Food defence: types of threat, defence plans and mitigation strategies

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Abstract (100-150 words)

Defending consumer, business and national food supply from intentional malicious attack is an essential public health and business resilience strategy that must be appropriately developed, be agile enough to address all potential threats and be built on strong knowledge of the industry sector and the mitigation strategies available. This chapter considers the present knowledge on food defence strategies, how they are developed using a risk based approach and how they can be applied within the food chain. At international, national and business level, food defence plans need to be designed, implemented and verified to ensure that they remain current and effective. There is still a significant knowledge gap when organisations are seeking to implement food defence plans and a need for greater capacity building to ensure that risk managers understand the methodological approaches that are currently being used, their value but also their limitations too.

Keywords: food defence, threat, assessment, defence plan, mitigation strategy

Maximum 14,000 words

Chapter points

1. Introduction

Food defence is widely discussed in the literature as concerning all forms of intentional malicious attack on a food batch, lot, or food supply chain (Spink & Moyer, 2011a, GFSI, 2014; Manning & Soon, 2016: GFSI, 2017; BRC, 2018; Manning, 2019). This includes ideological attack (GFSI, 2017); or terrorism (Spink & Moyer, 2011a; Manning, 2019); and where there is an intention by the perpetrators to cause wide scale public harm (FDA, 2019a) or political harm to a given nation, or political party. As a result, a food defence attack can lead to compromised food materials and products, supply chain disruption (PAS 96, 2017), and panic or fear (Spink, Moyer, Park, & Heinonen, 2013). Further, food defence can be described

as an active process or strategy to protect food, organisations and food supply chains (GFSI, 2017; FDA, 2020a). Food defence is said to contribute to "the mitigation of potential risks in intentional contamination and food fraud, which can have a harmful effect on humans and public health, business, economy, etc." (Bogadi et al. 2016, p.217). Some sources state that food defence is distinct from food safety, food quality and food fraud issues (Spink & Moyer, 2011a). Others suggest that food defence includes all intentional acts of adulteration, including food fraud, tampering, food terrorism, cyber-attacks, and hacktivism too (Davidson et al. 2016; PAS 96, 2017). Indeed, it is important to articulate, and then differentiate, what the intentional versus unintentional element of adulteration means in practice (Spink & Moyer, 2011a; Manning & Soon, 2016; Bandal et al. 2017; Kowalska, Soon & Manning, 2018; Manning, 2019). This confused narrative means there is a lack of consistency in how adulteration is defined in firstly legislation between different countries, academic literature and also supply chain standards (for a fuller explanation see Kowalska et al. 2018). The United States (US) Food and Drug Administration (FDA) make a distinction between food safety and food defence:

> "Food safety and food defence approaches consider contaminants differently. For food safety purposes, contaminants are often considered based on their historical association with a commodity and outbreaks of foodborne illness; whereas food defence considers intelligent adversaries who may attempt to contaminate food with a wide range of potential contaminants." (FDA, 2019, p.44)

The European Union (EU) do not define food defence specifically, instead they differentiate in terms of intentional deliberate acts of adulteration and ideologically motivated intentional adulteration which they term "bioterrorism" (European Commission, 2019). The potential for detection of the agent as well as the lethality of the agent material itself will all be considered by the perpetrators when they determine the consequence of their actions i.e. perpetrators are

52 "impact motivated" (Manning, 2019). This means when considering food defence issues, the
53 agent (contaminant) and the profile of the perpetrator should be assessed together. Intentional
54 ideologically motivated adulteration is "the deliberate contamination of food with a biological,
55 chemical, radiological, or physical agent by an individual or group of individuals with the intent
56 to cause wide scale public health harm" (FDA, 2019, p.14)." In comparison, economically
57 motivated adulteration (EMA) is associated with food fraud activities undertaken for economic
58 or competitive gain rather than public health harm. However, the legal and moral line between
59 competitively driven EMA, and the intentional sabotage of competitors' activities, for example,
60 is quite nuanced.

61 This book chapter will consider the different types of threat that can be considered as a food
62 defence issue and the means for their mitigation. Case study examples will be used to illustrate
63 the scope of food defence incidents and the challenges that occurred to identify appropriate
64 defensive action once the incident was identified. The term "threat" is now considered more
65 closely.

66 ## 2. Food defence threat

67 ### 2.1 Introduction

68 A threat is "something that can cause loss or harm which arises from the ill-intent of
69 people" (PAS 96, 2017, p.3). Food defence threats involve a motivation to do harm to distinct,
70 intended and targeted victim(s) with notions of personal benefit to the perpetrator in terms of
71 underpinning an ideological statement, a means to gain objective impact, or more emotively
72 drive results such as notoriety, revenge, or restorative justice (Hirschi, 1969; Cohen & Felson,
73 1979; Pease, 2006; Walklate, 2007; Hirschauer & Zwoll, 2008). Spink et al. (2013; 2014) pose
74 that an offender can be characterised by either their profile (offender-based) or their activity
75 (offense-based). Further, in a food defence incident the interaction between the perpetrator and

the potential victim(s) is of particular interest. The influence of the relationship between the offender/perpetrator and the victim(s) is important because it can include elements of control and power and is affected by how the victim is perceived by the perpetrator as person, victim or object (Canter, 1989; Canter, 2000). Studies have considered for example disgruntled employees (Lopes et al. 2020); employees more generally either within the business or working for suppliers or external contractors, or people with no connection to the business (de Abreu et al. 2020). Whilst offender profiling is not new, considering the profile of the perpetrator in order to develop appropriate and effective food defence mitigation strategies is still in its infancy. The food defence threat could be *personal* against a known group or individual e.g. religious group and thus halal or kosher food may be a target, or the action may be driven because of an event that occurred in the perpetrator's own personal life e.g. a disgruntled employee that then commits an act against a particular business (Lopes et al. 2020).

