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Use of a Stakeholder-Driven DACUM Process to Define Knowledge Areas for Food Protection and Defense

Richard H. Linton, Abbey Nutsch, David McSwane, Justin Kastner, Tejas Bhatt, Sheryl Hodge, Kelly Getty, Dirk Maier, Curtis Kastner, Alok Chaturvedi, and Cynthia Woodley

Abstract

One of the important areas of vulnerability that has been repeatedly identified following the events of September 11, 2001 is the potential for an intentional attack on America's food supply. Despite the importance of equipping professionals to protect our nation's food supply, educators face a scarcity of information on which to base food protection and defense curricula and training development efforts. This research sought to identify a set of knowledge content areas required by food protection and defense professionals. A Developing A CurriculUM (DACUM) process was employed to create a job task analysis that identified duties, tasks, steps, and associated knowledge, skills, and abilities for this occupational category. The knowledge areas identified during the DACUM process and validated through a stakeholder survey were used to frame the program for a training workshop and computer simulation in which participants responded to a mock intentional food contamination event. Results of this process can serve as foundational elements that can be shaped by instructional and curricular design experts to create educational programs in food protection and defense for graduate students and in-service professionals.

KEYWORDS: DACUM, curriculum, food protection, food defense, education, training, learning objectives, computer simulation, public health, decision-making, job task analysis, homeland security

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INTRODUCTION

Within the past decade, increased terrorist activities have generated substantial concerns for Americans and citizens throughout the world. One of the important areas of vulnerability that has been identified is the potential for an intentional attack, or introduction of hazards, on the food supply. Such an event could have considerable public health, economic, and emotional impacts with significant destabilizing effects. The agriculture and food sector has been formally identified by the U.S. Department of Homeland Security (DHS) as a critical infrastructure (Collins and Baggett, 2009), and Homeland Security Presidential Directive 9 ("Homeland Security Presidential Directive/HSPD-9: Defense of United States Agriculture and Food," 2004) establishes a national policy to defend the agriculture and food system against terrorist attacks, major disasters, and other emergencies.

It has always been difficult to access the potential impact of either inherent or intentional contamination of the food supply. The food supply chain is complex and interdependent on a global scale (Salin & Hooker, 2001). It is difficult to study the dynamic food flow and distribution system within reasonable time and cost constraints. Various federal agencies and industry groups have used exercises, usually in the form of tabletop discussion/simulations, to organize and test preparedness of potential attacks on other industries (Sobel et al., 2002). Food protection and defense computer simulations have also been used as an important learning tool for food protection professionals.

Despite the importance of equipping the next generation of professionals to protect the American food supply, educators face an absence of comprehensive data on which to base food protection and defense curriculum development efforts. A review of current research findings and graduate-level educational offerings found no systematic or comprehensive approach available to defining the critical aspects of food protection and defense that could be used as a basis for developing a course, learning modules, curriculum, or plan of study for students or professionals. Thus, there is a need for identification and development of evidence-based knowledge domains and learning modules that can be used to serve stakeholders involved in food protection and defense, especially those with positions requiring graduate-level or in-service education. While there are some entities that offer food defense education (such as university, regulatory, and industry-associated programs), current approaches usually only modify (in an ad hoc fashion) food safety programs and/or collect a series of curricula based on what is available and/or what the educational provider believes should be taught or has the resources to deliver.

Other emerging professions and disciplines related to homeland security, crisis management, and public health are also seeking to define elements required for education and training programs in their respective fields. Bellavita and Gordon (2006) describe the process used to define curricular elements comprising a homeland security curriculum and introductory course. Shaw and Harrald (2004) describe a framework to determine core competency requirements for business crisis and continuity managers. The Association of Schools of Public Health (2010) has developed draft core competencies for public health preparedness and response. McCreight (2009), Kiltz (2009), and Donahue et al. (2010) describe challenges associated with defining curricular elements for homeland security and emergency management and express foundational assertions that underpin various philosophical approaches.

One proven method used to identify knowledge domains is by performing a job task analysis through the **D**eveloping **A** **C**urricul**UM** (DACUM) process. The DACUM process provides an effective method for determining competencies or tasks that must be performed by persons employed in a given occupational area. DACUM has been used to analyze occupations at multiple levels including professional, technical, skilled, and semi-skilled. The process can also be used to identify the specific content that should be included in educational and training curricula. The process also helps to identify knowledge gaps within occupational categories. The DACUM process has been used by Zundel and Needham (1996) to define abilities required of professional foresters, by Halbrooks (2003) to develop a skills profile for a horticulture technology degree program, by DeOnna (2002) to assess a statewide training program for nurse aides, and by Bluestein (1993) to analyze the occupation of chiropractic paraprofessionals.

