience.

Undergraduate Research Credits (UR)

At the end of the capstone course, formulations were passed on to undergraduate students taking food science undergraduate research credits or work experience as a summer internship. In foodservice the

term “recipe” is used instead of “formulation” as in food science. A formulation only lists ingredients and percentages. A recipe includes production details, cooking equipment, garnishing tips, serving sizes, and consumption quality standards. These students then began to scale up the product using larger scale equipment in the dining center. They also collaborated with and received feedback from dining center staff. Throughout the development process, they collected data in the form of pictures, processing steps, yields, and descriptions of the formulations they tested. Once they had satisfactorily achieved the desired flavor profile and scale, they conducted consumer testing (university students and staff) in the form of convenience sampling. For example, they offered samples and a consumer acceptability questionnaire to patrons at the entrance of the dining center during mealtimes. Undergraduate food science research students then analyzed the data collected from consumer testing. Students also input their recipe(s) into the dining center recipe system (Computrition). This system allows for accurate recipe formatting, costing, and nutritional/allergy labeling. Once all data was collected and analyzed, students prepared a 400-word abstract (assessment included organization and completeness, readability and professionalism (grammar, spelling, word choice), and conciseness. They presented an oral poster presentation (3 to 5 minutes) at an undergraduate research symposium. An evaluation rubric for the symposium, which includes assessment for the abstract, poster, and presentation. Presentations were evaluated for students’ understanding and communication of project components, as well as ability to answer questions about the project. A mentor survey was used to evaluate student performance.

2024 Capstone Course with Scale-up (TF)

The 2024 senior-level capstone course in food product development was unique from previous semesters due to students' increased interactions with the dining center. Ten students were seniors majoring in food science and one student was a graduate student majoring in grain science. Students toured the dining center. The Registered Dietitian (RDN) who led the recipe development and menu writing process provided students with product concepts (such as a unique meatball product, vegan burger patty, and plant-based breakfast item). Students conducted market screenings based on concepts provided and presented their product pitches to another RDN. The two RDNs (Baogna and Schrader) selected five products for benchtop development. Students were divided into groups (2-3 students) to develop these products. Midway through the semester, RDNs selected two products for scale-up in the dining center using their large-scale equipment. Students were re-divided into two groups to scale up the two products so that all students had the opportunity to use the large-scale equipment. Consumer acceptability testing was conducted in the dining center for all products developed. The 2024 capstone course students also had the opportunity to interact with agricultural communications students to develop labels. They also prepared and presented final reports similar to previous years, but with the addition of quantity-formatted production recipes.

Collaboration with Dining Center

At the beginning of the semester, the dining center staff met with the capstone instructor to determine potential recipe needs within each category. These suggestions were provided to the students to complete a market screening and provide product concepts to the dining center staff. Several concepts (5-6) were selected each semester for the students to begin developing on the benchtop. Throughout the semester, the dining staff evaluated products and provided students’ feedback. For the F24 semester, the dining staff encouraged the students to use ingredients only available to the dining center and then selected two products that two groups of 5 or 6 could produce in the dining hall.

For the undergraduate research students, the dining staff and capstone instructor worked directly with the individual student. Products were scaled up in the dining hall and consumer acceptance was also completed in the dining hall.

Assessment of Framework

The proposed framework was assessed using two main metrics: tangible results and student learning outcomes and impact. The tangible results include the products developed, the publications, and the symposium posters and presentations that came from this framework. The student learning outcomes and impact were evaluated using reflective surveys and interviews.

Reflective Assessment of Student Learning Outcomes and Impact

Two surveys and one interview were used to evaluate the framework. The assessment tools and informed consents were reviewed and approved by the “University” Institutional Review Board (IRB approval # 12516). All participants provided informed consent before participating in the reflective survey or interview. The debriefing statement was sent to participants following their participation. A Qualtrics (Provo, UT) survey (Table 1) using a 5-point Likert scale (where 1=strongly disagree and 5=strongly agree) and open-ended questions asking about their overall experience and suggestions for course improvement was developed and distributed to FDSCI 740 students. Responses were collected anonymously. The question categories were “Research and Laboratory Skills,” (RL) “Food Production Knowledge,” (FP) “Interdisciplinary Aspects,” (IA) “Soft Skills,” (S) and “Career Preparedness and Course Experience/Personal Impact” (CP).

Students who took part in the undergraduate food science research course or work experience were interviewed over a recorded Zoom meeting by a third-party interviewer or were offered to type out their responses to the interview questions over email if they preferred not to meet over Zoom. For each of the 33 questions (Table 2), interviewees were asked to respond on the 5-point Likert scale and then elaborate on why they selected that rating. There were also open-ended questions that did not feature a scale.

Students of the 2024 fall capstone course were given a separate survey (Table 3) because they were the only capstone class that worked directly with the dining center. This was also a Qualtrics survey with the same categories as the other survey featuring 5-point Likert scale and open-ended questions. Because extra credit was offered for survey completion, some bias may have been present.

Table 1: Previous Years (PY) Survey Statements and Abbreviations.		
Label	Abbreviation	Full Question
<i>Research and Laboratory Skills (RL)</i>		
PY RL Q1	Scientific Method	This product development course/project improved my understanding of the scientific method.
PY RL Q2	Scientific/Technical Writing	This product development course/project improved my scientific/technical writing skills.
PY RL Q3	Collecting Data	Collecting data helped me to better understand product development research.
PY RL Q4	Data Interpretation	This product development course/project improved my data interpretation skills.
PY RL Q5	Analytical Equipment	This product development project gave me experience using analytical equipment.
PY RL Q6	Focus Group	This product development course/project taught me how to organize and run a focus group.
PY RL Q7	Evaluate Consumer Needs/Wants	Organizing and running a focus group helped me to understand how to evaluate consumer needs and wants.

PY RL Q8	Improve Product's Sensory Attributes	Organizing and running a focus group helped me to improve my product's sensory attributes (flavor, texture, color, etc.).
PY RL Q9	Informed Consent Practices	This product development course/project taught me about common informed consent practices.
PY RL Q10	Allergy Statements	This product development course/project taught me about the importance of including allergy statements when conducting consumer testing.
<i>Food Production Knowledge (FP)</i>		
PY FP Q1	Dining Center Categories/Guidelines	The categories/guidelines provided by the dining center helped me to develop an initial product concept.
PY FP Q2	Concept Pitch	Putting together a food product concept pitch after doing market screening developed my understanding of market desires and trends.
PY FP Q3	Novel Ingredients	This product development project gave me the opportunity to work with ingredients I had not previously used.
PY FP Q4	Ingredient Functionality	Developing a product increased my understanding of ingredient functionality.
PY FP Q5	Food Safety and Regulatory Controls	This course/project put my knowledge of food safety and regulatory controls into practice.
PY FP Q6	Quality Control Parameters	This course/project taught me about quality control parameters (such as color and size of product, specifications, grade standards, etc.) for food products.
PY FP Q7	Labeling Requirements	This course/project increased my understanding of nutritional and ingredient labeling requirements.
PY FP Q8	Economic Feasibility	This course/project helped me to understand economic feasibility and cost analysis when developing products.
<i>Interdisciplinary Aspects (IA)</i>		
PY IA Q1	Packaging Design Perspectives	Collaborating with the packaging design class gave me different perspectives on packaging design and layout.
PY IA Q2	Different Major's Skill Set	Collaborating with the packaging design class taught me about the skill set of a different major.
PY IA Q3	Collaboration Elevated Experience	Collaborating with the packaging design class elevated my experience in this class.
PY IA Q4	Dining Center Perspectives	Interacting with the dining center staff and advisory board gave me a different perspective on how to improve my product.
<i>Soft Skills (S)</i>		
PY S Q1	Communication	Presenting to and interacting with the dining center staff/advisory board provided experience that enhanced my communication skills.
PY S Q2	Teamwork	Working in a group enhanced my teamwork skills.
PY S Q3	Public Speaking	Giving a presentation enhanced my public speaking skills.
PY S Q4	Problem Solving	Facing difficulties while developing my product enhanced my problem-solving skills.

PY S Q5	Adaptability	Facing difficulties while developing my product enhanced my adaptability skills.
PY S Q6	Organization	Being responsible for managing, labeling, storing, and requesting more ingredients enhanced my organizational skills.
<i>Career Preparedness and Course Experience (CP)</i>		
PY CP Q1	Capstone Course	FDSCI 740 connected material I learned throughout my degree program.
PY CP Q2	Enjoyed Course	I enjoyed this product development course/project.
PY CP Q3	Influenced Career Path/Goals	My experiences with this course/project influenced my career goals/path.
PY CP Q4	Relevant Skills and Knowledge	I use/will use the skills and knowledge I learned in this product development course/project in my career.
PY CP Q5	Insight into Industrial Product Development	This course/project provided me with insight into industrial food product development practices.
PY CP Q6	Professional Presentation	Preparing and giving a presentation in this product development course/project was a similar experience to presentations I have given/would give in a professional setting.
PY CP Q7	Prepared for Career/Grad School	My experiences with this product development project prepared me for a career in food science and/or graduate school.
PY CP Q8	Similar Experience to Industry	The benchtop food product development project in FDSCI 740 is similar to product development in industry.

Figure 5. Previous Years (PY) Research and Laboratory Skills, for Full Statements (Table 1).

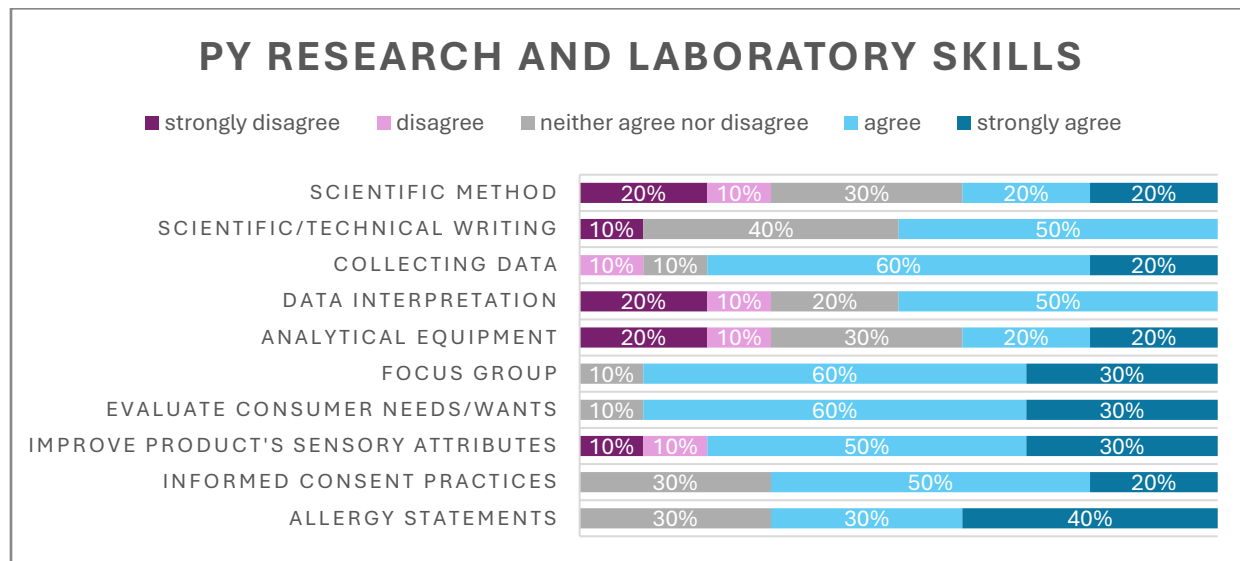


Figure 6. Previous Years (PY) Food Production Knowledge, for Full Statements (Table 1).

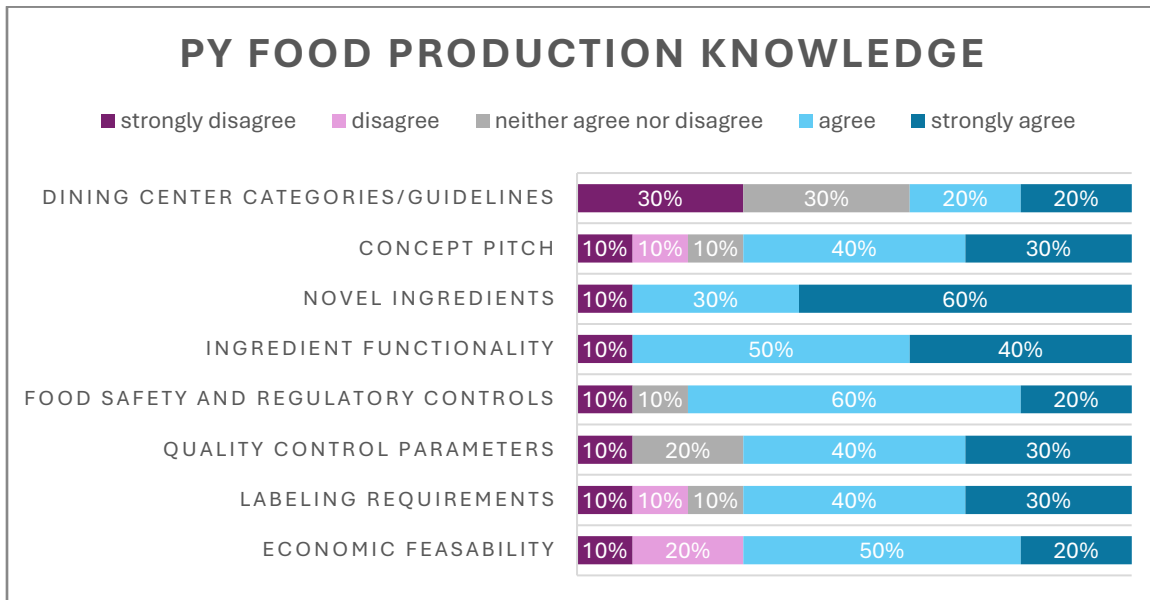


Figure 7. Previous Years (PY) Interdisciplinary Aspects, For Full Statements (Table 1).

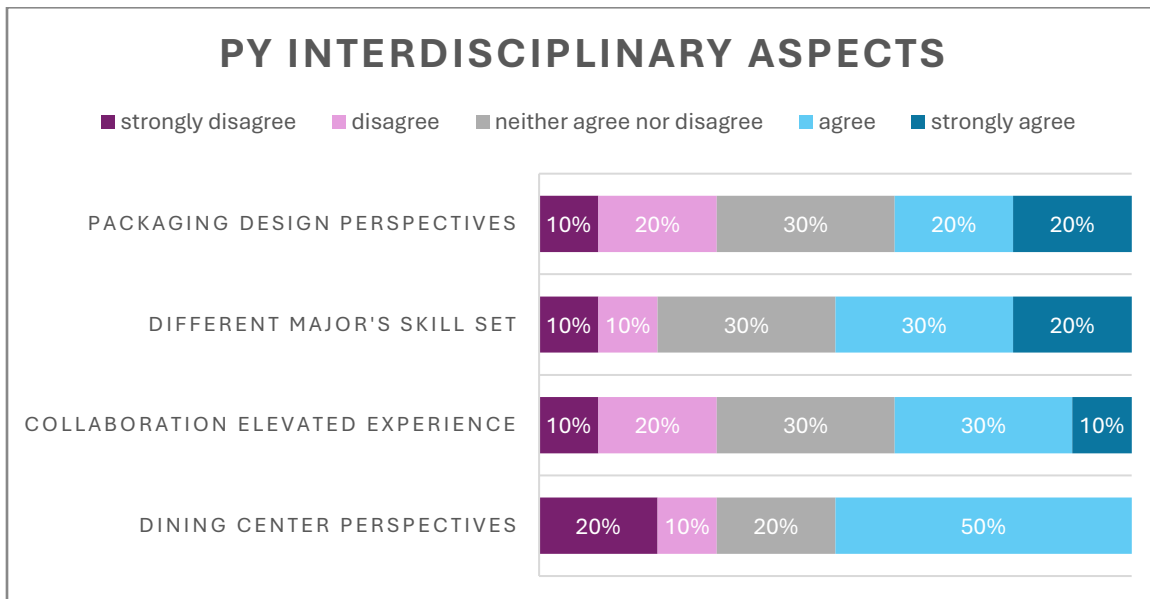


Figure 8. Previous Years (PY) Soft Skills, for Full Statements (Table 1).

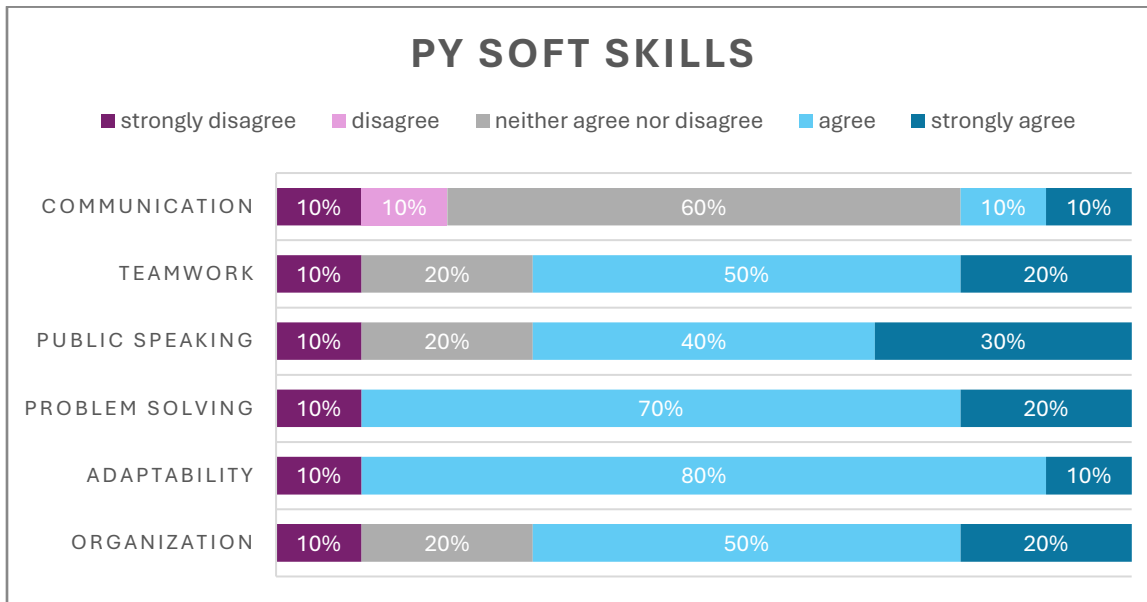


Figure 9. Previous Years (PY) Career Preparedness and Course Experience, for Full Statements (Table 1).

