

Research Manuscript

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

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## 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.

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## 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.

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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  $\geq 165^{\circ}\text{F}$  ( $74^{\circ}\text{C}$ ) for the refrigerated product and 35-40 minutes for the frozen product at  $\geq 165^{\circ}\text{F}$  ( $74^{\circ}\text{C}$ ) 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  $50^{\circ}\text{C}$  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.

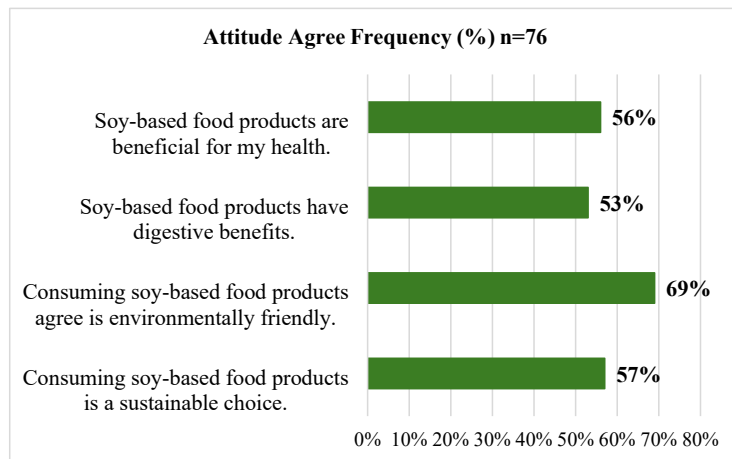
**Table 1:** Developed Themes from Focus Group Analysis (n=11)

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 (%)**

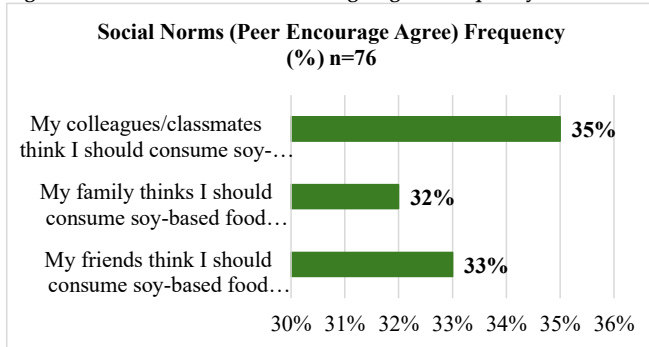


**Quantitative Research: Results**

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%).

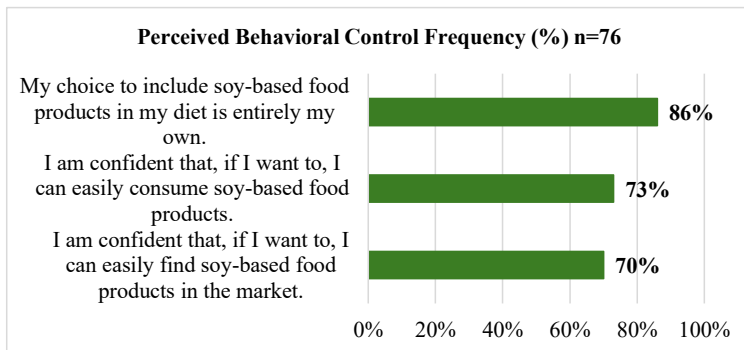
Figures 4, 5, and 6 present the college students' attitudes, social norms, and perceived behavioral control towards the intention to consume soy-based food products. Cronbach's alpha test was utilized to evaluate the construct's reliability (Santos, 1999). Cronbach's alpha ranged from 0.87 for attitude, 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**

<b>Soy Taco Crumble -V</b>		
<b>Category:</b> Vegan: Entree	<b>Yield:</b> ≈ 30 servings	
<b>Mater Ref:</b> 0.1253 pounds	<b>Portion:</b> 2 ounces	
<b>Ingredient</b>	<b>Amount</b>	<b>Method</b>
Texturized Vegetable Protein	1.3736 lb	(1) In 12x20x4 pan, add water and base. Stir to combine.
Vegetable Base	0.0554 lb	
Water	2.5688 lb	(2) Add TVP. Allow to soak for 15-20 minutes.
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**

<b>Category:</b> Sauce/gravy: Seasoning	<b>Yield:</b> 0.195 lb	
<b>Mater Ref:</b> For recipe	<b>Portion:</b> 0.007 pound	
<b>Ingredient</b>	<b>Amount</b>	<b>Method</b>
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 <sup>1</sup>	SEM
Cooking Loss Percent	13.22 $\pm$ 3.067	1.533
Water Holding Capacity	96.44 $\pm$ 1.135	0.507
<b>After Cooking</b>		
$L^*$ Before Cooking	55.07 $\pm$ 0.61 <sup>a</sup>	$\Delta E = 16.53$
$L^*$ After Cooking	39.63 $\pm$ 4.26 <sup>b</sup>	
$a^*$ Before Cooking	10.91 $\pm$ 0.29 <sup>a</sup>	
$a^*$ After Cooking	15.64 $\pm$ 0.81 <sup>b</sup>	
$b^*$ Before Cooking	25.82 $\pm$ 0.68 <sup>a</sup>	
$b^*$ After Cooking	29.35 $\pm$ 0.98 <sup>b</sup>	
pH Before Cooking	6.80 $\pm$ 0.056 <sup>a</sup>	0.025
pH After Cooking	6.47 $\pm$ 0.116 <sup>b</sup>	0.051

$L^*$ , lightness;  $a^*$ , redness;  $b^*$ , yellowness; <sup>1</sup>Data are expressed as means  $\pm$  standard deviations (SD). <sup>a</sup>-<sup>b</sup>indicate significant differences at  $p < 0.05$ ,  $\Delta E$  (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  $6.7 \pm 0.05$  (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 <sup>a</sup>	36.46 <sup>a</sup>	39.46 <sup>a</sup>	31.00 <sup>a</sup>	44.26 <sup>a</sup>
30 Minutes on Serving Line	41.00 <sup>a</sup>	36.00 <sup>a</sup>	41.53 <sup>b</sup>	25.46 <sup>b</sup>	44.00 <sup>a</sup>
60 Minutes on Serving Line	41.76 <sup>a</sup>	39.00 <sup>b</sup>	42.53 <sup>b</sup>	43.33 <sup>c</sup>	44.13 <sup>a</sup>

Data are expressed as moisture loss % means, <sup>a</sup> indicates no significant differences at  $p < 0.05$ , <sup>a-b-c</sup> 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

<b>Nutrition Facts</b>	
1 servings per container	
<b>Serving size</b>	<b>2 Ounce (67g)</b>
<b>Amount Per Serving</b>	
<b>Calories</b>	<b>100</b>
	<small>% Daily Value*</small>
<b>Total Fat</b> 2.5g	<b>3%</b>
Saturated Fat 0g	<b>0%</b>
Trans Fat 0g	
<b>Cholesterol</b> 0mg	<b>0%</b>
<b>Sodium</b> 330mg	<b>14%</b>
<b>Total Carbohydrate</b> 11g	<b>4%</b>
Dietary Fiber 4g	<b>14%</b>
Total Sugars 2g	
Includes 0g Added Sugars	<b>0%</b>
Sugar Alcohol 0g	
<b>Protein</b> 11g	<b>22%</b>
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 =  $7.54 \pm 1.17$ ) 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.

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