The DACUM process operates on three important premises: (1) expert workers are better able to describe/define their job than anyone else, (2) any job can be properly described in terms of the tasks that competent workers in that occupation perform, and (3) all tasks have direct implications for the knowledge and attitudes that workers must have in order to perform the tasks correctly (Norton, 2008).

The DACUM process starts by selecting a carefully chosen group of practitioners from the occupation being analyzed. These practitioners should have reputations for being top performers at their jobs. They form a DACUM committee, or panel of experts, and work with a qualified DACUM facilitator to collectively develop job profiles. This information can be used as the basis for creating educational training programs, certification exams, and needs-assessment materials. Once the results of the initial DACUM meeting have been defined, the information is evaluated and validated through a survey instrument, given to other practitioners and stakeholders in the field of study. Afterwards, educator teams can create learning modules, courses, and curricula based on the information validated through the DACUM process.

The purpose of this paper is to describe the process that was used by a multidisciplinary research team to identify desired skills, knowledge, behavior, and attitudes related to food protection and defense professionals. The main component of this stakeholder-based process included development and validation of knowledge domains using the DACUM method. Primary outcomes generated by the DACUM process included educational learning modules and an experiential computer-based food protection and defense simulation.

FOOD PROTECTION AND DEFENSE PROCESS: DACUM

METHODS

The DACUM committee comprised 13 individuals selected to represent various disciplinary perspectives and occupational sectors relevant to food protection and defense. These individuals have expertise in food defense and extensive experience in the food industry, public health, emergency management, law enforcement, academia, and regulatory agencies. A summary of the occupational characteristics of the DACUM Committee is presented in Table 1.

TABLE 1. Occupational characteristics of individuals comprising the DACUM committee for the DACUM job task analysis of a food defense professional.

Position Title	Organization Type	Segment Represented
Vice Pres., Food Safety & Quality Assurance	Private Company	Food Industry
Director of Food Security	Educ./Training Provider	Food Industry
President	Private Consultant	Food Industry
Senior Research Scientist	National Trade Association	Food Industry
Director, Food Safety Institute	University	Academia/Food Industry
Representative, DHS Center of Excellence	University	Academia
Food Defense Program Coordinator	State Dept. of Health	Government, State
Director, Office of Agriculture Biosecurity	Emergency Response	Government, State
Acting Director, Food Safety Office	Federal Agency	Public Health
Chief, Office of Food Protection	State Dept. of Health	Public Health
Food & Facility Defense Specialist	Training/Consult. Provider	Law Enforcement
Professor, Dept. of Emergency Medicine	Medical School	Emergency Mgmt.
Senior Homeland Security Planner	State Dept. Homeland Sec.	Emergency Mgmt.

The DACUM committee worked for three days under the guidance of a trained facilitator from The National Registry of Food Safety Professionals. Modified small-group brainstorming techniques were used to obtain the collective expertise and consensus of the committee. The outcome of the DACUM process (i.e., job task analysis) was a DACUM analysis chart that provided a graphic profile of the duties, tasks, and steps performed by successful workers employed in the food defense occupation. Additionally, the DACUM process elicited the knowledge, skills, and abilities (KSAs) required to perform each task. Importantly, KSAs were identified in concert with each task such that there is a direct link between the job tasks and corresponding knowledge and skills required. As stated by Wang et al. (2005), "It is important to identify the KSAs required to perform each task and establish a clear link between the tasks and the KSAs in order to develop a content outline that is logically and defensibly linked to the job."

RESULTS AND DISCUSSION

The committee began the DACUM process by creating a job description for a food defense professional as follows:

> ***"To protect public health, preserve the economy, enhance national security, and protect the environment, a food defense professional provides leadership; evaluates food systems, facilities, property, products, people, and procedures for vulnerabilities; develops and implements policies and preventative control measures for food security/defense; and develops and implements effective food emergency responses by using analytical, empirical, assessment, detection, communication, and observational techniques to address outcomes."***

A portion of the DACUM analysis chart depicting only the duties and tasks identified for a food defense professional is presented in Table 2. The complete DACUM analysis chart (including all duties, tasks, steps, and associated knowledge, skills, and abilities required) is presented in Appendix A. To serve as an example for discussion, the KSAs associated with one of the tasks identified during the DACUM process, namely task "A-2, Assess food system for risks and vulnerabilities," are depicted in Table 3.

