

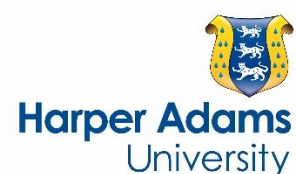
# Food safety, food fraud and food defense: a fast evolving literature

by Manning, L. and Soon, J.M.

**Copyright, Publisher and Additional Information:** This is the author accepted manuscript.  
The final published version (version of record) is available via Wiley

Please refer to any applicable terms of use of the publisher.

DOI: 10.1111/1750-3841.13256



Manning, L. and Soon, J.M. 2016. Food safety, food fraud and food defense: a fast evolving literature. *Journal of Food Science*, 81(4), R823-R834.

## Food safety, food fraud and food defense: a fast evolving literature

### Abstract

Intentional food crime is plural in nature in terms of the types of crime and the differing levels of financial gain. Successful models of food crime are dependent on how well the crime has been executed and at what point, or even if, detection actually occurs. The aim of this paper is to undertake a literature review and critique the often contradictory definitions that can be found in the literature in order to compare and contrast existing food crime risk assessment (FCRA) tools and their application. Food safety, food defense, and food fraud risk assessments consider different criteria in order to determine the degree of situational risk for each criteria and the measures that need to be implemented to mitigate that risk. Further research is required to support the development of global countermeasures that are of value in reducing overall risk even when the potential hazards may be largely unknown and specific countermeasures that can act against unique risks.

**Keywords:** adulteration; fraud; holistic; risk mitigation

**Abbreviations:** economically motivated adulteration (EMA); Food Crime Risk Assessment Model (FCRA)

### 1. Introduction

Contamination in the context of food can be described as “*the introduction or occurrence of an unwanted organism, taint or substance to packaging, food, or the food environment*” (BRC, 2015). Food safety hazards have been defined as “*a biological, chemical, or physical agent in, or condition of, food with the potential to cause an adverse health effect*” (CAC, 2003; BS EN ISO 22000; 2005; Wallace et al. 2011). The United States (US) Federal Food, Drug and Cosmetic Act Section 342 defines adulterated food principally as food that bears or contains: “*any poisonous or deleterious substance which may render it injurious to health; but in case the substance is not an added substance such food shall not be considered*

28 *adulterated under this clause if the quantity of such substance in such food does not*  
29 *ordinarily render it injurious to health.” Thus an adulterant can be deemed to be any*  
30 *poisonous or deleterious substance.* Section 343 of the same legislation defines *misbranded*  
31 *food* as food that is falsely or misleadingly labeled, offered for sale under another name, is an  
32 imitation of another food, where a container is misleading as to the contents. The term  
33 *adulterated food as described above* does not distinguish explicitly between intentional or  
34 unintentional addition of *an adulterant*. Lipp (2011) stated that to differentiate between the  
35 terms contamination and adulteration, *and by inference contaminant and adulterant*, the  
36 former should be considered in terms of unintentional activity and being technically  
37 unavoidable, whilst adulteration is intentional replacement of an ingredient that is specifically  
38 motivated e.g. for economic or ideological gain.

39 *It should be considered that although the terms contamination and malicious contamination*  
40 *have been used widely in the literature, some US literature distinguishes between*  
41 *contamination and adulteration in that the former is used to describe instances of*  
42 *unintentional contamination whilst the latter term is used to define all intentional activities*  
43 *whether motivated for economic gain (EMA) or not. In this paper if literature is quoted that*  
44 *has described an event as contamination, whereas the US definition would define it as*  
45 *adulteration, for purposes of accuracy to the original source that term has remained in the text.*  
46 *However, consideration should be given going forward when developing supply chain*  
47 *standards and regulations to ensure common terminology use as this would be of value.*

48 Whilst historically food safety was described as the concept that food will not cause harm to  
49 the consumer when it is prepared and/or eaten according to its intended use (BS EN ISO  
50 22000, 2005) i.e. a term encompassing both (a) intentional *acts* and (b) unintentional  
51 contamination, more recent literature seeks to differentiate between the two. *PAS 96 (2014)*  
52 *defines a hazard as something that can cause loss or harm which arises from a naturally*

53 occurring or accidental event or results from incompetence or ignorance of the people  
54 involved compared to a threat being something that can cause loss or harm which arises from  
55 the ill-intent of people. FSIS (2014) characterizes food safety and food defense as being  
56 distinct issues that need to be addressed namely that food safety refers to protecting the food  
57 supply from *unintentional* contamination whereas food defense refers to protecting the food  
58 supply from *intentional adulteration with a motive to cause harm*. Alternatively the Global  
59 Food Safety Initiative (GFSI, 2013) suggests that food defense is a sub-set of food safety  
60 issues (where the **adulterant** has the potential to cause harm and separate where the agent is  
61 non-harmful rather than the FSIS definition of them being a separate set of issues.

62 The potential for food crime is often influenced by a difference between availability and  
63 demand creating an opportunity for criminals or fraudsters to financially benefit from the  
64 shortfall. The World Food Summit of 1996 defined food security as existing “*when all people*  
65 *at all times have access to sufficient, safe, nutritious food to maintain a healthy and active*  
66 *life*” (WHO, nd). Defra (2006) goes further and defines levels of food security as: **individual**  
67 **or household food security** relating to purchasing power which is determined by income,  
68 access to resources, and affordability of food; **regional food security** where regions are  
69 dependent on key distribution routes for food; **national/trading block food security** relates  
70 to the ability of a country or trading block to assess sufficient foodstuffs, even in the face of  
71 severe disruptions to the supply chain; and **global food security** i.e. the ability of the world’s  
72 food producers to meet global demand, and ensure the efficiency and effectiveness of global  
73 trading and distribution systems. The interconnecting factors that frame food security also  
74 influence the opportunities for food crime.

75 Crime is defined as an offence or illegal acts punishable by law. The term “illegal” can be  
76 considered as being unlawful, contrary to law or an activity which the law directly forbids  
77 (Ropalje and Lawrence, 1997). Food crime can be described as an activity organized by

78 individuals or groups who knowingly set out to deceive, and or injure, those purchasing and  
79 consuming food (adapted from Elliott Review, 2014). *This rationale would suggest that food*  
80 *crime occurs when food is intentionally modified in order to bring harm to individuals or for*  
81 *purposes of economic gain and both situations may lead to issues of food safety or food*  
82 *quality. Two brothers who owned and operated Jensen Farms in Colorado pled guilty to*  
83 *charges associated with the introduction of cantaloupe adulterated with *Listeria**  
84 *monocytogenes rendering the product injurious to health into interstate commerce (FDA,*  
85 *2013). Thus it was determined that the cantaloupe bore a poisonous substance that rendered*  
86 *them injurious to health. In May of 2011 the Jensen brothers allegedly changed their*  
87 *cantaloupe cleaning system. The new system, built to clean potatoes, was installed, and was*  
88 *to include a catch pan to which a chlorine spray could be included to clean the fruit of*  
89 *bacteria. The chlorine spray, however, was never used. In this example the term adulteration*  
90 *is suggests that by intentionally failing to implement a process that is specifically designed to*  
91 *minimize the risk of harm to consumers then a criminal act has taken place.*

92 Fraud can simply be described as: a type of criminal activity that can be an abuse of position,  
93 or false representation, or prejudicing someone's rights for personal gain (SFO, nd). Food  
94 fraud is defined by the Food Standards Agency (FSA) as: *"deliberately placing food on the*  
95 *market, for financial gain, with the intention of deceiving the consumer"* (Elliott Review,  
96 2014). The Elliott Review (2014:6) states that *"food fraud becomes food crime when it no*  
97 *longer involves random acts by 'rogues' within the food industry but becomes an organised*  
98 *activity by groups which knowingly set out to deceive, and or injure, those purchasing food"*  
99 *thus building on the FSA definition.*