Alternatively, the perpetrator may relate to the victims as a *vehicle* or target e.g. a crime directed at children through a targeted food (milk powder, baby food) means that the offender may see the target for the attack, not necessarily as the direct target, but instead the one most likely to deliver the best impact for their cause or intention. These activities can be influenced by affective or emotive drivers e.g. political or religious ideology, anger at society as a whole or simply a means to extort money from a food business. This type of crime can therefore have multiple victims and whilst the action is directed at a target individual or group, the overarching impact is intended to be on society at large. Finally, according to Canter (1989; 2000), if the victim is seen as an *object* by the perpetrator then there will be few emotional elements to the food crime. The perpetrator will as a result see the victim as having very little significance as a person in the process of delivering their overall objectives. At the wider criminal level, this is observable in crimes such as human trafficking.

2.2 The vocabulary associated with threat analysis and the development of mitigation strategies

PAS 96 (2017) differentiates between four types of threats in terms of the activity i.e. malicious contamination, extortion, espionage, and cyber-crime. FDA (2019) uses the terms credible threat, insider threat, and threat landscape. A *credible threat* is a threat that exists when a perpetrator has the ability, motivation and opportunity to carry out that threat. A credible threat is thus a realistic concern for the target individual, business, supply chain or nation involved. *Insider threat* is determined to "be posed by an individual who exploits his/her position, credentials, or employment to achieve trusted access to the means, processes, equipment, material, location, facility, and/or target necessary to carry out [an ideologically motivated attack, intentional adulteration to cause harm or] a terrorist action" (FDA, 2019, p.38). Here, as highlighted by Spink et al., (2013; 2014), the term threat is focused on the perpetrator. The *threat landscape* is the scope of food defence threats under consideration when developing a food defence plan. The threat landscape includes characterisation of the threat agents, identifying the established threats themselves, and determining the potential for emerging threats.

Table 1. Examples of agent materials used in intentional adulteration of supply chains 1950-2008 (Adapted from Dalziel, 2009)

Stage of supply chain	Agents materials used
Post harvest, and manufacturing	Glass, mercury, needles, rat poison
Pre-harvest	Cyanide, glyphosate, plant toxin, rodenticide
Retail and food service	Acetone, arsenic, atropine, cyanide, herbicide, insecticide, pesticide, physical contaminants incl. rodenticide, rohypnol, Salmonella Typhimurium, thallium
Water Supply	Cyanide, insecticide, pesticide, sarin, sheep dip, VX (a nerve agent),

The *agent material* is any chemical, biological, radiological, nuclear (CBRN) or physical material used in a food defence threat i.e. maliciously and intentionally adulterate (contaminate) food which is then actively disclosed to organisations and the general public to derive personal, political or social impact (Elad, 2005; Manning, Baines & Chadd, 2005; Dalziel, 2009; Fredrickson, 2014; Meulenbelt, 2018; FDA, 2019; Manning, 2019). Some examples of known agent materials are synthesized in Table 1. The *threat agent* is an individual or group that wishes to perpetrate the threat on the threat target (Banjari, 2018). Examples of threat agents are evolving as more research is undertaken in this area (Table 2). The *established threat can be described* as a combination of the known agent material and threat agent. These threats are known and have been identified in previous incidents. An *emergent threat* is a threat where there is a low level of understanding or evidence, but its significance and credibility is expected to increase. This threat is a combination of a potential agent material and the motivations of the threat agent(s).

Table 2. Examples of threat agents (Adapted from Baybutt, 2002; Manning, 2019).

Internal organizational or supply chain threat agents	External threat agents	Internal & external threat agents
Contractors. Customers. Disgruntled employees. Former employees. Insider employees. Suppliers. Visitors.	Activists. Cults. Cyber criminals. Domestic terrorists. Disgruntled competitor. Extremists and Zealots Hacktivists. International terrorists. Racist groups. Supremacist organisations.	Extortionist. Individuals seeking retribution or harbouring a grudge. Individuals with health issues – mental health, psychopaths, deranged individuals. Saboteurs. Spies.

The threat target can be identified either as a *direct threat target* e.g. a country, government, organisation or individual that is the intended victim of the food defence threat or an *indirect threat* target. An indirect target is described here as a vehicle for the food defence

threat (e.g. baby food) where the resultant threat impact is intended to be on the organisation, nation or other direct threat target, but the indirect threat target e.g. baby food is chosen because it will create the greatest impact and concern. Indeed, Felson and Clarke (1988), in their routine activity approach, differentiate between the target (a person or an object) and the victim (a person) or in the context of food defence, the *threat victim* in the context of food defence would be an organisation or nation state. When seeking to develop a new terminology the *threat attack* can be described as the intentional malicious attack itself on a given point, step or procedure. The attack can be a *single threat attack*; i.e. a single instance and at a single point or can be a persistent attack where there are multiple instances and/or multiple points where the attack is perpetrated. This is explored further in the case studies.

Table 3. Motivations, goals and threat targets for food defence threats (Adapted from Baybutt, 2002).

Motivation	Goal	Threat target	
		Direct threat target	Indirect threat target
Economic failure	Deliver an economic impact on an organisation, group or nation	Multiple	The specific organisation, group or nation.
Ideological	Deliver an impact according to an ideological motive.	Multiple	Individuals or guardians that can drive an ideological change.
Issue-orientated	Protect or end something the perpetrator believes is important	Multiple	Individuals connected to or guardians of the issue that can protect or make the change.
Political	Change political beliefs or policies	Multiple	Governments.
Religious	Deliver an impact according to a religion based motive.	Multiple	Given religious group.
Revenge and retribution	Seek to deliver justice as perceived by the perpetrator.	Multiple	Individuals, groups or organisations specific to the issue.
Social	Change a way of life.	Multiple	Individuals, groups or organisations specific to the issue.

