Emerging Food System Defense Risks and Technology Needs

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Figure 1 shows how we tend to define the differences between security, safety, defense and protection. In engineering terms, security is a sufficiency definition: you have a sufficient supply. Safety is a reliability definition: the system reliably prevents unintended failures. Defense is a resiliency concept: how resilient the system is to intentional or catastrophic perturbations. Then protection is the continuum of safety and defense. Almost everything that impacts food safety also impacts food defense, and the reverse is also true.

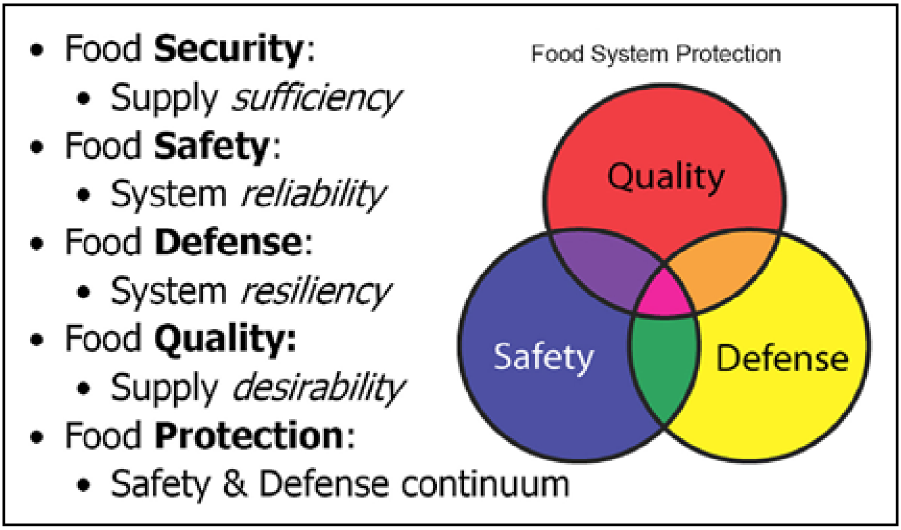

Figure 1. Food continuum paradigm.

I will discuss emerging intentional threats and examine technology needs in two areas: the food-system drivers that generate concerns for intentional contamination; and the intentional contamination drivers. We will deal with each of the items in Figure 2, because aspects inherent in our food system make intentional contamination a concern and there are behaviors of individuals and groups that also make intentional contamination a concern.

John Besser[1] talked about delay in identifying foodborne illness outbreaks and Figure 3 provides a simple way of illustrating part of that problem. First, the food has to be consumed, and then onset of illness presentation is delayed, during which there is no opportunity for public-health recognition. Therefore, foodborne-illness outbreaks usually occur after the peak of consumption, which is a problem for investigating the source. And while that is bad for normal foodborne illness, for intentional contamination with highly pathogenic agents, it can be catastrophic.

- Food system drivers
  - Public health surveillance system
  - System complexity & Globalization
  - Developing world value added agriculture
- Intentional contamination drivers
  - Economically motivated adulteration
  - Disgruntled employees
  - Criminals and deviants
  - Terrorists

Figure 2. Emerging intentional threats.

Epidemiology of an Outbreak

Figure 4 illustrates that delay with the epidemiological curve of the 2006 disease outbreak in the United States caused by *E. coli* O157:H7, associated with spinach. The initial contamination occurred on August 16, and the first case was reported on August 20. On September 8 the first clusters were detected through PulseNet in Oregon and western Wisconsin. And then, on September 14, the FDA made what was considered a rapid announcement of a recall of a product based solely on public-health information. The problem is that the circle (Figure 4) indicates when the product's shelf life had expired. Therefore, the product had expired 10 days before the announcement was made; the

[1]Pages 173–189.

product was gone by the time the recall was announced, and for episodic contamination events, this tends to be the case. Recalls are announced when there is actually very little left to be recalled. In systemic contamination events, like that of the Peanut Corporation of America (PCA), we have a greater opportunity to do a recall for effectiveness because

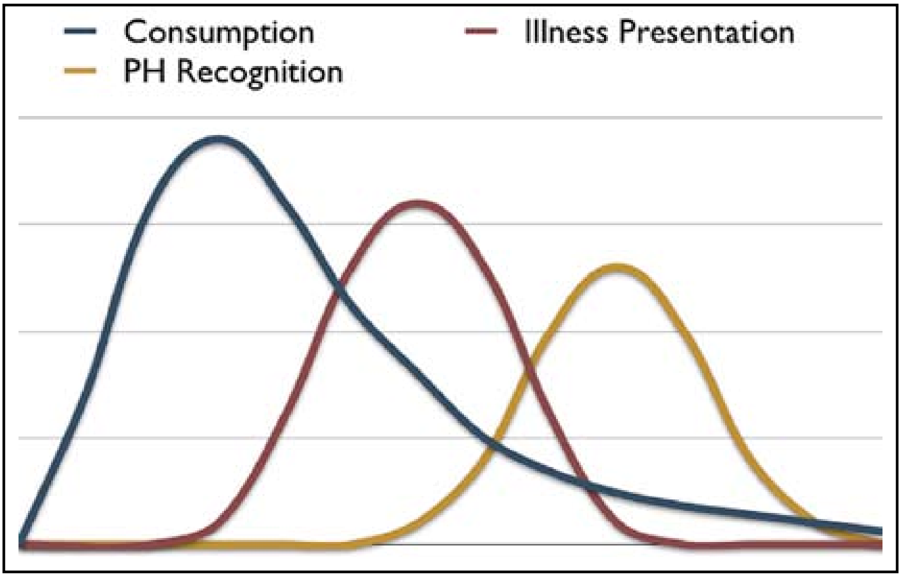

Figure 3. Food-event identification timing considerations.

