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Food Fraud Vulnerability assessment: reliable data sources and effective assessment approaches

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Available at <http://clock.uclan.ac.uk/29138/>

Soon, Jan Mei ORCID: 0000-0003-0488-1434 (2019) Food Fraud Vulnerability assessment: reliable data sources and effective assessment approaches. Trends in food science and technology, 91 . pp. 159-168. ISSN 0924-2244

It is advisable to refer to the publisher's version if you intend to cite from the work.
<http://dx.doi.org/10.1016/j.tifs.2019.07.007>

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1 **Food Fraud Vulnerability assessment: reliable data sources and effective assessment**
2 **approaches**

3
4 **Abstract**

5 Background: Multiple food fraud vulnerability assessment (FFVA) tools have been developed
6 and refined to capture and quantify food fraud issues in the supply chain.

7
8 Scope and approach: The aim of this research is to review existing FFVA tools and the
9 databases that underpin them and consider the challenges, limitations and opportunities in
10 their use. The databases considered include: the Rapid Alert for Food and Feed Safety
11 (RASFF) database, the Food Fraud Risk Information, Decernis Food Fraud Database,
12 FoodSHIELD, and HorizonScan. Four FFVA tools, Safe Supply of Affordable Food
13 Everywhere (SSAFE), the two Food Fraud Advisor's vulnerability assessment tools and
14 EMAlert, are also critiqued in this paper from the viewpoint of the tools available and their
15 efficacy for food fraud vulnerability assessment.

16
17 Key findings and conclusion: There is a clear requirement for more industry level
18 cohesiveness and consistency in how FFVA is undertaken to address both intrinsic and
19 extrinsic food fraud vulnerability. FFVA tools differ from conventional purely food safety
20 hazard analysis or risk assessment tools as FFVA also requires consideration of socio-
21 economic factors, knowledge levels of organization, and understanding of criminal behavior.
22 The challenge therefore is to develop FFVA tools further so that they support assessment of
23 existing vulnerabilities and overcome knowledge gaps to then assist food supply chain
24 professionals in understanding where and how fraud might occur, and the situational
25 vulnerabilities for a given organisation or food supply chain so this intelligence will effectively
26 inform the appropriate options for food fraud control and mitigation.

27
28 **Keywords:** food fraud, vulnerability, intentional, adulteration, database

29

30 **Highlights**

- 31 • Vulnerability has multiple attributes that need to be considered in a risk assessment.
- 32 • Multiple data source exist their use is limited by subscription only access.
- 33 • Behavioural assessment is a key aspect of FFVA tools

34

35

36 **1. Introduction**

37 Food fraud involves intentional modification of food products and/or associated
38 documentation for economic gain and may lead to issues of food safety, legality and/or quality
39 depending on the activities undertaken or the agent(s) used. Food manufacturers, as part of
40 the assessment of their vulnerability to food fraud need to identify the individual food materials
41 and products that they procure, supply and/or produce that have a history of illicit activity.
42 Supply chains are complex networks that are shaped by the inter-relationships between
43 actors, the processes undertaken and the inputs and outputs associated with those processes
44 (Wang, van Fleet & Mishral, 2017). Due to the high incidence of reported problems in the
45 past, certain food types, geographic sources and associated supply chains are seen as having
46 historically higher levels of concern with regard to food fraud. For a given supplier organisation,
47 service or ingredient, historic levels of compliance can be used to determine foods or
48 ingredients that are vulnerable to food fraud. These foods include fish, meat, cereals, milk,
49 olive oil, organic product and spices (Xiu & Klein, 2010; Silvis, van Ruth, van der Fels-Klerx &
50 Luning, 2017; van Ruth, Huisman & Luning, 2017). Food fraud is an overarching term and the
51 sub-types of food fraud determined in the literature and emergent standards are outlined in
52 Table 1.