Threat analysis describes how the risk manager(s) identify the threat agent and the agent material and then the likelihood of the threat being realised as well as the consequences should this threat occur (Baybutt, 2002). Vulnerability is the susceptibility to intentional adulteration of a point, step, or procedure in a facility's food process (FDA, 2019, p.11) or in a wider supply

chain. The potential for an intentional malicious attack on a food batch, lot, or food supply chain, where a vulnerability may be exploited *can be called the threat risk*. Threat risk is a calculation of the likelihood of the threat being realised and the severity of the impact of the threat if it is realised. The *threat profile* is a summary of the qualitative estimate of the likelihood of credible threats being realised (Baybutt, 2002); using existing information about known threats, and incidents (Muckin & Fitch, 2019). Another term that is used is *threat intelligence.* Threat intelligence is the information that can be used to determine the credibility of a given agent material, threat agent or vulnerability. This includes information and knowledge about threat agents, their modus operandi, objectives, tactics, techniques, and procedures (Muckin & Fitch, 2019). These terms, some used widely in the literature and food supply chain standards and others relatively new sit within the vocabulary used when developing threat assessment, management and threat mitigation strategies. *Threat mitigation strategies* are "those risk-based, reasonably appropriate measures that a person knowledgeable about food defence would employ to significantly minimise or prevent significant vulnerabilities identified at actionable process steps, and that are consistent with the current scientific understanding of food defence at the time of the analysis." (FDA, 2019, p.11). Key to determining appropriate mitigation strategies is to consider whether the threats are internal or external to the organisation.

Internal threat agents include contractors, customers, disgruntled, former and insider employees, suppliers and visitors. Interpersonal stressors in the internal and contractual work environment can lead to alienation and attempts of sabotage, retaliatory action or efforts to obtain restorative justice (Ambrose, Seabright & Schminke, 2002); or interactional justice where a lack of fairness or equity is perceived (Moorman, 1991). *External threat agents* represent a wide and diverse group (Table 2) and their perception as a credible threat will be situational to a given product, organisation and national situation. It is important to not only

identify the individual(s) of concern, but also their motivations, goals and threat targets (Table 3). There are multiple examples of threat agent, but five types of threat agents are considered un this chapter in more depth: industrial spies (espionage), and then extortionists, saboteurs, extremists, activists and cults, where although the mode of threat attack might be similar (tampering and sabotage of food products); the threat agent and their motives are different, and finally, the last type of threat agent is terrorists. However this review of threat agents does provide more generally a wider understanding of the range of threat agents outlined in Table 2 and their goals and motivations as described in Table 3.

2.3 Industrial spies (espionage)

Espionage, or industrial spying, involves the covert collection without the data owners consent of personally held, rather than publically held, information or data. This privately held data can include intellectual property such as copyrights, designs, blueprints or data that underpins brand value, patents, processing techniques, product formulations, recipes, software systems, trademarks, theories, for commercial advantage (van Arnam, 2001; Crane, 2005; O'Halloran, 2014; Bogadi, Banović, & Babić, 2016; Budiono, & Sawitri, 2017). The characteristic activities of espionage include:

- Breaking and entering into a competitor's premises to steal information or installing recording devices.
- Contacting competitors using a fake identity e.g. pretending to be a potential customer or supplier.
- Covert surveillance and recording through spy cameras and electronic eavesdropping.
- Hiring private detectives to track competitor's staff.
- Infiltrating competitor organisations with industrial spies and insider employees.
- Infiltrating computerised and digital systems remotely.

- Interviewing competitors' employees for a bogus job vacancy.
- Pressuring the customers or suppliers of competitors to reveal sensitive information about their operations, and
- Searching through a competitor's rubbish (van Arnam, 2001; Crane, 2005: PAS 96, 2017).

Espionage is a key threat that needs to be considered within food defence mitigation strategies.

2.3 Extortionists

Extortion can be described as the actions undertaken to obtain something which the perpetrator values (e.g. money, assets, influence or impact) from a person or organisation by force, intimidation, threat or illegal activity (Manning, 2019). Examples of food related extortion incidents often involving a demand for money or a list of demands include:

- The Heinz Baby Food incident in 1988 (see Fisher, 1989);
- The 2003 cyanide in sardines incident in South Africa (UPI, 2003)
- The 2014 Fonterra incident in New Zealand where anonymous threats targeted baby formula in order to threaten the dairy company and the wider dairy sector (Manhire, 2015; BBC, 2016; NZHerald, 2016; Cooney, Varelis & Bendall, 2016)
- The 2016 UK food cyanide extortion incident (Smith, 2016);
- The 2017 German extortion case with a demand for nearly £8.8 million (Licea, 2017: Rojas, 2017; BBC, 2018).
- In December 2019, Heinz and Tesco voluntarily recalled all 7+ months "Heinz By Nature" baby food range after a single jar of baby food was identified as having been tampered and two sharp metal fragments were found in the jar (FSA, 2019).

227 At the time of writing the 2019 case is ongoing and it is not known if this is a case of
228 extortion, but it is definitely an example of product sabotage.