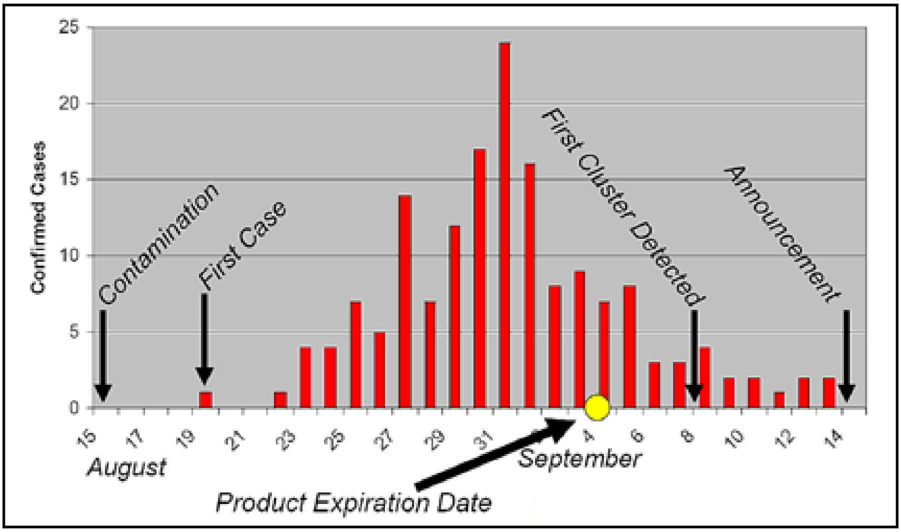

Figure 4. Spinach *E. coli* O157:H7 contamination challenges of rapid event detection.

low-level contamination is on-going. Unfortunately for food defense, foodborne illness is more likely to be episodic and developing methods for earlier detection is important. That is, as was pointed out[2], a function of the variability and effectiveness of the public-health system by state.

The Center for Science in the Public Interest went through data from the Centers for Disease Control and Prevention (CDC) from 1998 to 2007 and categorized the numbers of foodborne-illness outbreaks reported by state per million in population (Figure 5). This study revealed wide variation in the effectiveness of state public-health systems. From an intentional contamination standpoint, these data raise a concern; a terrorist is more likely to strike in the southern states. Trying to improve our public-health capabilities at the state level, including addressing the inherent technology bias, is an important part of our food-defense preparedness.

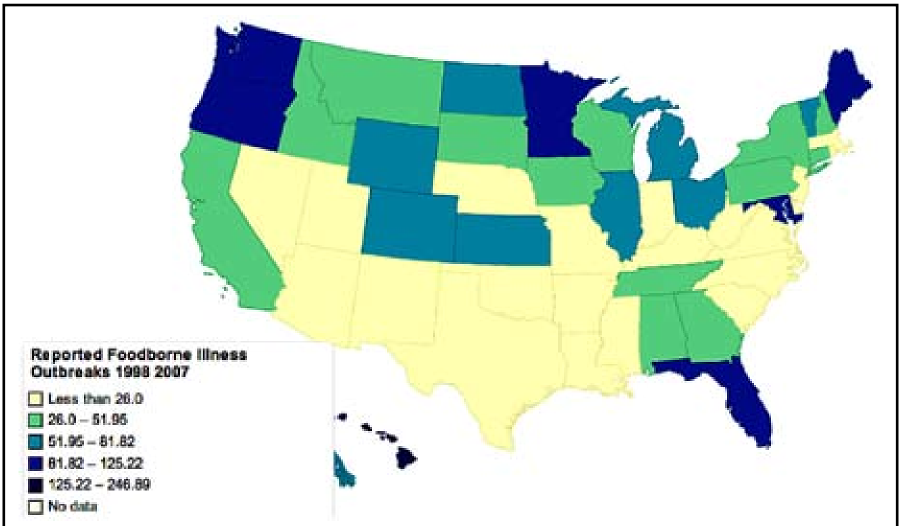

Figure 5. Wide variation in state outbreak performance:
Foodborne illness outbreaks per 1,000,000 population 1998–2007.
(source: Center for Science in the Public Interest)

Traceability

Traceability is affected by the complexity of our food system. Figure 6 provides a simplified characterization of the supply chain for a cheeseburger and, at the bottom of the figure, the major points of distribution from primary production through processing to consumers. If a terrorist announced that he had contaminated the supply chain at three points and nothing else, roughly 48,000 permutations and combinations of threat scenarios would have to be worked through to determine the contamination profile. A daunting task. Figure 7 shows the ingredients of a Big Mac, taken from the McDonald's nutrition

[2]By John Besser, page 187.

website. Now, if a terrorist announced the same thing—supply-chain contamination at three points—the potential contamination scenarios would be increased from 48,000 to 2.5 million. Furthermore, each ingredient has its own supply chain, therefore achieving traceability for all ingredients in all products is still not achievable, although it's something the industry is working toward.