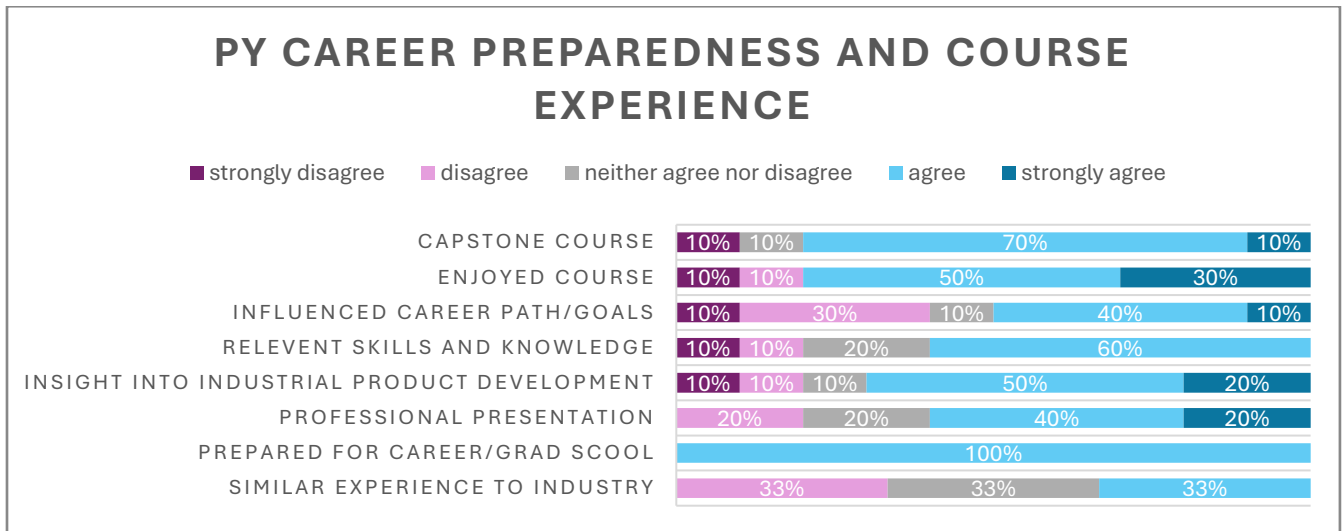


Table 2. Undergraduate Research (UR) Interview Statements and Abbreviations.

Label	Abbreviation	Full Question
<i>Research and Laboratory Skills (RL)</i>		
UR RL Q1	Collecting Data	Collecting data helped me to better understand product development research.

UR RL Q2	Scientific Method	This product development project improved my understanding of the scientific method.
UR RL Q3	Scientific/Technical Writing	This product development project improved my scientific/technical writing skills.
UR RL Q4	Analytical Equipment	This product development project gave me experience using analytical equipment.
UR RL Q5	Consumer Acceptability Test	This product development project taught me how to organize and run a consumer acceptability test.
UR RL Q6	Evaluate Consumer Needs/Wants	Organizing and running consumer acceptability test(s) helped me to understand how to evaluate consumer needs and wants.
UR RL Q7	Improve Product's Sensory Attributes	Organizing and running consumer acceptability test(s) helped me to improve my product's sensory attributes.
UR RL Q8	Data Interpretation	This product development project improved my data interpretation skills.
UR RL Q9	Scientific Abstract	This product development project enhanced my ability to write a scientific abstract.
UR RL Q10	Research Poster	This product development project enhanced my ability to put together and present a research poster.
<i>Food Production Knowledge (FP)</i>		
UR FP Q1	Larger Scale Food Production	Scaling up a product in the dining center increased my understanding of larger scale food production.
UR FP Q2	Dining Center Operations	This product development project increased my understanding of how dining centers operate.
UR FP Q3	Larger Food Production Equipment	This product development project gave me the opportunity to experiment with larger food production equipment I had not previously used.
UR FP Q4	Writing Processing Methods	Using Computrition, gave me experience with writing detailed methods that can be understood by dining center staff.
UR FP Q5	Dining Center Goals	This product development project increased my understanding of dining center menu goals related to wheat, sorghum, and/or soy products.
UR FP Q6	Technical Feasibility	This product development project increased my understanding of technical feasibility requirements in food service
UR FP Q7	Dining Center Perspectives	Working with the dining center staff gave me different perspectives on product development and scale up.
UR FP Q8	Impact of Scale on Formulation	Scaling up a product gave me insight into how scale-up can affect formulations/recipes.
UR FP Q9	Novel Ingredients	This product development project gave me the opportunity to work with ingredients I had not previously used.
UR FP Q10	Ingredient Functionality	Developing a product increased my understanding of ingredient functionality.
<i>Soft Skills (S)</i>		
UR S Q1	Public Speaking	Giving a presentation improved my public speaking skills.

UR S Q2	Communication	Working with the dining center staff improved my communication skills.
UR S Q3	Problem Solving	Facing difficulties, such as unacceptable flavor profile or texture, while developing my product(s) improved my problem-solving skills.
UR S Q4	Adaptability	Facing difficulties, such as unacceptable flavor profile or texture, while developing my product(s) improved my adaptability skills.
UR S Q5	Time management	Borrowing kitchen space and equipment from the dining center improved my time management and coordination skills.
UR S Q6	Organization	Being responsible for managing, labeling, storing, and requesting more ingredients improved my organizational skills.
<i>Personal Impact (CP)</i>		
UR CP Q1	Enjoyed Course	I enjoyed this product development project.
UR CP Q2	Influenced Career Path/Goals	My experiences with this product development project influenced my career goals/path.
UR CP Q3	Prepared for Career/Grad School	My experiences with this product development project better prepared me for a career in food science and/or graduate school.
UR CP Q4	Relevant Skills and Knowledge	I use/will use the skills and knowledge I learned in this product development project in my career.
UR CP Q5	Networking Connections	This product development project gave me networking connections
UR CP Q6	Work was Published	Participating in this product development project led to my work being published.
UR CP Q7	Presented Work at Conference	Participating in this product development project led to me presenting my work at a conference.

Figure 10. Undergraduate Research Experience (UR) Research and Laboratory Skills, for Full Statements (Table 2).

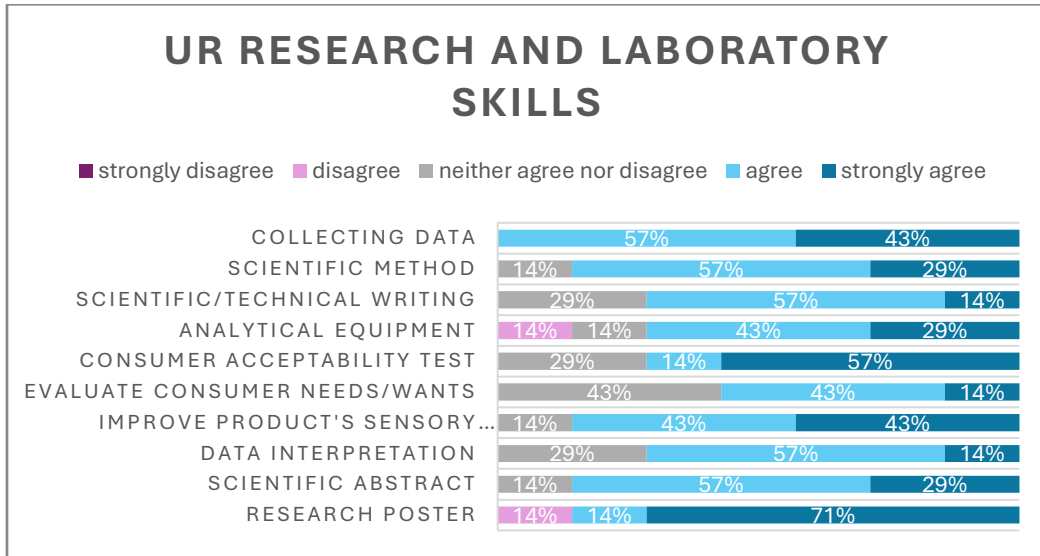


Figure 11. Undergraduate Research Experience (UR) Food Production Knowledge, for Full Statements (Table 2).

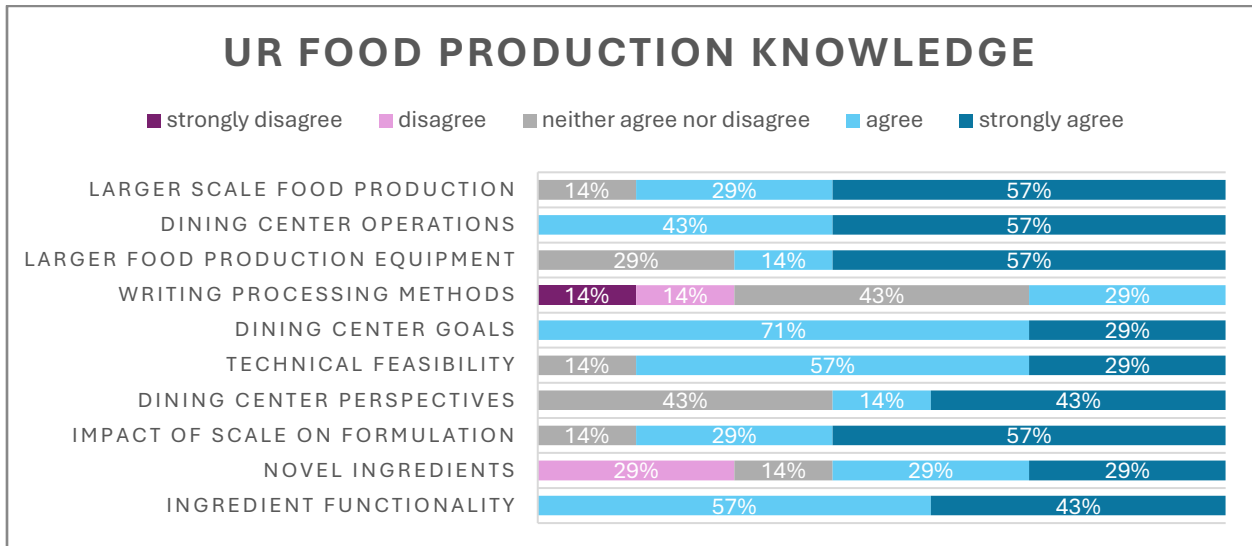


Figure 12. Undergraduate Research Experience (UR) Soft Skills, for Full Statements (Table 2).

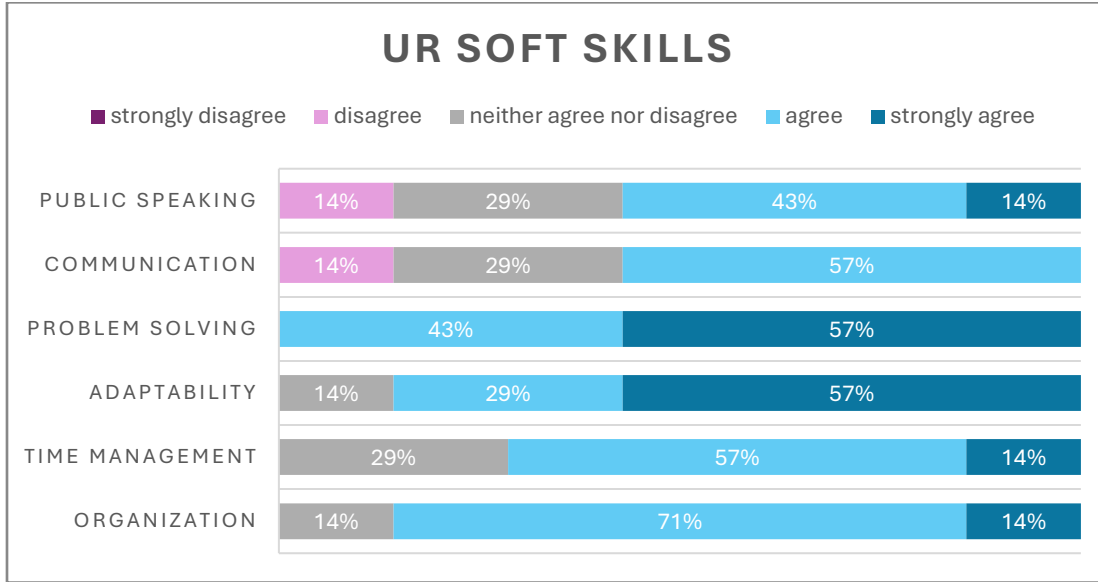


Figure 13. Undergraduate Research Experience (UR) Personal Impact, for Full Statements (Table 2).

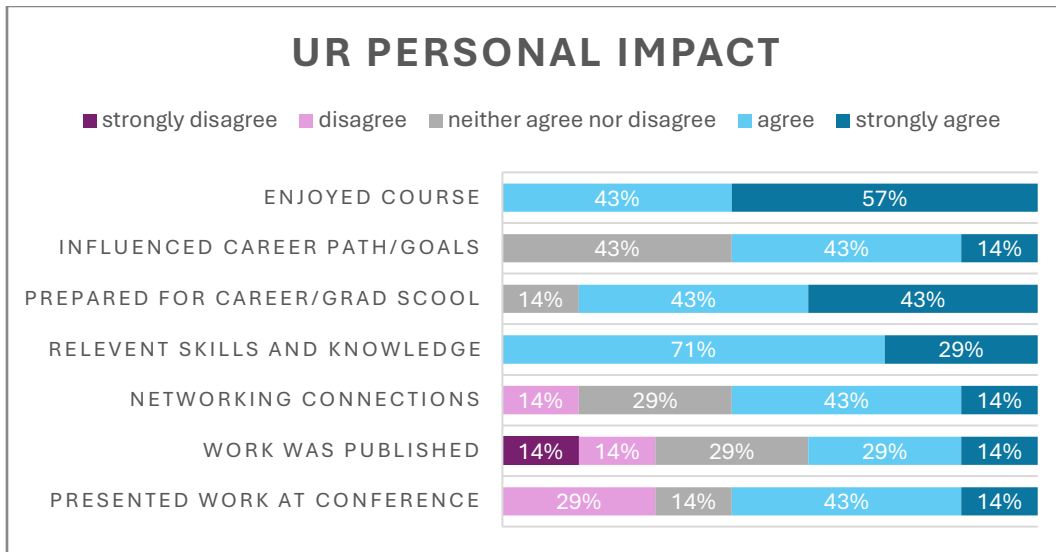


Table 3. 2024 (TF) Survey Statements and Abbreviations.

Label	Abbreviation	Full Question
<i>Research and Laboratory Skills (RL)</i>		
TF RL Q1	Scientific Method	This product development project improved my understanding of the scientific method.
TF RL Q2	Scientific/Technical Writing	This product development project improved my scientific/technical writing skills.
TF RL Q3	Collecting Data	Collecting data helped me to better understand product development research.

TF RL Q4	Data Interpretation	This product development project improved my data interpretation skills.
TF RL Q5	Analytical Equipment	This product development project gave me experience using analytical equipment.
TF RL Q6	Consumer Acceptability Test	This product development project taught me how to organize and run a consumer acceptability test. (This is referencing the consumer acceptability test you conducted in the dining center.)
TF RL Q7	Evaluate Consumer Needs/Wants	Organizing and running a consumer acceptability test helped me to understand how to evaluate consumer needs and wants.
TF RL Q8	Improve Product's Sensory Attributes	Organizing and running consumer acceptability test(s) helped me to improve my product's sensory attributes (flavor, texture, color, etc.).
TF RL Q9	Informed Consent Practices	This product development project taught me about common informed consent practices.
TF RL Q10	Allergy Statements	This product development project taught me about the importance of including allergy statements when conducting consumer testing.
<i>Food Production Knowledge (FP)</i>		
TF FP Q1	Dining Center Categories/Guidelines	The categories/guidelines provided by the dining center helped me to develop an initial product concept.
TF FP Q2	Concept Pitch	Putting together a food product concept pitch after doing market research developed my understanding of market desires and trends.
TF FP Q3	Novel Ingredients	This product development project gave me the opportunity to work with ingredients I had not previously used.
TF FP Q4	Ingredient Functionality	Developing a product increased my understanding of ingredient functionality.
TF FP Q5	Technical Feasibility	This course increased my understanding of technical feasibility requirements in food service.
TF FP Q6	Food Safety and Regulatory Controls	This course put my knowledge of food safety and regulatory controls into practice.
TF FP Q7	Quality Control Parameters	This course taught me about quality control parameters (such as color and size of product, specifications, grade standards, etc.) for food products.
TF FP Q8	Labeling Requirements	This course increased my understanding of nutritional and ingredient labeling requirements.
TF FP Q9	Economic Feasibility	This course helped me to understand economic feasibility and cost analysis when developing products.
TF FP Q10	Larger Scale Food Production	Scaling up a product in the dining center taught me about larger scale food production.
TF FP Q11	Impact of Scale on Formulation	Scaling up a product gave me insight into how scale-up can affect recipes.