Once all KSAs for a given occupation are identified, subject matter experts can then organize the KSAs into content categories for purposes of curriculum development. That is, "a job analysis first defines the profession using task-based descriptors, and then committees of Subject Matter Experts (SMEs) use the task-based information as the foundation to make judgments for a list of KSAs" (Wang et al., 2005). This is appropriate because "it is often the knowledge, skills, and abilities required for performing the tasks, rather than the job tasks themselves" that are used for assessing a learner's educational performance (Wang et al., 2005).

The KSAs identified through the DACUM process for a food defense professional were grouped by the research team into 11 content categories based on judgments about how the knowledge items might best be grouped for curricular purposes. A complete list of all knowledge items grouped by content category is provided in Appendix B.

TABLE 2. DACUM analysis chart depicting duties and tasks for a food defense professional.

DUTIES		TASKS				
A	**Preventing Food System Incidents**	A-1 Raise stakeholder food defense / emergency response awareness	A-2 Assess food system for risks and vulnerabilities	A-3 Provide expertise regarding food and agriculture sector to the intelligence community	A-4 Assess food defense and emergency response threats	A-5 Develop and implement food defense / emergency response plans
B	**Detecting and Diagnosing Food System Incidents**	B-1 Select detection strategies		B-2 Perform detection activities		
C	**Responding to Food System Incidents**	C-1 Manage agricultural and food system crises		C-2 Investigate food system incidents		
D	**Recovering from Food System Incidents**	D-1 Establish agency and company role in recovery	D-2 Evaluate similarly vulnerable systems	D-3 Dispose of contaminated product and decontaminate equipment, supplies, etc.	D-4 Assist in community and industry re-start	D-5 Evaluate response and response plan effectiveness
E	**Communicating with Stakeholders**	E-1 Communicate with stakeholders pre-incident	E-2 Communicate with stakeholders during an incident	E-3 Communicate with stakeholders post-incident	E-4 Evaluate communication effectiveness	
F	**Conducting Research and Development Activities**	F-1 Develop risk vulnerability assessment technologies/methods and innovative solutions for food system defense		F-2 Research technologies and methods that integrate considerations for public health, economics, risk benefit analysis, complexity, challenges, sustainability, etc.		

TABLE 3. Knowledge, skills, and abilities (KSAs) corresponding to one task identified through a DACUM process to describe the occupation of food defense professional.

DUTY: A – Preventing food system incidents	
TASK: A-2 – Assess food system for risks and vulnerabilities	
STEPS:	**KSAs:**
a) Select assessment technologies and methodologies	Awareness of good manufacturing practices, GAPs and prerequisite programs
b) Determine participants	Awareness of select or threat agents
c) Gather infrastructure/site/system specific information	Knowledge of allergen control programs
d) Identify vulnerabilities associated with intentional contamination/disruption or natural catastrophic events	Knowledge of biosecurity programs
e) Notify appropriate personnel of normal food safety related vulnerabilities incidentally observed	Knowledge of environmental considerations for disease transport
f) Conduct consequence assessment for identified vulnerabilities	Knowledge of foreign animal, plant, and zoonotic diseases
g) Define and apply counter measures/mitigation strategies	Knowledge of foreign material control programs
	Knowledge of inspections/audits
	Knowledge of pest control programs
	Knowledge of sanitation and chemical control programs
	Knowledge of statistics
	Knowledge of vulnerability assessment methods, including ORM (operational risk management), FDA/USDA guidance documents and checklists, CARVER+Shock, Systems Analysis, Private assessment guidance, NIOSH, EPA

FOOD PROTECTION AND DEFENSE PROCESS: DACUM VALIDATION

The results of a DACUM process are often verified or validated using surveys of other expert workers. According to Norton (n.d.), "verification can involve as few as 25 expert workers or supervisors responding to a survey—or as many as thousands." Validation surveys collect input about the characteristics of the DACUM results, which may include information about the importance, frequency, criticality, or difficulty of given tasks or KSAs (Raymond, 2005). Data from validation surveys can be used to inform decisions regarding the use of DACUM results for curriculum development purposes.

METHODS

To validate the results of the DACUM process for food defense professionals, an internet-based survey instrument was developed in which respondents were asked to rate each of the 107 knowledge items—identified during the DACUM workshop and grouped into content categories—according to importance and frequency of use. After pretesting with a small group of participants (including an evaluator with extensive experience in survey design and administration), the internet-based survey was conducted over a 20-day period. An invitation to participate in the survey was sent by email to 1,820 individuals representing the following groups:

- Experts who were considered for and/or invited to serve on the DACUM panel but could not;
- Public- and private-sector experts referred by DACUM panel members;
- Researchers, experts, and stakeholders affiliated with the Department of Homeland Security (DHS) National Center for Food Protection and Defense (NCFPD) established to address food protection and defense issues (including principle investigators, members of the external board of advisors, as well as members of the industry workgroup);
- Past participants (from both public and private sectors) in food defense computer simulations conducted by Purdue University; and
- Professionals who had participated in food defense training workshops on previous occasions;
- Members of the DACUM panel.