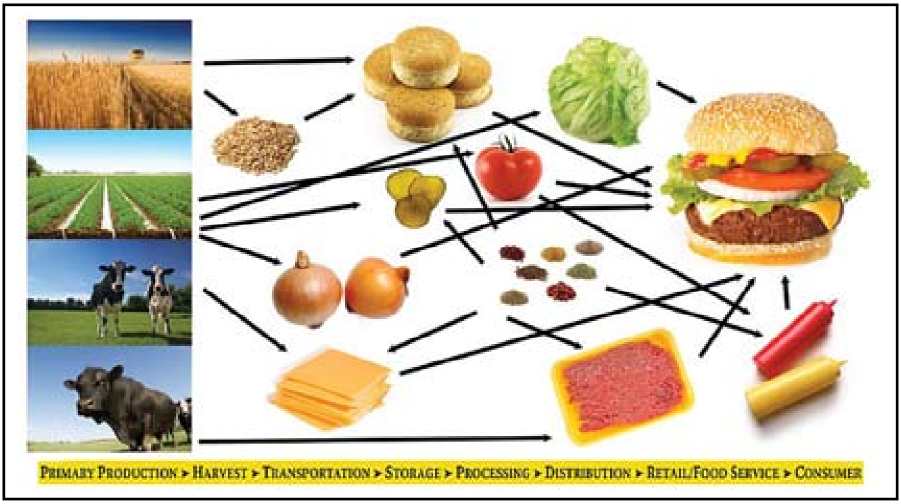

Figure 6. Global supply-chain complexity, cheeseburger–1.

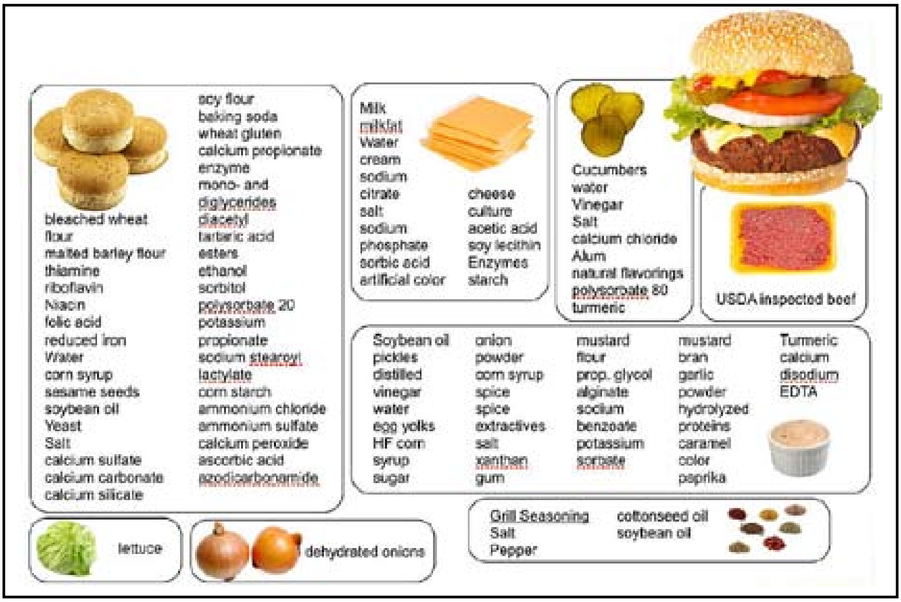

Figure 7. Global supply-chain complexity, cheeseburger–2.

Sometimes these supply chains fall back upon themselves, which was a complicating factor in the 2009 PCA case. Figure 8, from FDA, is a simplified characterization of the traceback of the PCA peanut paste, illustrating that some of the paste went from manufacturer to distributor back to manufacturer to distributor back to manufacturer to distributor before it finally entered retail trade. These multiple processing steps made it difficult for companies to deduce if they actually had the peanut paste in their products. The supplier of peanut paste to an ice-cream manufacturer may have no idea where the paste comes from. As an illustration of the complexity of this particular recall, from its announcement until the final product was recalled was 16 months; it took that long for the last company to figure out that it had shipped a product that contained the peanut paste. The needs for improved traceability to help us improve food safety and food defense are clear.

Global Economy

In Figure 9, countries in color are those to which the United States exported food products in 2010. We provide foodstuffs to almost every country. Figure 10 shows countries from which the United States imported food. Several of these source countries don't like us very much, like Iran, or don't have strong food-safety systems, like most of central Asia.

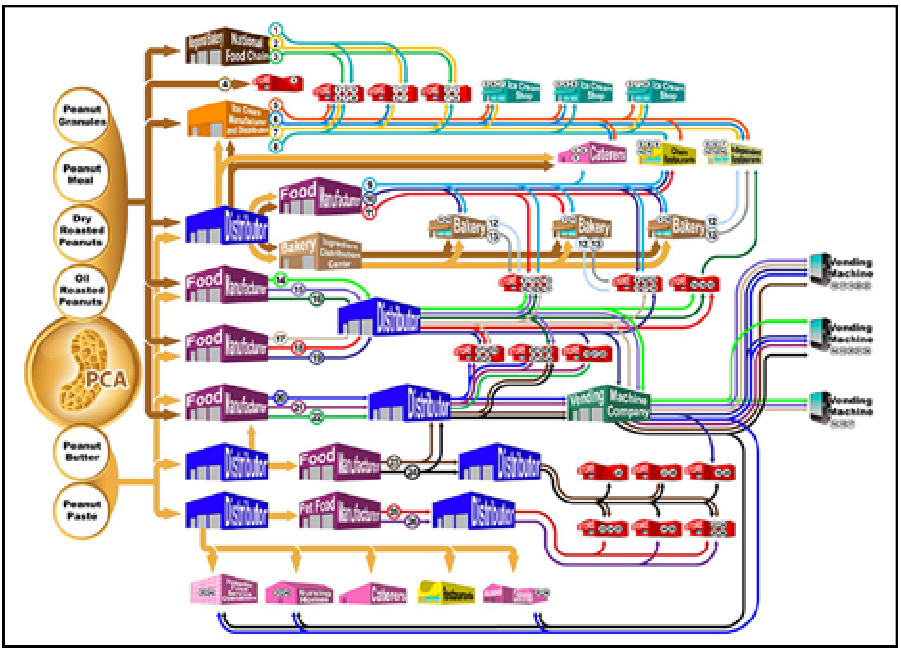

Figure 8. Peanut-paste supply chain.
The circled numbers represent products that were made using at least one ingredient originating from PCA's peanut-processing facility in Blakely, Georgia.
(source: FDA)

Some aren't logical sources of food products such as sugar from Zimbabwe, which has a dysfunctional food-system infrastructure; that we import any food from there is surprising, and whether it is safe is highly doubtful.