TF FP Q12	Benchtop Development to Full Scale	Taking my product from an initial concept to a scaled up and ready-to-produce formulation gave me insight into the product development process and how all the steps fit together.
<i>Interdisciplinary Aspects (IA)</i>		
TF IA Q1	Packaging Design Perspectives	Collaborating with the packaging design class gave me different perspectives on packaging design and layout.
TF IA Q2	Dining Center Goals	Interacting with the dining center staff helped me to better understand their needs and goals.
TF IA Q3	Dining Center Perspectives	Working with the dining center staff gave me different perspectives on product development and scale up for food service.
TF IA Q4	Dining Center Operations	This product development project increased my understanding of how dining centers operate.
TF IA Q5	Larger Food Production Equipment	Working with the dining center gave me the opportunity to experiment with larger food production equipment I had not previously used.
<i>Soft Skills (S)</i>		
TF S Q1	Communication	Interacting with the dining center staff provided experience that developed my communication skills.
TF S Q2	Teamwork	Working in a group improved my teamwork skills.
TF S Q3	Public Speaking	Giving a presentation improved my public speaking skills.
TF S Q4	Problem Solving	Facing difficulties while developing my product improved my problem-solving skills.
TF S Q5	Adaptability	Facing difficulties while developing my product improved my adaptability skills.
TF S Q6	Organization	Being responsible for managing, labeling, storing, and requesting more ingredients improved my organizational skills.
TF S Q7	Time management	Collaborating with dining center staff to borrow kitchen space and equipment improved my time management skills.
<i>Career Preparedness and Course Experience (CP)</i>		
TF CP Q1	Capstone Course	FDSCI 740 connected material I learned throughout my degree program.
TF CP Q2	Enjoyed Course	I enjoyed this product development project.
TF CP Q3	Influenced Career Path/Goals	My experiences with this course influenced my career goals/path.
TF CP Q4	Relevant Skills and Knowledge	I will use the skills and knowledge I learned in this product development project in my career.
TF CP Q5	Insight into Industrial Product Development	This course provided me with insight into industrial food product development practices.
TF CP Q6	Professional Presentation	Preparing and giving a presentation in this product development project was a similar experience to presentations I would give in a professional setting.

TF CP Q7	Dining Center Equipment Improved Experience	Using the dining center equipment improved my experience in learning product development.
-------------	--	--

Figure 14. 2024 Capstone Course (TF) Research and Laboratory Skills, for Full Statements (Table 3).

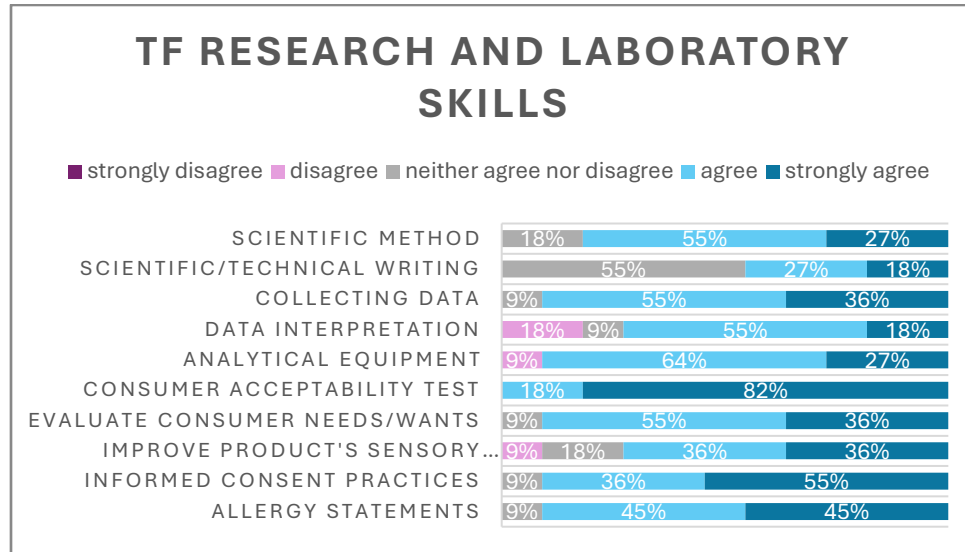


Figure 15. 2024 Capstone Course (TF) Food Production Knowledge, for Full Statements (Table 3).

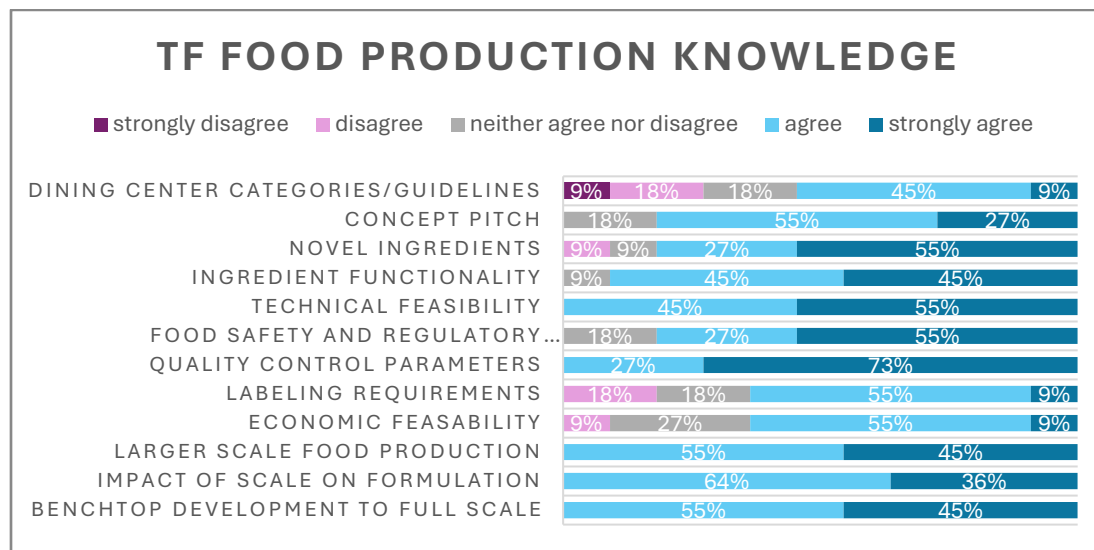


Figure 16. 2024 Capstone Course (TF) Interdisciplinary Aspects, for Full Statements (Table 3).

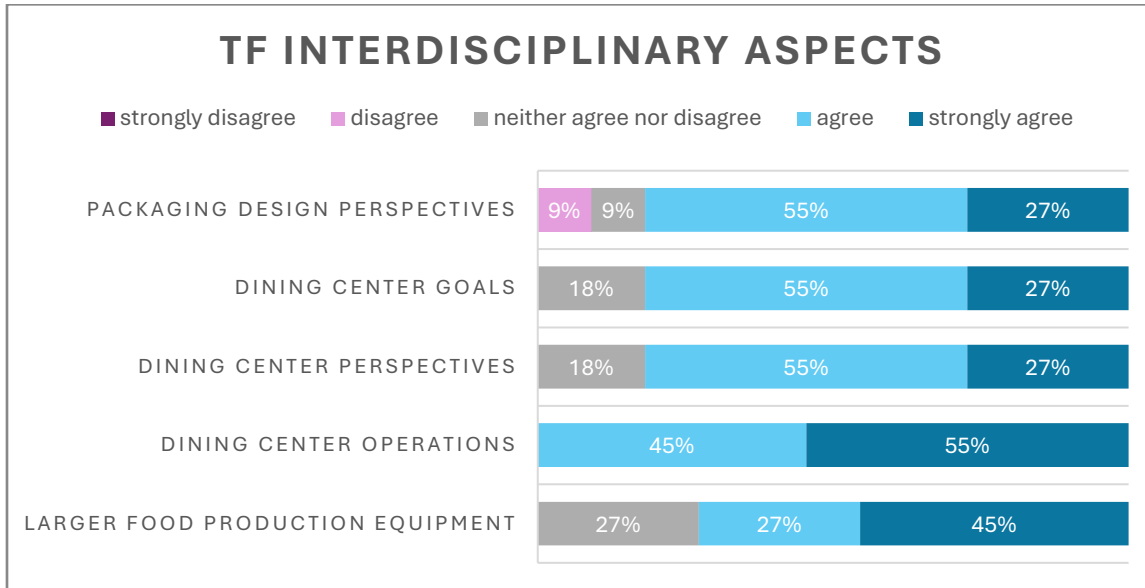


Figure 17. 2024 Capstone Course (TF) Soft Skills, for Full Statements (Table 3).

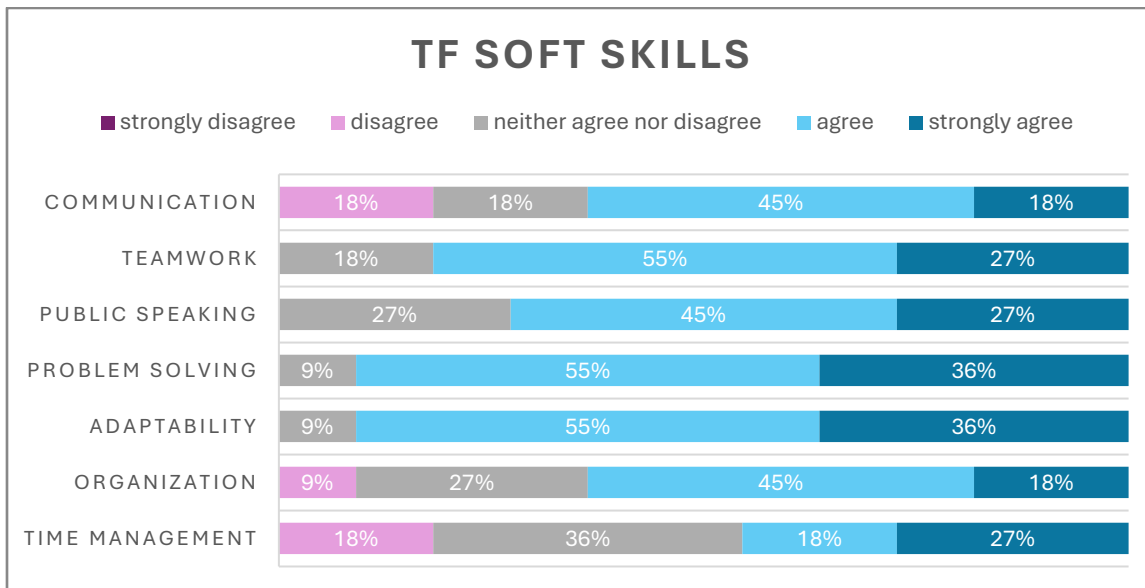
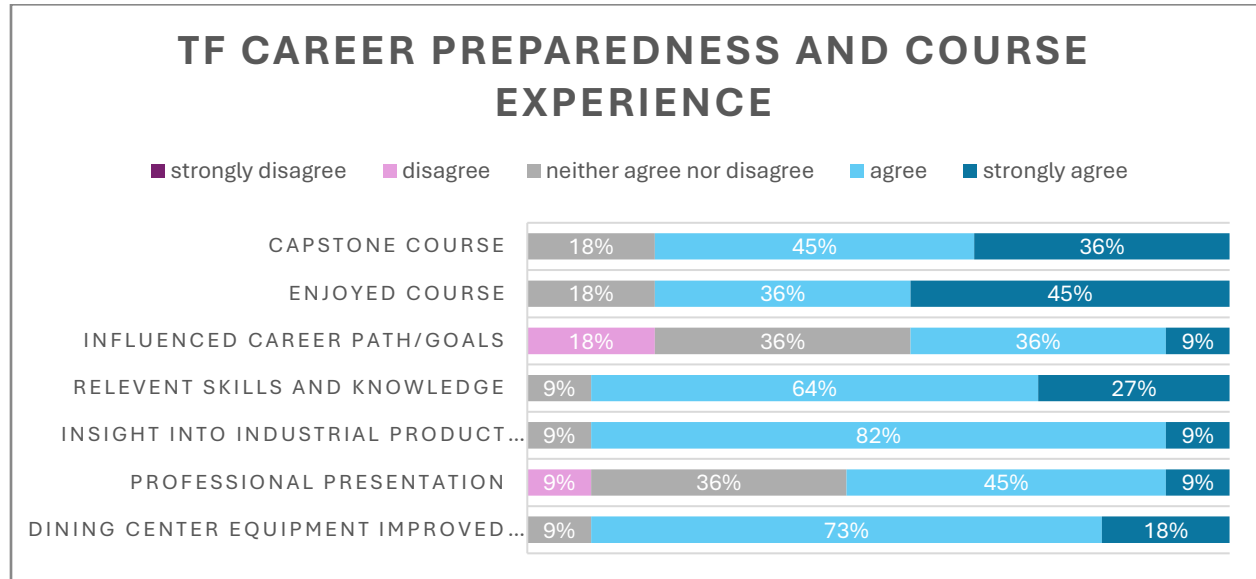


Figure 18. 2024 Capstone Course (TF) Career Preparedness and Course Experience, for Full Statements (Table 3).



RESULTS

Tangible Benefits

Over the three-year implementation period, the framework generated substantial tangible outcomes while demonstrating significant impacts on student learning across multiple domains. The project led to the successful development of 14 formulations/quantity production recipes (Table 4) that are now available in the “University” Dining Services recipe database (Computrition). Many continue to be served in the dining center on a regular basis. This work also led to several publications and presentations.

Publications:

1. FarmUS Recipe Book (was distributed to 40 university and community college dining centers and shared digitally with IFT Conference attendees and dozens of K-12 school foodservice organizations across the state) (example in Figure 2) https://drive.google.com/file/d/1Ilqf0C-RQ3htNh_97-G3Hroez3dGx_W9/view?usp=sharing (Getty & Whitehair, 2022)
2. Development and scale-up of gluten-free sorghum-based bakery goods for K-State Dining Services, DOI: 10.1016/j.jafr.2023.100840 (Cairns et al., 2023)

National Conference Presentations:

1. Formatting a product development capstone course for development of grain-based baked items for use in Kansas State University dining services (Getty et al., 2021)
2. Development and scale-up of the gluten-free sorghum-based bakery goods for K-State dining services (Getty, Whitehair, Brazington, et al., 2022)
3. Creating undergraduate research experiences in product development of grain-based food products for KSU dining halls (Getty, Whitehair, & Jones, 2022)

Figure 2: Tomato Basil Parmesan Sub Bun Recipe from FarmUS Recipe Book (Getty & Whitehair, 2022).

Tomato Basil Parmesan Sub Bun

Wheat-based
Yield: 48 each

Ingredient	Amount	Method
Tomatoes, Sun Dried	0.045 lb.	1. Coarsley chop tomatoes with knife or robot coupe. Hold for step 2.2.
Water	0.444 lb.	2.1. Combine in mixer bowl on low.
Oil, Canola	0.090 lb.	2.2. Add chopped tomatoes from step 1 and mix with dough hook to 65 Deg. F on low speed.
Tomato Paste	0.076 lb.	
Sugar, Granulated	0.030 lb.	
Salt	0.015 lb.	
Cheese, Parmesan, Shredded	0.123 lb.	
Basil, Dried	0.009 lb.	
Flour, Bread	0.787 lb.	
Yeast, Instant	0.012 lb.	3.1. Add to mixer bowl, run on medium speed until internal temperature of 78-82 Deg. F. Note: the dough may take some time to reach the desired dough temperature. 3.2. Cover, let rest for 20 minutes. 3.3. Scale into 1.3 lb. rounds. Place 3x4 on greased 18x26x1 inch bun sheets. 3.4. Utilizing sheeter (settings may vary by model) process each 1.3 lb. lump into a 26-inch long loaf. 3.5. Place 3 loaves onto greased 18x26x1 inch bun pan. 3.6. Spray tops with non-stick spray. (You may cover and refrigerate overnight if prepping for a later use). 3.7. Proof until double in bulk. 3.8. Bake at 350 Deg. F (Conventional) for 15-20 minutes or until 200 Deg. F internal temperature.
		
Margarine, Melted	0.040 lb.	4.1. Brush over hot loaves 4.2. Cut each loaf lengthwise down center leaving hinged on one side. Then cut into six equal lengths.

Undergraduate Food Science Research Course Presentations:

1. Scale-up of Japanese curry buns for K-State dining services (Cairns et al., 2021)
2. Development gluten-free blueberry muffin for K-State dining services (Holmes et al., 2021)
3. Development and scale-up of peanut butter apple muffin (Martin et al., 2021)
4. Development and scale-up of the gluten-free savory breakfast waffle sandwich for K-State dining services (Vavra et al., 2021)
5. Development and scale-up of a gluten-free sorghum sweet potato muffin top for K-State dining services (Brazington et al., 2022)
6. Scale-up of sorghum energy bites for K-State dining services (Salmen et al., 2022)
7. Development and scale-up of a vegetarian lasagna using texturized soy protein for K-State dining services (Honor's Project) (Bhatt et al., 2024).

Table 4. Formulations Developed.

Sorghum	Wheat	Other
Savory Sorghum Waffles	Tomato Basil Parmesan Sub Buns	Pizza Taquitos
Chocolate Sorghum Cookies	Peanut Butter Apple Muffin	Vegan Breakfast Bowl
Sorghum Lemon Blueberry Muffin	Japanese Curry Buns	Tofu Pho Bowl
Sorghum Energy Bites	Multigrain Sub Bun	Vegetarian Texturized Soy Lasagna
Sweet Potato Breakfast Cookies	Chocolate Chip Cookies with a Kick	Buffalo Chicken Meatballs

Summer Internship

Three undergraduate students majoring in food science that had just completed their junior year participated in developing products. The three students expressed an interest in the project to the authors (Getty and Whitehair) and projects were selected for them. Formulations (from the senior-level capstone course) that were tested but were not scaled up included a breakfast casserole with wheat, an oat milk shake, vegetable-based crackers, and breakfast biscuit bar. The chocolate sorghum cookies, tomato basil parmesan bun, multi-grain bun, and whole grain chocolate chip cookies with a kick were all successfully scaled up as dining center recipes.

Product Consumer Acceptability and Physiochemical Properties

Examples of data from the project included consumer acceptability scores using a 9-point hedonic scale (1=extremely dislike and 9=extremely like). Physiochemical properties collected included color, volume, moisture loss, water activity, holding time-qualities, and reheat-ability. One goal of “University” Dining Services was to determine if a product could be frozen/refrigerated and reheated while maintaining its qualities to decrease waste and allow for advance food preparation, and on-demand heating. This concept provided another learning opportunity for students in the undergraduate food science research course as they were encouraged to experiment with freezing and reheating processes.