100 The US Food and Drug Administration (FDA) determine economically motivated  
101 adulteration (EMA) as *"the fraudulent, intentional substitution or addition of a substance in a*  
102 *product for the purpose of increasing the apparent value of the product or reducing the cost*

103 *of its production*”, i.e., for economic gain (Lutter, 2009). EMA is therefore only one example  
104 of the types of fraudulent activity that can occur in the food supply chain and EMA as a  
105 definition should not be used when considering other types of fraudulent activity. This is  
106 discussed more fully later in the paper. The aim of this research is to undertake a literature  
107 review and critique the often contradictory definitions that can be found in the literature in  
108 order to compare and contrast existing food crime risk assessment (FCRA) tools and their use.  
109 The use of the term FCRA is novel and not currently used in the literature and as such is an  
110 evolving concept. Whilst Elliott (2014) proposed the use of food crime prevention networks  
111 FCRA **build on this as they** contain two **distinct** elements as is described in this paper. Firstly  
112 there is the risk assessment process itself and then the development of a series of  
113 countermeasures that are embedded in a food control system at organizational or national  
114 levels. **Thus adopting Felson’s approach (2006) of identifying events, sequences and settings**  
115 **is helpful in developing food crime risk assessment models.**  
116 The methodological approach **that has been** used in terms of critiquing existing academic and  
117 gray literature is of value **to academics and practitioners** to clarify the current contradictions  
118 in the literature and to develop a common, accepted vocabulary that is then utilized going  
119 forward in the food industry. This element of redefinition will also inform future reviews of  
120 regulatory standards and also global standards such as those developed through Codex  
121 Alimentarius and the International Standards Organization (ISO).

## 122 **2. Food defense**

123 Food defense is the collective term used to **describe** activities associated with protecting the  
124 nation's food supply from deliberate or intentional acts of contamination or tampering (FDA,  
125 2014). Food defense therefore encompasses intentional contamination (**perhaps better phrased**  
126 **as adulteration**) of the food supply contrasting with the unintentional contamination that is the  
127 focus of established food safety measures (Mitenius et al. 2014). The authors suggest that the

128 concept of intentional **adulteration** as being separate from unintentional contamination  
129 introduces the notion of a different set of vocabulary such as perpetrator, malicious intent and  
130 capabilities. Further, food defense has been described as the process to ensure the security of  
131 food and drink and their supply chains from all forms of intentional malicious attack  
132 including ideologically motivated attack leading to contamination or supply failure (GFSI,  
133 2013). This definition suggests that **the term** food defense is not only used to define national  
134 strategy towards intentional food **adulteration**, but also can be used at the supply chain and  
135 organizational level. Indeed BRC (2015) considers food defense as the procedures adopted to  
136 assure the safety of raw materials and products from malicious contamination or theft.  
137 Therefore, **food defense** has been said to reflect the protection activities, and/or the security  
138 assurance process or procedures that deliver product safety with regard to intentional acts of  
139 **adulteration**. These policies, processes and procedures will be defined in this paper as  
140 countermeasures (see Section 3). **Countermeasures are** the means and mechanisms  
141 **implemented** to mitigate risk and **as a phrase widely used in criminology literature**.  
142 Food defense strategies can therefore be implemented at national and local levels. The FDA  
143 (2015) has differentiated between national risk assessment models and supply chain or  
144 organizational food defense models. At national strategy level, in the US the CARVER+  
145 Shock method has been adopted where the acronym CARVER stands for: **Criticality** – a  
146 measure of the public health and economic impacts of an attack as a result of the batch size or  
147 network of distribution; **Accessibility** – the ability to gain physically access and egress where  
148 this can change over time and also as a result of the use of counter-measures; **Recuperability**  
149 – the ability of food system to recover from an attack; **Vulnerability** – the ease of  
150 accomplishing the attack. This too can change over time and as a result of the use of counter-  
151 measures; **Effect** – the amount of direct loss from an attack as measured by loss in  
152 production; **Recognizability** – the ease of identifying the target, with **Shock** a combined

153 measure of the health, psychological, and collateral **national** economic impacts of a  
154 successful attack on the target system being the final element (FDA, nd).

155 A vulnerability assessment (VA) tool can be developed to operate at the food facility or  
156 individual food process level. The VA tool specifically focuses on three elements that reflect  
157 the vulnerabilities that exist and the means for their mitigation for an organization that could  
158 potentially be under threat namely the attributes: **Criticality**, **Accessibility**, and  
159 **Vulnerability**. This approach is sometimes referred to as Vulnerability Analysis Critical  
160 Control Point or VACCP. The FDA and the US Department of Agriculture (USDA) adapted  
161 CARVER+ Shock to also develop a vulnerability assessment software (VAS) tool that can be  
162 used at food facility or process level in order to build a food defense plan (FDA, 2015). The  
163 food defense plan approach supports food business operators to develop personalized food  
164 defense plans by integrating existing FDA tools, guidance, and resources into one single  
165 application (FDA, 2015). Therefore a situational and premises focused food defense plan can  
166 be established to address the risk of intentional food **adulteration**.

167 **Situational risk has been explored within criminology literature (McGloin et al. 2011; Perline**  
168 **and Goldschmidt 2004). Situational risk factors, are often predictive, lie outside of the**  
169 **individual and include environmental factors such as corporate culture, work environment and**  
170 **can have a multiple compounding impact (Perlite and Goldschmidt, 2004: Carson and Bull,**  
171 **2003) and such risk can be reduced by strengthening environmental resilience to mitigate**  
172 **such risk (Clapton, 2014). Therefore, situational crime prevention seeks to reduce**  
173 **opportunities for specific categories of crime by increasing the associated risks and**  
174 **difficulties and reducing the rewards (Clarke, 1995) so situational crime prevention in terms**  
175 **of deterrence of food crime and reduction of crime risk is an important consideration (Spink**  
176 **and Moyer, 2011).**



177 Crime vulnerability can be defined as the extent to which an individual, organization, supply  
178 chain or national food system is at risk from, or susceptible to, attack, emotional injury or  
179 physical harm or damage from an intentional act. The WHO (2002) suggested that  
180 vulnerability should be assessed on the basis of the scientific, economic, political and social  
181 circumstances of a country to measure the extent of the threat and to set priorities for  
182 resources. The WHO further note that vulnerability should be assessed as a multidisciplinary  
183 activity, with input from legal, intelligence, medical, scientific, economic and political sectors  
184 (Manning et al. 2005). On a national level vulnerability may be assessed on the basis of a  
185 number of factors (Table 1). Further, the determined level of vulnerability needs to be  
186 routinely reassessed to ensure that the ranking and prioritization of risk remains appropriate  
187 and that suitable countermeasure(s) continue to be in place.

188 **Take in Table 1**

189

190 Independently PAS 96 (2014) has been developed as a standard to underpin the Threat  
191 Analysis Critical Control Point (TACCP) approach to assessing the risk associated with such  
192 threats. PAS 96 (2014) describes TACCP as the systematic management of risk through the  
193 evaluation of threats, identification of vulnerabilities, and implementation of controls to  
194 materials and products, purchasing, processes, premises, distribution networks and business  
195 systems by a knowledgeable and trusted team with the authority to implement changes to  
196 procedures. TACCP has been designed to interface with and build upon food safety risk  
197 management methodology such as hazard analysis critical control point (HACCP) as many  
198 precautions taken to assure the safety of food, are likely to also deter or detect deliberate acts  
199 of contamination (PAS 96, 2014). TACCP uses a matrix type approach to identify the  
200 likelihood of an incident occurring and how it might be mitigated through the use of  
201 appropriate countermeasures. This approach is only of value where potential threats and the

202 risk associated with them can be assessed so it is of little value in mitigating against emerging  
203 issues when as previously outlined the modus operandi is for the crime to continue  
204 undetected.