229 **2.5 Saboteurs**

230 Sabotage is a wide term with regard to the activities and motivations it represents.
231 Sabotage is the deliberate damage, disruptions or destruction of assets, infrastructure or
232 intangible assets (brand); or a wish to subvert an organisation's operations in order to weaken
233 a competitor. Sabotage is driven too by a motive to draw personal attention through the act or
234 make a protest or political point by creating unfavourable publicity, embarrassment, production
235 delays or harming relationships, employees or customers (Robinson & Bennett, 1995; Crino,
236 1994; Koc, Jernigan, & Das, 2007; Fiorino et al. 2019). Sabotage can be due to internal threat
237 agents including employees often seeking to damage the organisation itself (Spector & Fox,
238 2005; Krischer, Penney, & Hunter, 2010). There have been examples of food sabotage in food
239 service as an active retribution for customer hostility or rudeness (Zhou, Ma & Dong, 2018;
240 Huang et al. 2019).

241 **Table 4. Sabotage incidents involving the use of sewing needles and pins**

Year	Location	Description	Linked to published extortion attempt
2009	Canada	Seven deli products sold at a No Frills supermarket in Guelph, Ont., were found to have sewing needles inside them (CTV News, 2009)	No
2010	Canada	Five incidents recorded in Toronto of needles being embedded in food products; two at a No Frills supermarket (Foodsafetyblog, 2010)	No
2010	Japan	Employee at supermarket in Kitakyishu, Japan found three needles stuck to a plastic bag containing thinly sliced cabbage in April. A month before another supermarket in the same town discovered similar needles (three cases). Several products in another town were found with needles inserted into bread products. No link was identified at the time (JapanTimes, 2010)	No
2012	Canada	Needle found in Air Canada sandwich during a flight (BBC, 2012).	No
2012	Europe	Needles used to tamper with yoghurt (RASFF Portal, 2020)	No
2015	Canada	Nails and needles found inserted into potatoes (CFIA, 2015)	No
2016	Canada	Needle found inserted into children's candy (Pace, 2016)	No
2018	Canada	Sewing pins found in meat products (three separate incidents) purchased at grocery stores in Nanaimo, Vancouver (CBC News, 2018)	No
2018	Australia	Strawberries and other fruits were found to contain sewing needles after an initial incident and then multiple copycat events (March, 2018)	No

2019	Australia	Needle in grapes purchased in Melbourne (Offer, 2019)	No

Revenge or retribution is a powerful motive for the initial threat attack. In Australia in 2018, sewing needles were found by a consumer in strawberries in a pack purchased from a retail store. This sabotage incident is an example of a disgruntled employee who is said to have placed needles into the strawberries due to a workplace grievance (Marsh, 2018). In the subsequent weeks there were 186 reports of sewing needles found in strawberries, some found to be hoaxes (n=15), including Queensland (n=77) with sixty-eight strawberry brands affected (Peaarlman, 2018). A woman was seen putting a needle into a banana in what was believed to be a copycat act (Siddique, 2018). These copycat cases from other perpetrators influences the ability of investigators to identify the threat agent who undertook the first act i.e. to identify the threat intelligence around the original sabotage incident. Sewing needles have been used in a range of sabotage incidents often undertaken, or identified at the retail store (Table 4), some with associated extortion demands, others without any additional communication from the perpetrator. Food Standards Australia New Zealand in their subsequent report to government on the strawberry incident cited a need for further action to be able to give a co-ordinated response between regulators and industry in the event of another sabotage incident (FSANZ, 2018). The series of recommendations is discussed later in this chapter in the wider context of food defence mitigation strategies.

2.6 Extremists, activists and cults

Extremists have been linked to a number of food defence incidents (Table 5) including: anarchists, politically and ideologically motivated activists including hacktivists, extremists and cults. Anarchists aim to bring about anarchy and a dismantling of existing political and social structures and hierarchies in favour of new structures and systems. In December 2016, Greek anarchists claimed on a website that they had contaminated several food and drink

products linked with multinational companies such as Coca-Cola, Nestlé, Unilever and Delta Foods, a Greek company and as a result products were withdrawn from shelves in supermarkets in Athens (Michalopoulos, 2016; EUROPOL, 2017). The claim that foods contaminated with chlorine and hydrochloric acid were then put back on supermarket shelves was seen as a "credible threat" by authorities. Delta Foods stated:

> "This move affects a Greek company, which employs more than 1,200 workers, has been working with 1,400 Greek farmers for more than 60 years, and actively supports the Greek family, economy and region. Apart from the damage that it creates, it's directed against farmers and hundreds of affiliated stakeholders (distribution network, retail outlets, suppliers) and eventually it's turned directly against the Greek society itself" (Michalopoulos, 2016).

Activists are individuals or groups who organise with the aim of influencing public policy and/or an organisation, social norms and values through a concerted action to achieve their specific goals, which may be political, economic, or social (Grunig, 1992; Werder, 2006). In order to achieve their goals they need to position themselves and legitimise their group and their ideas and build a membership base (Werder, 2006). Hacktivism is the usually clandestine use of electronic hacking to help advance political or social causes (Manion & Goodrum, 2000). Hacktivists are able to use strong and complex digital connections to target specific attacks on organisations, governments or individuals. Hacktivists undertake cyber-attacks against a target that are ideologically or politically motivated e.g. data exposure to highlight potential unethical practices by institutions or defacement of organisational websites (Van Niekerk, 2017).