Using a 9-point hedonic scale, the sorghum waffle sandwich received scores of 7 and above for all attributes evaluated (acceptance, flavor, texture, aftertaste, and mouthfeel) (Cairns et al., 2023). The gluten-free muffins received scores of 7 and above in all categories except for texture (6.58) and mouthfeel (6.42) (Cairns et al., 2023). Figure 3 shows the volume of a gluten-free muffin during development (Cairns et al., 2023). Figure 4 was developed to provide a color scale for dining staff to use to determine if color was too light or dark (Cairns et al., 2023). The data collected showed that students were able to develop acceptable, desirable gluten-free products while using analytical methods during their participation in this undergraduate interdisciplinary research framework.

Figure 3. Lemon Blueberry Muffins Without Whipped Egg Whites (a and b) and With Whipped Egg Whites (c and d) (adapted from (Cairns et al. 2023)).



Figure 4. Gluten Free Waffle Color Scale (Light to Dark with Optimum Color Between Waffles 3 and 4) (adapted from Cairns et al. (2023)).



Student Learning Outcomes and Impact

Survey of Previous Capstone Course Years

Forty-one students took the capstone course with this interdisciplinary framework before the 2024 class. These students were mostly seniors majoring in food science. There were a few food science graduate students and a few undergraduate students majoring in baking science. All students were selected to be sent a survey. Survey links were sent to each of these past students with a 24.4% (n=10) response rate.

Responses for the previous year's survey were less positive than the 2024 survey and undergraduate research interviews. The average response percentages of strongly agree and agree responses for each category were 66% (research and laboratory skills), 73% (food production knowledge), 45% (interdisciplinary aspects), 68% (soft skills), and 67% (career preparedness and course experience/personal impact) (Figures 5-9). The previous year's survey was a survey of people who saw this framework in its earlier stages, and the framework's effectiveness increased over time, as evidenced by the more positive responses to the undergraduate research and 2024 surveys. Interdisciplinary aspects having the lowest average show that earlier in the development of the framework, students were not given equal opportunities to interact with dining center staff. This was improved in the 2024 class which observed a response of 84% for interdisciplinary aspects.

Some suggestions that were provided by respondents were to increase communication with the packaging design class, to have shorter homework assignments (and to focus more on product development than homework), and to increase the organization and guidance in the course. One respondent also mentioned that COVID-19 policies that were in place at the time impacted their course experience. There was also a respondent who credited their experiences in this course for helping them to get an internship at Kellogg's.

Interview of Undergraduate Research Course Participants

Of nine undergraduate research participants, seven agreed to be interviewed. The nine students were all food science majors with one student in chemical engineering later switching to food science. Three were sophomores and the remaining students were seniors. The average response percentages of strongly

agree and agree responses for each category were 79% (research and laboratory skills), 77% (food production knowledge), 76% (soft skills), and 71% (career preparedness and course experience/personal impact) (Figures 10-13). All averages were higher than those from the previous year's survey. The undergraduate research interview having a higher soft skill average could be due to the more independent and self-led structure of the undergraduate research class that requires students to develop skills such as time management, organization, and problem solving. This is supported by other feedback undergraduate research students gave. Multiple interviewees also brought up that this project was a great resume-builder that assisted them in obtaining their current job and improved their independent time-management and self-discipline.

Notable Quotes:

Aspects that were liked:

- "This class and the skills I learned from it were...a really great resume builder...I think this is part of the reason why I got my current job...Anything with R&D on it and showing that you almost led a project really looks really good...it shows you have those soft skills: time management, communication, you're able to adapt." - Interviewee 2
- "The time management...that really is something I was able to carry into my current job" - Interviewee 4

Suggestions for Improvement:

- "I would like to have been more organized from the beginning and have been able to have more time to run more trials and have had more time to collect more data." -Interviewee 1
- "I wish I had more opportunities for consumer feedback." - Interviewee 7

Survey of Fall 2024 Class

Eleven students took the senior-level capstone course in food product development in Fall 2024 with a 100% (n=11) response rate. The average response percentages of strongly agree and agree responses for each category were 83% (research and laboratory skills), 85% (food production knowledge), 84% (interdisciplinary aspects), 73% (soft skills), and 77% (career preparedness and course experience/personal impact) (Figures 14-18). The averages for this survey were higher than the undergraduate research interview responses in every category except for soft skills. These higher averages correlate to the framework's improvement over time as it was developed.

Packaging design interactions improved for the 2024 capstone course in comparison to previous years. Examples of packaging designs can be found in Figure 19.

Suggestions from respondents included requests for more structure/guidelines and interactions with dining center staff. This is likely because structure/guidelines were still being developed as 2024 was the first capstone class that worked to scale up their products in the dining center.

Figure 19. Packaging Designs from Fall 2024 Capstone Course (from left to right, designed by: Emerson Tarr, Kassidy Schuman, Kinsley Jordan, and Emma Sutherly).



DISCUSSION

The results demonstrate that this interdisciplinary framework successfully enhanced student learning across multiple domains. Viewed through the lens of Kolb's Experiential Learning Theory, students progressed through each stage of the learning cycle in ways that deepened their understanding of both food science and foodservice operations.

Concrete Experience Stage (CE)

The framework presented substantial, tangible experiences that were above traditional classroom activities. Students utilized real ingredients, commercial-scale equipment, and real operational constraints—experiences that are difficult to simulate in traditional laboratory settings. As one student noted in interviews, "Using the tilt skillet and convection ovens in the dining center made me realize how different large-scale production is from making a single batch in our lab." These authentic experiences created the foundation for meaningful learning by immersing students in the practical realities of food product development.

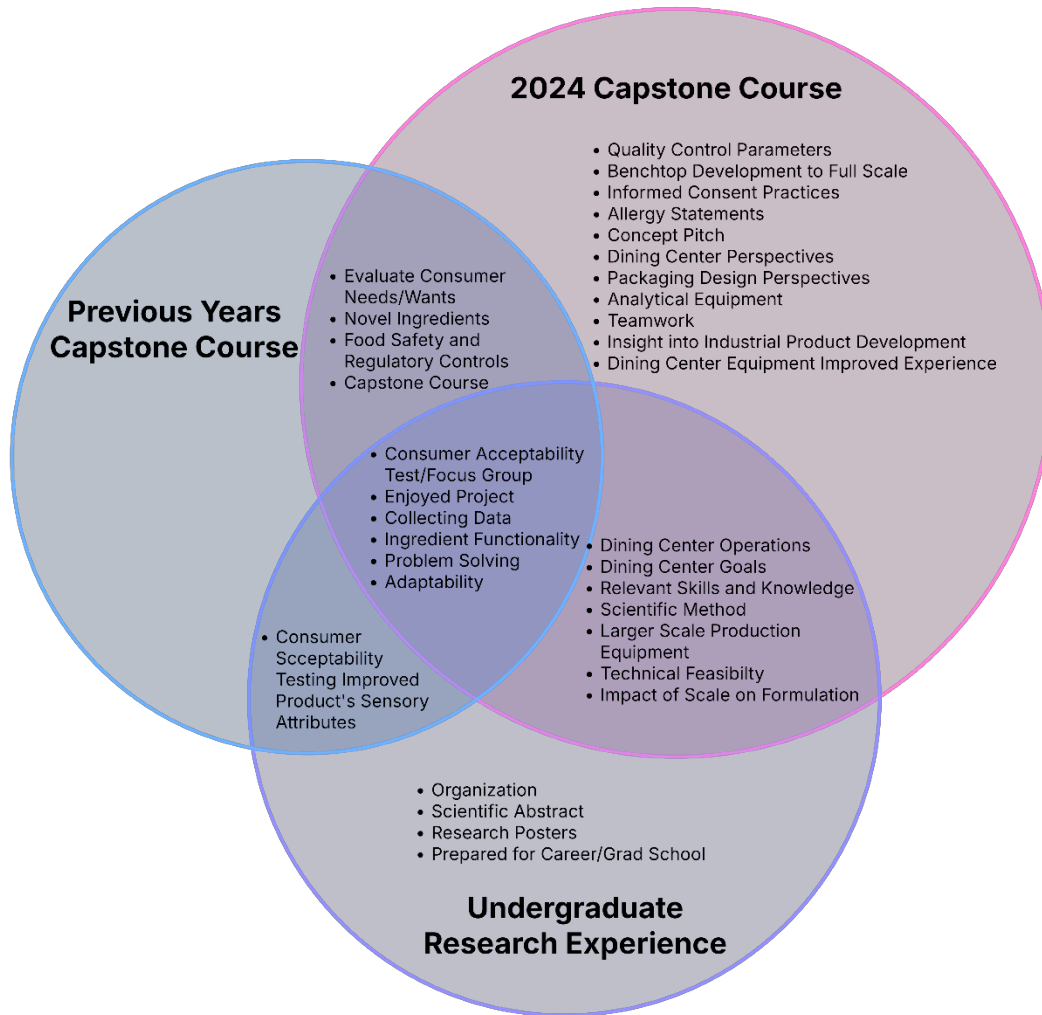
Reflective Observation Stage (RO)

The framework provided possibilities for reflective observation through multiple formulation trials, consumer feedback sessions, and reviews by dining center staff. Students had to think critically about their work and look at it from different points of view. The high ratings students gave for developing problem-solving skills (88% agreed or strongly agreed) suggest they engaged meaningfully in this reflective process.

Abstract Conceptualization Stage (AC)

Students' development of abstract conceptualization was evident in their ability to connect food science principles to practical applications. Survey responses indicated strong agreement (85%) that the experience helped them understand how ingredient functionality affects large-scale production. Students learned to conceptualize solutions based on scientific principles— For example, understanding that an increase in gluten-free sorghum flour required modifications to hydration levels and mixing durations to attain the desired product structure. The combination of theory and practice demonstrates profound understanding rather than basic knowledge.

Active Experimentation Stage (AE)

Figure 20. Benefits that 80% or More Agreed or Strongly Agreed With.

The framework provided numerous opportunities for new product development. Students did not just follow the instructions; they improved the formulations based on what they had learned before and looked at different ingredients, and adjusted processing parameters. The iterative nature of product development—with multiple formulation trials followed by scale-up testing—allowed students to experiment with their evolving understanding. This active testing and refinement of ideas completes the experiential learning cycle and prepares students for the iterative nature of professional product development work.

Beyond Kolb's Framework: Interdisciplinary Learning Benefits

The interdisciplinary aspect of the experience offered supplementary educational advantages beyond those encompassed in Kolb's framework. Students learned a practical comprehension of the operational limitations in foodservice that food scientists must consider when developing products for institutional environments. Student feedback indicates that understanding equipment limitations, labor costs, and production scheduling constraints offers valuable insights that traditional food science coursework often

overlooks. This aligns with research on multi-professional collaboration in food education, demonstrating that the incorporation of varied professional perspectives enhances students' systems thinking and their ability to address complex, real-world challenges (Janhonen & Elkjaer, 2022).

CONCLUSIONS AND APPLICATIONS

Future Use of Course Framework

This case study demonstrates that collaboration between food science programs and campus dining operations can create valuable experiential learning opportunities for undergraduate students. Based on Kolb's Experiential Learning Theory, the framework gave students real-world experiences in product development, organized chances to think about what they had learned, a conceptual understanding of food science principles in real-life situations, and hands-on experimentation with formulations and processes. Student outcomes included enhanced research skills, food production knowledge, understanding of foodservice operations, soft skills development, and increased confidence in their career preparedness.

The course framework has evolved over the years since it was initially implemented. The feedback we received from students throughout each version of the course development has assisted in identifying improved methods and recommendations for future implementation. Consistent benefits identified included improved student problem-solving and adaptability skills, experience with data collection and ingredient functionality, hands-on consumer acceptability testing, and student enjoyment (Figure 20). Dining Services consistently received formulations/quantity recipes throughout the program, providing them with new products without increased labor needs.

Students gained more experience and benefited most from iterations of the program where they worked more closely with the dining center staff (undergraduate research course and the 2024 senior-level capstone course). Students of the 2024 capstone course, who took the product from an initial concept to full scale, received the most hands-on experience (Figure 20).

Moving forward this program would continue to benefit from including both the capstone course and undergraduate research course component. The capstone course would involve students meeting with dining center representatives, touring facilities, learning about available production equipment, and identifying menu goals and expectations. Students would individually conduct market screening research and present product concepts. Based on enrollment and dining center needs, appropriate concepts would be selected to move forward into development. Students would work in groups of 2-3 to develop initial product prototypes. Initial product prototypes would be reviewed by dining center staff and products would be selected for scale-up and recipe formulation in the dining center. Students would be regrouped, allowing everyone to be involved in the scale-up of one of the selected formulations. Scaled-up products would be put forth for consumer acceptability testing in the dining center. Once all data is collected, students will compose industrial-style reports and quantity recipes.

Product concepts that were presented but not selected for further development can be used by an undergraduate research course, dietetic interns, or other courses needing applied recipe development experiences in partnership with the dining center. Each student would be assigned a product, allowing them to be responsible for the time management, project planning, and organization required for scale-up of the product. Guidance would still be provided by the instructor, preceptor, internship director, or mentor, but the project would be more independently run by the student. Dining center staff would still actively engage and provide feedback. These students would have access to large-scale equipment for

scale-up and access to run consumer acceptability tests in the dining center. The data and experience could then be utilized for an abstract, poster presentation, or internship competency report.

In conclusion, this interdisciplinary framework addresses a significant gap in food science education by providing students with authentic, hands-on experience that bridges academic coursework and professional practice. By partnering with existing campus resources, dining services that already prepare thousands of meals daily—institutions can create robust experiential learning opportunities without requiring extensive external partnerships or additional infrastructure. The framework benefits both students, who gain practical skills and confidence, and dining centers, which receive menu innovation and student engagement. As the food industry continues to demand graduates with both technical competencies and professional skills, models like this that integrate experiential learning with interdisciplinary collaboration will become increasingly important in food science education.

REFERENCES

Adebisi, Y. A. (2022). Undergraduate students' involvement in research: Values, benefits, barriers and recommendations. *Annals of Medicine and Surgery*, 81. <https://doi.org/10.1016/j.amsu.2022.104384>

Bhatt, A., Baonga, K., & Getty, K. J. K. (2024). *Development and scale-up of a vegetarian lasagna using texturized soy protein for K-State dining services (Honor's Project)* [Poster and Oral Presentation]. ASI/FDSCI Undergraduate Research Symposium.

Bohn, D. M., & Schmidt, S. J. 2008. Implementing experiential learning activities in a large enrollment introductory food science and human nutrition course. *Journal of Food Science Education*. <https://doi.org/10.1111/j.1541-4329.2007.00042.x>

Boyer Commission on Educating Undergraduates in the Research University. (1998). *Reinventing undergraduate education: A blueprint for America's research universities*. Stony Brook University.

Brazington, S., Getty, K. J. K., & Whitehair, K. (2022). *Development and scale-up of a gluten-free sorghum sweet potato muffin top for K-State dining services* [Poster and Oral Presentation]. ASI and FDSCI Undergraduate Research Symposium.

Cairns, A. C., Brazington, S., Gragg, E., Holmes, A., Vavra, C., Whitehair, K., & Getty, K. (2023). Development and scale-up of gluten-free sorghum-based bakery goods for K-state Dining Services. *Journal of Agriculture and Food Research*, 14, 100840. <https://doi.org/10.1016/j.jafr.2023.100840>

Caspi, C. E., Canterbury, M., Carlson, S., Bain, J., Bohen, L., Grannon, K., ... & Pratt, R. (2021). A behavioural economics approach to improving healthy food selection among food pantry clients. *Public Health Nutrition*, 24(10), 3027-3039. <https://doi.org/10.1017/S1368980020002256>

Cairns, A. C., Getty, K. J. K., & Whitehair, K. (2021). *Scale-up of Japanese curry buns for K-State dining services* [Poster and Oral Presentation]. KSU Gamma Sigma Delta Undergraduate Symposium and ASI and FDSCI Undergraduate Research Symposium.

Choi, B. C. K., & Pak, A. W. P. (2006). Multidisciplinarity, interdisciplinarity and transdisciplinarity in health research, services, education and policy: 1. Definitions, objectives, and evidence of effectiveness. *Clinical and Investigative Medicine. Medecine Clinique Et Experimentale*, 29(6), 351–364.

Edwards, J. S. A. (2013). The foodservice industry: Eating out is more than just a meal. *Food Quality and Preference*, 27(2), 223–229. <https://doi.org/10.1016/j.foodqual.2012.02.003>

Frodeman, R., Klein, J. T., Mitcham, C., & Holbrook, J. B. (Eds.). (2010). *The Oxford handbook of interdisciplinarity*. Oxford University Press.

Getty, K. J. K., & Whitehair, K. (2022). *FarmUS Recipe Book*. <https://acrobat.adobe.com/link/review?uri=urn%3Aaaid%3Ascds%3AUS%3Ac3834f7d-4470-3f2e-814d-73dd60b36c3d>

Getty, K. J. K., Whitehair, K., & Amamcharla, J. (2021). *Formatting a product development capstone course for development of grain-based baked items for use in Kansas State University dining services* [Poster Presentation]. Ann. Mtg., Inst. of Food Technologist, Chicago (Virtual Format).

Getty, K. J. K., Whitehair, K., Brazington, S., Gragg, E., Holmes, A., & Vavra, C. (2022). *Development and scale-up of the gluten-free sorghum-based bakery goods for K-State dining services* [Poster Presentation]. Cereal and Grains Association 2022 Ann. Mtg.

Getty, K. J. K., Whitehair, K., & Jones, C. (2022, July 10). *Creating undergraduate research experiences in product development of grain-based food products for KSU dining halls* [Poster Presentation]. Ann. Mtg., Inst. of Food Technologist, Chicago.