53 **Take in Table 1**

54 For perpetrators, successful modes of food fraud are measured in terms of the degree of
55 financial gain when compared with the risk of detection (Manning & Soon, 2014). As
56 opportunities arise, and the risk of detection decreases, the effort required to commit crime for
57 the benefit derived is reduced. In contrast, the higher the probability of being detected or
58 caught, the lower the returns for the fraudster (Spink & Moyer, 2011a). From an anti-fraud
59 perspective, it is difficult to predict where fraud may occur as fraudsters, if their modus
60 operandi is to remain undiscovered, are constantly required to identify new opportunities and
61 channels for committing fraud (Kingston, 2017). The key to preventing food fraud is the
62 development of measures to assess, detect, mitigate and where possible prevent it from
63 occurring. However, Everstine, Spink & Kennedy (2013) assert that economically motivated

64 adulteration (EMA) differs from other food threats as it is not readily predicted through food
65 safety risk assessments and intervention strategies. Instead food fraud vulnerability
66 assessment (FFVA) systematically considers the factors that create vulnerabilities in a supply
67 chain, *i.e.* where food fraud is more likely to occur (Nestle, n.d.).

68 The Global Food Safety Initiative (GFSI, 2018) defines a **food fraud vulnerability** as “the
69 susceptibility or exposure to a food fraud risk, which is regarded as a gap or deficiency that
70 could place consumer health at risk if not addressed”. It is important to differentiate between
71 **intrinsic vulnerabilities** *i.e.* those vulnerabilities that occur within the business at the micro
72 (individual) and meso (organisational level) and **extrinsic vulnerabilities** that occur at the
73 macro level in the external environment, and as a result are more difficult for the business to
74 control. GFSI (2018) distinguishes between a *hazard*, (something with the a potential to cause
75 harm), and *risk* (the probability of loss or injury from a hazard), stating that susceptibility to a
76 [given] risk is not only linked to the severity of the risk, but also to the company’s awareness
77 of their weakness and also how they manage it. This concept provides a distinct approach to
78 considering vulnerability, and underpins the rationale for this paper. In this context, the aim of
79 this review is to provide context through comparing and contrasting risk assessment and
80 vulnerability assessment and then analysing existing FFVA tools and the databases that
81 underpin them. This approach allows assessment of the consistency of how food fraud
82 vulnerability is determined by different models.

83

84 **2. Risk assessment versus vulnerability assessment**

85 **2.1 Risk assessment**

86 Risk assessment is the overall process of risk identification, risk analysis and risk
87 evaluation. International Standardisation Organisation (ISO) Guide 73 (2009) states risk
88 assessment (finding, recognising and describing risk) leads into **risk analysis**, (the process
89 to understand the risk and determine its likelihood), and **risk evaluation**. The Guide highlights
90 that risk evaluation is the process of comparing the results of risk analysis with risk criteria to
91 determine firstly the significance of the risk and whether that degree of risk is acceptable *i.e.*

92 it is a risk identification and quantification process. This approach is thus a separate activity
93 from **risk management**. Risk management is situated to an organisation's activities and drives
94 an approach that leads to continuous improvement in seeking to eliminate or reduce risk. Risk
95 management is integrated into all organisational activities; involves a structured and
96 comprehensive focus that is dynamic and reflects internal and external risk factors; is inclusive
97 and ensures appropriate and timely involvement of necessary stakeholders and considers the
98 degree of uncertainty in the data available; and uses a holistic approach that considers the
99 social (human and cultural) factors that influence risk (ISO 31000, 2018).

100 Zio (2016, p141) highlights the dangers of reducing risk assessment to a given number or
101 value because "the values of probability in two different situations could be the same, but their
102 assignment may be based on quite different knowledge, data and information, and eventually
103 assumptions [or degrees of uncertainty], which leave quite different room for surprises of
104 unforeseen events and related consequences." These concerns have particular emphasis
105 when considering food fraud risk assessment to then inform risk management systems.
106 Indeed Manning (2019) argues that predictive risk assessment tools such as hazard analysis
107 critical control point (HACCP), threat analysis critical control point (TACCP), and vulnerability
108 analysis critical control point, (VACCP) have limited value in terms of unknown or
109 unquantifiable food crime threats creating the potential for supply chain vulnerabilities to be
110 both unknowable and unrecognised.