### 205 **3. Food fraud and wider food crime**

206 Most food fraud cases are not harmful, but notable exceptions include the melamine in  
207 Chinese skimmed milk powder (Gossner et al. 2009), sudan dyes in spices (Stiborova et al.  
208 2002), **false labeling** of puffer fish as monkfish (Cohen et al. 2009) and the plasticizer di (2-  
209 ethylhexyl) phthalate (DEHP) being used as a cheaper substitute of clouding agents in food  
210 and beverages (Yang et al. 2013). Different types of food fraud generate various levels of  
211 monetary gains, dependent on how well the 'fraud' has been carried out, and if detection  
212 occurs and form an element of wider food crime. Spink and Moyer (2011) proposed seven  
213 types of food fraud: namely adulteration, counterfeit product, diversion of products outside of  
214 intended markets, over-run, simulation, tampering and theft (Table 2).

#### 215 **Take in Table 2**

216

217 Criminal attributes can also be characterized into ideological, occasional, occupational,  
218 professional and recreational types (Spink et al. 2013). PAS 96 (2014) using a different  
219 approach identifies a number of threats that need to be considered when undertaking TACCP  
220 namely: EMA, malicious contamination, extortion, espionage, counterfeiting and cybercrime  
221 with an associated typology for individuals that pose a threat:

- 222 • The extortionist.
- 223 • The opportunist.
- 224 • The extremist.
- 225 • The irrational individual.
- 226 • The disgruntled individual.

227 • The hacktivist and other cyber criminals.

228 • The professional criminal.

229 This extends beyond the product-orientated types of food fraud to consider wider  
230 organizational fraud associated with accounting, organizational “secrets” e.g. recipes, unique  
231 processing standards etc. When seeking to mitigate supply chain fraud assessment activities  
232 must consider countermeasures that are implemented at the supply chain level not just at the  
233 facility level. This parallels with the procurement requirement for the adoption of pre-  
234 requisite programs such as good agricultural practice by suppliers that are designed to prevent  
235 food safety issues from occurring in the first place rather than focusing on activities within a  
236 site-HACCP plan for detection at facility level as the predominant level of control.

237 Criminology and understanding of behavioral science provides a wider insight into the  
238 motivation and causation behind food crime. This research has considered the extent to which  
239 food fraud and food defense fit into these theoretical criminological frameworks (Table 3).  
240 Table 3 considers six crime motivation theories and shows the difference between traditional  
241 HACCP style risk assessment and the type of assessment that needs to be included in  
242 approaches such as TACCP and VACCP. Using HACCP whilst the *cause* of a food safety  
243 hazard is considered in terms how the hazard can arise in order to implement an appropriate  
244 preventive measure the mindset of the perpetrator or the incentives to intentionally  
245 contaminate have not been explicitly addressed. Furthermore if there is an argument that food  
246 safety, food fraud and food defense need to be risk assessed separately there is no requirement  
247 to include intentional food **adulteration** during the HACCP process. Food defense needs to  
248 consider the perpetrator, the relevance of impact and their motivation to cause harm. Food  
249 fraud is driven by singular motivation i.e. the desire for gain and in order to implement  
250 appropriate countermeasures the motivational element of food fraud needs to be fully  
251 understood.

252 **Take in Table 3**

253

254 The magnitude of harm caused by intentional **adulteration** in terms of likelihood and severity  
255 will increase according not only to the agent used, but also if an individual can operate  
256 unnoticed in an organization or operates in collaboration with the organization. The degree of  
257 mitigation achieved by implementing appropriate countermeasures will vary by type of crime  
258 and by the commitment of the management of the organization to minimize vulnerability to  
259 crime (Table 4). Seven types of criminal are outlined in Table 4 from the ideologically  
260 motivated individual to those who see crime as a recreational activity for entertainment and  
261 amusement, occasional criminals that are opportunist and commit crime infrequently,  
262 occupational criminals who are active within their place of employment and professional  
263 criminals who fund their lifestyle completely from criminal activity. The magnitude of risk  
264 (in terms of likelihood and severity) is considered in Table 4 and will be unique to the  
265 situation that arises. Typical countermeasures have been described for different types of  
266 criminal that need to be considered within an effective food control program.

267 This complexity is shown further in Table 5, and by using a slight modification of the  
268 questioning (5 Whys see Motarjemi and Wallace, 2014) technique of root causes analysis  
269 firstly food fraud and then food defense with regard to both internal employees and external  
270 agents and the risk of intentional food **adulteration** is considered. The root cause analysis  
271 demonstrates that a proactive approach to improving work and supply chain related practices  
272 and that focus on *intentional* **adulteration** i.e. countermeasures and the utilization of FCRA  
273 tools to determine vulnerability is essential in order to mitigate risk.

274 **Take in Tables 4 and 5**

275

276 This argument extends as shown in Tables 4 and 5 to the development of measures to mitigate  
277 risk developed as a result of using threat or vulnerability analysis tools. Mitigation measures  
278 or countermeasures are designed not only to lessen the impact, but also to make intentional  
279 contamination less likely in the first place (Mitenius et al. 2014). Countermeasures developed  
280 to minimize food crime risk can include: the use of unique serial numbers at batch, product or  
281 lot level; traceability through measures such as Radio Frequency Identification Devices  
282 (RFID), and features on the packaging of individual items such as special inks, holograms,  
283 etc. on cases of product or on each pallet (Spink et al. 2010). HACCP as a risk assessment  
284 tool was developed initially to consider contamination in its entirety both intentional and  
285 unintentional a differentiation between the terms food safety and food defense would mean  
286 that this may have to be revisited especially in light of an organization using a combination of  
287 HACCP, VACCP and TACCP as risk assessment tools. A HACCP approach considers the  
288 development of an operational pre-requisite program (OPRP). An OPRP is identified within  
289 hazard analysis approaches as essential in order to control the likelihood of introducing food  
290 safety hazards and/or the contamination or proliferation of food safety hazards in the  
291 product(s) or in the processing environment (BS EN ISO 22000: 2005). Further the  
292 development of an OPRP alongside the integration within an organizational management  
293 systems of an effective portfolio of food crime countermeasures is of great importance when  
294 considering the degree of risk associated with both **adulteration and unintentional**  
295 contamination in a given operational situation.

296 The Global Food Safety Initiative (GFSI) position paper on mitigating the public health risk  
297 of food fraud (July 2014) considers the interaction of food defense, food fraud, food safety  
298 and food quality. This approach does not clearly separate food safety, food quality, food  
299 defense and food fraud but this may simply be a causal result of using a Venn diagram to  
300 pictorially describe the interaction. This overlapping representation is in contrast to FSIS

301 (2014) and the FAO Assuring Food Safety and Quality: Guidelines for Strengthening  
302 National Food Control Systems publication (2003:3) that states that:

303 *“Food safety refers to all those hazards, whether chronic or acute, that may make food*  
304 *injurious to the health of the consumer. It is not negotiable. Quality includes all other*  
305 *attributes that influence a product’s value to the consumer”.*

306 The FAO (2003) publication places particular importance on the fact that the clear distinction  
307 between food safety and food quality and this has public policy implications and also  
308 implications for the development of organizational management systems. Thus this separating  
309 of terminology can be extended to the organizational development of food safety, food  
310 defense and food quality plans, and determining their purpose in terms of what factors they  
311 are seeking to control. Therefore the four elements of a food control system, otherwise  
312 determined as the four elements of food protection (see Spink and Moyer, 2011) can be  
313 described as follows:

- 314 • **Food defense** – ideologically motivated intentional adulteration that makes the food  
315 injurious to health.
- 316 • **Food fraud** – economically motivated intentional adulteration that may or may not  
317 make the food injurious to health. Thus some food fraud issues may overlap with the  
318 definition of food defense whilst others may be a food quality issue.
- 319 • **Food safety** – unintentional contamination of food that makes the food injurious to  
320 health; and
- 321 • **Food quality** – delivery of attributes that influence a product’s value to consumers.