Figure 9. 2010 US food-export destinations. (source: USDA-ERS)

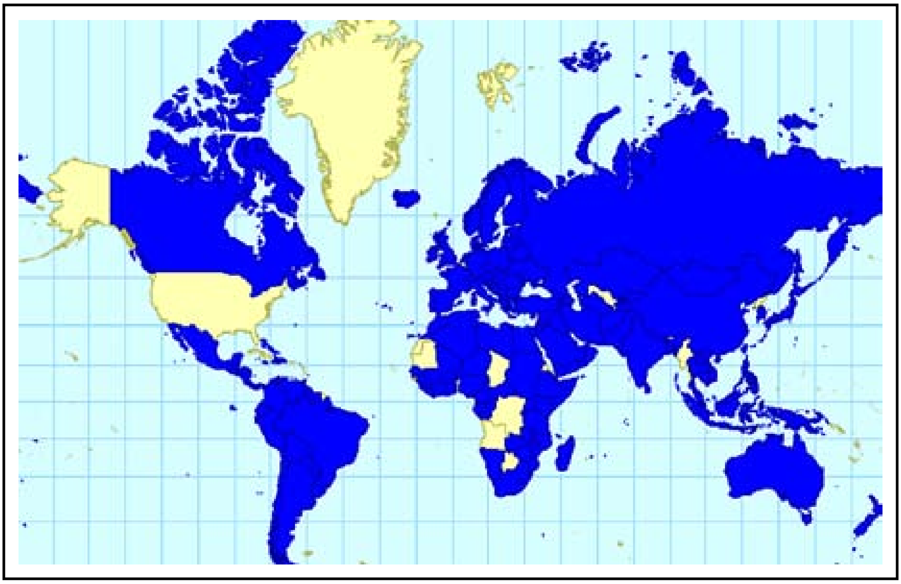

Figure 10. 2010 US food-import sources. (source: USDA-ERS)

Clearly, the food system is globally interconnected, and, to illustrate further its complexity, the numbers in Figure 11—from the FDA's bioterrorism registration database—show suppliers of food to the United States that are either in the United States or at foreign locations. More foreign processing sites are registered overseas to provide food to the United States than are registered in the United States. More foreign packers and repackers are registered to provide food to the United States than are registered in the United States. We are heavily dependent on the global system. Internationally, we have no idea how many farms supply the United States. On a recent visit to China, I asked representatives of several agencies how many farms are in the country and the estimates ranged from 20 million to 200 million. With an error bar so large, it is impossible to estimate the risk profile, and characterizing and understanding our supply chains is an important aspect both in food safety and food defense. We refer to this as "supply chain visibility."

Returning to the cheeseburger, Figure 12 shows source countries for some ingredients—vinegar, garlic powder, tomatoes, beef and wheat gluten—some of which, again, don't make sense. On the other hand, the fact that we import beef from Australia is a good thing as their food-safety system is probably better than ours. The fact that we import wheat gluten from Kazakhstan may be not such a good thing. Understanding where ingredients come from and what risk they pose is a challenge for industry and for the government.

As a developing country progresses from commodity production to value-added production, it becomes a different type of contributor to our supply chain, which may introduce new risks. The United States funds such development because it helps promote local economies. For example, the United States has helped develop the pomegranate business

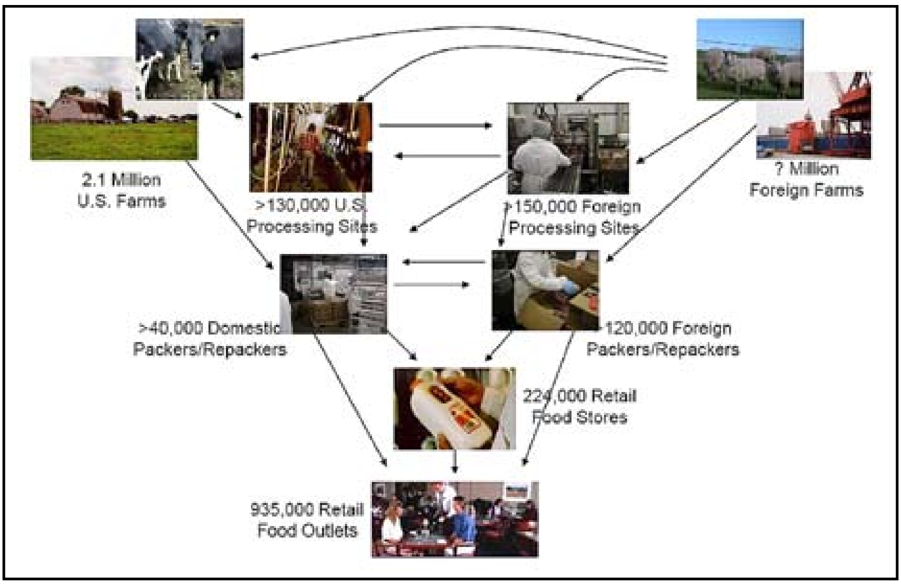

Figure 11. The US food system is increasingly global.

in Afghanistan, partly because Afghanistan produces perhaps the tastiest pomegranates in the world. However, "product of Afghanistan" on the label probably is not a selling point for many US consumers.

