Chapter 11

PROTECTING THE FOOD SUPPLY CHAIN FROM TERRORIST ATTACK

Maria Jesus Alvarez, Ainara Alvarez, Maria Carla De Maggio, Ainhoa Oses, Marcella Trombetta and Roberto Setola

Abstract The food supply chain is a critical infrastructure that is an attractive target for terrorist attacks. Despite its importance, relatively little research has focused on improving the security of the food supply chain infrastructure. This is largely due to a lack of awareness on the part of food supply chain stakeholders and authorities about the threats. This paper describes a methodology for assessing the risk associated with threats to the food supply chain, with the goal of enhancing awareness and helping develop appropriate security measures.

Keywords: Food supply chain, threats, food defense, risk assessment

1. Introduction

The food supply chain is an attractive target for terrorist attacks. In the aftermath of the attacks of September 11, 2001, the World Health Organization (WHO) stressed the risks due to food terrorism. Of particular concern is "an act or threat of deliberate contamination of food for human consumption with biological, chemical or physical agents or radionuclear materials for the purpose of causing injury or death to civilian populations and/or disrupting social, economic or political stability" [8]. The need to protect the food supply chain was also underscored by Resolution WHA 55.16 [24] at the *Fifty-Fifth World Health Assembly*, which stressed that food is a likely and highly effective way to disseminate biological, chemical or radionuclear agents and materials.

The protection of the food supply chain – termed "food defense" – has attracted considerable attention in the United States [15]. Agriculture and food is recognized as one of the seventeen national critical sectors [4, 5] and a specific work plan [20] was released in 2007. Despite the efforts, many instances of *salmonella* and *E. coli* contamination have been reported in the United States. These outbreaks – large and small – mostly led to hospitalization and, in some cases, death. Interestingly, the authorities were unable to determine the causes of the outbreaks in the majority of cases [3].

The U.S. incidents demonstrate that compromises of the food supply chain can have a significant impact on public health. The food infrastructure is massive and highly distributed. As emphasized by the U.K. Centre for the Protection of National Infrastructure (CPNI) [6] and the Asia-Pacific Economic Cooperation (APEC) Counter Terrorism Task Force (CTTF) [2], every country and geographic region is exposed to a wide range of threats.

The European Commission's Green Paper on Bio-Preparedness [9] highlights efforts for reducing biological risks and enhancing preparedness and response with regard to the food supply chain. Nevertheless, few comprehensive initiatives are underway to secure the European food supply chain from attack. One example is the Rapid Alert System on Food and Feed (RASFF) [10], but it focuses on food safety warnings, not on preventing malicious contamination.

The U.K. CPNI and British Standard Institute (BSI) define food defense as "the security of food and drink and their supply chains from all forms of malicious attack including ideologically motivated attacks leading to contamination or supply failure" [6]. As explained in [8], the potential effects of a terrorist attack on the food supply chain are many, the most significant of which are human disease and death. Terrorist acts are also designed to create fear and anxiety in the population and reduce confidence in the government, which can lead to political instability.

Dalziel [7] has conducted a systematic examination of incidents involving the intentional and malicious contamination of food from 1950 to 2008. The analysis reveals that almost 98% of the incidents occurred downstream in the food supply chain (e.g., at retail outlets, food service establishments, homes and the workplace). Typically, the incidents involved commonly-available household, agricultural or industrial chemicals. When more esoteric chemicals were used, the perpetrators often had access to these agents at work and also possessed the knowledge to use them. Incidents involving biological or radiological agents typically occurred at the retailer or at the consumer and had little impact on public health.

Analysis of the data indicates that the most common reason for the deliberate contamination of food was to disrupt business or tourism and cause economic loss rather than injure people. Thus, a distinction should be made between actions aimed at spreading pathogens in large populations and "symbolic" attacks designed to provoke social anxiety and economic loss. Contaminated food products often spread panic in the population. The mad cow disease and avian flu scares modified consumer behavior in a very significant manner, creating negative effects on the market and massive losses for producers.