Because initial recipients were encouraged to share the survey invitation with peers or colleagues who had food defense as part of their current or former job responsibilities, the exact number of individuals who ultimately received the survey invitation is not known. The survey was "open" in that anyone who received the email invitation could participate.

Demographic information including job title, employment sector, years of relevant experience, education level, geographic location, age, gender, and race was collected. Survey participants were also asked to rate each of the 107 knowledge items as per the following instructions: "With respect to developing a food defense curriculum and educating future professionals, please provide your opinion regarding (a) how important each knowledge/skill area is and (b) how frequently each knowledge/skill area would be used by food defense professionals." Survey respondents rated knowledge items according to 5-point Likert response option scales for importance (I) and frequency (F). Respondents were not required to provide a rating for every knowledge item, and responses of "I don't know" were treated as missing data (i.e., no response).

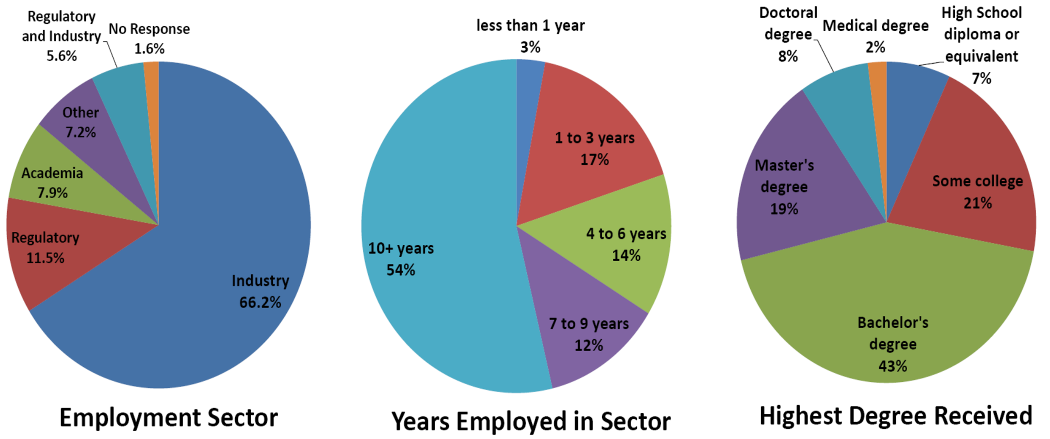
The mean importance value and mean frequency value were calculated for each knowledge item across all survey respondents. In addition, a composite value (denoted as I*F and having a maximum value of 5), was derived by averaging I and F values for each knowledge item for each survey respondent, then calculating the mean I*F value for each knowledge item across all respondents.

RESULTS AND DISCUSSION

A total of 387 respondents were documented within the web-based survey system; of these, 71 were eliminated because the respondent accessed the survey but did not answer any questions, and 11 were eliminated because the respondent indicated that issues related to food defense were not a part of their current or former job responsibilities. Thus, a total of 305 valid responses were received.

The respondent pool was geographically diverse, with 42 U.S. states represented and no individual state comprising more than 8% of the total. Just over one third (37%) of respondents were female. As shown in Figure 1, two thirds of all respondents were employed in the food industry. Additional demographic results, including years of employment experience and highest degree received are also provided.

FIGURE 1. Demographic results for the DACUM validation survey.



Mean **importance** ratings for all knowledge items ranged from 3.4 to 4.6, indicating that all of the knowledge items were considered relevant and should be considered for inclusion in a food defense curriculum. Mean **frequency** ratings for all knowledge items ranged from 2.8 to 4.3. When importance and frequency were considered together, mean I*F values for the knowledge items ranged from 3.1 to 4.4. Knowledge items with the 10 highest mean I*F values are shown in Table 4.