111 The PAS 96 (2017) Guide highlights the process of undertaking risk assessment for food
112 crime including food fraud throughout a food business. The risk assessment process requires
113 the semi-quantitative determination of likelihood and impact, deriving a risk score and then
114 prioritising a risk management process to reduce risk. The process is supported by a risk
115 matrix leading to the development of a threat identification matrix that at each process step
116 identifies threats, vulnerabilities, access, mitigation, and testing programmes. TACCP is thus
117 a risk assessment and a risk management methodology that uses a risk matrix to prioritise
118 internal and external risk associated with fraud in order to prioritise the allocation of resources
119 and the weighting can be arbitrary.

120

121 2.2 Vulnerability assessment

122 Vulnerability is a measure of a system's susceptibility, or conversely resilience, to threat
123 scenarios whereas the level of risk focuses on the consequences and their severity should a
124 threat be realised (Ezell, 2007). Zio (2016) suggests there are multiple perceptions of
125 vulnerability and this will ultimately affect how individuals or teams assess vulnerability.
126 Vulnerability can be considered as a product, technical or system attribute namely:

- 127 a. The extent to which vulnerability is a *weakness or flaw* i.e. vulnerability as a “gap or an
128 element of the system that is missing”. An organisation can apply vulnerability
129 assessment internally or externally to a whole supply chain in order to identify the weak
130 areas or **hotspots** that are vulnerable to food fraud. An internal vulnerability
131 assessment aids understanding of the weaknesses, criticalities and access points
132 within a specific manufacturing environment where there are food fraud vulnerabilities;
- 133 b. By seeing vulnerability as a *risk* i.e. the degree of exposure (likelihood x severity)
134 through the use of tools such as HACCP, TACCP or VACCP;
- 135 c. Through considering vulnerability in terms of the *consequences* i.e. the degree of loss
136 or damages;
- 137 d. By assessing vulnerability in terms of it reducing the *capacity of an organisation or*
138 *supply chain to return to a steady state* i.e. determining vulnerability in terms of ability
139 to return to the status quo; or
- 140 e. As *failure to be resilient* where resilience is seen as continuous improvement into the
141 long term i.e. determining vulnerability as a failure to be sustainable.
- 142 f.

143
144 As previously explored in this paper, vulnerability can also be assessed at the micro, meso
145 and macro level of a food system with the resultant challenge that vulnerability assessment
146 requires systems rather than linear (cause and effect) thinking. Vulnerability assessment, if
147 undertaken appropriately, can define the actions required to eliminate weak points, or

148 vulnerability points, and reduce the potential for food fraud to a level the organisation deems
149 acceptable. The GFSI Position Statement on Mitigating the Public Health Risk of Food Fraud
150 (GFSI, 2014) defines FFVA as a two-stage approach. Firstly, “ information is collected at the
151 appropriate points along the supply chain (including raw materials, ingredients, products,
152 packaging) and evaluated to identify and prioritise significant vulnerabilities for food fraud”
153 and then secondly, appropriate control measures need to be in place to reduce the risk arising
154 from these vulnerabilities. (GFSI, 2014). Thus, a relevant FFVA informs the development of a
155 control plan. Four years later, the GFSI develop this rationale further into two elements a
156 FFVA, and then a food fraud mitigation plan (GFSI, 2018). Therefore, vulnerability assessment
157 considers the strength, or weakness, of an organisation’s food fraud mitigation strategy (Cavin,
158 Cottenet, Blancpain, Bessaire, Frank, & Zbinden, 2016).