Symbolic attacks on the food supply are both efficient and effective. These attacks are easy to perpetrate, and can target any aspect of the food supply chain, especially the least controlled and protected portions of the chain. Widespread monitoring of contamination is complicated by food imports. Most countries import significant quantities of food; the figure for the United States is about 15%. Illegally-imported food poses additional problems because it bypasses government testing.

This paper presents an approach for analyzing the risk to the food supply chain in terms of potential threats, system vulnerabilities and countermeasures. The research, which has been performed under the SecuFood Project [17], has considered a broad sampling of foods consumed in Europe (e.g., milk, yoghurt, juice, bread, oil, salads, fish and baby food). However, this paper specifically examines the major issues related to securing the European milk supply chain.

2. SecuFood Methodology

Ezell and von Winterfeldt [11] have noted that estimating the probabilities of an attack on the food supply chain is a hard task, requiring knowledge about the motivation, intent and capabilities of attackers. In addition, these probabilities change with the defensive measures that are implemented. For these reasons, we focus our attention on food supply chain vulnerabilities with the goal of identifying them in order to implement preventive measures.

To estimate the risk posed by terrorist attacks, and more generally, criminal attacks, we consider the threats posed by the availability of various biological and chemical agents and their potential consequences. This is because any attack on the food supply chain requires the introduction of a dangerous agent. The agent can be added during harvest, storage, processing, preparation, retail or food service.

To conduct a more effective analysis, we decomposed the food supply chain into its main macroscopic steps, taking into account the peculiarities of each step in terms of vulnerabilities and countermeasures. To this end, we assume that a generic food supply chain can be decomposed into the five macroscopic steps shown in Figure 1. A typical workflow starts with a large set of production sites that supply one or more industries. The food is processed, transformed and packaged at these sites, and is then sent, via a logistic system, to wholesalers. The wholesalers distribute the food items to retailers and food service establishments who pass them on to consumers. Note that the decomposition in Figure 1 represents an abstraction; the actual process is very complex and includes numerous sources, processes and exchanges of raw materials between various entities.

We identified specific threats at each macroscopic step for each food type in terms of contamination by chemical and biological agents and by other instruments [18]. Our analysis revealed that the types of threats at the different steps are essentially the same, although the impact and the ability to detect and neutralize the threats can be very different. In fact, the impact of a contaminant is greater when the agent is introduced early in the supply chain. This complicates and delays the localization of the contamination, especially when the adverse effects are not immediate. Also, a contaminant that is introduced in an early step of the food supply chain is difficult to identify and isolate, especially if the problem is discovered after processing and delivery. However, some agents can be detected by quality control testing and neutralized during

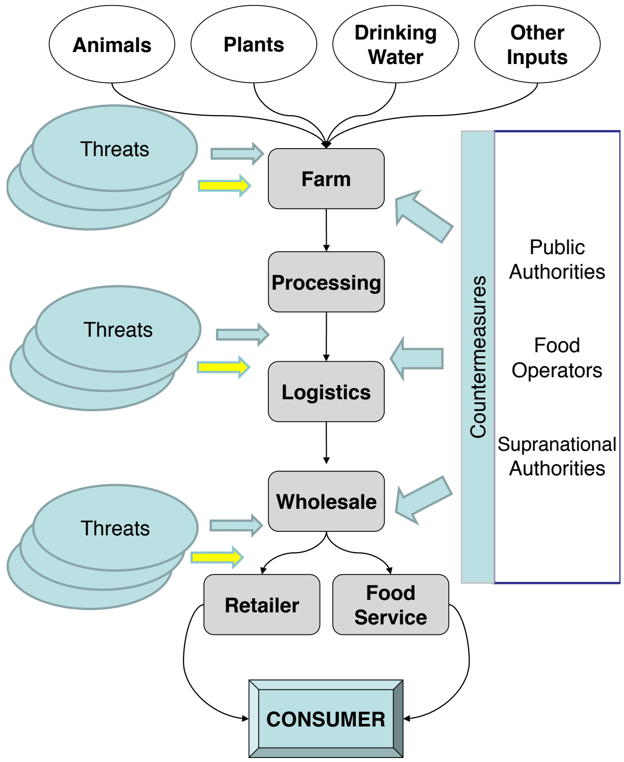


Figure 1. Food supply chain decomposition.

processing. On the other hand, as reported by Lee, *et al.* [14], the most probable targets in the supply chain are food vendors, which includes food producers, retailers, restaurants and other food service establishments. This is because, even if the overall impact is limited in terms of the concrete consequences, the attacker would obtain a large "return on investment."

