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 adulterated under*

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

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

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

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

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

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

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

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

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

production", i.e., for economic gain (Lutter, 2009). EMA is therefore only one example of the types of fraudulent activity that can occur in the food supply chain and EMA as a definition should not be used when considering other types of fraudulent activity. This is discussed more fully later in the paper. The aim of this research 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 use. The use of the term FCRA is novel and not currently used in the literature and as such is an evolving concept. Whilst Elliott (2014) proposed the use of food crime prevention networks FCRA build on this as they contain two distinct elements as is described in this paper. Firstly there is the risk assessment process itself and then the development of a series of countermeasures that are embedded in a food control system at organizational or national levels. Thus adopting Felson's approach (2006) of identifying events, sequences and settings is helpful in developing food crime risk assessment models.

The methodological approach that has been used in terms of critiquing existing academic and gray literature is of value to academics and practitioners to clarify the current contradictions in the literature and to develop a common, accepted vocabulary that is then utilized going forward in the food industry. This element of redefinition will also inform future reviews of regulatory standards and also global standards such as those developed through Codex Alimentarius and the International Standards Organization (ISO).

2. Food defense

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

concept of intentional adulteration as being separate from unintentional contamination introduces the notion of a different set of vocabulary such as perpetrator, malicious intent and capabilities. Further, food defense has been described as the process to ensure the security of food and drink and their supply chains from all forms of intentional malicious attack including ideologically motivated attack leading to contamination or supply failure (GFSI, 2013). This definition suggests that the term food defense is not only used to define national strategy towards intentional food adulteration, but also can be used at the supply chain and organizational level. Indeed BRC (2015) considers food defense as the procedures adopted to assure the safety of raw materials and products from malicious contamination or theft. Therefore, food defense has been said to reflect the protection activities, and/or the security assurance process or procedures that deliver product safety with regard to intentional acts of adulteration. These policies, processes and procedures will be defined in this paper as countermeasures (see Section 3). Countermeasures are the means and mechanisms implemented to mitigate risk and as a phrase widely used in criminology literature.

Food defense strategies can therefore be implemented at national and local levels. The FDA (2015) has differentiated between national risk assessment models and supply chain or organizational food defense models. At national strategy level, in the US the CARVER+ Shock method has been adopted where the acronym CARVER stands for: **Criticality** – a measure of the public health and economic impacts of an attack as a result of the batch size or network of distribution; **Accessibility** – the ability to gain physically access and egress where this can change over time and also as a result of the use of counter-measures; **Recuperability** – the ability of food system to recover from an attack; **Vulnerability** – the ease of accomplishing the attack. This too can change over time and as a result of the use of counter-measures; **Effect** – the amount of direct loss from an attack as measured by loss in production; **Recognizability** – the ease of identifying the target, with **Shock** a combined measure of the health, psychological,

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

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

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

Crime vulnerability can be defined as the extent to which an individual, organization, supply chain or national food system is at risk from, or susceptible to, attack, emotional injury or

physical harm or damage from an intentional act. The WHO (2002) suggested that vulnerability should be assessed on the basis of the scientific, economic, political and social circumstances of a country to measure the extent of the threat and to set priorities for resources. The WHO further note that vulnerability should be assessed as a multidisciplinary activity, with input from legal, intelligence, medical, scientific, economic and political sectors (Manning et al. 2005). On a national level vulnerability may be assessed on the basis of a number of factors (Table 1). Further, the determined level of vulnerability needs to be routinely reassessed to ensure that the ranking and prioritization of risk remains appropriate and that suitable countermeasure(s) continue to be in place.

Take in Table 1

Independently PAS 96 (2014) has been developed as a standard to underpin the Threat Analysis Critical Control Point (TACCP) approach to assessing the risk associated with such threats. PAS 96 (2014) describes TACCP as the systematic management of risk through the evaluation of threats, identification of vulnerabilities, and implementation of controls to materials and products, purchasing, processes, premises, distribution networks and business systems by a knowledgeable and trusted team with the authority to implement changes to procedures. TACCP has been designed to interface with and build upon food safety risk management methodology such as hazard analysis critical control point (HACCP) as many precautions taken to assure the safety of food, are likely to also deter or detect deliberate acts of contamination (PAS 96, 2014). TACCP uses a matrix type approach to identify the likelihood of an incident occurring and how it might be mitigated through the use of appropriate countermeasures. This approach is only of value where potential threats and the risk associated with them can be assessed so it is of little value in mitigating against emerging issues when as previously outlined the modus operandi is for the crime to continue undetected.