In some instances, knowledge items with either a high importance value or a high frequency value did not appear among the list of knowledge items with the highest combined I*F values. This is because an item may have been considered very important, but would not be performed frequently. In other cases items were rated as being performed frequently but had lower importance ratings. For example, two knowledge items with relatively high importance ratings but rated as being performed less frequently included "Knowledge of appropriate response strategies in the event of a food defense event" (food safety and defense category) and "Knowledge of vulnerability assessment methods and tools" (threat assessment and vulnerability category). These two items, therefore, do not appear within Table 4. Similarly, two knowledge items had relatively high frequency ratings but were rated as less important (and thus did not appear within Table 4); these included "Knowledge of food processing facility and system operations" (food and ag systems category) and "Knowledge of how food processing systems prevent, control, and mitigate food safety hazards" (food safety and defense category).

TABLE 4. Knowledge items with the highest mean I*F values.[1]

Content Category	Knowledge Item	Mean I*F
Food and Ag	Knowledge/awareness of food industry best practices, good agricultural practices (GMPs, GAPs, and "prerequisite programs")	4.41
Food and Ag	Knowledge of vulnerabilities in food and agricultural systems	4.39
Capstone	Knowledge of the necessary components of a food defense plan	4.37
Capstone	Knowledge of how to develop and implement a food defense plan for a specific facility	4.36
Food Safety Defense	Knowledge of potential food safety hazards (biological, chemical, physical, radiological)	4.34
Facility and Site Security	Knowledge of how to implement appropriate security systems and procedures to prevent a deliberate food contamination event	4.34
Communication	Proficiency in written and verbal communication	4.33
Food Safety Defense	Knowledge of food defense plan development	4.32
Food and Ag	Knowledge of food production systems and food product characteristics	4.31
Food Safety Defense	Knowledge of traceability (methods, processes, and systems)	4.27

[1]Mean I*F = derived by averaging importance (I) and frequency (F) values for each knowledge item. Because respondents were not required to answer every question, the number of responses (n) varied by content category and ranged from 240 to 295.
Importance scale: 1 = Not at all important, 2 = Minimally important, 3 = Of average importance, 4 = Very important, 5 = Extremely important.
Frequency scale: 1 = Never, 2 = Rarely, 3 = Sometimes, 4 = Frequently, 5 = All of the time.

In addition to considering the combined importance and frequency results (I*F) of individual knowledge items, overall I*F values were determined for each content category. To determine an overall I*F value for a given content category, for each respondent the I*F values for all knowledge items in a given category were averaged, then these mean category values were averaged across all respondents. The mean I*F values for content categories are shown in Table 5.

TABLE 5. Mean I*F content category ratings.[1]

Content Category	Number (%) of Knowledge Items in Each Category	Mean Category I*F
Capstone	7 (6.8%)	4.08
Food and Ag	10 (9.3%)	4.05
Food Safety and Defense	15 (14.0%)	4.02
Communication	7 (6.5%)	3.93
Facility and Site Security	5 (4.7%)	3.90
Threat Assessment and Vulnerabilities	7 (6.5%)	3.84
Risk Analysis	6 (5.6%)	3.73
Policy Issues	11 (10.3%)	3.69
Criminal Justice and Investigation	4 (3.7%)	3.67
Emergency Management	22 (20.6%)	3.57
Public Health	13 (12.1%)	3.47
TOTAL	107 (100%)	

[1]Mean I*F = derived by averaging importance (I) and frequency (F) values for each knowledge item. Because respondents were not required to answer every question, the number of responses (n) varied by content category and ranged from 182-269.
Importance scale: 1 = Not at all important, 2 = Minimally important, 3 = Of average importance, 4 = Very important, 5 = Extremely important.
Frequency scale: 1 = Never, 2 = Rarely, 3 = Sometimes, 4 = Frequently, 5 = All of the time.

FOOD PROTECTION AND DEFENSE OUTCOMES: LEARNING MODULES

The knowledge items and core content categories identified during the DACUM process (and subsequently validated through the stakeholder survey) formed the basis for a lecture-based workshop and development of distance education modules (PowerPoint presentations with audio). The workshop's lecture-based component illustrated the practical operation of the curriculum for the benefit of bona fide food defense professionals, who then provided feedback on their educational experience.

METHODS

During the spring and summer of 2009, lecturers (principally, but not exclusively, drawn from the project team) were asked to develop their one-hour modules, based on the list of relevant knowledge items and core content categories. The lecturers' learning modules were then reviewed during the summer of 2009 for correspondence with the relevant knowledge items and content categories. This process ensured a systematic approach that promoted fidelity between the workshop content and the DACUM-derived knowledge areas and content categories. In the fall of 2009, the research team convened a two-day Food Protection and Defense Training Workshop at Purdue University that included lectures rooted in the knowledge items and content categories identified by the DACUM process and subsequent survey work. Invited participants included representatives from production agriculture, food manufacturing, food retail, academia, and regulatory agencies. A number of students and future food defense professionals—for example, one Department of Homeland Security-funded graduate student fellow—also attended.