We also considered the "likelihood" of attacks. The likelihood takes into account the availability and manageability of the agents, the vulnerability of the specific product supply chain, and the possible effects in terms of causalities, economic loss and psychological impact. Specifically we considered:

- Processes in terms of their ability to neutralize agents and product accessibility.
- Company policies regarding employees and visits (e.g., monitoring and access control).
- Security measures adopted (e.g., alarms, cameras and guards).
- Quality control mechanisms implemented (e.g., number and types of controls and hazard analysis and critical control points (HACCP)).

Consequences

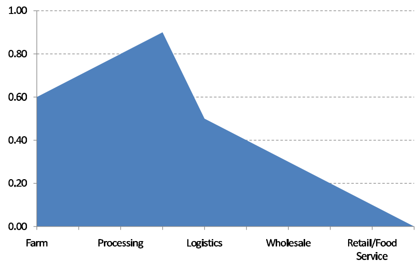
Likelihood	Insignificant	Minor	Moderate	Major	Catastrophic
Almost Certain	M	H	H	E	E
Likely	L	M	H	H	E
Possible	L	L	M	H	H
Unlikely	T	L	L	M	H
Rare	T	T	L	L	M

Figure 2. Risk assessment matrix [21].

Next, for each of the eight types of food items (milk, yoghurt, juice, bread, oil, salads, fish and baby food), we performed a risk analysis based on the research literature and interviews with principal stakeholders and public authorities. We collected about 40 questionnaires and performed inspections of several food processing facilities. Also, we analyzed all the incidents reported by Dalziel [7] and others, amounting to more than 450 cases of malicious contamination of food. Finally, we evaluated and classified about 50 biological and chemical agents in terms of their availability, manageability and possible pathological effects.

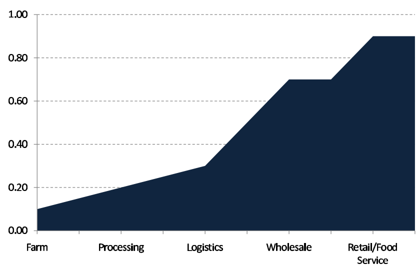
These activities enabled us to collect a large quantity of qualitative and quantitative data about threats to the food supply chain. The data was analyzed with the help of experts from a specialized police corps [1]. An operational risk management (ORM) approach [21] was used to classify the attacks from extreme to tolerable. We also identified the degree of likelihood for each agent with respect to each food item and step in the supply chain. The likelihood was evaluated in terms of the availability of the agent and the vulnerability of the corresponding supply chain step. We created a risk matrix taking into consideration the ability to detect the attack and the possible consequences (Figure 2). The risk matrix employs the following risk categories:

- **Extreme (E):** Causes a large number of injuries, several deaths and catastrophic economic consequences.
- **High (H):** Causes severe injuries, some deaths and severe economic consequences.
- **Moderate (M):** Causes some injuries that may require medical attention, and significant economic consequences.

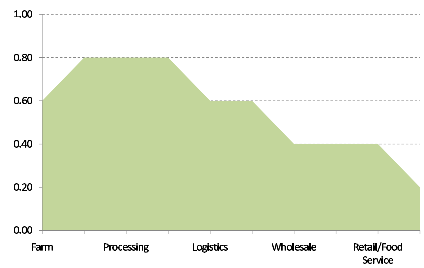


(a) Significant contamination;

(b) Effectiveness of surveillance.



(c) Symbolic contamination;



(d) Effectiveness of countermeasures.

Figure 3. Risks related to different steps in the food supply chain.

- **Limited (L):** Causes no injuries, but some economic consequences.

- **Tolerable (T):** Causes no health effects, but has a limited impact on reputation and some economic consequences.