3. Food fraud and wider food crime

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

Take in Table 2

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

- The extortionist.
- The opportunist.
- The extremist.
- The irrational individual.
- The disgruntled individual.
- The hacktivist and other cyber criminals.
- The professional criminal.

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

Criminology and understanding of behavioral science provides a wider insight into the motivation and causation behind food crime. This research has considered the extent to which food fraud and food defense fit into these theoretical criminological frameworks (Table 3). Table 3 considers six crime motivation theories and shows the difference between traditional HACCP style risk assessment and the type of assessment that needs to be included in approaches such as TACCP and VACCP. Using HACCP whilst the *cause* of a food safety hazard is considered in terms how the hazard can arise in order to implement an appropriate preventive measure the mindset of the perpetrator or the incentives to intentionally contaminate have not been explicitly addressed. Furthermore if there is an argument that food safety, food fraud and food defense need to be risk assessed separately there is not requirement to include intentional food adulteration during the HACCP process. Food defense needs to consider the perpetrator, the relevance of impact and their motivation to cause harm. Food fraud is driven by singular motivation i.e. the desire for gain and in order to implement appropriate countermeasures the motivational element of food fraud needs to be fully understood.

Take in Table 3

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

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

Take in Tables 4 and 5

This argument extends as shown in Tables 4 and 5 to the development of measures to mitigate risk developed as a result of using threat or vulnerability analysis tools. Mitigation measures or countermeasures are designed not only to lessen the impact, but also to make intentional

276 contamination less likely in the first place (Mitenius et al. 2014). Countermeasures developed
277 to minimize food crime risk can include: the use of unique serial numbers at batch, product or
278 lot level; traceability through measures such as Radio Frequency Identification Devices (RFID),
279 and features on the packaging of individual items such as special inks, holograms, etc. on cases
280 of product or on each pallet (Spink et al. 2010). HACCP as a risk assessment tool was developed
281 initially to consider contamination in its entirety both intentional and unintentional a
282 differentiation between the terms food safety and food defense would mean that this may have
283 to be revisited especially in light of an organization using a combination of HACCP, VACCP
284 and TACCP as risk assessment tools. A HACCP approach considers the development of an
285 operational pre-requisite program (OPRP). An OPRP is identified within hazard analysis
286 approaches as essential in order to control the likelihood of introducing food safety hazards
287 and/or the contamination or proliferation of food safety hazards in the product(s) or in the
288 processing environment (BS EN ISO 22000: 2005). Further the development of an OPRP
289 alongside the integration within an organizational management systems of an effective portfolio
290 of food crime countermeasures is of great importance when considering the degree of risk
291 associated with both adulteration and unintentional contamination in a given operational
292 situation.
293 The Global Food Safety Initiative (GFSI) position paper on mitigating the public health risk of
294 food fraud (July 2014) considers the interaction of food defense, food fraud, food safety and
295 food quality. This approach does not clearly separate food safety, food quality, food defense
296 and food fraud but this may simply be a causal result of using a Venn diagram to pictorially
297 describe the interaction. This overlapping representation is in contrast to FSIS (2014) and the
298 FAO Assuring Food Safety and Quality: Guidelines for Strengthening National Food Control
299 Systems publication (2003:3) that states that:

300 "*Food safety refers to all those hazards, whether chronic or acute, that may make food*
301 *injurious to the health of the consumer. It is not negotiable. Quality includes all other*
302 *attributes that influence a product's value to the consumer*".