322 These definitions have been drawn together visually (Figure 1). This approach differs from  
323 (i) that of Spink and Moyer (2011) where they identified the four elements described above,  
324 as being distinct i.e. no food fraud overlap between food quality and food safety (see Figure  
325 2) and (ii) that of GFSI (2014) where all four terms are seen as overlapping.

326 **Take in Figures 1 and 2**

327 The rationale for determining the four elements food safety, food defense, food fraud and  
328 food quality as highlighted in this research is important when developing either a national or  
329 an organizational food control system.

330

331 **4. Approaches to developing independent food crime risk assessment (FCRA)**

332 Increasingly there is a requirement to consider a more holistic approach that encompasses not  
333 only scientific criteria, but also aspects of social science in order to risk assess **adulteration**.

334 **Six** of the existing FCRA models have been compared (Table 6) in terms of their aims,  
335 mechanisms of operation and practicalities of use. Table 6 highlights the value of each model  
336 in different situations. The ability to actually quantify the likelihood of a threat or  
337 vulnerability in a given situation is in many ways influenced by the degree of adoption of  
338 countermeasures and their effectiveness.

339 **Take in Table 6**

340 The standard BS EN ISO 31000: 2009 – Risk management: principles and guidance provides  
341 principles, framework and a process for managing risk. The standard defines *uncertainty* (or  
342 lack of certainty) as a state or condition that involves a deficiency of information and leads to  
343 inadequate or incomplete knowledge or understanding. In the context of risk management,  
344 uncertainty exists whenever the knowledge or understanding of an event, consequence, or  
345 likelihood is inadequate or incomplete. Once determined, BS EN ISO 31000: 2009 provides a  
346 hierarchy of how risk should be dealt with:

- 347 1. Avoiding the risk by deciding not to start or continue with the activity that gives rise  
348 to the risk;
- 349 2. Accepting or increasing the risk in order to pursue an opportunity;

- 350 3. Removing the risk source;
- 351 4. Changing the likelihood;
- 352 5. Changing the consequences;
- 353 6. Sharing the risk with another party or parties (including contracts and risk financing);
- 354 and
- 355 7. Retaining the risk by informed decision.

356 HACCP too develops a hierarchy for assessing and mitigating food safety risk (CAC, 2003)

357 the so called seven principles of HACCP:

358 **PRINCIPLE 1** Conduct a hazard analysis.

359 **PRINCIPLE 2** Determine the Critical Control Points (CCPs).

360 **PRINCIPLE 3** Establish critical limit(s).

361 **PRINCIPLE 4** Establish a system to monitor control of the CCP.

362 **PRINCIPLE 5** Establish the corrective action to be taken when monitoring indicates that a

363 particular CCP is not under control.

364 **PRINCIPLE 6** Establish procedures for verification to confirm that the HACCP system is

365 working effectively.

366 **PRINCIPLE 7** Establish documentation concerning all procedures and records appropriate to

367 these principles and their application.

368 In order to develop a food safety control system CCPs are identified using qualitative, semi-

369 quantitative or quantitative means of assessment. Matrices, scoring systems and decision trees

370 are commonly used to identify specific CCPs and mechanisms to eliminate or reduce risk to

371 an acceptable level. The degree of uncertainty is difficult to determine absolutely so semi-



372 quantitative mechanisms are often used. This approach is also favored with TACCP to  
373 determine threats and vulnerabilities. The TACCP approach considers the following questions  
374 (PAS 96, 2014):

- 375 1. Who might want to attack us?
- 376 2. How might they do it?
- 377 3. Where are we vulnerable?
- 378 4. How can we stop them?

379 The threat assessment uses a similar semi-quantitative matrix approach, but despite the name  
380 CCPs are not identified as TACCP is more of a threat prioritization system based on the  
381 presence or absence of appropriate countermeasures. The Carver+ Shock or CAV approach of  
382 VACCP again uses a semi-quantitative scoring approach through a scoring system without  
383 defining CCPs specifically. Marsh (2015) suggests that VACCP and TACCP must be  
384 undertaken simultaneously so an organization can have a clear picture of both threats and  
385 vulnerabilities. Instead of using CCPs, Marsh (2015) decided to use Vulnerability and Threat  
386 Points (VTP) as a mechanism for prioritizing risk. In another approach, the NSF Fraud  
387 Protection Model can be used to assist organizations to ‘think like a criminal’ – particularly in  
388 assessing vulnerability from the perspective of what is advantageous to the fraudster (NSF,  
389 2015). Hence, the model was based on the assumption that fraudsters tend to target food  
390 products of higher value where the **adulteration** is difficult to detect. This can be used to  
391 create a hierarchy of low medium and high food fraud risk scenarios (Figure 3).

### 392 **Take in Figure 3**

393 Six models have been analysed TACCP, VACCP, the food protection risk matrix (Spink and  
394 Moyer, 2011), the food fraud model (NSF, 2014), the USP Preventive Food Fraud  
395 Management System and the CARVER + Shock Tool (FDA, 2014). The mechanisms

396 employed are ones of semi-quantitative risk assessment using prioritization matrices or  
397 weighted scoring systems. This approach is often weakened by the degree of uncertainty as to  
398 the exact nature of the threat and its likelihood of occurrence. This means that “unknown”  
399 threats cannot be mitigated using this approach alone. The most important element of FCRA  
400 is the development of a holistic hierarchy (adapted from BS EN ISO 31000: 2009) of how  
401 risk should be mitigated:

- 402 1. Avoiding the risk by ceasing activity or removing the source (only of value with risks  
403 that can be quantified);
- 404 2. Avoiding the risk by not commencing the activity (only of value with risks that can be  
405 quantified);
- 406 3. Reducing the risk by implementing countermeasures to reduce the likelihood of  
407 occurrence (this approach can address both known and unknown threats where they  
408 are controlled by the same countermeasure);
- 409 4. Sharing the risk with another party or parties including contracts, insurance and risk  
410 financing - again this of limited value if a threat and its potential impact cannot be  
411 quantified; and
- 412 5. Retaining the risk or accepting the level of risk by informed management decision  
413 with the associated monitoring and verification activities.

414 In many cases there is a requirement at national or organizational level for informed decision  
415 making with regard to degree of risk that is also centered on the balance between cost and  
416 benefit derived which is often difficult to determine in the case of unknown or un-quantified  
417 threat.