Table 5. Incidents involving activists, extremists and cults

Year	Country	Description
1952	Kenya	The Mau Mau used African Bush Milk (a plant toxin) to poison cattle of the Kikuyu tribe (Wilson et al. 2000; Manning et al. 2005)

1978	Israel	In 1978, another Palestinian group, the "Arab Revolutionary Council", targeted Israeli citrus fruit, using liquid mercury as an agent material and in 1988, Israeli grapefruit exports were threatened with contamination (WHO, 2002).
1981	UK	In 1981, an eco-activist group, "Dark Harvest", threatened placing anthrax contaminated soil in places throughout the UK to highlight the ecological dangers of chemical and germ warfare (Carus, 1999).
1984	US	In September 1984, the Rajneeshee group (some described as a cult) intentionally contaminated salad bars in ten restaurants in the town of The Dalles with Salmonella, in order to influence the voting in a local election. There were 751 cases of illness (Sobel et al. 2002; Manning et al. 2005).
1986	Sri Lanka	Tamil militants threatened to destroy the national economy either by using potassium cyanide or by bringing in non-indigenous diseases to devastate rubber and tea plantations (Manning et al. 2005).
2014	US	The hacktivist group Anonymous caused major disruption in hospital operations at Boston's Children's Hospital (Mohammed, 2017);
2016	Italy	In June 2016, Italian anarchists threatened to contaminate foodstuff in supermarkets in Lombardy with herbicide (EUROPOL, 2017).
2016	Greece	In December 2016, Greek anarchists claimed they had contaminated several food and drink products of multinational companies (EUROPOL, 2017).

In creating a typology of food defence issues, it is difficult to distinguish between the forms of intentional contamination described here and incidents described as terrorism.

2.7 Terrorism

Terrorism at its simplest is the politically motivated violence or threat of such violence with the intention of causing fear (Levy & Sidel, 2012). In Title 22 Chapter 38 of US. Code 2656f, terrorism is defined as "premeditated, politically motivated violence perpetrated against noncombatant [civilian] targets by subnational groups or clandestine agents." Terrorist activities are enacted to attain a specific ideological or political goal (Nestle, 2003), engender fear, terror, panic and anxiety in the general population or a particular group and as a result reduce the level of confidence in the government, leading to uncertainty and political instability (Alvarez et al. 2010: Fredrickson, 2014). There are multiple definitions of food-related terrorism (Table 6). These focus on deliberate adulteration of food with an agent material to cause harm, injury or death.

Table 6. Definitions of food related terrorism

	Definition	**Source**

Agroterrorism	The deliberate introduction of a disease agent, either against livestock or into the food chain, for purposes of undermining stability and generating fear.	(Haleem et al. 2019)
Agroterrorism	The deliberate use of biological or chemical means to depreciate, stunt, halt, or destroy an agricultural asset or set of assets.	(Grieco, 2015)
Agroterorism	The deliberate introduction of an animal or plant disease with the goal of generating fear, causing economic losses, and/or undermining social stability.	(Monke, 2007)
Bioterrorism	The deliberate release of viruses, bacteria or other agents used to cause illness or death in people, but also in animals or plants.	(Jansen et al. 2014)
Bioterrorism	The deliberate poisoning or contamination of the food supply to achieve some political goal.	(Nestle, 2003)
Bioterrorism	The deliberate release of viruses, bacteria, or other germs (agents) used to cause illness or death in people, animals, or plants.	(PHE, 2020)
Food terrorism	An act or threat of deliberate contamination of food for the purpose of causing injury or death to civilian populations.	(WHO, 2002)
Food terrorism	The deliberate (or threat of) contamination of food with hazardous agents (biological, chemical, physical, or radionuclear) for the purpose of causing injury or death and/or disrupting social, economic, or political stability.	(Fredrickson, 2014)

Food terrorism can cause severe implications for the health of the population, weaken or destroy economic growth and cause significant trade disruption, and consequential loss to the local or national economy (Manning et al. 2005). The resultant direct or indirect impact could lead to the culling of livestock, and the potential compensation paid to farmers and producers, collection and disposal of rejected food products and a loss of consumer and political confidence and the direct impact on public health services including hospitalisation and illness related costs. Green et al. (2017) argue that there is a typology of food terrorism starting with terrorism of which a sub-set is bioterrorism which may or may not be related to food; to food terrorism of which a subset is agro-terrorism that relates specifically to primary production. Agro-terrorism in itself could be driven by a range of threat agents and may prove an all-encompassing theme that includes: (i) militant activists and animal rights groups; (ii) international terrorists; (iii) domestic terrorists; (iv) disgruntled insider employees or industry specialists; (v) economic opportunists wishing to cause economic disruption and market volatility (Thomas, 2018). Agro-defence, the actions that can be taken to reduce the likelihood of an agro-terrorism incident, specifically can be addressed by specific mitigation strategies and through the use of food testing methods, and farm security checks. However, convictions for planning of terrorism acts in the UK are often delivered through traditional policing/anti-

terrorism methods showing that routine surveillance measures are as important as implementing prevention and mitigation strategies. The World Health Organisation (WHO) in their 2002 Report "*Terrorist threats to food: guidance for establishing and strengthening prevention and response systems*" states that an essential means to preventing food terrorism is the development, validation, implementation, monitoring and effective verification of management programmes and their associated security measures. Further, the WHO report states that effective prevention requires food defence mitigation strategies that deliver a concerted defence approach between government and industry.

2.8 Food defence vulnerability and threat assessment

Food defence vulnerability assessment considers the potential public health impact of the agent material (a factor of severity and scale), and accessibility i.e. the potential for the threat agent to access and successfully adulterate the product if a contaminant were added (FDA, 2019). Supply chain vulnerability has been suggested as being a combination of opportunity, the motivation of threat agents and what drives this motivation and the efficacy of control measures that have been adopted at all levels of the supply chain and national food supply (see van Ruth et al. 2017). The FDA suggests the use of Carver + SHOCK, an adapted military tool where Carver is an acronym for the six attributes used to evaluate the potential for an attack on a threat target: criticality, accessibility, recuperability, vulnerability, effect, and recognisability (FDA, 2019). SHOCK recognises the combined economic, public health and psychological impacts of a given threat attack. This approach can select given targets and risk rank them using a scoring system that helps to prioritise mitigation strategies (de Abreu et al. 2020). The introduction in 2016 of the FDA Food Defence Plan Builder, supported create standardisation of the methodologies for US food operators and countries seeking to export into the US (Manning, 2019; de Abreu et al. 2020; Lopes et al. 2020).