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

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

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

322 **Take in Figures 1 and 2**

323 The rationale for determining the four elements food safety, food defense, food fraud and food
324 quality as highlighted in this research is important when developing either a national or an
325 organizational food control system.
326
327 **4. Approaches to developing independent food crime risk assessment (FCRA)**

328 Increasingly there is a requirement to consider a more holistic approach that encompasses not
329 only scientific criteria, but also aspects of social science in order to risk assess adulteration. Six
330 of the existing FCRA models have been compared (Table 6) in terms of their aims, mechanisms
331 of operation and practicalities of use. Table 6 highlights the value of each model in different
332 situations. The ability to actually quantify the likelihood of a threat or vulnerability in a given
333 situation is in many ways influenced by the degree of adoption of countermeasures and their
334 effectiveness.

335 **Take in Table 6**

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

343 1. Avoiding the risk by deciding not to start or continue with the activity that gives rise to
344 the risk;
345 2. Accepting or increasing the risk in order to pursue an opportunity;
346 3. Removing the risk source;

4. Changing the likelihood;
5. Changing the consequences;
6. Sharing the risk with another party or parties (including contracts and risk financing); and
7. Retaining the risk by informed decision.

HACCP too develops a hierarchy for assessing and mitigating food safety risk (CAC, 2003) the so called seven principles of HACCP:

PRINCIPLE 1 Conduct a hazard analysis.

PRINCIPLE 2 Determine the Critical Control Points (CCPs).

PRINCIPLE 3 Establish critical limit(s).

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

PRINCIPLE 5 Establish the corrective action to be taken when monitoring indicates that a particular CCP is not under control.

PRINCIPLE 6 Establish procedures for verification to confirm that the HACCP system is working effectively.

PRINCIPLE 7 Establish documentation concerning all procedures and records appropriate to these principles and their application.

In order to develop a food safety control system CCPs are identified using qualitative, semi-quantitative or quantitative means of assessment. Matrices, scoring systems and decision trees are commonly used to identify specific CCPs and mechanisms to eliminate or reduce risk to an acceptable level. The degree of uncertainty is difficult to determine absolutely so semi-quantitative mechanisms are often used. This approach is also favored with TACCP to

determine threats and vulnerabilities. The TACCP approach considers the following questions (PAS 96, 2014):

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

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

Take in Figure 3

Five models have been analysed TACCP, VACCP, the food protection risk matrix (Spink and Moyer, 2011), the food fraud model (NSF, 2014) and the CARVER + Shock Tool (FDA, 2014). The mechanisms employed are ones of semi-quantitative risk assessment using prioritization matrices or weighted scoring systems. This approach is often weakened by the degree of

uncertainty as to the exact nature of the threat and its likelihood of occurrence. This means that "unknown" threats cannot be mitigated using this approach alone. The most important element of FCRA is the development of a holistic hierarchy (adapted from BS EN ISO 31000: 2009) of how risk should be mitigated:

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

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

5. Conclusion

The aim of this research is to undertake a literature review and critique the definitions that can be found in the literature in order to compare and contrast existing FCRA models and their application. Figure 1 has been developed to demonstrate the clear distinction between food safety, food quality and food defense and the overlapping nature of food fraud incidents

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

443 required to support the development of global countermeasures over and above the critique in
444 Table 4. A framework of countermeasures that are developed in consort with FCRA activities
445 is of value to any organization as has been demonstrated with the development of OPRP to
446 address potential hazards and mitigate food safety risk at facility and supply chain levels.
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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
• The effectiveness of the countries food safety management infrastructure and current surveillance mechanisms; • Availability of potential food contamination agents; • Motivation for perpetrators of food terrorism; • Potential for the agent to contaminate mass produced food and gain widespread distribution; • Potential of human-to-human transmission of the agent; • Capability for an effective emergency response and; • Potential size of the threat to the food supply chain, animal health and welfare, export food trade, tourism and public health.

Table 2. Types of food crime (Adapted from BRC, 2015[1]; Spink and Moyer, 2013[2] and Croall, 2009[3])

Type[2]	Definition[1]	Definition[2]	Definition[3]
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)[2]			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[2]			Use of overlarge packaging

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. *Attachment* 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. *Commitment* i.e. conformity to a particular lifestyle. The higher the level of commitment, the less likely the individual will deviate from it. *Involvement* - 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 *belief* 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 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).