## 418 **5. Conclusion**

419 The aim of this research is to undertake a literature review and critique the definitions that can  
420 be found in the literature in order to compare and contrast existing FCRA models and their

421 application. Figure 1 has been developed to demonstrate the clear distinction between food  
422 safety, food quality and food defense and the overlapping nature of food fraud incidents  
423 depending on whether the intentional criminal activity has the potential to cause harm or  
424 impact on product quality. This builds on existing literature by clearly differentiating what is  
425 and is not included in terms of threat, or as in food safety defined as a food safety hazard, i.e.  
426 the cause and then how the effect before and after countermeasures have been implemented is  
427 quantified when undertaking a VACCP, TACCP or HACCP assessment. The challenge is that  
428 the distinction between a potential threat (hazard) and the consequences (effect) should it  
429 arise, and the difference between **adulteration** and unintentional contamination of food and  
430 thus the associated countermeasures that should be adopted, is not always fully appreciated by  
431 individuals at the facility level who are involved in developing an overarching food  
432 protection/control system. This is an organizational weakness that can then lead to the  
433 implementation of an adequate food protection/control system which is of little value to the  
434 organization in mitigating threat. Intentional food crime is plural in nature in terms of the  
435 types of crime and the differing levels of financial gain. This can also be said in terms of the  
436 multiplicity of definitions of food safety, food defense, food fraud and food quality found in  
437 both academic and gray literature. This plurality creates confusion and multiple  
438 interpretations when FCRA is adopted and implemented. In further iterations of regulations,  
439 standards and industry protocols increasing harmonization will benefit the industry in  
440 developing cohesive food protection/control programs that address all four elements described  
441 in this paper and clearly differentiate between contamination and adulteration. Successful  
442 modes of food crime are dependent on how well the crime has been carried out and at what  
443 point, or even if, detection actually occurs. BS EN ISO 31000: 2009 provides a hierarchy of  
444 how risk should be dealt with including avoiding, accepting or retaining risk. Appropriate  
445 countermeasures should be adopted as a result of the use of an FCRA model and reassessment

446 to either remove the risk source; change the likelihood of the risk or the consequences should  
447 it occur, sharing or spreading the risk or retaining but monitoring the risk on an ongoing basis.  
448 Further research is therefore required to support the development of global countermeasures  
449 over and above the critique in Table 4. A framework of countermeasures that are developed in  
450 consort with FCRA activities is of value to any organization as has been demonstrated with  
451 the development of OPRP to address potential hazards and mitigate food safety risk at facility  
452 and supply chain levels.

453

454 **6. References**

455

456 BRC (2015), *British Retail Consortium Global Standard Food Safety*. Issue 7. BRC, London.

457

458 BS EN ISO 22000:2005, *Food Safety management systems – Requirements for any*  
459 *organization in the food chain*, BSI London.

460

461 BS ISO 31000, *Risk management – Principles and guidelines* BSI London

462

463 CAC (Codex Alimentarius Commission) (2003), *Hazard Analysis and Critical Control Point*  
464 *(HACCP) System and Guidelines for its application*, Codex Alimentarius Commission Food  
465 Hygiene Basic Texts (Revision 4). Available at: <http://www.codexalimentarius.org> [Accessed  
466 on: 15th October 2015]

467

468 Carson, S. and Bull, R. (2003), *Handbook of Psychology in Legal Contexts*, John Wiley &  
469 Sons.

470

471 Clapton, W. (2014), *Risk and Hierarchy in International Society: Liberal Interventions in the*  
472 *Post-Cold War Era*. Palgrave Macmillan

473

474 Clarke, R.V. (1995), *Situational Crime Prevention, Crime and Justice Vol. 19, Building a*  
475 *Safer Society: Strategic Approaches to Crime Prevention (1995)*, pp. 91-150

476

477 Cohen, N. J., Deeds, J. R., Wong, E. S., Hanner, R. H., Yancy, H. F., White, K. D.,  
478 Thompson, T. M., Wahl, M., Pham, T. D., Guichard, F. M., Huh, I., Austin, C., Dizikes, G.  
479 and Gerber, S. I. (2009). Public health response to puffer fish (Tetrodotoxin) poisoning from  
480 mislabeled product, *Journal of Food Protection* 72(4): 810-817

481

482 Cohen, L. and Felson, M. (1979). Social change and crime rate trends: a routine activity  
483 approach. *American Sociological Review* 44(4): 588-608.

484

485 Croall, H. (2009). White collar crime, consumers and victimization, *Crime, Law and Social*  
486 *Change*, 51: 127-146

487

- 488 Defra (2006) *Food Security and the UK: An Evidence and Analysis Paper*. Food Chain  
489 Analysis Group. Defra. December 2006  
490
- 491 Elliott Review (2014), *Elliott Review into the Integrity and Assurance of Food Supply*  
492 *Networks – Final Report A National Food Crime Prevention Framework*. HM Government  
493 July 2014. London.  
494
- 495 FAO (2003), *Assuring food safety and quality: Guidelines for strengthening national control*  
496 *systems*. FAO Food and Nutrition Paper 76. ISBN 0254-4725  
497
- 498 FDA (2015) Vulnerability Assessment Software. Available at:  
499 <http://www.fda.gov/Food/FoodDefense/ToolsEducationalMaterials/ucm295900.htm#whatme>  
500 [an](#) [Accessed on: 15/10/15]  
501
- 502 FDA, (2014), US Food and Drug Administration, Food Defense Acronyms, Abbreviations &  
503 Definitions, Available at:  
504 <http://www.fda.gov/food/fooddefense/toolseducationalmaterials/ucm296330.htm> [Date  
505 accessed 07 October 2015]  
506
- 507 FDA (2013) Eric and Ryan Jensen Plead Guilty to all Counts of Introducing Tainted  
508 Cantaloupe into Interstate Commerce Available at:  
509 <http://www.fda.gov/ICECI/CriminalInvestigations/ucm373174.htm> [Date accessed 04  
510 January 2016]  
511
- 512 FDA (nd) Vulnerability Assessments of Food Systems Final Summary Report June 2009 –  
513 February 2012 Available at:  
514 <http://www.fda.gov/downloads/Food/FoodDefense/UCM317547.pdf> [Accessed on: 15/10/15]  
515
- 516 US Federal Food, Drug and Cosmetic Act, Section 342 Available at:  
517 [https://www.law.cornell.edu/uscode/pdf/uscode21/lii\\_usc\\_TI\\_21\\_CH\\_9\\_SC\\_IV\\_SE\\_342.pdf](https://www.law.cornell.edu/uscode/pdf/uscode21/lii_usc_TI_21_CH_9_SC_IV_SE_342.pdf)  
518 [Accessed 28.12.15]  
519
- 520 US Federal Food, Drug and Cosmetic Act, Section 342 Available at:  
521 [https://www.law.cornell.edu/uscode/pdf/uscode21/lii\\_usc\\_TI\\_21\\_CH\\_9\\_SC\\_IV\\_SE\\_343.](https://www.law.cornell.edu/uscode/pdf/uscode21/lii_usc_TI_21_CH_9_SC_IV_SE_343.pdf)  
522 [Accessed 28.12.15]  
523
- 524 Felson, M. (2006), *The ecosystem for organized crime*, Heuni paper No 26.
- 525 FSIS (2014), FSIS Food Safety and Food Defense - Information for In-Commerce Firms,  
526 May 2014 USDA Available at:  
527 [http://www.fsis.usda.gov/wps/wcm/connect/86cc4d8e-c963-4be2-936a-745e2da9063a/food-](http://www.fsis.usda.gov/wps/wcm/connect/86cc4d8e-c963-4be2-936a-745e2da9063a/food-defense-incommerce-firms.pdf?MOD=AJPERES)  
528 [defense-incommerce-firms.pdf?MOD=AJPERES](#) [Accessed on: 15/10/15]  
529
- 530 GFSI (2014), GFSI Position on mitigating the public health risk of food fraud. July 2014.  
531 Available at: [http://www.mygfsi.com/news-resources/news/295-gfsi-position-paper-on-](http://www.mygfsi.com/news-resources/news/295-gfsi-position-paper-on-mitigating-the-public-health-risk-of-food-fraud.html)  
532 [mitigating-the-public-health-risk-of-food-fraud.html](#) [Accessed on: 15/10/15]  
533
- 534 GFSI (2013), The Global Food Safety Initiative GFSI Guidance Document. Version 6.3.  
535 October 2013  
536