It is important to understand that the tariff system can blind us as to where imported foods and ingredients actually come from. Figure 13 shows the relative sizes of imports to the United States of cocoa and cocoa preparations, revealing that Canada is our single largest source of cocoa and cocoa products. Under the sugar tariff, it costs less to import sweetened cocoa liquor than to bring in cocoa powder and sugar separately. Realizing this, industry has set up supply chains that utilize Canada as a blending site. Clearly, using import data as a basis for raising concerns for food safety or food defense is entirely insufficient.

Economically Motivated Adulteration

Other trade data are surprising. We import wheat gluten from Singapore and shrimp from a landlocked country in central Asia that doesn't like us. From the challenges of understanding developing agriculture and how we must ensure that those countries develop their food-safety and food-defense infrastructures as they expand their agriculture, we must be concerned also regarding economic crises and greed leading to economically motivated adulteration (EMA)—intentional contamination of food products to make money. The most recent familiar example is the contamination of proteins in dairy products in China with melamine—for financial gain—that resulted in 290,000 children being made ill. EMA is viewed as a food-defense issue not because it is an intentional threat to public health, but because it illustrates the ability to evade the quality-assurance systems that are in place, simply to make a profit. If someone with a profit motive can get around the quality-assurance systems he could get around them to cause harm. One of our concerns is that some EMA events are test runs before serious contaminants are applied.

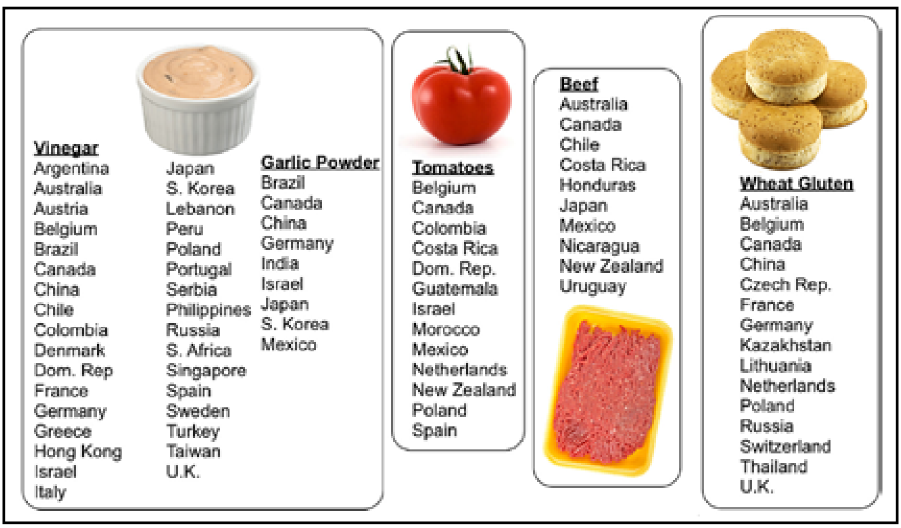

Figure 12. Globalizing the cheeseburger.

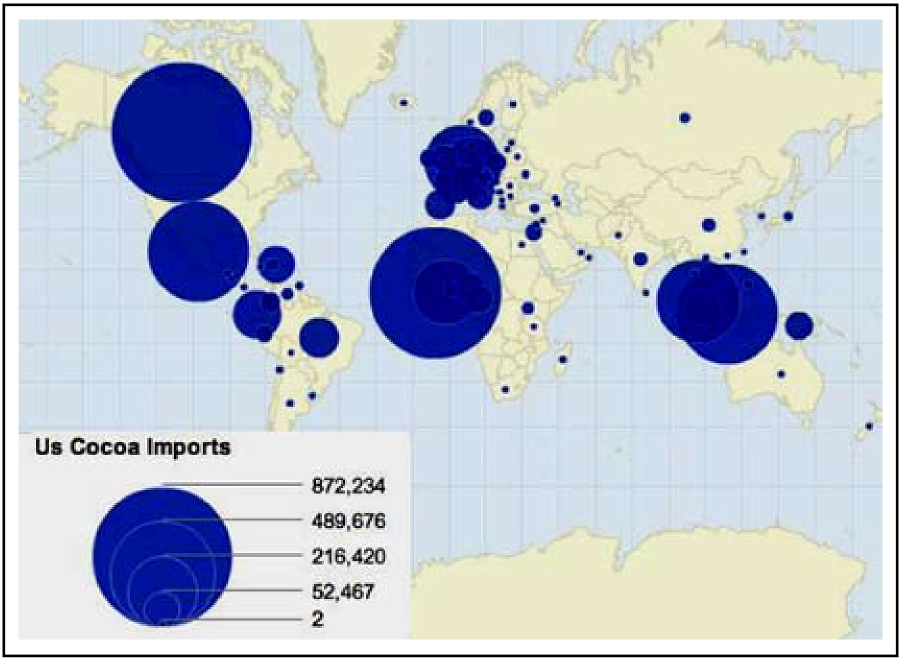

Figure 13. 2010 Cocoa and cocoa-preparation imports to the United States. (source: USDA-ERS)

It is surprising how commonly EMA occurs and in how many ways. The data in Figure 14 are from FreightWatch, a trade group that appraises problems in the freight industry. In 2009, electronics and food/drink, at 23% and 20%, respectively, were the largest causes of theft from over-the-road trucks. Several semi trailers disappear each week and the goods sold. How can one be sure that the robbers don't contaminate the product before selling? Three years ago, a truck of contaminated ground-beef patties was stolen from a detainment lot before they could be disposed of. The patties were sold door to door in Texas and to restaurants.