Horizon scanning is the thorough examination of potential threats and vulnerabilities in order to identify uncertainties or market forces that can influence food related crime, prioritise threats and the means for their effective mitigation and management, and provide early warning of particular established and emerging threats (Roy et al. 2014; Smith & Byrne, 2019; Stanley et al. 2015). Therefore, horizon scanning is a systematic approach to consider evidence of trends and scenarios in order to determine whether an organisation is adequately prepared for established and emerging threats and if the organisation has implemented, or can readily adopt adequate means for their elimination, mitigation or control.

The Global Food Safety Initiative (GFSI, 2017) highlights food defence threat assessment tools such as threat analysis critical control point (TACCP). The application of TACCP in the PAS 96 process aims to identify the likelihood and consequences of a threat being realised. The scope of TACCP is wider in terms of the threats considered than simply food defence, as it also addresses food fraud, cyber-crime and so on (see PAS 96, 2017). TACCP also considers the typology and impact of the perpetrators (Manning, 2019). TACCP and Carver + SHOCK both have a risk based semi-quantitative element to prioritise threats (Manning, 2019) and then to inform food defence mitigation strategies. Vulnerability analysis critical control point (VACCP) focuses on vulnerability, exposure or susceptibility to an incident (Soon & Manning, 2019; Soon et al. 2019a).

3 Food defence mitigation strategies

In general, mitigation strategies are used in the food supply chain to manage risk. Mitigation strategies require the organisation to take precautionary, and preventive actions to reduce risk and in doing so incur cost for a potential event that might never be realised (Talluri, Kull, Yildiz, & Yoon, 2013). For food defence attacks to be successful they rely on a lack of preparedness by the threat target or victim that then creates a vulnerability (Olson, 2012:

369 Wiśniewska, 2015). Increasingly, manufacturers, retailers and food service organisations are
370 requiring formal food defence mitigation strategies as a pre-requisite to supply (Wiśniewska,
371 2015). These mitigation strategies include the active steps taken, the protection activities,
372 process or procedures, often called security measures or countermeasures, that reduce the risk
373 associated with food defence threats (Spink et al. 2015; Manning & Soon, 2016; Manning,
374 2019).

375 Facility-wide security measures, may include the need to address a particular
376 vulnerability at a given point but are usually: "general, non-targeted, protective measures that
377 are implemented at the facility-wide level to protect personnel, property, or product" (FDA,
378 2011, p.11). This means that security measures can be global in nature and may form part of
379 general good manufacturing practice (GMP) pre-requisite programmes or can be specific and
380 address a single vulnerability (Manning, 2019). Mitigation strategies derived from a food
381 defence vulnerability assessment form one element of a food defence plan along with
382 validation, monitoring, corrective action and verification procedures (FDA, 2019). These terms
383 amongst others are described in more detail in Table 7.

384 **Table 7. Food defence plan definitions (Adapted from Cohen & Felson, 1979;**
385 **Manning, 2013; Spink et al. 2015; FDA, 2019**)

Term	Definition	Source
Food defence guardian	Guardians monitor and protect food, processes, organisations, supply chains and nations against food defence issues and the absence of effective guardians makes an attack more likely.	(Cohen & Felson, 1979).
Food defence monitoring	Means to conduct a planned sequence of observations or measurements to assess whether mitigation strategies are operating as intended.	(FDA, 2019)
Food defence plan	A set of written documents that is based upon food defence principles and incorporates a vulnerability assessment, includes mitigation strategies, and delineates food defence monitoring, corrective action, and verification procedures to be followed.	(FDA, 2019).
Food defence system	The result of the implementation of the food defence plan.	(FDA, 2019)
Food defence validation	The activities undertaken to ensure that security measures (countermeasures) are functioning as intended i.e. within established pre-defined limits. Target levels and tolerances may be set to provide assurance that loss of security will be detected before vulnerability actually occurs.	(Manning, 2013)
Food defence verification	The application of methods, procedures, and other evaluations, in addition to food defence monitoring, to determine whether a mitigation	(FDA, 2019)

	strategy or combination of mitigation strategies is or has been operating as intended according to the food defence plan.	
Hurdles	The formal components in a food defence system that reduce opportunity for intentional adulteration to occur by either assisting detection or by acting as a deterrent.	(Spink et al. 2015)
Hurdle gap	The vulnerability that occurs when a hurdle that is part of a mitigation strategy is either not in place or if it is in place is not effective.	(Spink et al. 2015)

386

387 *Guardians* monitor and protect food, processes, organisations, supply chains and
388 nations against food defence issues and the absence of effective guardians makes an attack
389 more likely (Cohen & Felson, 1979). Guardians are visible individuals who have positions of
390 authority in organisations combined with the relevant knowledge, skills and understanding and
391 are able to implement, monitor and verify a food defence system (Reynald, 2009; Hollis &
392 Wilson, 2014; Soon et al. 2019b). *Hurdles* are the formal components in a food defence system
393 that either reduce opportunity for intentional adulteration to occur by either assisting detection
394 or act as a deterrent (Spink & Moyer, 2011a; Spink et al. 2015; Manning, 2019; Soon et al.
395 2019b; Spink et al. 2019). A *hurdle gap* is the vulnerability that can occur when a hurdle that
396 is part of a mitigation strategy is either not in place, or if it is in place is not effective (Spink et
397 al. 2015).