- 537 Gossner, C.M., Schlundt, J., Embarek, P.B., Hird, S., Lo-Do-Wong, D., Beltran J.J.O., Teoh,  
538 K.N., and Tritscher, A., (2009) The Melamine Incident: Implications for International Food  
539 and Feed Safety Environ, *Health Perspect.* 2009 December; 117(12): 1803–1808.  
540
- 541 Hirschauer, N. and Zwill, S. (2008). Understanding and managing behavioural risks: the case  
542 of malpractice in poultry production. *European Journal of Law and Economics* 26: 27-60  
543
- 544 Hirschi, T. (1969). Causes of delinquency. Berkeley: University of California Press.  
545
- 546 Leathers, R. (2014). Guideline no. 72. TACCP Threat assessment and critical control point: A  
547 practical guide. Chipping Campden: Campden BRI, pp. 1-96.  
548
- 549 Lipp, M. (2011), A closer look at chemical contamination. Available at:  
550 [http://www.foodsafetymagazine.com/magazine-archive1/augustseptember-2011/a-closer-](http://www.foodsafetymagazine.com/magazine-archive1/augustseptember-2011/a-closer-look-at-chemical-contamination/)  
551 [look-at-chemical-contamination/](http://www.foodsafetymagazine.com/magazine-archive1/augustseptember-2011/a-closer-look-at-chemical-contamination/) Accessed on 28<sup>th</sup> December 2015  
552
- 553 Lutter, R (2009), Addressing challenges of economically motivated adulteration. Available  
554 from: [www.fda.gov/downloads/newsevents/meetingsconferencesworkshops/ucm163631.ppt](http://www.fda.gov/downloads/newsevents/meetingsconferencesworkshops/ucm163631.ppt)  
555 Accessed on 28<sup>th</sup> December 2015  
556
- 557 Manning L., Baines, R.N. and Chadd, S.A. (2005), Deliberate contamination of the food  
558 supply chain, *British Food Journal*, 107 (4) 225-245.  
559
- 560 Marsh, K. (2015). BRC Newsletter 10. TACCP and VACCP demystified! Available from:  
561 [http://www.techni-k.co.uk/Newsletter\\_10](http://www.techni-k.co.uk/Newsletter_10) Date accessed 24 September 2015  
562
- 563 McGloin, J.M., Sullivan, C.J., and Kennedy, L.W., (2011), *When Crime Appears: The role of*  
564 *emergence*. Routledge  
565
- 566 Mitenius, N., Kennedy, S.P. and Busta, F.F. (2014), *Chapter 35 – Food Defense, Food safety*  
567 *management: A Practical Guide for the Food Industry*, (2014), 937-958.  
568
- 569 Motarjemi, Y. and Wallace, C. A. (2014). Food safety assurance systems: Root cause  
570 analysis of incidents. In, Y. Motarjemi (Ed.). *Encyclopedia of Food Safety Vol. 4 Food*  
571 *Safety Management*. San Diego, CA: Academic Press, 331-339.  
572
- 573 NSF Safety and Quality UK Ltd. (2014). Risk modelling of food fraud motivation – “NSF  
574 Fraud Protection Model” intelligent risk model scoping project. FS 246004. Available from:  
575 <https://www.food.gov.uk/sites/default/files/NSF%20Final%20report.pdf> Date accessed 7  
576 October 2015.  
577
- 578 PAS 96 (2014), Guide to protecting and defending food and drink from deliberate attack. BSI  
579 London  
580
- 581 Pease, K. (2006). Rational choice theory. In, McLaughlin, E. and Muncie, J. (eds.). *The Sage*  
582 *Dictionary of Criminology*. London: Sage.  
583
- 584 *Perline, I.H and Goldschmidt, J. (2004), The Psychology and Law of Workplace Violence: A*  
585 *Handbook for Mental Health Professionals and Employers*, Charles C Thomas Publisher  
586

- 587 Rapalje, S., and Lawrence, R.L. (1997), A Dictionary of American and English Law, The  
588 Lawbook Exchange Ltd.  
589
- 590 SFO (nd) What is fraud? Available at: <http://www.sfo.gov.uk/fraud/what-is-fraud.aspx>  
591 <http://www.sfo.gov.uk/fraud/what-is-fraud.aspx> Date accessed at 28<sup>th</sup> November 2015  
592
- 593 Spink, J., Moyer, D.C, Park, H. and Heinonen, J.A (2013), Defining the types of  
594 counterfeiters, counterfeiting and offender organizations, *Crime Science*, 2:8  
595
- 596 Spink, J. and Moyer, DC. (2013), Understanding and Combating Food Fraud, *Food*  
597 *Technology*, 67(1): 30-35.  
598
- 599 Spink, J. and Moyer, D. C. (2011). Defining the public health threat of food fraud. *Journal of*  
600 *Food Science* 76(9): 157-163  
601
- 602 Spink, J., Helferich, O.K., and Griggs, J.E. (2010). Combating the Impact of Product  
603 Counterfeiting. *Distribution Business Management Journal* 10(1), 6.  
604
- 605 Stiborová, M., Martínek, V., Rýdlová, H., Hodek, P. and Frei, E. (2002). Sudan I is a  
606 potential carcinogen for humans. Evidence for its metabolic activation and detoxication by  
607 human recombinant cytochrome P450 1A1 and liver microsomes 1. *Cancer Research*, 62:  
608 5678-5684.  
609
- 610 USP (nd) Appendix XVII: Guidance on Food Fraud Mitigation Available at:  
611 [http://www.usp.org/sites/default/files/usp\\_pdf/EN/fcc/Notices/guidance\\_on\\_food\\_fraud\\_mitigation.pdf](http://www.usp.org/sites/default/files/usp_pdf/EN/fcc/Notices/guidance_on_food_fraud_mitigation.pdf) [Accessed on 4th January 2016]  
612
- 613
- 614 WHO (2002), Food Safety Issues: Terrorist Threats to Food: Guidance for Establishing and  
615 Strengthening Prevention and Response Systems 2002. ISBN 9241545844  
616
- 617 WHO (nd), Food Security, Available at: <http://www.who.int/trade/glossary/story028/en/>  
618 [Accessed on 4<sup>th</sup> January 2016]  
619
- 620 Walklate, S. (2007). Understanding criminology. Buckingham: Open University Press.  
621
- 622 Wallace, C.A., Sperber, W.H., and Mortimore, S.E., (2011), Managing HACCP and Food  
623 Safety Through the Global Supply Chain. Wiley Blackwell ISBN 9781405189118  
624
- 625 Yang, J., Hauser, R. and Goldman, R. H. (2013). Taiwan food scandal: the illegal use of  
626 phthalates as a clouding agent and their contribution to maternal exposure. *Food and*  
627 *Chemical Toxicology* 58: 362-368.  
628  
629



630  
631  
632  
633

**Table 1. Factors that can be used to assess national food system vulnerability (Source: Manning et al. 2005)**

Factors that can be used to assess national food system vulnerability
<ul style="list-style-type: none"> <li>• The effectiveness of the countries food safety management infrastructure and current surveillance mechanisms;</li> <li>• Availability of potential food contamination agents;</li> <li>• Motivation for perpetrators of food terrorism;</li> <li>• Potential for the agent to contaminate mass produced food and gain widespread distribution;</li> <li>• Potential of human-to-human transmission of the agent;</li> <li>• Capability for an effective emergency response and;</li> <li>• Potential size of the threat to the food supply chain, animal health and welfare, export food trade, tourism and public health.</li> </ul>

634

635 **Table 2. Types of food crime (Adapted from BRC, 2015<sup>1</sup>; Spink and Moyer, 2013<sup>2</sup> and**  
636 **Croall, 2009<sup>3</sup>)**