Figure 15 shows products that, in recent years, have been the focus of EMA activity. When a company is hit by an EMA event that goes public, it results, according to the Grocery Manufacturers Association (GMA), in significant loss of revenue, between 2% and 15% for that year. The total annual impact is estimated at $10 billion to $15 billion and, based on a GMA survey, up to 10% of products in retail may contain an adulterant.

Intentional Adulteration for Other Reasons

Another longstanding problem, as far as food defense is concerned, is the disgruntled employee, who, in frustration, does something to a product, usually to cause a loss of income to the company. For example, a former supermarket employee in Michigan added insecticide to ground beef, and, in Kansas, a woman contaminated salsa with another insecticide. In both cases the perpetrators—subsequently jailed—had issues with their

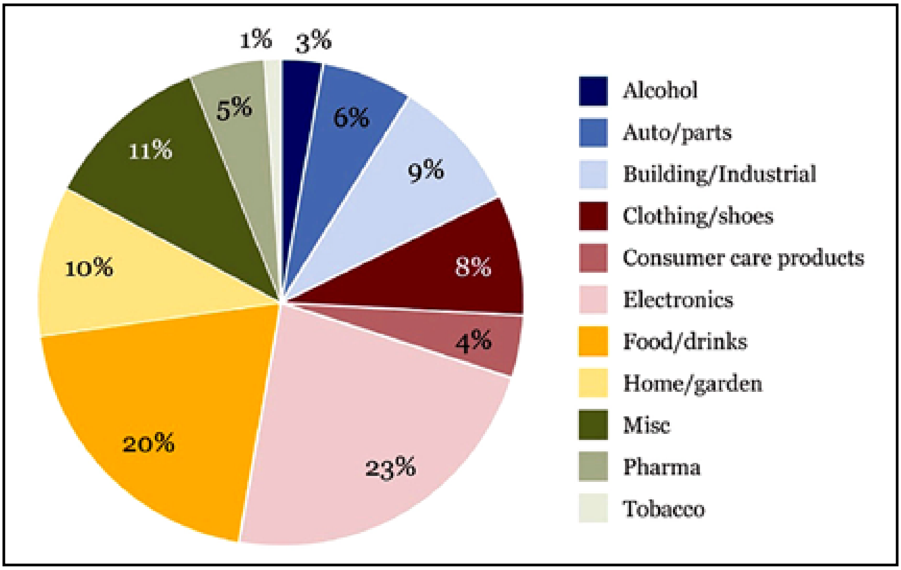

Figure 14. 2009 thefts by commodity: thefts of food and drinks are a significant problem. (source: FreightWatch)

employers and contaminated the food as a means of getting back at them. Forty and seventy people, respectively, were sickened, but if these crimes had been committed in large production facilities, the results would have been much worse.

Then there are challenges from criminals and deviants. For example, in the United Kingdom a man claimed to have contaminated baby food—with ricin—at nine branches of Morrisons Supermarkets. Because of the difficulty of proving a negative, the company had to remove all baby food from its stores in order to demonstrate safety. A hoax alone can cause significant problems for a food company. In Italy in 2008, someone injected a soapy solution into plastic bottles of water, the discovery of which caused mass economic harm to the bottled-water industry. Of greater concern was that the Italian police believe that it was a practice run to determine how many bottles could be contaminated before discovery, to see if it would be worthwhile as a terrorist target.

Intentional contamination by disgruntled employees and the like is not uncommon. From a study by Greg Dalziel, Figure 16 shows agents that have been used to contaminate food and the countries in which those contaminations occurred. These were contamination events designed to cause mass casualties, meaning three or more people. The list becomes lengthy with inclusion of the most common form of intentional contamination of food: spouse on spouse.

Then we get to extremist special-interest groups and threats they posed—such as the Rainforest Agribusiness Campaign, the Animal Liberation Front and the Earth Liberation Front that have issues with agribusiness in general and animal agriculture in particular. For example, the mission of the Animal Liberation Front mission is "to inflict economic damage on those who profit from the misery and exploitation of animals." Cases have been documented in which they have considered causing human-health harm as a way of eliminating agribusiness.

- Pet Food
- Vegetable Proteins
- Cooking Oils
- Mushrooms
- Apple juice
- Orange juice
- Grape juice
- Grapefruit juice
- Maple syrup
- Honey
- Infant formula
- Alcohol
- Bottled water
- Wheat flour
- Cough syrup
- Milk
- Dairy Proteins
- Liquid Eggs
- Gums
- Honey
- Vanilla Extract
- Olive oil
- Sunflower oil
- Seafood
- Horseradish
- Tofu
- Maple syrup
- Infant formula
- Toothpaste
- Shell Eggs
- Rice
- Cheese
- Tomato Sauce
- Fiber Supplements
- Luncheon Meats
- Pomegranate Juice
- Ground Beef - Water
- Ground Meat - Species
- Reduced Butter Fat Cream
- Basil
- Oregano
- Shrimp
- Dog Treats

Figure 15. Recently documented economic adulteration events.