Figure 3 summarizes the results obtained by averaging the behavior corresponding to each of the 50 contaminating agents with respect to the eight classes of food considered in our analysis. Figure 3(a) illustrates how the risk due to an exposure to significant contamination increases from the farm to the processing phase, reaching a maximum just before the packaging operation. After this, it reduces monotonically due to the decreasing sizes of the lots in the subsequent steps.

In contrast, the graph in Figure 3(c) shows that the risk due to symbolic contamination reaches its maximum close to the consumer. This happens because, as seen in Figures 3(b) (effectiveness of surveillance) and 3(d) (effectiveness of countermeasures), the last steps in the food supply chain are less controlled and less secure. Indeed, most of the controls and countermeasures in the food supply chain are intended to guarantee the safe production of food. Therefore, they are largely concentrated in the production step, where tests are conducted on raw materials, semi-processed goods and final products. After the production step, security-related activities are mostly focused on preventing theft and only minimally on preventing food tampering.

Table 1. Biological and chemical agents [13, 16, 19].

Agent	**Lethality**	**Availability**
Biological Agents		
E. coli	3–5%	Easy
Yersinia	100% (pneumonic) 50% (bubonic)	Easy
Salmonella	<5% (*S. enteritidis*) 12–30% (*S. typhi*)	Easy
Staphylococcus aureus	< 5%	Easy
Brucella	Low	Easy
Francisella tularensis	30–40%	Difficult
Coxiella burnetii	<5%	Difficult
Chemical Agents		
Abrin	Fatal (no antidote)	Very Easy
Aflatoxin	Fatal (no antidote)	Easy
Tetrahydrocannabinoids	Toxic at high levels	Easy
Safrol	Carcinogen	Moderately Easy
Diphosgene Lewisite	Fatal at high levels	
Nicotine	Fatal	
Ricin	Fatal (no antidote)	Very Easy
Tetrodotoxin	Fatal at low levels	Difficult
Saxitoxin	Fatal at low levels	Moderately Easy
Shigatoxin	Fatal at low levels	Easy
Nitrogen Mustard Gas	Fatal at high levels	Difficult
Cadmium	Fatal	Moderately Difficult
Chromium VI	Fatal	Easy
Mercury	Fatal at high levels	Easy
Red Phosphorus	Fatal	Easy
Thallium	Fatal at high levels	Difficult
Titanium	Fatal at high levels	
White phosphorus	Fatal	Easy
Arsenic	Fatal	Very Easy

3. Milk Case Study

This section focuses on a case study of the milk sector. Milk was selected because it is a basic component of the European diet; as such, it is consumed in large quantities either directly or indirectly in other food products. Moreover, it has been the target of malicious attacks [23].

Table 1 lists the main biological and chemical agents that can be used to contaminate milk. Information is also provided about the lethality and ease of availability of these agents.

In the case of milk, it is important to distinguish between biological and chemical agents. Most processed milk goes through a pasteurization (thermal) process that kills biological agents. The subsequent cooling of milk to 4°C

Consequences

Likelihood	**Insignificant**	**Minor**	**Moderate**	**Major**	**Catastrophic**
Almost Certain					
Likely				**Abrin** **Ricin**	
Possible		**Titanium**	**Aflatoxin** **Mercury** **Phosphorus** **Nicotine**	**Arsenic** **Shigatoxin** **Chromium VI** **Saxitoxin** **Cadmium**	
Unlikely		*Staphylococcus Aureus* *Brucella* *E-Coli* *Shigella* *Campylobacter* **Safrol** **Tetrahydrocannabinoids** **Thallium** **BZ**	*Salmonella*	*Bacillus Anthracis* *Listeria monocytogenes* *Yersinia* **Tetrodotoxin**	
Rare		*Coxiella Burnetii* **Nitrogen Mustard** **Diphosgene Lewisite**		*Francisella Tularensis*	

Figure 4. ORM matrix for the milk supply chain.

makes it very difficult for most biological agents to grow. On the other hand, the heating and cooling process does not affect chemical agents, enabling them to be added at any time during milk production.