Type <sup>2</sup>	Definition <sup>1</sup>	Definition <sup>2</sup>	Definition <sup>3</sup>
Adulteration	The addition of an undeclared material into a food item for economic gain.	A component of the finished product is fraudulent	Product adulteration
Counterfeit		All aspects of the fraudulent product and packaging are fully replicated	
Diversion		The sale or distribution of legitimate products outside of intended markets	
Over-run		Legitimate product is made in excess of production agreements	
Simulation		Illegitimate product is designed to look like but does not exactly copy the legitimate product	
Tampering		Legitimate product and packaging are used in a fraudulent way	
Theft		Legitimate product is stolen and passed off as legitimately procured	
Malicious poisoning, bioterrorism or sabotage		Intentional adulteration with a view to cause harm, fear or dread using other types of food crime identified by Spink and Moyer (2013).	Food poisoning
Misleading indications (words/pictures) <sup>2</sup>			Use of words such as “natural”, “traditional”. Use of pictures e.g. depictions on packaging that do not reflect the nature of the product inside or the methods of production
Packaging size <sup>2</sup>			Use of overlarge packaging

637



Table 3. Motivation behind food fraud and food defense activities

Types of food crime	Rational Choice Theory (Pease, 2006)	Routine Activity Approach (Cohen and Felson, 1979)	Social Control Theory (Hirschi, 1969)	Relative Deprivation (Walklate, 2007)	Game-theoretic approach (Hirschauer and Zwoll 2008)	Common sense (Walklate 2007)
Food fraud	Perpetrator weighs the costs and benefits of committing a crime and makes his or her choice. In this context, choice is governed by time, ability and access to relevant information. Economic incentive as pull factor	Offenders decided to commit crime according to a particular time, targeted victims and place. Categorized into a triangular relation – a motivated offender, potential victim and the presence or absence of a guardian. It is important in this scenario for the offender to be aware of the victim's routine	Bound by fear of consequences. Social controls exerted by four types of bonds. <i>Attachment</i> level of strength or weakness of relationships between an individual and others as via relationships. The stronger the social expectation, the stronger the attachment, the more likely the individual will conform. <i>Commitment</i> i.e. conformity to a particular lifestyle. The higher the level of commitment, the less likely the individual will deviate from it. <i>Involvement</i> - the time spent in conventional behavior or law abiding practices. The longer the time spent in engaging in these activities, the less time the individuals will have for other things. The final bond explains that if an individual had been brought up with the <i>belief</i> that they are law abiding citizens, the less likely they are to break the law.	Occurs when an individual feels deprived or perceive themselves as deprived. The sense of deprivation is commonly (but not exclusively) connected to material circumstances Economics / incentives as pull factor	Reconstructs the monetary incentives of profit-oriented actors. The likelihood for these economic actors to break rules increase with the probability of profits they expect to earn and reduces if losses are anticipated due to risk of detection. At the same time, fraud activities will decrease with an increase in social factors that could 'protect' or 'shield' the profit-oriented actors from yielding to the economic temptation. Estimates the incentives of actors in farm or food industries. Helps to identify or expose critical settings where economic temptations may arise.	Food fraud is driven by monetary needs or gains and / or greed.
Food defense	Time, ability and information. Motivation to do harm.	Motivated offender with a clear potential victim.	No fear of consequences.	Impact oriented.	Impact oriented.	Sadist, enjoy thrill of 'excitement' caused by the harm, revenge, envy.

**Table 4. Criminal types and attributes, risk and typical countermeasures (Adapted from Spink et al. 2013)**

Types of Criminals	Definition	Magnitude of risk (Likelihood/Severity)	Typical countermeasures and controls in the food supply chain to mitigate risk
Ideological poisoning- (usually single motive group or individual)	Domestic or international terrorist who commits the criminal act to make an ideological statement or to economically harm an entity, or to create panic and fear in the target population.	Magnitude will depend on the nature of the product, organization, supply chain and/or the population targeted.	Currently the use of risk assessment by organizations to identify appropriate controls e.g. security, tamper evidence, supplier assurance
Recreational tampering and or theft.	Undertakes crime for entertainment or amusement	Low risk potentially mitigated by implementing appropriate countermeasures.	Traditional technical risk assessment to implement supply chain and onsite security e.g. enclosed containers, secure vehicles and containers, tamper evident seals etc.
Occasional diversion, tampering or theft	Infrequent, opportunistic individual	Low risk potentially mitigated by implementing appropriate countermeasures.	Traditional technical risk assessment to implement supply chain and onsite security e.g. enclosed containers, secure vehicles and containers, tamper evident seals etc.
Occasional over-run	Infrequent, opportunistic individual	Low risk potentially mitigated by implementing appropriate countermeasures.	Stock control measures and mass balance exercises to ensure that resources utilized equate to product sold legitimately on invoices, dispatch notes etc.
Occasional adulteration (substitution) e.g. product with different provenance or method of production i.e. conventional product sold as organic, different ingredients etc.	Infrequent, opportunistic individual	Low risk potentially mitigated by implementing appropriate countermeasures.	This activity would be reactive and not systemic within the organization or the food supply network. Controls will be different depending on whether perpetrators are inside or outside the business and whether there is internal pressure to substitute to meet supply chain requirements e.g. order size. Measures such as stock control, mass balance exercises, internal audits, CCTV cameras may identify but risk level increases especially if adulteration cannot be identified readily by laboratory or visual analysis.
Occupational	Crime occurs at the place of employment, either as an individual acting alone or in collaboration with the modus operandi of the organization	Magnitude of risk increases especially if individual can operate unnoticed in an organization or operates in collaboration with the organization. Potentially a degree of mitigation by implementing appropriate countermeasures unless the activity is deliberately ignored or encouraged by management.	Crime occurs at the place of employment, either lone individuals or through collaboration with the modus operandi of the organization. Perpetrators understand the controls and countermeasures in place and are able to work around them falsifying documentation if necessary
Professional	Criminal activity fully finances their lifestyle	Magnitude of risk increases and will depend on the nature of the product, organization, supply chain and/or the population targeted.	Existing measures and controls in place can be vulnerable to professional criminals and their networks

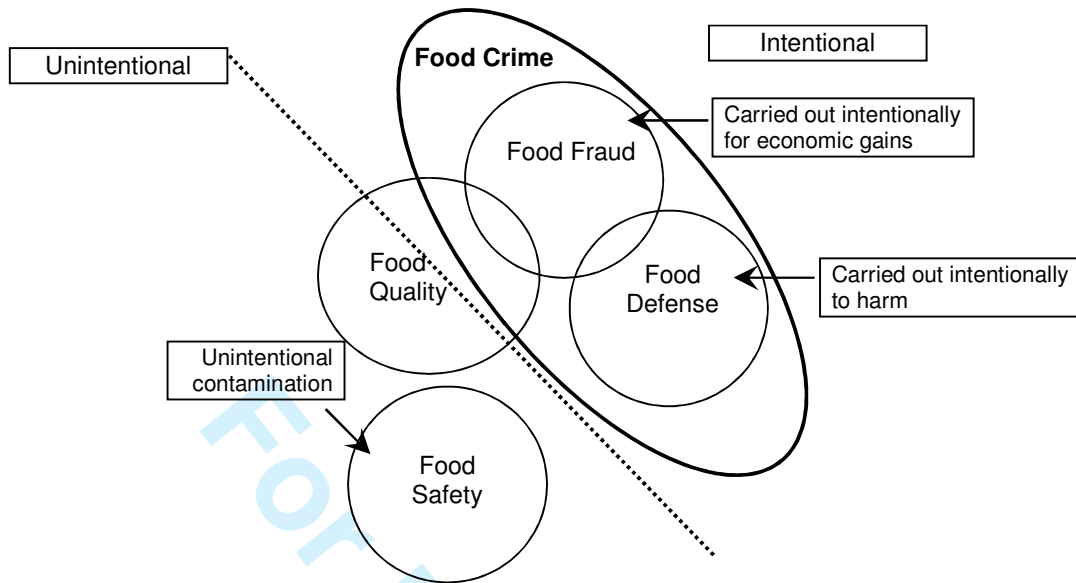
**Table 5. Root cause analysis of intentional food adulteration (Adapted from Motarjemi and Wallace, 2014).**