Hollis, F. H., & Eren, F. (2016). Implementation of real-world experiential learning in a food science course using a food industry-integrated approach. *Journal of Food Science Education*, 15(4), 109-117. <https://doi.org/10.1111/1541-4329.12092>

Holmes, A., Getty, K. J. K., & Whitehair, K. (2021). *Development gluten-free blueberry muffin for K-State dining services* [Poster and Oral Presentation]. ASI and FDSCI Undergraduate Research Symposium.

Institute of Food Technologists [IFT]. (2011). *Feeding the minds that will feed the world: IFT education update 2011*. <https://www.ift.org/>

IFT. (2018). *IFT Guidelines for Undergrad Programs*. IFT. <https://www.ift.org/-/media/community/pdfs/educators-herb/ift-2018-herb-guidelines-for-initial-ift-approval-april-2025.pdf>

Janhonen, K., & Elkjær, B. (2022). Exploring sustainable food education as multi-professional collaboration between home economics and school food catering. *Journal of Education for Sustainable Development*, 16(1-2), 19-41. <https://doi.org/10.1177/09734082221120101>

Kolb, D. A. (2014). *Experiential learning: Experience as the source of learning and development* (2nd ed.). Pearson Education.

Kolb, A. Y., & Kolb, D. A. (2017). Experiential learning theory as a guide for experiential educators in higher education. *Experiential Learning & Teaching in Higher Education*, 1(1), 7-44.

Linn, M. C., Palmer, E., Baranger, A., Gerard, E., & Stone, E. (2015). Undergraduate research experiences: Impacts and opportunities. *Science*, 347(6222), 1261757. <https://doi.org/10.1126/science.1261757>Malan, H.,

Watson, T. D., Slusser, W., Glik, D., Rowat, A., & Prelip, M. (2020). Challenges, opportunities, and motivators for developing and applying food literacy in a university setting: A qualitative study. *Journal of the Academy of Nutrition and Dietetics*, 120(1), 33-44. <https://doi.org/10.1016/j.jand.2019.06.003>

Martin, R., Getty, K. J. K., & Whitehair, K. (2021). *Development and scale-up of peanut butter apple muffin* [Poster and Oral Presentation]. KSU Gamma Sigma Delta Undergraduate Symposium and ASI and FDSCI Undergraduate Research Symposium.

Masdarina, M., & Martsiti, Y. (2024). The effect of project-based learning on collaboration skills in food and beverage service courses. *Journal of Vocational Education Studies*, 7(1), 45-58.

Morton, L. W., Eigenbrode, S. D., & Martin, T. A. (2015). Architectures of adaptive integration in large collaborative projects. *Ecology and Society*, 20(4). <https://www.jstor.org/stable/26270306>

National Academy of Sciences, National Academy of Engineering & Institute of Medicine. (2005). *Facilitating Interdisciplinary Research*. National Academies Press (US). <https://doi.org/10.17226/11153>

Petrella, J., & Jung, A. (2008). Undergraduate Research: Importance, Benefits, and Challenges. *International Journal of Exercise Science*, 1(3), 91-95. <https://doi.org/10.70252/MXRI7483>

Reinventing Undergraduate Education: A Blueprint for America's Research Universities. (1998). Boyer Commission on Educating Undergraduates in the Research University, Room 310, Administration Bldg. <https://eric.ed.gov/?id=ED424840>

Russell, S. H., Hancock, M. P., & McCullough, J. (2007). Benefits of Undergraduate Research Experiences. *Science*, 316(5824), 548-549. <https://doi.org/10.1126/science.1140384>

Salmen, K., Getty, K. J. K., & Whitehair, K. (2022). *Scale-up of sorghum energy bites for K-State dining services* [Poster and Oral Presentation]. ASI and FDSCI Undergraduate Research Symposium.

Specht, A., & Crowston, K. (2022). Interdisciplinary collaboration from diverse science teams can produce significant outcomes. *PLOS ONE*, 17(11), e0278043. <https://doi.org/10.1371/journal.pone.0278043>

Struijk, L. N. S. A., Kanstrup, A. M., Bai, S., Bak, T., Thøgersen, M. B., Mohammadi, M., Bengtson, S. H., Kobbelaar, F. V., Gull, M. A., Bentsen, B., Severinsen, K. E., Kasch, H., & Moeslund, T. B. (2022). The impact of interdisciplinarity and user involvement on the design and usability of an assistive upper limb exoskeleton—A case study on the EXOTIC. *2022 International Conference on Rehabilitation Robotics (ICORR)*, 1-5. <https://doi.org/10.1109/ICORR55369.2022.9896500>

USDA ERS - Food Service Industry. (n.d.). Retrieved November 7, 2024, from <https://www.ers.usda.gov/topics/food-markets-prices/food-service-industry/>

Vavra, C., Gragg, E., Getty, K. J. K., & Whitehair, K. (2021). *Development and scale-up of the gluten-free savory breakfast waffle sandwich for K-State dining services* [Poster and Oral Presentation]. KSU Gamma Sigma Delta Undergraduate Symposium and ASI and FDSCI Undergraduate Research Symposium.

Research Manuscript

Development and Scaling Soy Taco Crumble: A Study of University Students' Perceptions and Preferences for Soy-Based Foods

Sadaf Azhar¹, Jacqueline (Aenlle) Wegley², Nellie Hill-Sullins³, Kelly J. Whitehair⁴ and Kelly J.K. Getty⁵

¹Department of Grain Science and Industry, Kansas State University 1; Sadafa@ksu.edu

²Department of Communications and Agricultural Education, Kansas State University 2; jaenlle@ksu.edu

³Agricultural & Natural Resources Communications, Kansas State University 3; nlhill@ksu.edu

⁴College of Health and Human Sciences, Kansas State University 4; stirtz@ksu.edu

⁵Department of Grain Science and Industry, Kansas State University 5; kgetty@ksu.edu

ABSTRACT

The abstract should not contain references, tables, drawings, diagrams, or unrecognized abbreviations. Our study explores the development and scaling of a soy taco crumble, a plant-based menu item, for university dining centers. Through a mixed-methods approach including focus groups, surveys, and sensory evaluations, our study assessed college students' perceptions and preferences regarding soy-based foods. Focus group participants indicated limited knowledge about soy and its nutritional benefits. To address this gap, educational infographics, visually designed materials highlighting the health and nutritional benefits of soy-based proteins, were developed and displayed alongside the soy taco crumble at dining centers. After viewing the infographics, 56% of students expressed increased willingness to try soy-based products. Sensory evaluation revealed strong consumer acceptance, with high ratings for flavor ($M = 7.41 \pm 1.35$), aroma ($M = 7.19 \pm 1.51$), and overall acceptability ($M = 7.54 \pm 1.17$) on a 9-point Hedonic Scale ($n = 208$). This research provides valuable insights for promoting sustainable plant-based food options in foodservice settings.

Keywords: Plant-based foods; Consumer acceptance; Foodservice; Sustainable food systems; Foodservice innovation.

Acknowledgement: The authors thank the participating students for their valuable contributions to this study. Funding was received from the Kansas Soybean Commission, Topeka, Kansas.

INTRODUCTION

The global food system faces complex challenges as the world population is projected to reach approximately 9.7 billion by 2050 (Karabulut et al., 2024). Meeting the nutritional needs of this growing population in a sustainable and health-conscious manner requires a fundamental transformation in how food is produced, consumed, and perceived. Among the most urgent priorities is the need to reduce the environmental footprint of food production while ensuring broad access to high-quality protein sources (Institute of Food Technologists [IFT], 2023). In response, the food industry, particularly the foodservice sector, is placing greater emphasis on sustainability and exploring alternative protein solutions (Seo et al., 2023).

Plant-based proteins have gained considerable attention from food manufacturers, restaurants, and consumers for their potential to address environmental degradation, public health concerns, and ethical considerations (Seo et al., 2023). Plant-based proteins offer many nutritional benefits and are seen as more environmentally sustainable and ethical options, addressing growing concerns related to environmental degradation, human health, and animal welfare (Karabulut et al., 2024; Lin et al., 2017; Sun et al., 2018).

Among plant-based protein options, soybeans (*Glycine max*) stand out for their nutritional density, functional versatility, and global availability (Dias et al., 2024). Comprising approximately 35–40% protein and 21% oil by dry weight, soybeans contain all nine essential amino acids, along with vitamins, flavonoids, and polysaccharides (Capriotti et al., 2014; Henkel, 2000; Sasi et al., 2022). Their physicochemical properties, such as water-holding capacity, emulsification, and gelling, further enhance their value in formulating diverse plant-based products (Ahmad et al., 2022).

Despite these advantages, broader adoption of soy-based foods has been hindered by consumer concerns related to sensory attributes, such as taste, texture, and appearance, as well as perceptions of over-processing and lack of natural properties (Broad, 2020; Fresán et al., 2020; Hartmann & Siegrist, 2020; Jahn et al., 2021; Michel et al., 2021;). These barriers illustrate the complexity of food choices, which are shaped not only by nutritional content but also by psychological, cultural, and contextual factors. Consequently, researchers have increasingly drawn on qualitative methods such as focus groups and quantitative methods including behavioral science frameworks to better understand how attitudes, beliefs, and social norms affect consumer intentions and behaviors (Arkorful et al., 2022; McEachan et al., 2011; Riebl et al., 2015;).

Focus group discussions offer a dynamic platform for participants to build on one another's ideas, generating rich, contextual data (Belk et al., 2013; Maitiniyazi & Canavari, 2020). The Theory of Planned Behavior (TPB) is a widely accepted model for predicting consumer behavior (Ajzen, 1991). According to TPB, behavioral intentions are shaped by three cognitive factors: attitudes toward behavior, subjective norms, and perceived behavioral control (Ajzen, 1985; Tian et al., 2023). This theoretical framework has been used extensively to examine food-related behaviors such as healthy eating, fruit and vegetable consumption, and the adoption of plant-based diets (Biasini et al., 2021; Carfora et al., 2016; Contini et al., 2020; Gifford et al., 2024; Wang & Scrimgeour, 2021).

University students represent a particularly relevant demographic for examining these issues, as they are in a formative stage of developing long-term dietary habits (Deliens et al., 2014). Their food choices are often influenced by a combination of emerging independence, peer dynamics, campus food environments, and evolving health beliefs (Deliens et al., 2014). Yet limited research exists on this college students' perceptions and acceptance of soy-based foods, despite their potential to drive future shifts in consumption patterns (Malan et al., 2020). Investigating their attitudes can yield valuable insights for promoting sustainable eating practices within university dining centers.

To address this limited research on college students' perceptions and acceptance of soy-based foods, and the lack of studies integrating behavioral theory with product development and sensory evaluation in college dining settings. The present study employed mixed-methods design. Focus group discussions were conducted to explore qualitative perspectives and uncover the nuances of college student attitudes towards soy-based foods. The focus group discussion questions were constructed to explore college students' prior knowledge of soy, attitudes toward plant-based proteins, and reactions to educational materials. Findings from the focus group discussions informed the design of an online survey grounded in the TPB, enabling a quantitative assessment of students' attitudes perceived behavioral control regarding soy food consumptions. Our study also evaluates the sensory dimensions of soy-based food acceptance among university students. A soy taco crumble product was formulated, scaled up, and evaluated at Kansas State University dining centers for key physicochemical attributes—such as moisture content, pH, color, and water-holding capacity—as well as sensory acceptance through a structured consumer panel with university students. By integrating behavioral, educational and sensory aspects, our study provides a more comprehensive understanding of the factors influencing plant-based food adoption among university students.

MATERIALS AND METHODS

Prior to conducting the research, the research protocol approval was obtained from Kansas State University's Institutional Review Board (IRB#11516). The study incorporated qualitative and quantitative methods, leveraging focus groups, online surveys based on the TPB, and product development aspects.

Qualitative Research: Focus Groups

In the first phase, the researchers conducted focus groups to gather qualitative data on college students' perceptions of soybeans and soy-based food products. A moderator's guide was developed by a master's student, which was reviewed and refined for clarity, neutrality, and question flow by undergraduate students to minimize bias and improve the quality of the research under the direction of one of the researchers (Creswell & Creswell, 2017). The undergraduate students were enrolled in the course "Undergraduate Research in Agricultural Communications" and were taught qualitative methods for conducting research. The undergraduate students' revisions suggested to reduce leading questions and improve the logical sequencing of topics.

Focus group participants were recruited using a pre-focus group survey registration form linked to a flyer that contained a quick response (QR) code. The flyer was distributed (approximately n=150) in the dining centers and public spaces in residence halls. Two focus group discussions were conducted based on participant availability, as scheduling was constrained by college students' class schedules and dining center operating hours. Each focus group discussion lasted 60–75 minutes and moderated by undergraduate students. The focus group discussions took place in private rooms near the dining centers at Kansas State University. The round table seating arrangement was used, which promoted inclusivity and equal participation among the participants, a common strategy in focus group research (Stewart & Shamdasani, 2014). To ensure an accurate and thorough analysis of the focus groups, conversations (audio) of each focus group were captured through Owl microphones (360° video conferencing device)(Makeev & Schnittman, 2014) and recorded through the Zoom software (Zoom Video Communication, Inc., San Jose, CA) on a laptop. For backup recording, a mobile phone with Otter.ai® Transcription Software (Mountain View, California) also captured and transcribed the audio in real time and kept for future analysis. These recordings were securely stored in Microsoft Teams® (Microsoft, Redmond, WA) for further analysis by the research team.

The first focus group discussion consisted of five participants, two moderators, and two note-takers, while the second group had six participants, two moderators, and one note-taker. The five and six

participants for each focus group discussion are respectively consistent with recommendations for small, manageable group size of 4-8 participants that facilitate in-depth discussion and ensure all voices are heard (Krueger & Casey, 2015). Moderators distributed informed consent forms and sample infographics before the discussion began. The researchers refrained from participating by not being present in focus groups to avoid bias. All participants provided written informed consent, including consent for audio and video recording of the focus group sessions, as approved by the Institutional Review Board (IRB#11516). After reading the consent forms, participants engaged in discussions on soy-based food products and infographics (soy sauce, hidden sources of soy, and soy-based food products). Participants were general college students recruited without any requirement for prior knowledge or expertise in soy-based products, as the study aimed to capture a range of familiarity levels. At the end of the discussions the ice cream coupons were distributed as a token of appreciation.

Quantitative Research: Online Surveys

In the second phase, the infographics were developed by one of the researchers to cover various aspects of soy-based foods, aiming to influence the college students' willingness to consume these products. Four distinct infographics were created—"Meat-Alternative Protein," "Plant-Based Protein," "Soy-Based Protein," and "Soybean-Based Protein" (Figure 1). While the content of each infographic remained identical, the main heading was varied to evaluate which title resonated most with college students and whether the wording influenced their intention to consume soy-based food products. Each infographic was designed to educate college students about the health benefits of soy, particularly its status as a complete protein containing all nine essential amino acids. Since focus group findings indicated limited nutritional knowledge about soy, the infographics used simple visuals, comparisons between protein sources, and concise text to present this information in an accessible format.

A survey was designed using the TPB to assess college students' attitudes, social norms, and perceived behavioral control constructs regarding soy-based foods. The TPB framework was used to evaluate how college students' intentions to consume soy-based food products change after viewing the infographic. The survey was adapted and modified from previous studies, utilized a 5-point Likert scale. (Devraj et al., 2022; Egan et al., 2021; Pandey et al., 2021; Van Hecke et al., 2020. Attitudinal items addressed sustainability, health benefits, and eco-friendliness; social norms examined peer and family influence; and perceived control measured confidence in decision-making (Ajzen, 1991). The results offered insights into how educational tools like infographics can impact consumer behavior by shaping key cognitive factors. The key cognitive factors were identified by the TBP, specifically by improving attitudes toward soy-based foods, increasing perceived social acceptance, and enhancing students' confidence in choosing plant-based options.

A pilot survey with 30 college students was conducted to assess reliability. Cronbach's alpha showed high reliability for attitudes (0.880) and social norms (0.917), while items on perceived behavioral control (0.609) and intention (0.618) were revised for improvement. The questions about perceived behavioral control and intention needed revision to improve internal consistency among the construct items, as Cronbach's alpha values are below the acceptable threshold of <0.70 (Bonett & Wright, 2015). The questions were rephrased for perceived behavioral control and intentions to ensure stronger alignment with one another and with the underlying TPB constructs, thereby improving the scientific rigor of the instrument and achieving higher Cronbach's alpha values for these scales. The final survey, distributed via Qualtrics®, an online survey platform (Qualtrics®, Provo, UT, USA), from March 4 to April 15, 2024, targeted college students dining at Kansas State University's dining centers. Participants were shown one of four randomly assigned infographics for 30 seconds, then responded to questions on attitudes, social norms, perceived control, and intention to consume soy-based foods. Two \$100 Amazon gift cards were offered as incentives.

Commented [JR1]: remove the period here

Figure 1: Developed Infographic With “Plant-Based Protein” Heading



Product Development, Scale-up, and Evaluation

The third phase focused on developing a soy taco crumble as a scalable menu item for Kansas State University dining centers, which serve approximately 2,200 college students daily. The graduate student led the scale-up process, adjusting the recipe (spice levels, oil usage, and soaking times for TSP) based on consumer preferences and enduring compatibility with industrial kitchen equipment. The product was prepared four times at Kramer Dining Center and three times at Derby Dining Center to assess large-scale feasibility.

Cooking methods and conditions for the soy taco crumble were adapted from Heywood et al. (2002), following a standardized protocol. Texturized soy protein (TSP) from Bob’s Red Mill Natural Foods® (Milwaukie, OR, USA) was soaked in vegetable broth from Sysco® (Houston, TX, USA) for 15-20 minutes, then drained. Post-draining weight was recorded to calculate cooking loss percentage.

The rehydrated TSP was then transferred to a preheated tilt skillet at 250°F (121°C) with Crisco® vegetable oil and cooked for 5 minutes at 200-250°F (93-121°C) to achieve uniform texture. A blend of seasonings, including dried onions, salt, chili powder, cornstarch, cayenne pepper, garlic powder, oregano, cumin, and cilantro was folded in. And cooking continued for an additional 5 minutes, maintaining a temperature of 135-145°F (57-63°C) to allow for flavor development. Internal temperature was monitored using an AquaTuff® 352 thermometer (Middlefield, CT, USA).