During the workshop, fourteen one-hour training modules were presented on key food protection and defense topics (Table 6). These one-hour training modules were developed through a systematic process tied to the project-derived knowledge areas and content categories.

TABLE 6. Training modules for the Food Protection and Defense Workshop.

Module 1 – The Food and Agricultural System as a Critical Infrastructure	Module 8 - Food Defense Plan Development, Part 1
Module 2 - The Food and Agricultural System as a Potential Target of Attack	Module 9 - Food Defense Plan Development, Part 2
Module 3 - Policy and Risk Assessment	Module 10 - Responding to Food Defense Incidents
Module 4 - Threats to Food and Agricultural Systems – Part 1	Module 11 - Emergency Management
Module 5 - Threats to Food and Agricultural Systems – Part 2	Module 12 - Public Health Systems
Module 6 - Vulnerability Assessment Methods	Module 13 - Risk and Crisis Communication, Part 1
Module 7a - Vulnerability Assessment Example for the Meat Industry	Module 14 - Risk and Crisis Communication, Part 2
Module 7b - Vulnerability Assessment Example for the Grain Industry	

Following each lecture delivered at the workshop, the research team administered a brief survey requesting feedback on the extent to which the module learning objectives were met, along with general module self-perception indicators of presentation value, knowledge gained, an overall module "grade," and additional comments. The first module survey was preceded by a one-page demographic questionnaire, coded by packet numbers so each participant's feedback could be matched across modules. All surveys were administered via pencil and paper over the three-day event and collected by the project PIs immediately following each session.

RESULTS AND DISCUSSION

A summary of selected participant demographic characteristics and pre-workshop knowledge is provided in Figure 2, and the evaluation responses are summarized in Table 7. Despite moderate levels of pre-workshop knowledge regarding food protection and defense (73% of workshop participants indicated they had a "fair amount" of knowledge), the workshop clearly found favor with this demographically balanced group of stakeholders. Mean responses for the overall quality of the workshop all indicated "very good" (Table 7), and when asked if they would recommend the workshop to others, responses were unanimously "yes."

FIGURE 2. Responses to demographic questions, "Which of the following sectors most closely describes your current job?" and, "Before attending this workshop, your knowledge about food protection and defense can be best described as:"

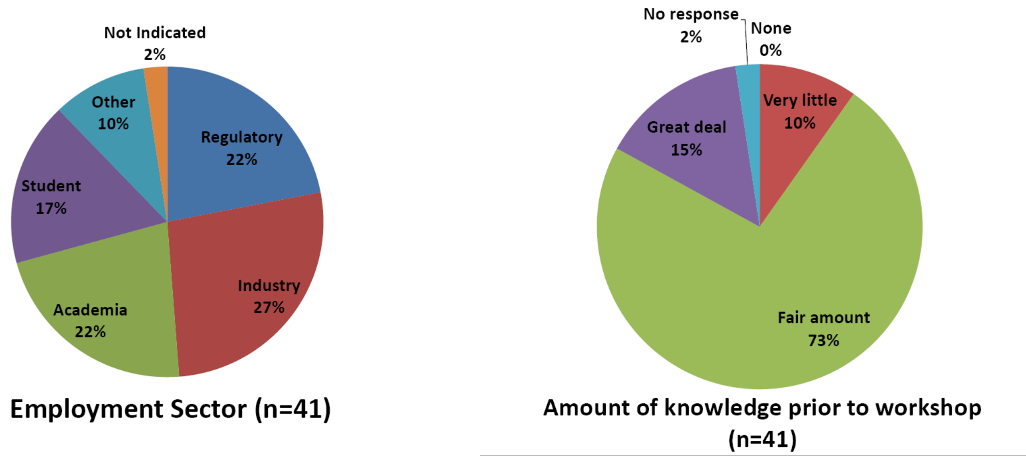


TABLE 7. Participants' evaluation of the overall workshop program (n=29).