Milk producers perform several tests on raw milk to check its quality and detect the presence of biological agents. However, these tests are not comprehensive and tests for dangerous agents such as *botulinum* are not performed.

In general, the deliberate contamination of milk at the output stage is much more complicated than at the input stage because the product is packaged in small lots. However, Blasco and Bledsoe [16] observe that with the appropriate technical knowledge and access, any product can be tampered with during the distribution or retail steps. Indeed, packaged food can be sabotaged by terrorists or criminals with a relatively low degree of sophistication.

The ORM matrix in Figure 4 demonstrates that, in the case of milk, the adverse consequences of chemical agents (bold) are much higher than those due to biological agents (italics). This is because few, if any, controls are in place for chemical agents. Furthermore, detecting some chemical agents is very difficult because they are colorless and odorless. However, the most important factor is that chemical agents, unlike biological agents, are not destroyed by the heating and cooling processes involved in milk production.

In summary, the milk sector is prepared to prevent spontaneous contamination via the implementation of controls against zoonosis and other health risks of a microbiological origin. However, it is woefully unprepared to deal with malicious contamination using chemical agents.

4. Conclusions

Food is an unconventional weapon in the hands of terrorists. Despite the worldwide attention paid to the malicious tampering of food products, the majority of the stakeholders in the food supply sector have little understanding of the risks related to deliberate contamination. In general, they believe that their production processes are secure and that their controls and countermeasures are adequate. However, they concede that malicious entities can target food products almost anywhere in the supply chain. This means that they admit that many vulnerabilities exist in food production and distribution.

The consequences of contamination vary according to the specific step in the supply chain that is targeted. An attack that targets a step closer to the consumer has a greater probability of success but affects fewer people. On the other hand, an attack in the early steps of the supply chain affects many more people, but has to evade many controls and countermeasures to be successful.

The transportation and storage steps are, in general, more vulnerable that the manufacturing step. Raw materials are more vulnerable than packaged products, but it is difficult to successfully target raw materials because of strong quality controls. Packaged products are more susceptible to contamination during transportation and storage. The risk is high and the probability of detection is very low – until consumers are affected.

With regard to the milk supply chain, pasteurization and quality control processes reduce the likelihood of a successful attack involving biological agents. However, because of the absence of controls and countermeasures, attacks using chemical agents have a high probability of success.

The absence of major food contamination events leads us to believe that the food supply is relatively safe, but we cannot afford to be complacent. All the entities in the food supply chain should develop security plans for managing the risk. The hazard analysis and critical control points (HACCP) approach is an effective technique as it focuses on proactive (preventive) measures instead of reactive measures, which is prudent in any critical infrastructure sector.

Acknowledgements

This research was partially supported by the European Commission Directorate General for Justice, Freedom and Security under the SecuFood – Security of European Food Supply Chain Project (Grant No. JLS/2008/CIPS/022).

References

[1] Arma dei Carabinieri, Comando Carabinieri per la Tutela della Salute, Rome, Italy (www.carabinieri.it/Internet/Cittadino/Informazioni/Tutela/Salute).

[2] Asia-Pacific Economic Cooperation, APEC to increase protection of the food supply from terrorist attack, News Release, APEC Secretariat, Da Nang, Vietnam, September 15, 2006.

[3] W. Boddie and L. Kun, Health care, public health and the food and agriculture critical infrastructures, *IEEE Engineering in Medicine and Biology*, vol. 27(6), pp. 54–58, 2008.

[4] G. Bush, Critical Infrastructure Identification, Prioritization and Protection, Homeland Security Presidential Directive 7 (HSPD-7), The White House, Washington, DC, December 17, 2003.

[5] G. Bush, Defense of United States Agriculture and Food, Homeland Security Presidential Directive 9 (HSPD-9), The White House, Washington, DC, January 30, 2004.

[6] Centre for the Protection of National Infrastructure and British Standards Institute, Defending Food and Drink: Guidance for the Deterrence, Detection and Defeat of Ideologically Motivated and Other Forms of Malicious Attack on Food and Drink and their Supply Arrangements, Report PAS 96:2010, London, United Kingdom (www.cpni.gov.uk/Docs/PAS96_vis14.pdf), 2010.