To evaluate performance under foodservice conditions, soy taco crumble was tested under refrigerated (3 and 7 days) and frozen (14 and 21 days) conditions. Storage intervals of 3 and 7 days (refrigerated) and 14 and 21 days (frozen) were selected to represent typical short-term and extended storage durations

encountered in university dining center operations. Reheating in a steamer took 12-15 minutes at $\geq 165^{\circ}\text{F}$ (74°C) for the refrigerated product and 35-40 minutes for the frozen product at $\geq 165^{\circ}\text{F}$ (74°C) without thawing. Reheating time can be reduced if the product is thawed in advance.

Physicochemical Analysis

After finalizing the recipe, physicochemical properties—moisture content, pH, color, cooking loss, and water-holding capacity—were evaluated following established methods (Wi et al, 2020; Zhou et al, 2022). Cooking loss was calculated as the percentage weight difference between rehydrated TSP before and after cooking (Zhou et al., 2022). Water-holding capacity was measured using low-speed centrifugation (3,000 RPM) for 15 minutes, comparing sample weight before and after centrifugation (Wi et al., 2020; Zhang et al., 1995). Color measurements (L^* , a^* , b^*) were taken using a portable HunterLab MiniScan EZ colorimeter (Model 4500L, Reston, VA, USA) calibrated with black-and-white standards. pH was measured using a digital pH meter (Fisherbrand™ Accumet™ AP110, Pittsburgh, PA, USA) with 3 g of sample homogenized in 20 ml distilled water. Moisture content was determined by oven-drying 5 g samples at 50°C for 24 hours (AOAC, 2005). Moisture was measured at three intervals: immediately after cooking, and after 30 and 60 minutes on the serving line. Approximately 30 g samples were collected before and after cooking for color, pH, cooking loss, and water-holding capacity analyses.

Sensory and Consumer Evaluation

Sensory evaluation, a key predictor of consumer acceptance (Aschemann-Witzel et al., 2019). Sensory evaluations were conducted with college students and dining staff. During product development, (n=86) undergraduate college students in “Fundamentals of Food Processing” course evaluated two versions (standard seasoning and 125% increased seasoning) of soy taco crumble, using the 9-point Hedonic Scale (1 = dislike extremely, 9 = like extremely) for flavor, texture, color, aroma, saltiness, and overall acceptability (Lawless & Heymann, 2010). Dining center staff (n=9) also evaluated the product using the same scale.

Each panelist evaluated only one version, served with tortilla chips, at a designated classroom testing station. This feedback guided adjustments to seasoning and other key characteristics for final scale-up. Based on the results, seasoning increased by 125% to better align with consumer preferences. Dining center staff also conducted a sensory evaluation, using the same Hedonic Scale to rate acceptance, flavor, texture, color, seasoning, and aroma (n=9). This feedback reinforced the decision to increase seasoning and served as operational validation.

To test the effectiveness of the infographic, a soy-based food product (soy taco crumble) was served at Kansas State University’s Kramer and Derby dining centers. The “plant-based protein” infographic, which received the most positive feedback, was displayed alongside the soy taco crumble at Kramer dining center for two hours on two different days at the southwestern serving line. The same food product was served without the infographic at Derby dining center for a similar duration. This setup was designed to allow for a preliminary comparison of the infographic’s effect on consumer selection behavior, acknowledging that a controlled experimental design would be needed to establish causality.

Figure 2: Kramer Dining Center Consumer Acceptance Testing Station**Figure 3: Derby Dining Center Consumer Acceptance Testing Station (Infographic Not Viewable In This Picture But At The Left Of The Serving Line)**

For final consumer testing, soy taco crumble was served for two hours at both dining centers. At Kramer, a testing table was placed near the entrance (Figure 2), while Derby served it directly on the line due to space constraints (Figure 3). The product was served with tortilla chips and accompanied by a “Plant-Based Protein” infographic to provide educational context. Consumer acceptance is essential for successful adoption of plant-based meat alternatives, as it is influenced by taste along with ethical considerations (e.g., animal welfare), political factors (e.g., agricultural policy, food labeling regulations, and government subsidies for plant-based versus animal agriculture), and environmental concerns (e.g., carbon footprint reduction) (Fiorentini et al., 2020).

DATA ANALYSIS

Qualitative Research: Focus Groups

Qualitative analysis of focus group data provided in-depth insights into college students' perceptions of soybeans and soy-based foods. Audio recordings were transcribed using the Otter.ai® and reviewed for accuracy. Thematic analysis, a popular method for organizing qualitative data into thematic groups, was employed to identify patterns and themes within the data (Braun & Clarke, 2006). Coding was performed in two cycles.

In the first cycle, inductive line-by-line coding allowed themes to emerge organically without preconceived categories. The second cycle used pattern coding to identify recurring themes and align findings with the research questions. Themes were formed by grouping related codes to construct a

coherent narrative of college students' attitudes and perceptions. To enhance credibility, peer debriefing was conducted, ensuring accurate and unbiased interpretations (Hadi & José Closs, 2016).

Quantitative Research: Online Survey Statistical Analysis

The internal consistency of the survey constructs (attitude, social norms, perceived behavioral control, and intention) was assessed using Cronbach's alpha. Values greater than 0.70 indicated high internal reliability. The Spearman rank-order correlation was applied to examine the relationships between intention and other constructs. All analyses were conducted using SAS® software, Version 9.4 (SAS Institute Inc., Cary, NC, USA).

Product Development: Data Analysis

Focus group audio recordings were transcribed and analyzed using thematic analysis (Braun & Clarke, 2006). Inductive line-by-line coding was followed by pattern coding to identify recurring themes, with peer debriefing to ensure credibility (Hadi & José Closs, 2016). Survey construct reliability was assessed using Cronbach's alpha, and Spearman rank-order correlations examined relationships between intention and other TPB constructs. Physicochemical results are presented as mean \pm standard deviation and SEM, with factorial ANOVA and post hoc Tukey HSD tests performed. All quantitative analyses were conducted using SAS® software, Version 9.4 (SAS Institute Inc., Cary, NC, USA).

RESULTS AND DISCUSSION

Qualitative Research: Focus Group Results

Two focus groups with 11 student participants were conducted, and key themes are summarized in Table 1. Participants reported learning about soybeans through schools, personal experiences, cultural influences, and informal discussions. While they recognized soy as a protein-rich meat alternative, most lacked awareness of its broader nutritional benefits. Participants also emphasized the importance of balancing familiar and new experiences when it comes to soy foods. They expressed comfort with soy sauce due to its flavor and versatility and noted that tofu could be incorporated in various ways—as a main dish, side, or complement. Overall, savory soy foods were preferred over sweet ones. Participants also suggested innovative uses for soy-based ingredients, such as adding soy flour to pizza dough and using soy milk in smoothies or juice blends. However, they expressed concern about soy being marketed solely as a hidden protein source or meat substitute, preferring soy products with unique identities. They also responded positively to infographics that featured clear, concise titles, clean layouts, and visually engaging designs in larger formats.

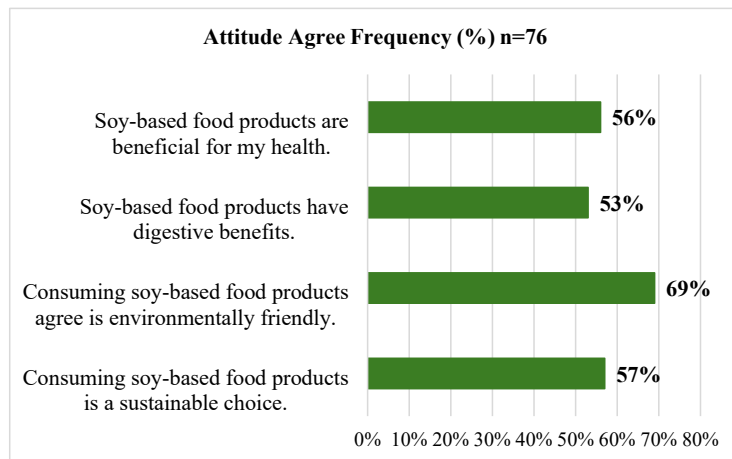
Table 1: Developed Themes from Focus Group Analysis (n=11)

Themes	Description
Source of Awareness	Awareness of soy stemmed from education, culture, or personal exposure.
Nutritional Knowledge	Participants recognized soy as a protein source but lacked deeper nutrition knowledge.
Familiarity & Openness	Preference for familiar foods with openness to innovative soy-based products.
Savory Preference	Soy was favored in savory dishes, with shared ideas for creative uses.
Soy Stigma	Concerns were raised about soy being viewed only as a meat substitute.
Infographic Appeal	Visually engaging, well-structured infographics were preferred for learning.

Focus Group Discussion and Implications

These qualitative findings carry several implications for foodservice operations and plant-based product development. The limited nutritional knowledge reported by participants suggested that university dining centers should consider integrating educational strategies, such as infographics and point-of-sale signage, to bridge the gap between awareness and consumption. The preference of savory soy-based products over sweet alternatives provides actionable guidance for menu development, suggesting that soy-based items positioned as flavorful entrées rather than health-oriented substitutes may achieve greater acceptance. Notably, participants' concerns about soy being marketed solely as a "hidden" protein or meat substitute highlight the importance of branding and product identity in shaping consumer perceptions. This finding aligns with previous research indicating that how plant-based products are framed significantly influences consumer willingness to try plant-based products (Jahn et al., 2021; Michel et al., 2021). Additionally, participants' positive response to well-designed infographics underscores the potential of visual educational tools to improve attitudes toward unfamiliar food products, a finding that directly informed the development of the infographic intervention used in the subsequent survey phase of this study.

Figure 4: Participants' Attitude Agree Frequency (%)

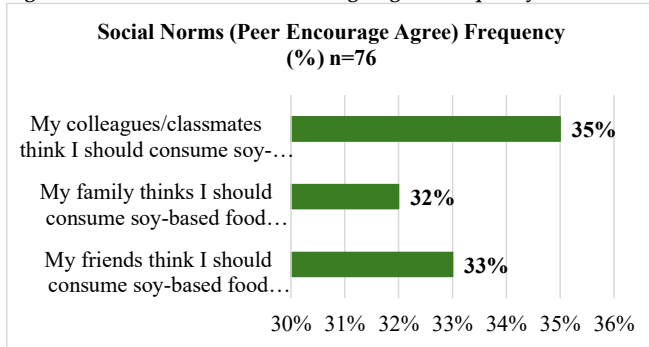


Quantitative Research: Results

Out of 82 survey respondents, 76 valid responses were collected. The average participant age was 25.41 years, with 18 males (23.68%), 54 females (71.05%), and four others (5.26%). Most participants were freshmen (65.79%), and majors spanned fields like agriculture (14.47%), arts and sciences (25%), and engineering (15.79%).

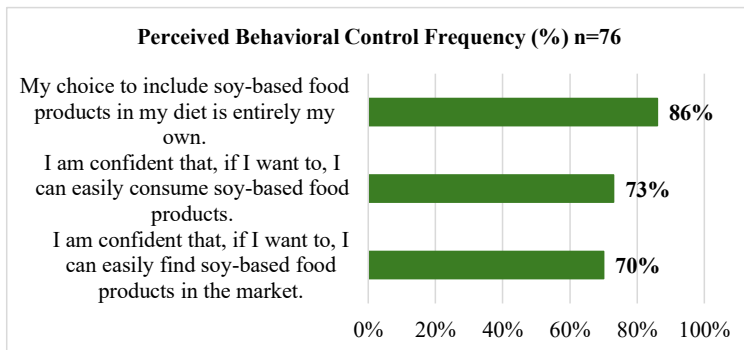
Figures 4, 5, and 6 present the college students' attitudes, social norms, and perceived behavioral control towards the intention to consume soy-based food products. Cronbach's alpha test was utilized to evaluate the construct's reliability (Santos, 1999). Cronbach's alpha ranged from 0.87 for attitude, 0.92 for social norms, and 0.87 for intention indicating an acceptable consistent limit of >0.70 among the items of respective construct (Bonett & Wright, 2015). The proposed theoretical model has adequate convergent and discriminant validity and reliability measures except perceived behavioral control construct with a Cronbach's alpha of 0.52.

Figure 5: Social Norms (Peer Encourage Agree) Frequency (%)



After viewing the infographic, 38% of college students reported a change in perception toward soy products, and 56% expressed willingness to try them. The “plant-based protein” infographic, with a Cronbach’s alpha of 0.808, was identified as the most effective and selected for dining center testing. To assess the infographic impact, soy taco crumble was served at Kramer Dining Center with the infographic for 2 hours and at Derby without infographic but with a placard entitled “taco seasoned vegan protein *contains soy” during a similar timeframe. At Kramer, 20 consumers selected the dish, compared to 9 at Derby, suggesting that infographics may positively influence consumer behavior. However, other factors such as seating capacity and other menu offerings may also have contributed to the difference.

Figure 6: Perceived Behavioral Control (Agree) Frequency (%)



Survey Discussion and Implications

The survey results, grounded in the Theory of Planned Behavior (TPB), provide meaningful insights into the cognitive factors influencing college students’ intentions to consume soy-based foods. The high Cronbach’s alpha values for attitude (0.87), social norms (0.92), and intention (0.87) constructs confirm the reliability of the survey instrument, while the lower value for perceived behavioral control (0.52) suggests that future research should refine this construct to better capture students’ confidence in accessing and choosing soy-based options. The finding that 56% of students expressed willingness to try soy-based products after viewing the infographic is particularly noteworthy for foodservice practitioners, as it demonstrates that brief educational interventions can meaningfully shift consumer attitudes. The preliminary comparison between Kramer (with infographic) and Derby (without infographic) dining

centers, where consumer selection was more than double at the infographic-equipped location, further supports the practical value of point-of-sale educational materials. However, it is important to acknowledge that this comparison was observational rather than experimentally controlled, and differences in foot traffic, seating capacity, menu variety, and dining center layout may have contributed to the observed difference. Future studies should employ randomized, controlled designs with larger sample sizes to establish a causal relationship between infographic exposure and consumption behavior.

Product Development: Results

Ingredients and Formulations

Texturized soy protein from Bob’s Red Mill Natural Foods® (Milwaukie, OR, USA) was used to develop the soy taco crumble. Soy protein is widely utilized in meat alternatives for its functional properties— including water-holding, gelling, fat absorption, and emulsifying capabilities— along with its cost-effectiveness (Ahmad et al., 2022).

To improve the acceptability of the soy taco crumble, functional ingredients were incorporated. A vegetable broth prepared using a base from Sysco® (Houston, TX, USA) was used to hydrate the soy protein, while Crisco® vegetable oil (Parsippany, NJ, USA) was added to enhance flavor, moisture, and texture. Pre-prepared meat taco seasonings from the dining center— including dried onions, salt, chili powder, cornstarch, cayenne pepper, garlic powder, oregano, cumin, and cilantro— were used for added flavor and color. Table 2 lists the final ingredients and their weights. Various ingredient ratios were tested to optimize the formulation, which can be served at either lunch or dinner. Final cooked product is displayed in Figure 7. The recipe was inputted into Computrition (a food service management system, Canoga Park, CA, USA). Computrition formats recipes for quantity use, procurement, pricing (Table 4), and nutritional content (Figure 8).

Table 2: Soy Taco Crumble Ingredients and Formulation

Soy Taco Crumble -V		
Category: Vegan: Entree	Yield: ≈ 30 servings	
Mater Ref: 0.1253 pounds	Portion: 2 ounces	
Ingredient	Amount	Method
Texturized Vegetable Protein	1.3736 lb	(1) In 12x20x4 pan, add water and base. Stir to combine. (2) Add TVP. Allow to soak for 15-20 minutes.
Vegetable Base	0.0554 lb	
Water	2.5688 lb	
Oil	0.1495 lb	(3) Heat tilt skillet to medium heat.
Taco Seasoning	0.3008 lb	(4) Add oil and allow it to coat the surface of the pan. (5) Add hydrated TVP product and seasoning mix. (6) Sautee to heat, brown, and allow product to absorb seasonings. (7) Cover. Hold at or above 140°F for service. (8) One portion is a #24 disher (0.1253 lb). (9) Quality Standard: The soy crumble will resemble taco-seasoned beef in texture, moisture, flavor, and coloration. Serve with taco/nacho bar toppings.

- (10) Refrigerate leftovers at or below 40°F.
- (11) Cover, label, and date when cool.
- (12) Reheat to a minimum of 165°F.

Equipment:

- Tilt Skillet
- 12 x 20 x 4-inch pans
- Rubber Spatula
- 12x20x2 inch pans
- #24 Disher

Date Entered in Computrition:

4/16/2024 – for Food Science Institute Research Study.

Formulation Discussion and Implications

The successful formulation of the soy taco crumble using commercially available, cost-effective ingredients demonstrates its scalability and practical viability for university dining operations. At a total recipe cost of \$5.34 (approximately \$0.18 per serving), the product offers a cost-effective alternative to traditional meat-based taco options, which is an important consideration for budget-conscious institutional foodservice settings. The use of texturized soy protein (TSP) as the primary ingredient leverages its well-documented functional properties, including water-holding, gelling, and fat absorption capabilities (Ahmad et al., 2022), while the incorporation of familiar taco seasonings enhances flavor and visual appeal. The iterative development process, involving multiple preparations at both Kramer and Derby dining centers, ensured compatibility with industrial kitchen equipment and standard foodservice workflows. This approach serves as a practical model for foodservice educators and operators seeking to introduce plant-based menu items, demonstrating that novel products can be developed and refined within existing institutional infrastructure without requiring specialized equipment or ingredients. The recipe's entry into Computrition further supports operational adoption by providing standardized portioning, procurement, and nutritional information.