398 The term hurdle or hurdle technology is not new in food science (Leistner & Gorris,
399 1995). Hurdle technology is the combined methods, processes, security measures, techniques
400 or barrier technologies to ensure safe food, thus the higher the hurdle the greater the effort
401 needed to overcome it (Leistner & Gorris, 1995). This approach considers the synergistic effect
402 of combined hurdle strategies rather than individual discrete hurdles, and how this provides a
403 higher level of security and confidence than an individual single security measure (Leistner &
404 Gorris, 1995; Khan et al. 2017). Hurdles can be described as either *physical hurdles or hard*
405 *controls* in terms of active measures protecting structural assets (barriers, enclosed production
406 systems, security systems), or *artefact-based hurdles or soft controls* such as passive measures
407 including procedures, policies and protocols e.g. management practices, product recall and

crisis management planning (Mitenus, Kennedy & Busta, 2014; van Ruth, Huisman & Luning, 2017; FDA, 2019; Manning, 2019). Indeed van Ruth et al. (2018) identify twenty-one control measures that address food fraud. These have been adapted at the facility level in the context of food defence (Table 8). In van Ruth et al.'s tudy of forty-two businesses, whilst 85% had a traceability system in place, 65% has whistle blowing measures but only half were undertaking employee integrity screening.

Table 8. Example control measures in a food defence system (Adapted from van Baybutt, 2002; Bendovschi, 2015; Ruth et al. 2018; FDA, 2019; Soon et al. 2019b).

		General measures	
		Hard	**Soft**
Preventive security measures	Design	Cyber-secure computer system and servers.	Information system (internal and external) Employee system access controls. Website controls
		Biometric or fingerprint checking equipment on entry to facility.	People integrity screening including criminal background and credit check tests. Designated coloured clothing for specific areas. ID badges and visitor protocols Ethical code of conduct. Whistleblowing procedure. Insider attacker control procedure
		Physical material and product segregation in stores, production areas and on vehicles.	Tracking and tracing system (internal and external) incl. supplier. Risk assessment of all materials on site to determine potential internal agent materials
		Enclosed tanks and transfer systems to move materials and product to reduce the potential for an attacker to access the product. Locked access caps on all hoses and pipework especially external access points.	Tamper-evident seals protocols requiring resealing of ingredient storage containers when tamper-evident packaging has been opened and tamper evident sealing of all containers when not in use.
		Automated and enclosed equipment, such as automated computer-weighing, measuring, and addition equipment, to reduce human interaction with secondary ingredients or rework;	Weighing and handling procedures.
		Faculty design to minimise risk of attack (visibility and security). CCTV systems on the premises. Building design including adequate lighting and minimising locations where individuals can access materials or product unseen. Restricted access and physical site zoning, locking doors and barriers. Enable vulnerable points with alarms and sirens if they are opened. Motion detection sensors in vulnerable areas.	Security controls. Site maps and access controls. Security personnel protocols with designated access to keys, swipe cards and access codes. Buddy system to prevent lone working. Increased supervision of highly vulnerable areas.
		Operating hours. Covered systems. Use of sight glasses. Use of cleaning in place (CIP) systems to minimise the risk of intentional contamination during cleaning.	Protocols for staffing levels, lone worker protocols and worker procedures in sensitive areas Ensuring all protective clothing is without pockets so items cannot be concealed.
		Material segregation on arrival until goods inwards inspection.	Supplier approval protocols and contractual arrangements. Reference checks. Financial checks. Driver check-in and identification procedures. Drivers do not leave vehicles when on site.

			Product design procedures and identification of particular risk associated with ingredients, product identity or provenance
			Training protocols
	Validation		Validation protocol
Detective security measures	Monitoring System	Equipment and facilities Foreign body detection equipment e.g. metal and foreign body detection and xray.	Raw material protocol Finished product protocol Supplier protocol Stock inventories of harmful materials. Monitoring of hurdles and guardians
	Verification System	Equipment and facilities	Raw material protocol Finished product protocol Supplier protocol Verification of hurdles and guardians
Corrective security measures	Corrective action system	Quarantine facilities	Contingency plan Product recall plan Product disposal plan

Bendovschi (2015) determines three kinds of countermeasure: *preventive security controls* that aim to prevent the realisation of a threat; *detective security controls* that assist in identifying a particular threat and *corrective security controls* that are implemented if non-conformity is identified. Other sources (Spink et al. 2015; Spink et al. 2016; Soon & Manning, 2017; van Ruth et al. 2017; van Ruth et al, 2018; Soon et al. 2019 amongst others) categorise countermeasures into four categories: two preventive (deterrence and prevention), another detective (detection) and the other corrective (disruption). Deterrence seeks to inhibit threat agent activity by limiting opportunity to act (prevention) and promoting the negative personal consequences of taking, detection activities identify incidences of food defence activities and disrupt activities minimise their impact (Soon et al. 2019b).

Whilst preventive security measures at the facility and supply chain level have been considered in the literature (see Table 8), it is only after a food defence incident that the efficacy of detective security control and corrective security controls can be truly determined. However, de Abreu et al. (2020) in their study in Brazil demonstrate the value of undertaking food defence related audits with an associated gap analysis. The gap analysis can then inform an action plan that individual businesses can develop and implement. A case study is now used in this chapter to consider the efficacy of food defence systems more specifically.

After the 2018 Australian strawberry sabotage incident, the FSANZ (2018) report highlighted a number of food defence vulnerabilities within the supply chain (preventive) and also the detective security control and corrective security controls (Table 9) and the lessons learned (Table 10). The major lessons learned from the incident were around clear and consistent messaging and an understanding of the positive and negative role of mainstream and social media in a food defence incident. Social media can play a role in accelerating copycat activities that mask the actual issue of concern. There also needs to be better national coordination in the event of a food defence incident and relationships and networks need to be developed prior to crises.