[7] G. Dalziel, Food Defense Incidents 1950-2008: A Chronology and Analysis of Incidents Involving the Malicious Contamination of the Food Supply Chain, Technical Report, Centre of Excellence for National Security, S. Rajaratnam School of International Studies, Nanyang Technological University, Singapore, 2009.

[8] Department of Food Safety, Terrorist Threats to Food: Guidance for Establishing and Strengthening Prevention and Response Systems, World Health Organization, Geneva, Switzerland, 2008.

[9] European Commission, Green Paper on Bio-Preparedness, COM (2007) 399 Final, Brussels, Belgium (ec.europa.eu/food/resources/gp_bio_preparedness_en.pdf), 2007.

[10] European Commission, Rapid Alert System for Food and Feed (RASFF), Brussels, Belgium (ec.europa.eu/food/food/rapidalert/index_en.htm).

[11] B. Ezell and D. von Winterfeldt, Probabilistic risk analysis and bioterrorism risk, *Biosecurity and Bioterrorism: Biodefense Strategy, Practice and Science*, vol. 7(1), pp. 108–110, 2009.

[12] A. Khan, D. Swerdlow and D. Juranek, Precautions against biological and chemical terrorism directed at food and water supplies, *Public Health Reports*, vol. 116(1), pp. 3–14, 2001.

[13] R. Lawley, L. Curtis and J. Davis, *Food Safety Hazard Guidebook*, Royal Society of Chemistry, London, United Kingdom, 2008.

[14] R. Lee, R. Harbison and F. Draughon, Food as a weapon, *Food Protection Trends*, vol. 23(8), pp. 664–674, 2003.

[15] J. Monke, Agroterrorism: Threats and Preparedness, CRS Report for Congress RL32521, Congressional Research Service, Washington, DC (www.fas.org/irp/crs/RL32521.pdf), 2004.

[16] B. Rasco and G. Bledsoe, *Bioterrorism and Food Safety*, CRC Press, Boca Raton, Florida, 2005.

[17] SecuFood Project Secretariat, SecuFood: Security of the European Food Supply Chain, University Campus Bio-Medico, Rome, Italy (secufood.uni campus.it).

[18] M. Sekheta, A. Sahtout, F. Sekheta, N. Pantovic and A. Al Omari, Terrorist threats to food and water supplies and the role of HACCP implementation as one of the major effective and preventive measures, *Internet Journal of Food Safety*, vol. 8, pp. 30–34, 2006.

[19] D. Shea and F. Gottron, Small-Scale Terrorist Attacks Using Chemical and Biological Agents: An Assessment Framework and Preliminary Comparisons, CRS Report for Congress RL32391, Congressional Research Service, Washington, DC (www.fas.org/irp/crs/RL32391.pdf), 2004.

[20] U.S. Department of Homeland Security, U.S. Department of Agriculture and U.S. Food and Drug Administration, Agriculture and Food: Critical Infrastructure and Key Resources Sector-Specific Plan as Input to the National Infrastructure Protection Plan, Washington, DC (www.dhs.gov /xlibrary/assets/nipp-ssp-ag-food.pdf), 2007.

[21] U.S. Food and Drug Administration, CARVER Software, Washington, DC (www.fda.gov/Food/FoodDefense/CARVER/default.htm#whatis).

[22] P. Valle, A. Girard and O. Saldate, Defensa alimentaria, *Mundo Lácteo y Cárnico*, pp. 12–19, September/October 2007.

[23] L. Wein and Y. Liu, Analyzing a bioterror attack on the food supply: The case of botulinum toxin in milk, *Proceedings of the National Academy of Sciences*, vol. 102(28), pp. 9984–9989, 2005.

[24] World Health Organization, Global Public Health Response to Natural Occurrence, Accidental Release or Deliberate Use of Biological and Chemical Agents or Radionuclear Material that Affect Health, Resolution WHA 55.16, *Fifty-Fifth World Health Assembly*, Geneva, Switzerland (apps .who.int/gb/archive/pdf_files/WHA55/ewha5516.pdf), 2002.