Table 3: Soy Taco Crumble Seasoning Formulation

Soy Taco Crumble Seasoning Mix-Sub-V

Category: Sauce/gravy: Seasoning	Yield: 0.195 lb	
Mater Ref: For recipe	Portion: 0.007 pound	
Ingredient	Amount	Method
Dried Chopped Onions	0.049 lb	(1) Combine in bakers bowl using French whip. (2) Store tightly covered at room temperature.
Salt	0.021 lb	
Chili Powder	0.047 lb	
Cornstarch	0.041 lb	
Ground Red Cayenne Pepper	0.002 lb	
Garlic Powder	0.017 lb	
Dried Oregano Leaves	<0.001 lb	
Ground Cumin	0.017 lb	
Dried Cilantro	<0.001 lb	

(3) Follow recipe for procedure.

(4) NOTE: Use 0.50 lb. of seasoned mix and one cup of water (0.50 lb) for each 10.0 lb. of A.P. meat after it is cooked and drained (6.5 lb. E.P.).
 (5) Stir well to blend before using mix in ground beef.
 Equipment:
 Bakers Bowl
 French Whip
 Appropriate Storage Containers

Table 4: Soy Taco Crumble Cost Report

Ingredients	Amount (AP)	Cost Per Person	Cost Per Recipe	Percentage (%)
Texturized Vegetable Protein	1.37 lb	\$ 0.11	\$ 3.45	65
Vegetable Base	0.05 lb	\$ 0.01	\$ 0.36	7
Water	2.57 lb	\$ 0.00	\$ 0.00	0
Oil	0.15 lb	\$ 0.01	\$ 0.19	4
Taco Seasoning	0.3 lb	\$ 0.04	\$ 1.35	25
Total Costs		\$ 0.18	\$ 5.34	

Physiochemical Characteristics Results

During cooking, plant-based meat alternatives undergo key physicochemical changes, including protein denaturation, aggregation, water absorption, and moisture evaporation, which can lead to shrinkage and reduced final product mass and volume (Kondjoyan et al., 2013). Therefore, measuring cooking loss (CL) and water-holding capacity is critical when evaluating the performance and quality of texturized vegetable proteins (TVPs) such as soy taco crumble, as these parameters directly influence juiciness, texture, and yield (Aaslyng et al., 2003; Wi et al., 2020; Zhou et al., 2022). In this study, the soy taco crumble exhibited approximately 13.22% cooking loss. This result is comparable to findings from Zhou et al. (2022), which reported a 10% cooking loss in plant-based burgers, indicating similar structural and functional properties between products using texturized soy protein.

Water-holding capacity (WHC) is a critical quality attribute in texturized vegetable proteins, as it directly impacts the juiciness, yield, and consumer appeal of plant-based meat alternatives (Aaslyng et al., 2003; Wang et al., 2015; Wi et al., 2020). WHC represents a protein’s ability to retain moisture and support the formation of a stable gel network, especially under the influence of heat during cooking. In this study, the cooked soy taco crumble exhibited a high WHC indicating excellent moisture retention. This strong performance is likely attributable to the initial soaking and heating processes, which enhance gel network formation through hydrophobic interactions in soy proteins (Wi et al., 2020). The high WHC helps preserve texture and juiciness, making the product more desirable to consumers. Previous research confirms that heat treatment improves the gel structure of soy proteins (Gómez et al., 2019; Huang et al., 2010; Wang et al., 2015). Additionally, the inclusion of soy has been shown to reduce free water and minimize syneresis, further enhancing WHC (Wi et al., 2020). The incorporation of oil has also been identified as a factor that boosts WHC in both cooked and uncooked plant-based products (Wi et al., 2020; Xia et al., 2018).

Color parameters are key physical attributes that significantly influence consumer acceptance of food products (Bakhsh et al., 2021). In this study, cooking the soy taco crumble led to a noticeable decrease in

lightness (L^*) and significant increases in both red/green (a^*) and yellow/blue (b^*) values, indicating visual shifts toward red and yellow hues. These changes reflect typical transformations associated with heat-induced reactions and the presence of added spices. The increase in b^* values can be attributed to the light beige color of rehydrated texturized soy protein, which darkens to a rich brown during the cooking process. The more pronounced variation in a^* values—compared to earlier studies involving partial soy additions—results from the complete replacement of animal protein with texturized soy and the substantial influence of pigmented seasonings such as cayenne pepper, chili powder, and paprika, which impart characteristic red-orange hues to the cooked taco crumble (Deliza et al., 2002). This contrast underscores how formulation choices can influence the appearance of plant-based meat alternatives. T-test results confirmed that the changes in L^* , a^* , and b^* values before and after cooking were statistically significant ($p < 0.05$), indicating that these color differences are not due to chance. The observed shifts are

Table 5: Physiochemical Characteristics Of Soy-Taco Crumble

Parameters (n=5)	Percent Mean \pm SD ¹	SEM
Cooking Loss Percent	13.22 \pm 3.067	1.533
Water Holding Capacity	96.44 \pm 1.135	0.507
After Cooking		
L^* Before Cooking	55.07 \pm 0.61 ^a	$\Delta E = 16.53$
L^* After Cooking	39.63 \pm 4.26 ^b	
a^* Before Cooking	10.91 \pm 0.29 ^a	
a^* After Cooking	15.64 \pm 0.81 ^b	
b^* Before Cooking	25.82 \pm 0.68 ^a	
b^* After Cooking	29.35 \pm 0.98 ^b	
pH Before Cooking	6.80 \pm 0.056 ^a	0.025
pH After Cooking	6.47 \pm 0.116 ^b	0.051

L^* , lightness; a^* , redness; b^* , yellowness; ¹Data are expressed as means \pm standard deviations (SD). ^a-^bindicate significant differences at $p < 0.05$, ΔE (Delta E) = total color difference calculated from L^* , a^* , and b^* values.

likely caused by Maillard reactions, and the interaction of heat with spices, all of which contribute to the browning and color intensification of the final product. Understanding these visual transformations is essential for optimizing sensory appeal and supporting effective product development strategies aimed at enhancing consumer acceptance of soy-based meat alternatives.

The pH of the soy taco crumble decreased after cooking, indicating a significant increase ($p < 0.01$) in acidity due to the cooking process. This notable decrease suggests that cooking has a measurable impact on the acidity of the soy taco crumble, potentially influenced by the addition of seasonings. A pH above 6 suggests that texturized soy protein is mildly alkaline, consistent with previously reported values of pH 7.42–7.43 (Anjum et al., 2011). Prior research has shown that the inclusion of soy elevates pH in meat products; for example, minced meat with soy exhibited higher pH than meat-only controls, and soy protein isolates at 25% significantly raised the pH of meat sausages to 6.7 ± 0.05 (Ahmad et al., 2010; Bell & Shelef, 1978). Understanding this chemical change is important for evaluating the effects of cooking on the overall quality and stability of soy-based products.

Physiochemical Discussion and Implications

Collectively, the physiochemical results confirm that the soy taco crumble meets the quality benchmarks necessary for institutional foodservice applications. The cooking loss of 13.22%, while slightly higher than the 10% reported for plant-based burgers by Zhou et al. (2022), remains within an acceptable range and reflects the inherent differences in product format and cooking method between a crumble and a formed

patty. The high water-holding capacity (96.44%) is a particularly favorable outcome, as it indicates that the product retains moisture effectively during cooking, which directly contributes to the juiciness and textural appeal that consumers expect from taco-style entrées. The significant color changes observed during cooking — driven by Maillard reactions and the pigmented seasonings — produced a visually appealing final product that closely resembles traditional seasoned ground meat, an important factor for consumer acceptance of plant-based alternatives (Bakhsh et al., 2021). The post-cooking pH of 6.47 falls within a safe and stable range for foodservice holding conditions. For foodservice operators, these findings provide confidence that the soy taco crumble can be prepared, held, and served under standard dining center conditions without significant quality degradation, supporting its inclusion as a reliable plant-based menu option.

Figure 7: Final Cooked Product (Soy Taco Crumble)



Moisture Results

Texture in plant-based meat alternatives is closely linked to moisture content (Bakhsh et al., 2021). Moisture analysis under various storage and reheating conditions provides valuable insight into how time and temperature impact product quality. The results for moisture percent of freshly cooked, refrigerated, and frozen samples are presented in Table 6. The results show that storage and reheating conditions significantly influence ($p < 0.05$) the moisture content of soy taco crumble. Freshly cooked samples maintained consistent moisture levels regardless of serving line holding time. Refrigeration tended to reduce moisture, particularly with shorter reheating periods, while longer reheating partially restored it. Freezing, especially for shorter durations, caused substantial moisture loss; however, extended freezing followed by reheating appeared to enhance moisture retention. As a result, freezing is not recommended as a storage method for plant-based meat alternatives (Bakhsh et al., 2021). These findings provide valuable guidance for optimizing storage and reheating practices to preserve product quality. Based on the moisture retention data, freezing soy taco crumble for up to 14 days followed by reheating is the recommended maximum storage duration, as moisture content remained relatively stable during this period. Beyond 14 days of frozen storage, moisture values showed significant increases after 60 minutes on the serving line, suggesting potential quality degradation with extended frozen storage. Refrigerated storage for 3-7 days also maintained acceptable moisture levels, with minimal variation across serving times, making it a suitable option for short-term storage.

These parameters are essential for successfully serving soy taco crumble in dining centers. Storage and reheating conditions directly impact on the product's quality and help establish appropriate storage

durations to meet serving standards. Evaluating these factors ensures that the soy taco crumble maintains the quality, safety, and appeal necessary for consumer satisfaction in a dining center setting.

Table 6: Moisture (%) Across Various Holding Times On The Serving Line

Parameters (n=5)	Freshly Cooked	Refrigerated 3 Days	Refrigerated 7 Days	Frozen 14 Days	Frozen 21 Days
Freshly Heated	41.70 ^a	36.46 ^a	39.46 ^a	31.00 ^a	44.26 ^a
30 Minutes on Serving Line	41.00 ^a	36.00 ^a	41.53 ^b	25.46 ^b	44.00 ^a
60 Minutes on Serving Line	41.76 ^a	39.00 ^b	42.53 ^b	43.33 ^c	44.13 ^a

Data are expressed as moisture loss % means, ^a indicates no significant differences at $p < 0.05$, ^{a-b-c} indicates significant differences at $p < 0.05$.

Moisture Discussion and Implications

The moisture analysis results offer practical guidance for foodservice operators managing storage and reheating protocols for soy taco crumble. The stability of moisture content in freshly cooked samples across the 60-minute serving window is encouraging, as it indicates that the product can be held on a serving line without significant quality loss during typical service periods. The finding that refrigerated storage for 3–7 days maintained acceptable moisture levels provides flexibility for advance preparation, a common practice in high-volume dining operations. However, the substantial moisture loss observed with short-duration freezing (14 days), followed by partial recovery after reheating, suggests that frozen storage should be approached with caution. Based on these findings, the recommended practice for dining centers is to prioritize refrigerated storage for short-term use and limit frozen storage to no more than 14 days, with thorough reheating to restore product quality. These storage and reheating guidelines can be directly incorporated into standard operating procedures for university dining centers, supporting consistent product quality across multiple service periods. For foodservice educators, these results illustrate the importance of evaluating holding and storage conditions as part of product development, a consideration that is often overlooked in academic settings but is critical for real-world foodservice implementation.

Sensory Evaluation Results

Sensory studies play a vital role in enhancing product characteristics, aligning with consumer expectations, and improving acceptance (Aschemann-Witzel et al., 2019). A sensory evaluation of soy taco crumble was conducted by Kramer dining center staff and undergraduate students in food science, baking science, and animal science enrolled in the "Fundamentals of Food Processing" course. Using the 9-point Hedonic Scale (described previously), panel assessed acceptance, flavor, texture, color, seasoning, and aroma.

The comparative analysis of overall acceptability scores among different sensory panels revealed insightful patterns. Undergraduate students who evaluated the soy taco crumble with the original seasoning level (100%) rated their overall acceptability at 6.54, indicating moderate approval. When the seasoning increased by 125%, the overall acceptability score slightly declined to 6.08, suggesting that the increase in seasoning did not enhance and may have slightly reduced product appeal. The variation in feedback may be attributed to changes in preparations, specifically, the addition of water mixed with seasoning and reheating on the stovetop. As cooking methods significantly impact final product quality,

adjustments were made based on consumer input, including modifying seasoning levels and shifting final preparation to a tilt skillet instead of a stovetop pan. In contrast, the Kramer Dining Center managing staff, who also evaluated the less-seasoned version, reported a higher overall acceptability of 6.88. These results suggest that while college students responded positively to the initial formulation, experienced food service professionals perceived the product more favorably, possibly due to differing expectations or culinary experience.

Figure 8: Soy Taco Crumble Nutrition Facts

Nutrition Facts	
1 servings per container	
Serving size	2 Ounce (67g)
Amount Per Serving	
Calories	100
% Daily Value*	
Total Fat 2.5g	3%
Saturated Fat 0g	0%
Trans Fat 0g	
Cholesterol 0mg	0%
Sodium 330mg	14%
Total Carbohydrate 11g	4%
Dietary Fiber 4g	14%
Total Sugars 2g	
Includes 0g Added Sugars	0%
Sugar Alcohol 0g	
Protein 11g	22%
Vitamin D 0mcg	0%
Calcium 0mg	0%
Iron 2.7mg	15%
Potassium 94mg	2%

*The % Daily Value (DV) tells you how much a nutrient in a serving of food contributes to a daily diet. 2,000 calories a day is used for general nutrition advice.

Sensory Evaluation Discussion and Implications

The sensory evaluation findings highlight the iterative nature of product development and the value of incorporating diverse perspectives during the formulation process. The moderate overall acceptability scores (6.08–6.88 on the 9-point Hedonic Scale) from both undergraduate students and dining center staff provided actionable feedback that directly guided recipe refinement. The observation that increasing seasoning by 125% did not improve and may have slightly reduced acceptability is a valuable insight for product developers, suggesting that flavor optimization requires careful calibration rather than simply intensifying seasoning levels. The difference in scores between students and dining staff may reflect varying frames of reference, students evaluated the product as consumers, while experienced foodservice professionals may have assessed it relative to operational benchmarks and expectations for plant-based alternatives. This dual-perspective approach to sensory evaluation is recommended for future product development efforts, as it captures both consumer preference and operational feasibility. The decision to shift final preparation from a stovetop pan to a tilt skillet, informed by this feedback, demonstrates how sensory data can drive practical improvements in cooking methodology that enhance product quality at scale.

Consumer Acceptability Results

Consumer acceptance of the soy taco crumble at both Kramer (n=141) and Derby (n=67) Dining Centers was strong, as evidenced by positive sensory evaluations across key attributes. At both locations, sensory analysis revealed high acceptability, with most attributes, including overall acceptability, flavor, aroma, and seasoning, scoring around 7 on the nine-point hedonic scale, indicating favorable consumer responses. Although color and texture received slightly lower scores at both centers, they remained within an acceptable range, confirming the product's appeal. Over 80% of respondents at both Kramer and Derby Dining Centers expressed a definite willingness to try the soy taco crumble as a menu item. Overall, these findings confirm that the soy taco crumble is well-received and suitable for service in dining centers, meeting consumer expectations for quality and sensory appeal. Table 7 presents consumer acceptance attributes.

Overall, these combined findings confirm that the soy taco crumble is well-received and appropriate for service in dining centers and similar settings. High acceptability scores across multiple sensory attributes indicate that the product meets consumer expectations for quality and sensory appeal.

Table 7: Consumer Acceptance Attributes

Attribute	Kramer (n=141)	Derby(n=67)	Kramer + Derby (n=208)
Overall Acceptability	7.60 ± 1.25	7.48 ± 1.06	7.54 ± 1.17
Flavor	7.55 ± 1.23	7.12 ± 1.53	7.41 ± 1.35
Color	7.11 ± 1.51	6.99 ± 1.31	7.07 ± 1.45
Texture	7.21 ± 1.73	6.96 ± 1.59	7.13 ± 1.69
Aroma	7.26 ± 1.55	7.06 ± 1.53	7.19 ± 1.51
Seasonings	7.65 ± 1.43	7.49 ± 1.32	7.60 ± 1.40

Data are expressed as means ± standard deviation (SD).

Consumer Acceptability Discussion and Implications

The consumer acceptability results represent the strongest evidence for the viability of the soy taco crumble as a university dining center menu item. With overall acceptability scores of 7.60 ± 1.25 at Kramer and 7.48 ± 1.06 at Derby on the 9-point Hedonic Scale, the product performed well above the threshold typically considered favorable for consumer acceptance (scores ≥ 6). The consistency of scores across two different dining locations and service formats — a dedicated testing table at Kramer versus direct line service at Derby — suggests that the product's appeal is robust and not dependent on a specific presentation context. The finding that over 80% of respondents expressed willingness to try the soy taco crumble as a regular menu item is particularly significant for dining operations considering the integration of plant-based options, as it indicates demand beyond novelty-driven trial. The slightly lower scores for color and texture, while still within the acceptable range, identify specific areas for future formulation refinement. For foodservice practitioners, these results demonstrate that a well-formulated soy-based product, when paired with appropriate educational materials and familiar serving formats, can achieve strong consumer acceptance among university students. This finding supports the broader trend in university dining toward expanding sustainable and plant-based menu offerings while maintaining the quality and appeal necessary to satisfy diverse consumer preferences.

Limitations

The findings of this study should be interpreted within the context of its scope and participant pool. Data were collected from a modest sample of university dining center users, including focus groups (n = 11) and an online survey (n = 76), which represents a small proportion of the overall campus population. Because participants were recruited within dining centers, the results primarily reflect the perspectives of

college students who regularly utilize campus dining services and may not fully capture the views of college students who rely on alternative food sources. As such, the generalizability of the findings beyond university dining environments may be limited.

Sensory acceptance testing was conducted in an operational dining setting where the soy taco crumble was offered alongside other meat-based entrée options. While this approach reflects typical dining conditions and supports real-world applicability, the presence of multiple entrée choices may have influenced participants' numbers (n) and sensory evaluations. Additionally, variation in participation across dining locations and service periods may affect reproducibility under different institutional contexts.