Agents

- Arsenic
- Cyanide
- Feces
- Herbicide
- Household cleaner
- Insecticide
- Nicotine sulfate
- Pesticide
- Rat poison
- Tetramine
- Thallium

Countries

- Australia
- Canada
- China
- Hong Kong
- Iraq
- Italy
- Japan
- Korea
- Philippines
- Taiwan
- Thailand
- U.S.A.

Figure 16. Contamination events since 1998.

Terrorism

Perhaps our greatest concern is the possibility of catastrophic events caused by terrorists. As an example that this is something that people are considering, in 2006 there was an intentional contamination in Iraq of food served in a mess hall, run by Australia, that supplied the police force. The motivation was Shiite/Sunni sectarianism and resulted in at least 350 policeman suffering severe food poisoning, with many air-lifted out. In this low-tech event, the perpetrators simply let a couple of chickens ferment for a few days at ambient temperature before introducing them into the lunch-preparation process.

Such intentional contamination is not new. The first documented case occurred in 590 BC, when the Athenians poisoned the water and food supplies for Kirrha so that they could overrun that city. And during World War II, the Japanese experimented with a number of food vehicles as means of delivering pathogens in China and Manchuria, presumably as test runs for similar attacks on the United States. This included airdropping candies containing *Yersinia pestis* over a village to determine if infecting children would be more effective than infecting adults. In 1996, a laboratory technician at a hospital in Dallas, Texas, contaminated pastries in the break-room with *Shigella dysentariae*, poisoning twelve coworkers. As early as 2002, the Central Intelligence Agency identified contamination of food and water supplies with chemicals and the like as being of significant interest to terrorist groups. After the invasion of Afghanistan, documents found at Tarnak Farms training grounds showed how to prepare botulinum neurotoxin, how much would have to be introduced into the food supply to cause harm and the relative infective rates of other pathogens by oral ingestion. Al-Qaeda had been working on intentional contamination of food systems well before September 11, 2001.

Although there hasn't been a large-scale attack in the United States, effort in food-system defense is justified partly because of public opinion. Figure 17 shows that consumers would invest more in protecting the food system from intentional contamination than from any other type of homeland-security threat. The fact that consumers are most interested in protecting the food system makes sense because they can't take themselves out of the

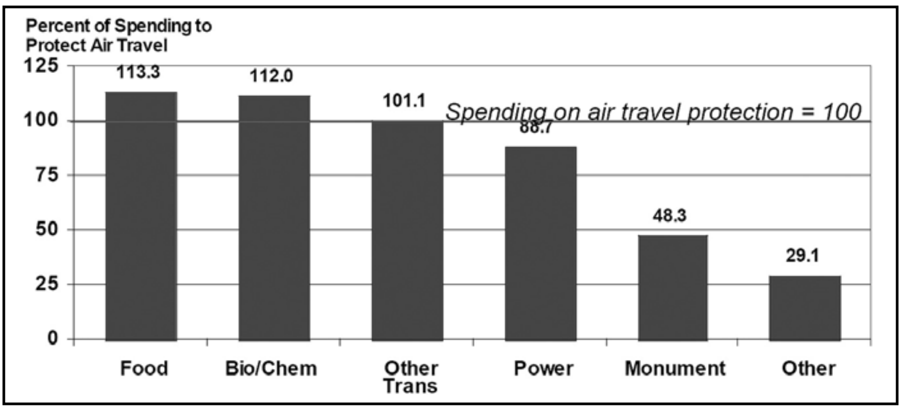

Figure 17. Public would spend more for food defense than for other threats. (source: Jean Kinsey)

target population. In their lives, they don't have to go to major-metro areas, they don't have to get on airplanes, they don't have to use trains, but they have to eat. Therefore, they want to be sure that the food system is protected. For the same reason, food-safety events have a high profile in the United States and other developing countries. People want to feel safe.

Risk Analysis

There are important conceptual differences between food safety and food security especially in terms of evaluating potential risks and vulnerabilities. Food-safety risks, as defined by the Food Safety Modernization Act, are reasonably foreseeable—events that are likely to occur and, therefore, have a probability function. Accordingly, it is possible to build economic models for investment of funds to address it. In contrast, food-defense risk is a deterministic problem that requires an intelligent adversary and not probable system failure; probability is driven by threat, which requires intelligence information. And given that we generally have little intelligence information on what adversaries are doing until they've already done it, determining probability for food defense is challenging. From an industry standpoint, companies that we have been working with approach this problem by looking at the difference in what the consequences are. They look at things as whether they are an operational risk vs. an enterprise risk:

- If it will be a write-off if it occurs, they will accept that risk and won't mitigate.
- If it will result in the potential for the firm ceasing to exist, they will invest to mitigate that risk.

The Society for Risk Analysis defines risk assessment as an analytical process to provide information regarding undesirable events. It's the process of quantification of the probabilities and expected consequences for identified risk; it's the probability of something occurring. Vulnerability assessment attempts to understand the effectiveness of the defense system. Therefore, the concept for food safety is risk assessment. For food defense it is generally vulnerability assessment. Now the Department of Homeland Security makes it a little more complicated for us because they define risk as including vulnerability; this is from Secretary Michael Chertoff[1]:

> *Our risk analysis is based on these three variables: threat, vulnerability, and consequences. These variables are not equal. For example, some infrastructure is quite vulnerable, but the consequences of an attack are relatively small; other infrastructure may be much less vulnerable, but the consequences of a successful attack are very high, even catastrophic.*

The important point here is understanding vulnerability. Chertoff pointed out that although some things are very vulnerable, the consequences of an attack would not be significant. There are other things that are relatively invulnerable, but the consequences of an attack would be high or catastrophic. With respect to intentional contamination, the government is more concerned over events that would be catastrophic rather than situations that are most vulnerable. Consideration of the aggressor is necessary because, without understanding the aggressor, the potential consequences cannot be understood.