	<b>Food fraud</b>	<b>Food Defense (internal employee)</b>	<b>Food Defense (external agent)</b>
1	<b>Why was the fraud committed?</b>	<b>Why did the employee deliberately adulterate the product?</b>	<b>Why did the agent deliberately adulterate the product?</b>
	Motivated for monetary gain. Deliberately modifying the food to achieve more \$	Motivated to harm or insinuate harm had been caused.	Motivated to harm, publicity, other motive
2	<b>Why did the agent want monetary gain?</b>	<b>Why did the employee want to bring harm?</b>	<b>Why did the agent want to bring harm?</b>
	Motivation to access money especially if perpetrator can identify a vulnerability	Revenge, dissatisfaction, excitement in causing chaos, financial gain e.g. blackmail,	Revenge, dissatisfaction, envy (competitor), excitement in causing chaos, financial gain e.g. blackmail
3	<b>Why did the agent target this organization?</b>	<b>Why did the employee feel dissatisfied or resentful?</b>	<b>Why did the agent target this organization?</b>
	Ability to perpetrate the crime without discovery, magnitude of financial gain compared to risk.	Unjust work-related practices, termination, personal grudge	Unjust business-related practices, personal grudge, ability to gain publicity due to organization's profile.
4	<b>Why did illicit business related practices arise? What is it about the organization's profile that draws attention?</b>	<b>Why was the employee terminated? Why did unjust work-related practices arise in the company?</b>	<b>Why did unjust business-related practices arise with the company? What is it about the organization's profile that draws attention?</b>
	In order to answer the above specific questions, the respective organization can investigate reasons e.g. vulnerability to fraud, networks in which the business operates etc.	In order to answer the above specific questions, the respective organization can investigate if the above claims are true and find ways to resolve unjust work-related practices.	In order to answer the above specific questions, the respective organization can investigate reasons e.g. country of origin of organization, religious or ideological background, previous business practice that could warrant organization being seen as unjust.
5	<b>How should the company react?</b>	<b>How should the company react?</b>	<b>How should the company react?</b>
	Investigate the incident and identify vulnerabilities through the use of an appropriate analysis tool	Change of keys /access number to reduce accessibility, security and utilization of threat analysis tool	Change of keys /access number to reduce accessibility, security and utilization of CARVER + Shock tool
6	<b>How proactive should the company be to reduce future risk of threats</b>	<b>How proactive should the company be to reduce future internal food threats?</b>	<b>How proactive should the company be to reduce future external food threats?</b>
	Adopt proactive approach to improve work related practices and conditions and utilization of appropriate analysis tool.	Adopt proactive approach to improve work related practices and conditions and utilization of threat analysis tool.	Adopt proactive approach to improve work and supply chain related practices and conditions and utilization of threat analysis tool.

Table 6. Comparison of existing FCRA models

	Threat Assessment Critical Control Point (TACCP)	Vulnerability Assessment and Critical Control Point (VACCP)	Food Protection Risk Matrix (Spink and Moyer 2011)	NSF Fraud Protection Model (NSF, 2014)	USP Preventive Food Fraud Management System (USP, nd)	CARVER + Shock Tool (US FDA)
Aims	To assess threats and prevent behaviorally or ideologically motivated intentional adulteration (Leathers 2014)	To assess how exposed/ susceptible organization or premise is to food fraud incidents. Prevention of intentional EMA (Spink 2014)	To differentiate food fraud among other food control elements such as food safety, food defense and food quality.	To better anticipate the likelihood of fraudulent attack on food products especially according to product value.	To assist users in how to develop and implement a preventive system specifically for the adulteration of food ingredients.	Allows user to think like an attacker and to determine the most vulnerable point within a system or premise to an attack. To focus resources on protecting the most susceptible points in the system.
Mechanisms	Qualitative assessments (likelihood x impact) of threats	Qualitative assessments (likelihood x impact) of threats	Risk matrix is designed to identify the cause of risk and the motivations driving the fraud but not the effect.	Built on a 4 quadrant Boston Consulting Group (BCG) matrix. -Top right = products most attractive to fraudster -Bottom left = least attractive to fraudster -Size of circle of a food product represents the perceived difficulty of conducting the fraud.	Structured approach to characterize food fraud vulnerabilities with associated guidance to develop mitigation strategies.  Nine contributing factors considered and how they impact on vulnerability using a matrix approach.  Lifecycle approach proposed for food fraud management.	Based on seven attributes which are scored on a scale of 1-10 (FDA 2014) <ul style="list-style-type: none"> <li>• Criticality - measure of public health and economic impacts of an attack</li> <li>• Accessibility – ability to physically access and egress from target</li> <li>• Recuperability – ability of system to recover from an attack</li> <li>• Vulnerability – ease of accomplishing attack</li> <li>• Effect – amount of direct loss from an attack as measured by loss in production</li> <li>• Recognizability – ease of identifying target</li> <li>• Shock – combined health, economic, and psychological impacts of an attack.</li> </ul> Provides relative risk rankings for nodes / process steps in a production process or national food system.
Practicalities	Likelihood and impact scores and use of priority matrix in TACCP provides hierarchy for action by risk for organizations. Assess threats within manufacturing environment or within an organization but will be difficult to assess suppliers i.e. prior to delivery (Marsh 2015)	Can be used in the wider supply chain.	The four quadrants in the matrix assist in exploring criteria <b>Food quality</b> – may be caused by mishandling <b>Food safety</b> – may be caused by unintentional contamination <b>Food fraud</b> – intentionally done to increase profit margin <b>Food defense</b> – deliberately carried out to cause harm (Spink and Moyer, 2011)	Food industries and regulatory teams can use the model to anticipate which products are most likely to be targeted by fraudsters, the factors for targeting and whether previous frauds had occurred.	Four step process. First three characterize fraud vulnerabilities associated with an ingredient by considering occurrence and impact. Last step is guidance.	Critical or vulnerable nodes / process steps are identified based on the scores. Prioritize mitigation measures and resources to reduce likelihood of attack.  Another option in CARVER + Shock would be to only use the Criticality, Accessibility and Vulnerability (CAV) scores and facility or process line level.
Suggestions / Extensions	To assess both threats and vulnerabilities and combined under one system. Combine threat and vulnerability assessment and manage risk under one management system.					

For Peer Review



**Figure 1. Intentional and unintentional modifications of food (food fraud, defense, safety and quality) that need to be addressed in a food control system. (Adapted from GFSI, 2014; FSIS, 2014; Leathers, 2014; Spink and Moyer, 2011)**

Unintentional	Intentional	Motivation
Food Quality	Food Fraud	Economic gain
Food Safety	Food Defense	Harm

**Figure 2. The food protection risk matrix (Adapted from Spink and Moyer, 2011)**

High profit: high likelihood of detection Medium food fraud risk	High profit: low likelihood of detection High food fraud risk
Low profit: high likelihood of detection Low food fraud risk	Low profit: low likelihood of detection Low food fraud risk

**Figure 3. Food fraud quadrant model (Adapted from NSF, 2015)**