Table 9. Vulnerabilities identified in the 2018 Strawberry sabotage incident (Adapted from FSANZ, 2018)

Factor	Vulnerabilities identified
Communication and coordination arrangements	Inconsistent public communication messages are damaging to the industry and to the investigations being undertaken by food regulators and police. The interface between multiple local regulators and national regulators can be weak if suitable protocols are not in place. The volume of communication during the crisis on multiple media channels was unexpected and difficult to manage for all actors. Communications on social media can play a role in instigating copycat incidents. There can be an impact on brands that are named in communications but are not part of the actual recall.
Crisis management	Assumption was made that industry had the capacity to respond in crises and this was not the case. Other horticultural organisations provided support and Queensland Strawberries employed a crisis communication expert.
Food safety culture	There was a lack of food safety culture at farm level.
Product recall process	There was some confusion about the terminology and wording used by all agencies during the incident relating to product recall e.g. product withdrawal from shelf, product recall from consumers, removed from sale. The mapping of the supply chain involved in the recall was problematic.
Supply chain vulnerability	Deliberate sabotage (tampering) can occur at any stage in the supply chain and factors that increase this vulnerability are: too many opportunities for attack; the seasonal nature of work and labour hiring practices creates challenges in ensuring people integrity; co-mingling of product from more than one farm (preventing traceability) and the packaging itself that may prevent tampering may reduce shelf-life. The use of metal detection too may mean the perpetrators just change the agent material to plastic or other materials.
Traceability	Traceability to source was affected by a lack of regulatory requirements for business notification/registration. Locating farms and the nature of operations was an issue. Practices such as co-mingling of produce from more than one farm/supplier led to a loss of traceability and there was an inability to easily track and trace the product. Current supply chain mapping to identify all actors and interactions is inadequate.

The lack of registration of fruit businesses and the lack of discrete product lots and full traceability systems being in place hampered the response to the incident. There was also

limited mapping ability for the supply chain, ineffective preparedness and a lack of resources to respond. Reflecting on this case study highlights there needs to be:

(a) Clear and well communicated food defence incident response protocols and formal communication linkages between regulators, health departments and police.

(b) A central agency to ensure national coordination of messaging and information associated with a food defence incident and also better co-ordination of the terminology used so the messaging is constant. This is especially important where there are emotions such as fear or dread associated with the incident.

(c) Police and enforcement bodies should play a headline role in national food incident debriefs with the media when intentional food tampering is involved.

Table 10. Lessons learned in the 2018 Strawberry sabotage incident (Adapted from FSANZ, 2018)

Factor	Lessons learned
Communication and coordination arrangements	• Clear leadership structures and early and consistent messaging (by police and health agencies) is vital to successful public communication during a food defence incident. • When an incident becomes national, a single point of contact and a single website that provides real-time public information is required. • Communications on social media can play a role in instigating copycat incidents so during the corrective security phase communication protocols must include a social media strategy. However, social media can also have a positive impact in developing consumer support for the industry. • Clear communication is needed so that products that are not affected do not become part of the recall. • Communication activities need to ensure they do not interfere with criminal investigations and potential prosecutions. • There should be clear police/government/industry incident debrief protocols in place. • Communication protocols need to be in place to address the impact on export markets and trade.
Crisis management	• Industry bodies need to have access to crisis management resources and have a crisis management preparedness plan that can be used in the event of a food defence incident.
Product recall	• There is a need for better communication, collaboration and consistency in the terminology used during the product recall phase.
Regulatory control	• Regulatory and enforcement authorities require a strong contact list developed before a food defence crisis • There is a need for a formal reactive national coordination strategy in place with industry to address a crisis and the optimum methods of communication with mainstream media and social media.
Resilience	• Measures are needed to increase consumer confidence in the fresh produce sector.

	• Protocols need to be in place that allow for better crisis management preparedness measures and increase industry resilience during and after a crisis.
Risk assessment and mitigation	• Risk assessment is required that understands supply chain vulnerabilities. • This approach should be co-created by government and industry and be broad, scalable, proportionate and scalable.
Traceability	• Notification and registration of food premises and horticultural production is required. • Traceability along the supply chain needs to be better understood and measures identified and adopted to enhance supply chain integrity. The customary 'one step forward, one step back' approach rather than field to fork full chain traceability may be inadequate. • Traceability protocols needs to be universal, address tracking and tracing and appropriate for a timely response and must encompass food defence issues.

(d) Risk assessment that understands supply chain vulnerabilities and the approach should be co-created by government and industry and be broad, proportionate to the incident and scalable.

(e) Notification and registration of food premises and horticultural production so they can be identified and mapped during a food defence crisis.

(f) Traceability (both tracking and tracing) and traceability protocols must be established that are universal and appropriate for a timely response in the event of a food defence incident.

This case study demonstrates the breadth of protocols, and response in the event of a food defence incident. A failure to address such an incident in a timely and proportionate manner could lead to public panic, total boycotting of certain foods with resultant economic loss and the realisation of a food scare. In this context a food scare can be described as "the response to a food incident (real or perceived) that causes a sudden disruption to the food supply chain and to food consumption patterns." (Whitworth et al. 2016, p.133). The motivation for such incidents is the scare, concern or fear factor and this is a challenge for all food regulators seeking to safeguard the food supply chain

Research Gaps and Future Direction

This chapter has considered food defence which is a contemporary topic in the food science and food supply chain literature. At international, national and business level, food defence mitigation strategies need to be designed, implemented and verified to ensure that they remain current and effective. There is still a significant knowledge gap when organisations are seeking to implement food defence plans and associated mitigation strategies and also to reduce vulnerability to such activities. There is also a need for greater capacity building to ensure that risk managers understand the methodological approaches that are currently being used, their value but also their limitations too.

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