[1]See page 106.

Figure 18 provides a limited list of aggressor types, from the disgruntled insider to the compromised insider to the inserted insider, covert intrusion or perhaps one's own supplier. When food-defense work started in 2001, in most cases the focus was on covert intrusion; a lot of money was spent on guns, gates and guards. We were more worried about the compromised insider or the inserted insider—because they would have legitimate access to the facility and would know where to act—or the supplier because unless supply-chain verification is possible you don't know whether your supplier is a potential source of risk. Important also are potential aggressor objectives, ranging from system disruption to wholesale public confidence crisis that would result in a change in government:

- System disruption
- Brand damage
- Category damage
- Trade disruption
- Foreign affairs crisis
- Mass morbidity
- Mass mortality
- Wholesale public confidence crisis

Changes in government have occurred because of food-system failures. Look at the United Kingdom, the Netherlands and Taiwan. If we had a catastrophic food attack in the United States, we would likely have a change in government.

Detection

One of the technology needs for food defense and food safety is detection. But in detection we need to think about the approach. Are you detecting to prevent in order to control things at a site level so it never gets beyond the point where it is contaminated? Are you detecting to protect?; you may not detect it before it leaves the facility but you will detect

Disgruntled Insider	More likely to want to cause disruption/economic loss
Compromised Insider	Could be twisted to cause more significant harm
Inserted Insider	Will be able to find the most significant attack point
Covert Intrusion	Vulnerability varies significantly by system
Supplier	Importance of supply chain verification

Figure 18. Consider the aggressor.

it before it reaches the consumer. Or are you detecting to recover, also known as detect to regret; it's already out there and you are trying to find out how much is still out there. Detection raises challenges of what to test for and how. With respect to food defense, it becomes more challenging because, unlike the six most common organisms that are the focus of PulseNet, we have microorganisms that are normally associated with food and also those that are not normally associated with food as well as literally thousands of chemicals and toxins that are not associated with food at all, but are potential threats for intentional inclusion. And, unfortunately, for many of those micro-organisms, we don't understand their viability, toxicity or infectivity within the food system.

Reconsidering our public-health system and its capabilities, we have the challenge of an intentional food-system event being responded to even more slowly. Figure 19 shows data generated four years ago, when Sara Cox gave internal medicine program directors presentations for certain illnesses and asked them to make diagnoses. So, 70% of the time they got anthrax right on the first occasion. But they got plague right initially only 16% of the time. This goes back to the public-health problem of being trained to look for horses, not zebras; you are looking to diagnose something you are used to seeing, not something you are not used to seeing. If it is something you are not used to seeing, you are not likely to get it right the first time. We have a challenge on how rapidly we can identify these organisms with respect to how very rapidly our supply chains function (Figure 20). For example, bottled water, which has a potential shelf-life of several years, is likely to have an actual shelf life of only about 10 days. That's how fast it moves through the supply chain. If we don't improve our ability to detect contamination, any attack is likely to be of significant consequence.

Primary suppliers to quick-serve restaurants produce between 500,000 and a million pounds of hamburger patties a day. Once they clear quality assurance, they are shipped within 12 hours and after they get to the restaurant they are generally consumed within 48 hours. That's the speed at which the cold supply chain functions because of the cost of refrigeration. Carbon dioxide is a processing aid that speeds grinding and keeps the ground beef at about 1–2°C during grinding for good mouth-feel. An average of 66,000 pounds of CO_2 are used per 900,000 pounds of daily production. The CO_2 could be effectively used as a carrier to get a large quantity of contaminants into the ground beef. Depending on assumptions, perhaps 3.6 million people could be affected in less than 7 days by contamination of one CO_2 shipment.

In Summary

We need better capability for systems-based risk and vulnerability assessment. We need better tools for supply-chain visibility and traceability. We need improved ability to check threat agents, the ability to identify events as they occur and the ability to inactivate the agents and safely dispose of the product after the event.

At the National Center for Food Protection and Defense, our vision is defending the safety of the food system through research and education. Our mission is to reduce the likelihood of an attack, to improve the nation's ability to respond effectively and to reduce the consequences of an attack. Our goal, in brief, is to render targets unattractive.

- Based on case history presentations, correct diagnosis 30 internal medicine programs:
  - Anthrax: 70%
  - Smallpox: 51%
  - Botulism: 50%
  - Plague: 16%
- After a select agent training module, diagnoses improved to >70%

Figure 19. Physicians' ability to diagnose select agents.

- Leading yogurt manufacturer goes from plant to retail in all 48 states in <48 hours
- Quick serve restaurants can go from supplier to consumption in 24-96 hours for primary products (burgers, chicken, salad)
- Bottled water has an effective shelf life of ~10 days for 80% of production
- Only seasonally harvested and canned/frozen or specialty products have effective shelf lives of significance

Figure 20. Product speed to consumer: risks of supply-chain efficiency.

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Prior to joining the University of Minnesota, Kennedy held executive positions in Procter & Gamble and Ecolab. At Ecolab, he was vice president of global food and beverage research and development, leading his organization in developing a wide range of animal-health and food-safety technologies. These included novel sanitizers, FDA-approved process additives, new sanitation technologies, and animal-health products. Prior to this, he was director of strategic and emerging technologies at Ecolab, guiding internal and outsourced technology programs. At Procter & Gamble his positions included assignments in Japan and China, leading research and development teams and global programs.