Evaluation Statement	Mean Response	Std. Deviation
Overall quality of program content.	4.41	0.68
Overall quality of program modules.	4.21	0.68
Overall quality of program presenters.	4.24	0.74
Overall quality of handouts and materials.	4.10	0.98
Above means based on five-point Likert scale: 1 = Poor, 2 = Fair, 3 = Good, 4 = Very Good, 5 = Excellent		
Did the program meet your needs?	2.97	0.19
Did the program meet your expectations?	2.93	0.26
Was the overall experience valuable to you?	3.00	0.00
Would you recommend this workshop program to others?	3.00	0.00
Above means based on three-point scale: 1 = No, 2 = Somewhat/ Maybe, 3 = Yes		

The workshop provides an illustration of the practical operation of the curriculum for the benefit of actual food defense professionals. However, it remains to be seen how the curriculum might be operated across, for example, a semester-long course for university-based students. Some members of the research team are already involved in teaching or facilitating food defense-related courses, which provide additional metaphorical "laboratories" in which the curriculum might be further evaluated.

FOOD PROTECTION AND DEFENSE OUTCOMES: COMPUTER SIMULATION

A computer simulation model was developed as a hands-on training and evaluation tool for the key knowledge areas identified during the DACUM process. A model of the food supply chain from farm to fork was created to represent the interdependent dynamic system of systems.

METHODS

Data was collected from various food companies to create a realistic supply chain simulation. Real-world production and consumption patterns were fed into the simulation to drive the virtual supply and demand of food. Several sources of data were used to build a virtual food supply chain and artificially intelligent consumers, as depicted in Table 8. The simulation was developed using technologies including Java, XML, Adobe Flash, and Flex run on Dell Xeon Servers.

TABLE 8. Sources of information for the food defense simulation.

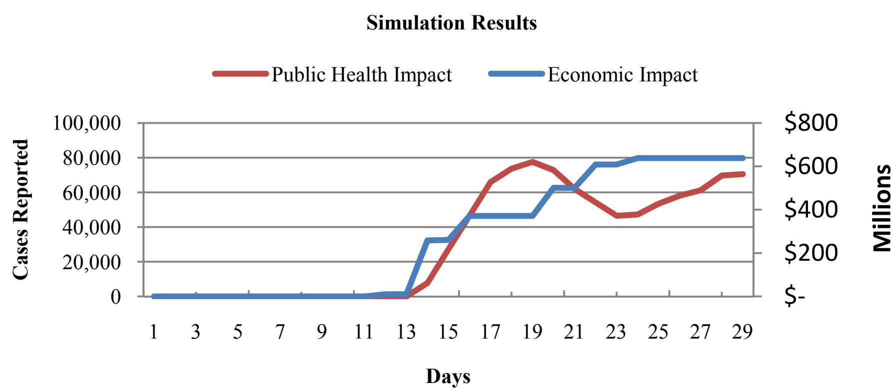
Data Source	Data Type	Examples
Literature review	Food safety, food microbiology	Lethal dose, resistance to processing techniques, optimum growth period, and conditions
Annual reports	Company production and financial information	Number of lots per day, number of units per lot, wholesale prices, annual revenues, operating costs, suppliers, and distributors
Governmental reports	Foodborne outbreaks	Contamination agent, contamination product, morbidity and mortality rates, intervention strategies, costs
Personal interviews	Costs associated with recalls	Holding costs, testing costs, traceability costs, recall costs, liability
Local food retail stores	Retail prices and consumer buying behavior	Retail prices of products, market share, frequency of purchases, number of purchases per visit, dollars spent per visit
Subject matter experts	Verification and validation of data collected	Feasibility of virtual contamination scenario, magnitude of public health and economic impact, supply chain dynamics

During each simulated day, the supply chain produced food and distributed them downstream while the consumers purchased and consumed foods based on their individual preferences. A virtual contaminant was then introduced in the supply chain and its propagation was monitored. Public and private sector participants used the core content and knowledge domains taught during the workshop to respond to the virtual food contamination scenario and visualize the impact of their decisions. The participants interact with the simulation by monitoring their own supply chain, receiving media releases, and interacting with other participants. Participants were placed within different groups representing production agriculture, manufacturing or retail food establishments. The ability to hold, test, recall, release, and trace inventory enabled the participants to create intervention strategies based on their training and background.