CONCLUSIONS AND APPLICATIONS

The development and scaling of the soy taco crumble demonstrated strong consumer acceptance and operational feasibility for university dining centers. Sensory evaluations at both Kramer and Derby dining centers confirmed favorable scores across key attributes, with overall acceptability (Mean \pm standard deviation = 7.54 ± 1.17) well above the threshold for positive consumer response. The "Plant-Based Protein" infographic effectively increased college students' willingness to try soy-based products, highlighting the value of point-of-sale educational strategies. Physicochemical and storage analyses confirmed that the product meets quality and stability requirements for institutional foodservice, with refrigerated storage of 3–7 days and frozen storage of up to 14 days as recommended protocols.

This study carries implications for both foodservice operations and education. The mixed-methods approach by integrating focus groups, TPB-based surveys, product development, and sensory evaluation, can serve as a pedagogical model for food science and hospitality curricula. At a total recipe cost of approximately \$0.18 per serving, the soy taco crumble offers a cost-effective alternative to traditional meat-based options, supporting its adoption in budget-conscious institutional settings. Future research should employ larger sample sizes, probability sampling, and controlled experimental designs to strengthen causal inferences about the role of educational interventions in promoting plant-based food consumption.

REFERENCES

- Aaslyng, M. D., Bejerholm, C., Ertbjerg, P., Bertram, H. C., & Andersen, H. J. (2003). Cooking loss and juiciness of pork in relation to raw meat quality and cooking procedure. *Food Quality and Preference*, 14(4), 277–288. [https://doi.org/10.1016/S0950-3293\(02\)00086-1](https://doi.org/10.1016/S0950-3293(02)00086-1)
- Ahmad, M., Qureshi, S., Akbar, M. H., Siddiqui, S. A., Gani, A., Mushtaq, M., Hassan, I., & Dhull, S. B. (2022). Plant-based meat alternatives: Compositional analysis, current development and challenges. *Applied Food Research*, 2(2), 100154. <https://doi.org/10.1016/j.afres.2022.100154>
- Ahmad, S., Rizawi, J., & Srivastava, P. (2010). Effect of soy protein isolate incorporation on quality characteristics and shelf-life of buffalo meat emulsion sausage. *Journal of Food Science and Technology*, 47, 290–294. <https://doi.org/10.1007/s13197-010-0045-x>
- Ajzen, I. (1985). From intentions to actions: A theory of planned behavior. In J. Kuhl & J. Beckmann (Eds.), *Action control: From cognition to behavior* (pp. 11–39). Springer. https://doi.org/10.1007/978-3-642-69746-3_2
- Ajzen, I. (1991). The theory of planned behavior. *Organizational Behavior and Human Decision Processes*, 50(2), 179–211. [https://doi.org/10.1016/0749-5978\(91\)90020-T](https://doi.org/10.1016/0749-5978(91)90020-T)

Anjum, F. M., Naeem, A., Khan, M. I., Nadeem, M., & Amir, R. M. (2011). Development of texturized vegetable protein using indigenous sources. *Pakistan Journal of Food Sciences*, 21(1–4), 33–44.

AOAC International. (2005). *Official methods of analysis* (18th ed.). AOAC International.

Arkorful, V. E., Hammond, A., Lugu, B. K., Basiru, I., Sunguh, K. K., & Charmaine-Kwade, P. (2022). Investigating the intention to use technology among medical students: An application of an extended model of the theory of planned behavior. *Journal of Public Affairs*, 22(2), e2460. <https://doi.org/10.1002/pa.2460>

Aschemann-Witzel, J., Ares, G., Thøgersen, J., & Monteleone, E. (2019). A sense of sustainability? How sensory consumer science can contribute to sustainable development of the food sector. *Trends in Food Science & Technology*, 90, 180–186. <https://doi.org/10.1016/j.tifs.2019.02.021>

Bakhsh, A., Lee, S.-J., Lee, E.-Y., Hwang, Y.-H., & Joo, S.-T. (2021). Evaluation of rheological and sensory characteristics of plant-based meat analog with comparison to beef and pork. *Food Science of Animal Resources*, 41(6), 983–993. <https://doi.org/10.5851/kosfa.2021.e50>

Bakhsh, A., Lee, S.-J., Lee, E.-Y., Sabikun, N., Hwang, Y.-H., & Joo, S.-T. (2021). A novel approach for tuning the physicochemical, textural, and sensory characteristics of plant-based meat analogs with different levels of methylcellulose concentration. *Foods*, 10(3), 560. <https://doi.org/10.3390/foods10030560>

Belk, R. W., Fischer, E., & Kozinets, R. V. (2013). *Qualitative consumer and marketing research*. Sage.

Bell, W., & Shelef, L. (1978). Availability and microbial stability of retail beef-soy blends. *Journal of Food Science*, 43(2), 315–333. <https://doi.org/10.1111/j.1365-2621.1978.tb02294.x>

Biasini, B., Rosi, A., Giopp, F., Turgut, R., Scazzina, F., & Menozzi, D. (2021). Understanding, promoting and predicting sustainable diets: A systematic review. *Trends in Food Science & Technology*, 111, 191–207. <https://doi.org/10.1016/j.tifs.2021.02.062>

Bonett, D. G., & Wright, T. A. (2015). Cronbach's alpha reliability: Interval estimation, hypothesis testing, and sample size planning. *Journal of Organizational Behavior*, 36(1), 3–15. <https://doi.org/10.1002/job.1960>

Braun, V., & Clarke, V. (2006). Using thematic analysis in psychology. *Qualitative Research in Psychology*, 3(2), 77–101. <https://doi.org/10.1191/1478088706qp063oa>

Broad, G. M. (2020). Making meat, better: The metaphors of plant-based and cell-based meat innovation. *Environmental Communication*, 14(7), 919–932. <https://doi.org/10.1080/17524032.2020.1725085>

Capriotti, A. L., Caruso, G., Cavaliere, C., Samperi, R., Stampachiachiere, S., Zenezini Chiozzi, R., & Laganà, A. (2014). Protein profile of mature soybean seeds and prepared soybean milk. *Journal of Agricultural and Food Chemistry*, 62(40), 9893–9899. <https://doi.org/10.1021/jf5034152>

Carfora, V., Caso, D., & Conner, M. (2016). The role of self-identity in predicting fruit and vegetable intake. *Appetite*, 106, 23–29. <https://doi.org/10.1016/j.appet.2015.12.020>

- Contini, C., Boncinelli, F., Marone, E., Scozzafava, G., & Casini, L. (2020). Drivers of plant-based convenience foods consumption: Results of a multicomponent extension of the theory of planned behaviour. *Food Quality and Preference*, 84, 103931. <https://doi.org/10.1016/j.foodqual.2020.103931>
- Creswell, J. W., & Creswell, J. D. (2017). *Research design: Qualitative, quantitative, and mixed methods approaches* (4th ed.). Sage.
- Deliens, T., Clarys, P., De Bourdeaudhuij, I., & Deforche, B. (2014). Determinants of eating behaviour in university students: A qualitative study using focus group discussions. *BMC Public Health*, 14(1), 53. <https://doi.org/10.1186/1471-2458-14-53>
- Deliza, R., Saldivar, S. S., Germani, R., Benassi, V., & Cabral, L. (2002). The effects of colored textured soybean protein (TSP) on sensory and physical attributes of ground beef patties. *Journal of Sensory Studies*, 17(2), 121–132. <https://doi.org/10.1111/j.1745-459X.2002.tb00337.x>
- Devraj, R., Wilhelm, M., & Deshpande, M. (2022). Consumer perceptions of a shingles infographic intervention and vaccination plans in community pharmacy settings. *Innovations in Pharmacy*, 13(3). <https://doi.org/10.24926/iip.v13i3.4918>
- Dias, C., Costa, J., Mafra, I., Fernandes, D., Brandão, A. T. S. C., Silva, A. F., Pereira, C. M., & Costa, R. (2024). Electrochemical immunosensor for point-of-care detection of soybean Gly m TI allergen in foods. *Talanta*, 268, 125284. <https://doi.org/10.1016/j.talanta.2023.125284>
- Egan, M., Acharya, A., Sounderajah, V., Xu, Y., Mottershaw, A., Phillips, R., Ashrafian, H., & Darzi, A. (2021). Evaluating the effect of infographics on public recall, sentiment and willingness to use face masks during the COVID-19 pandemic: A randomised internet-based questionnaire study. *BMC Public Health*, 21(1), 367. <https://doi.org/10.1186/s12889-021-10356-0>
- Fiorentini, M., Kinchla, A. J., & Nolden, A. A. (2020). Role of sensory evaluation in consumer acceptance of plant-based meat analogs and meat extenders: A scoping review. *Foods*, 9(9), 1334. <https://doi.org/10.3390/foods9091334>
- Fresán, U., Errendal, S., & Craig, W. J. (2020). Influence of the socio-cultural environment and external factors in following plant-based diets. *Sustainability*, 12(21), 9093. <https://doi.org/10.3390/su12219093>
- Gifford, R., Lacroix, K., Asgarizadeh, Z., Ashford Anderson, E., Milne-Ives, M., & Sugrue, P. (2024). Applying the theory of behavioral choice to plant-based dietary intentions. *Appetite*, 197, 107271. <https://doi.org/10.1016/j.appet.2024.107271>
- Gómez, I., Ibañez, F. C., & Beriain, M. J. (2019). Physicochemical and sensory properties of sous vide meat and meat analog products marinated and cooked at different temperature–time combinations. *International Journal of Food Properties*, 22(1), 1693–1708. <https://doi.org/10.1080/10942912.2019.1666869>
- Hadi, M. A., & Closs, S. J. (2016). Ensuring rigour and trustworthiness of qualitative research in clinical pharmacy. *International Journal of Clinical Pharmacy*, 38(3), 641–646. <https://doi.org/10.1007/s11096-015-0237-6>

Hartmann, C., & Siegrist, M. (2020). Our daily meat: Justification, moral evaluation and willingness to substitute. *Food Quality and Preference*, 80, 103799. <https://doi.org/10.1016/j.foodqual.2019.103799>

Henkel, J. (2000). Soy: Health claims for soy protein, questions about other components. *FDA Consumer*, 34(3), 13–20.

Heywood, A. A., Myers, D. J., Bailey, T. B., & Johnson, L. A. (2002). Effect of value-enhanced texturized soy protein on the sensory and cooking properties of beef patties. *Journal of the American Oil Chemists' Society*, 79(7), 703–707. <https://doi.org/10.1007/s11746-002-0546-y>

Huang, X., Li, C., Yang, F., Xie, L., Xu, X., Zhou, Y., & Pan, S. (2010). Interactions and gel strength of mixed myofibrillar with soy protein, 7S globulin and enzyme-hydrolyzed soy proteins. *European Food Research and Technology*, 231, 751–762. <https://doi.org/10.1007/s00217-010-1329-0>

IFT FIRST: 2023 trends. (2023, July 31). *Trilogy Flavors*. <https://www.trilogyflavors.com/iftfirst-2023-trends/>

Jahn, S., Furchheim, P., & Strässner, A.-M. (2021). Plant-based meat alternatives: Motivational adoption barriers and solutions. *Sustainability*, 13(23), 13271. <https://doi.org/10.3390/su132313271>

Karabulut, G., Goksen, G., & Mousavi Khaneghah, A. (2024). Plant-based protein modification strategies towards challenges. *Journal of Agriculture and Food Research*, 15, 101017. <https://doi.org/10.1016/j.jafr.2024.101017>

Kondjoyan, A., Oillic, S., Portanguen, S., & Gros, J.-B. (2013). Combined heat transfer and kinetic models to predict cooking loss during heat treatment of beef meat. *Meat Science*, 95(2), 336–344. <https://doi.org/10.1016/j.meatsci.2013.04.061>

Krueger, R. A., & Casey, M. A. (2015). *Focus groups: A practical guide for applied research* (5th ed.). Sage.

Lin, D., Lu, W., Kelly, A. L., Zhang, L., Zheng, B., & Miao, S. (2017). Interactions of vegetable proteins with other polymers: Structure-function relationships and applications in the food industry. *Trends in Food Science & Technology*, 68, 130–144. <https://doi.org/10.1016/j.tifs.2017.08.006>

Maitiniyazi, S., & Canavari, M. (2020). Exploring Chinese consumers' attitudes toward traceable dairy products: A focus group study. *Journal of Dairy Science*, 103(12), 11257–11267. <https://doi.org/10.3168/jds.2020-18408>

Malan, H., Watson, T. D., Slusser, W., Glik, D., Rowat, A. C., & Prelip, M. (2020). Challenges, opportunities, and motivators for developing and applying food literacy in a university setting: A qualitative study. *Journal of the Academy of Nutrition and Dietetics*, 120(1), 33–44. <https://doi.org/10.1016/j.jand.2019.06.003>

McEachan, R. R. C., Conner, M., Taylor, N. J., & Lawton, R. J. (2011). Prospective prediction of health-related behaviours with the theory of planned behaviour: A meta-analysis. *Health Psychology Review*, 5(2), 97–144. <https://doi.org/10.1080/17437199.2010.521684>

Michel, F., Hartmann, C., & Siegrist, M. (2021). Consumers' associations, perceptions and acceptance of meat and plant-based meat alternatives. *Food Quality and Preference*, 87, 104063.

<https://doi.org/10.1016/j.foodqual.2020.104063>

Pandey, S., Ritz, C., & Perez-Cueto, F. J. (2021). An application of the theory of planned behaviour to predict intention to consume plant-based yogurt alternatives. *Foods*, 10(1), 148.

<https://doi.org/10.3390/foods10010148>

Riebl, S. K., Estabrooks, P. A., Dunsmore, J. C., Savla, J., Frisard, M. I., Dietrich, A. M., Peng, Y., Zhang, X., & Davy, B. M. (2015). A systematic literature review and meta-analysis: The theory of planned behavior's application to understand and predict nutrition-related behaviors in youth. *Eating Behaviors*, 18, 160–178.

<https://doi.org/10.1016/j.eatbeh.2015.05.016>

Santos, J. R. A. (1999). Cronbach's alpha: A tool for assessing the reliability of scales. *Journal of Extension*, 37(2), 1–5.

Sasi, M., Kumar, S., Hasan, M., S. R., A., Garcia-Gutierrez, E., Kumari, S., Prakash, O., Nain, L., Sachdev, A., & Dahuja, A. (2022). Current trends in the development of soy-based foods containing probiotics and paving the path for soy-synbiotics. *Critical Reviews in Food Science and Nutrition*, Advance online publication, 1–19. <https://doi.org/10.1080/10408398.2022.2078272>

Seo, E.-H., Jang, H.-W., & Cho, M. (2023). Enabling the foodservice industry to transition consumers toward plant-based meat alternatives: A behavioral reasoning perspective. *International Journal of Hospitality Management*, 114, 103559. <https://doi.org/10.1016/j.ijhm.2023.103559>

Stewart, D. W., & Shamdasani, P. N. (2014). *Focus groups: Theory and practice* (3rd ed.). Sage.

Sun, X. M., Wang, C. N., & Guo, M. R. (2018). Interactions between whey protein or polymerized whey protein and soybean lecithin in model system. *Journal of Dairy Science*, 101(11), 9680–9692.

<https://doi.org/10.3168/jds.2018-14998>

Tian, Y., Chan, T. J., Suki, N. M., & Kasim, M. A. (2023). Moderating role of perceived trust and perceived service quality on consumers' use behavior of Alipay e-wallet system: The perspectives of technology acceptance model and theory of planned behavior. *Human Behavior and Emerging Technologies*, 2023, 5276406. <https://doi.org/10.1155/2023/5276406>

Van Hecke, O., Lee, J. J., Butler, C. C., Moore, M., & Tonkin-Crine, S. (2020). Using evidence-based infographics to increase parents' understanding about antibiotic use and antibiotic resistance: A proof-of-concept study. *JAC–Antimicrobial Resistance*, 2(4), dlaa102. <https://doi.org/10.1093/jacamr/dlaa102>

Wang, O., & Scrimgeour, F. (2021). Willingness to adopt a more plant-based diet in China and New Zealand: Applying the theories of planned behaviour, meat attachment and food choice motives. *Food Quality and Preference*, 93, 104294. <https://doi.org/10.1016/j.foodqual.2021.104294>

Wang, Z., Liang, J., Jiang, L., Li, Y., Wang, J., Zhang, H., Li, D., Han, F., Li, Q., & Wang, R. (2015). Effect of the interaction between myofibrillar protein and heat-induced soy protein isolates on gel properties. *CyTA—Journal of Food*, 13(4), 527–534. <https://doi.org/10.1080/19476337.2015.1011240>

Wi, G., Bae, J., Kim, H., Cho, Y., & Choi, M.-J. (2020). Evaluation of the physicochemical and structural properties and the sensory characteristics of meat analogues prepared with various non-animal-based liquid additives. *Foods*, 9(4), 461. <https://doi.org/10.3390/foods9040461>

Xia, W., Ma, L., Chen, X., Li, X., & Zhang, Y. (2018). Physicochemical and structural properties of composite gels prepared with myofibrillar protein and lecithin at various ionic strengths. *Food Hydrocolloids*, 82, 135–143. <https://doi.org/10.1016/j.foodhyd.2018.03.044>

Zhang, M., Mittal, G. S., & Barbut, S. (1995). Effects of test conditions on the water holding capacity of meat by a centrifugal method. *LWT – Food Science and Technology*, 28(1), 50–55. [https://doi.org/10.1016/S0023-6438\(95\)80012-3](https://doi.org/10.1016/S0023-6438(95)80012-3)

Zhou, H., Vu, G., Gong, X., & McClements, D. J. (2022). Comparison of the cooking behaviors of meat and plant-based meat analogues: Appearance, texture, and fluid holding properties. *ACS Food Science & Technology*, 2(5), 844–851. <https://doi.org/10.1021/acsfoodscitech.2c00016>