	Food fraud	Food Defense (internal employee)	Food Defense (external agent)
1	**Why was the fraud committed?**	**Why did the employee deliberately adulterate the product?**	**Why did the agent deliberately adulterate the product?**
	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	**Why did the agent want monetary gain?**	**Why did the employee want to bring harm?**	**Why did the agent want to bring harm?**
	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	**Why did the agent target this organization?**	**Why did the employee feel dissatisfy or resentful?**	**Why did the agent target this organization?**
	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	**Why did illicit business related practices arise? What is it about the organization's profile that draws attention?**	**Why was the employee terminated? Why did unjust work-related practices arise in the company?**	**Why did unjust business-related practices arise with the company? What is it about the organization's profile that draws attention?**
	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	**How should the company react?**	**How should the company react?**	**How should the company react?**
	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	**How proactive should the company be to reduce future risk of threats**	**How proactive should the company be to reduce future internal food threats?**	**How proactive should the company be to reduce future external food threats?**
	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) • **C**riticality - measure of public health and economic impacts of an attack • **A**ccessibility – ability to physically access and egress from target • **R**ecuperability – ability of system to recover from an attack • **V**ulnerability – ease of accomplishing attack • **E**ffect – amount of direct loss from an attack as measured by loss in production • **R**ecognizability – ease of identifying target • **S**hock – combined health, economic, and psychological impacts of an attack. 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 **Food quality** – may be caused by mishandling **Food safety** – may be caused by unintentional contamination **Food fraud** – intentionally done to increase profit margin **Food defense** – 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.					

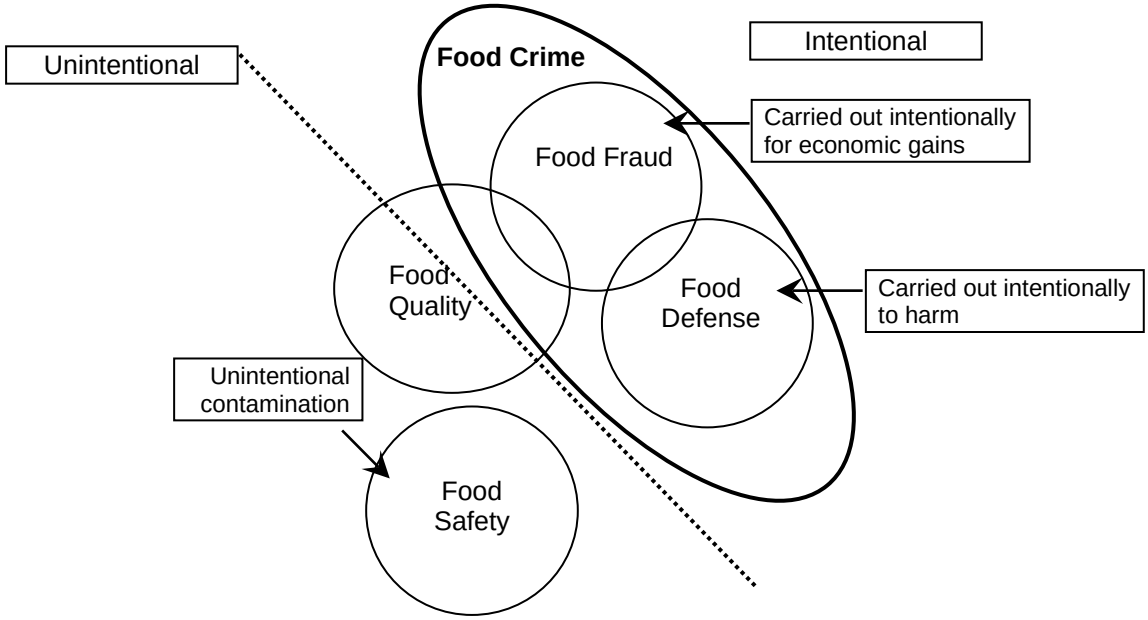

Figure 1. Intentional and unintentional modifications of food (food fraud, defense, safety and quality) that need to be addressed in a food control system. (Adapted from GFSI, 2014; FSIS, 2014; Leathers, 2014; Spink and Moyer, 2011)

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)