Results and Discussion

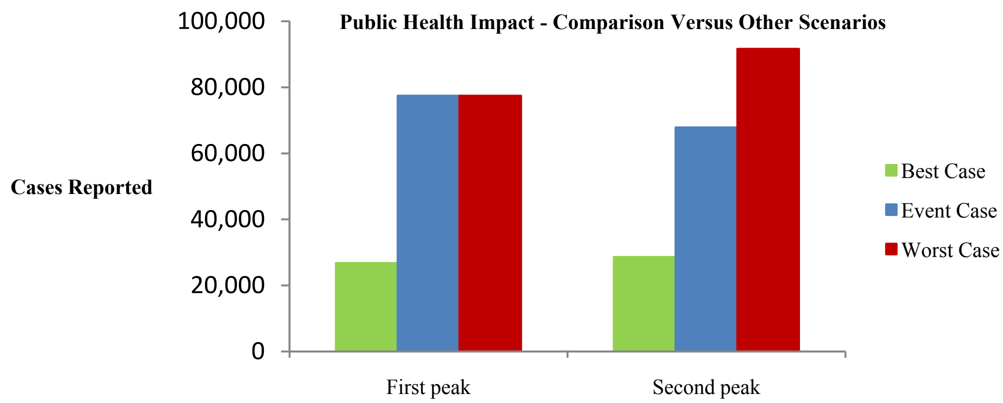
Two key datasets resulted from the simulation event. The first dataset describes the impact of intervention strategies within one scenario. A contaminant was introduced into a bulk ingredient which was then distributed into two different types of products—a long shelf-life product and a short shelf-life product. The results of the simulation event show two peaks in the number of cases of illness—one on simulation day 19 and another on simulation day 28 (Figure 3). The difference in shelf-life of the two contaminated products could explain this phenomenon. The long-term economic impact from the recalls was estimated in the hundreds of millions of dollars. As observed during gameplay, if the companies involved in the recall of the short shelf-life product had shared their test results with the rest of the industry, the long shelf-life product could perhaps have been recalled sooner, resulting in reduced public health and economic impacts. These results suggest that effective risk communication within the horizontal and vertical supply chain helps improve the response to a foodborne outbreak.

FIGURE 3. Number of cases (illnesses) and economic impact reported during the food defense simulation.



The second dataset is the comparison of the simulation event results with the theoretical best-case and worst-case scenario results (Figure 4). The worst-case scenario assumes no intervention and allows the food contamination to propagate freely. The best-case scenario assumes prior knowledge of the entire supply chain and the scenario by all participants. The second dataset suggests that the participants of the simulation event achieved results similar to the worst-case scenario for the short shelf-life product, but got significantly better results for the long shelf-life product. One explanation for this trend is the inherent limitation of test results taking two to three days for positive identification. Most participants chose to wait for test results before conducting a recall which resulted in metrics similar to the projected worst-case scenario. By improving the time to test as well as the accuracy of the tests, intervention strategies may be executed faster, resulting in lower public health impact. The public health impact relies more on the "time to test" factor, while the economic impact depends more on the "accuracy of the test" factor. Finally, the dynamics of communication and the cautious approach to the foodborne outbreak suggest that the participants were treating an intentional contamination as a food safety issue instead of a food defense issue. While the two issues are related, when attempting to identify the source of a contamination, a comprehensive review of the risks associated with each product allows for a more informed decision-making process. Therefore, the research concludes that better training for food professionals in risk assessment would result in improved responses to foodborne outbreaks.

FIGURE 4. Number of cases (illnesses) reported during the food defense simulation event (blue) compared to best-case (green) and worst-case (red) scenarios.



Food Protection and Defense: Concluding Remarks

Today's food supply chain features innumerable vulnerabilities to intentional attack (Dupont, 2003). Beresford (2004) noted that in a post-September 11, 2001 era, homeland security involves not only the "reduction of terrorism" but also preserving "the ability to pursue and maintain social practices and opportunities that Americans hold dear." In order for Americans to possess and exercise this ability, they need to have a safe and secure food supply; food safety and security professionals—including those involved in food defense—recognize this and seek to ensure access to a safe, adequate, and cost-effective food supply (Kastner & Ackleson, 2006).

The project team notes that several of the core knowledge domains derived from the DACUM process feature insights from several Department of Homeland Security areas of priority, most notably, food and agriculture security. We have also learned that food defense professionals must possess a genuinely interdisciplinary understanding of U.S. agriculture and food systems. Food defense professionals also need to understand the complex and inter-related aspects of food science, economics, international trade, emergency preparedness, and models of cooperation that foster the critical public-private partnerships needed in times of agriculture and food-related crises. The complexity of food protection, food safety and security, and food defense and the diversity of professionals involved in these endeavors demands that educators use training programs and materials that are customized to the target audiences.

The job task analysis, training modules, and computer simulation created in conjunction with this project can provide valuable tools for individuals who wish to create and deliver food protection and defense training in support of homeland security in the United States.

The information generated from this project is currently being used as a component for graduate level courses, mainly in food science, agriculture, and public health disciplines. The curriculum provides a sound foundation of both food safety and food defense principles. It also incorporates the role of different stakeholders from public health, the food industry, regulatory agencies and emergency management.

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