159 Marvin et al. (2016) drew together a set of variables that influence an organisation’s
160 vulnerability to food fraud. These criteria including **economic factors** (e.g. price, supply and
161 demand); **national factors** associated with the country of origin (e.g. governance) and
162 **specific incident related factors** such as fraud type, complexity and the potential for fraud
163 detection to then be able to identify headline predictors of food fraud. Price Waterhouse
164 Cooper (PwC, 2016) differentiates between economic and market factors such as economic
165 conditions, value attributes, financial strains, level of competition and associated strategies,
166 and supply/demand and pricing and **cultural and behavioral factors** such as personal gain
167 or desperation, corruption level, blackmail, victimisation and ethical business culture. As well
168 as the determination of what vulnerability is and how vulnerability is articulated within FFVA
169 tools, the other factor that influences the effectiveness of these tools is the source, situational
170 applicability, quality and validity of the data and then the type of methodological assessment
171 approach in which the data is used. A typology of sampling has been synthesized in this
172 research that is utilised within this paper to differentiate between data and information sources
173 used for a given FFVA (Table 2).

174 **Take in Table 2**

175 The type of sampling is important because it has an impact on how the dataset that is
176 derived can be interpreted. The data can be influenced by whether its source is from regulatory
177 sampling that is based on purposive, random, probability or suspect sampling (see Table 2).
178 Further, the sampling method will influence the accuracy of assessment and also the level of
179 confidence that can be attributed to the result. Further, differentiated categorisation of
180 incidents in databases together with differences in the rationale for how the data is collected
181 can reduce the opportunity for comparative analysis and influence the ability to compare or
182 pool data from multiple datasets (Kowalska, Soon & Manning, 2018). This makes the
183 assessment of food fraud vulnerability based on information held in databases an evolving art.

184

185 **3. Food information databases**

186 This section compares a series of databases that contain information that can be used
187 by an organisation in assessing their internal or external vulnerability to food fraud. Five
188 databases critiqued here are either open access platforms e.g. the European Union (EU)
189 Rapid Alert for Food and Feed Safety Portal (RASFF) and others are commercial databases
190 that require a subscription payment for access or have some free to access components and
191 other pay to download elements.

192

193 **3.1 Rapid Alert for Food and Feed Safety (RASFF) Portal - Information Exchange**

194 **Forum**

195 The RASFF provides an information exchange forum for member states and regulatory
196 bodies to provide food and feed control authorities with information about the measures taken
197 to respond to serious problems either detected in relation to food or feed being imported into
198 the EU or being transferred within the EU (RASFF, 2017). These problems include food safety
199 issues and instances of food fraud. The EU RASFF database is a centralised and searchable
200 database where urgent notifications can be sent, received and responded to (RASFF, 2018).
201 Members, including the European Commission, EU members, the European Food Safety

202 Authority (EFSA), the European Free Trade Association (EFTA) Surveillance Authority, (i.e.
203 Iceland, Liechtenstein and Norway) and Switzerland (RASFF, 2018).

204 The EU Administrative Assistance and Cooperation (AAC) system operates alongside
205 the RASFF system with the aim of effective information sharing to ensure a swift reaction
206 following detection of public health risks in the food chain and the EU Food Fraud
207 Network (FFN) exchanges information within this system (EC, 2019a). However, data is not
208 freely available except in the form of historic reports. The FFN was established to manage
209 requests for cross-border cooperation and to ensure the rapid exchange of information
210 between the Commission and national authorities in the event of suspected fraudulent
211 practices (Bouzembrak et al. 2018). The use of the RASFF database, either solely or in
212 conjunction with data from national databases has informed research into the types of
213 incidents as well as the value of such databases in informing risk or vulnerability assessment
214 (Tähkääpää, Majjala, Korkeala & Nevas, 2015; Bouzembrak & Marvin, 2016; Marvin et al.
215 2016). However it should be noted that the data comes from a variety of sources and whilst
216 some standardisation of food classifications has taken place these classifications do not
217 replicate those in other databases which limits the drawing of inference from the pooling of
218 information from multiple datasets

219 The European Food Safety Authority (EFSA, nd) states: “A standardised system for
220 classifying and describing food makes it easier to compare data from different sources and
221 perform more detailed types of data analysis.” The system used by the EFSA for classification
222 is FoodEx2. The EFSA uses RASFF data together with other data from competent authorities
223 throughout the EU to inform the risk assessments undertaken. The EFSA also differentiate
224 between databases in terms of the degree of openness of a dataset and define four maturity
225 levels:

- 226 • **Beginners:** in the early stages of transition to an open data policy;
- 227 • **Followers:** with a basic open data policy and some advanced features on their
228 portal, but there are limitations for the public use/reuse of datasets;

- 229
- **Fast trackers:** greater advancement in their open data journey than followers; and
 - **Leaders:** who have implemented an advanced open data policy with extensive portal
- 230 features (Foster et al. 2019).
- 231

232 These criteria will be used to determine the maturity of the databases considered in this paper

233 in the critique in Table 3.

234 **Take in Table 3**

235

236 **3.2 Food Fraud Risk Information Database**

237 Food Fraud Risk Information ([https://trello.com/b/aoFO1UEf/food-fraud-risk-](https://trello.com/b/aoFO1UEf/food-fraud-risk-information)

238 [information](https://trello.com/b/aoFO1UEf/food-fraud-risk-information)) is a free and accessible database on incidences of food fraud and emerging

239 threats (Food Fraud Advisors, 2017; Food Fraud Risk Information, n.d.). The site is designed

240 in an easy to navigate manner with highlights of the most recent food fraud incidences by

241 month or by product category. The site allows users to view incidences according to food and

242 drink categories including packaging materials and marketing claims. There is an internal risk

243 rating (low through to high), but the criteria for how risk has been determined is not outlined.

244 Individual incidents can be accessed for free but there is no free downloadable reporting

245 function. A static off-line historic database can be downloaded as an Excel spreadsheet for a

246 on-off fee. The source of information is important here especially in terms of its validity and

247 representativeness. Through exposing incidents, the media plays an increasingly important

248 role in providing the evidence that underpins food fraud governance, influencing the behaviour

249 and attitudes of government, food producers and consumers. However, Zhu, Huang and

250 Manning (2019) highlight there is a difference between the number and type of incident being

251 reported by government reports and those by the media as the media tends to report incidents

252 that have a public interest element and outline more of a “story” associated with the problem

253 (see also the work of Bouzembrak et al. 2018). In essence, developing databases through the

254 use of media material as a source of evidence means that such databases are socially rather

255 than an objectively constructed, thus the evidence is not independent of the social norms that

256 frame it.

257

258 **3.3 Decernis Food Fraud Database**

259 The former US Pharmacopoeia (USP) Food Fraud Mitigation Database has been
260 renamed the Food Fraud Database and is owned by Decernis. The food fraud database
261 contains information about more than 4000 ingredients with 9000 related records that arise
262 from a variety of sampling activities and methods of data collection (Decernis, 2019). The
263 global database is continuously updated with information from scientific articles, media,
264 regulatory and judicial reports and food industry and trade associations. The database is not
265 open access. The database is developed with incident and inference reports, surveillance
266 records, and analytical methods classified by ingredient (Decernis, 2019). The database
267 allows searching and trend identification with weekly EMA incident reports. The incident
268 reports are given a weighting factor based on the quality of source/evidence with high being
269 allocated to scientific or legal sources and media sources being assigned either a medium or
270 low weighting.

271 This means that the weighting is based on an objective-subjective paradigm i.e. from
272 objective scientific or legal data to subjective, often socially constructed reports.

273

274 **3.4 Food Adulteration Incidents Registry (FAIR)**

275 The US Food Protection and Defense Institute (FPDI), is located at the University of
276 Minnesota. The FPDI's Food Adulteration Incidents Registry (FAIR) is a database that
277 compiles global data on both EMA and intentional adulteration of foods. It provides limited
278 access to all users to search entries such as food category, date, adulterated food products,
279 adulterants, method of adulteration and originated location (FAIR, 2019). However, access to
280 recent incidents (within the 5 past years) requires the payment of a subscription. The database
281 catalogues a wide range of EMA incidents and is searchable according to incident
282 characteristics such as food adulterant, production location, data, morbidity or mortality data
283 within a wider interaction of databases for food fraud and food defense.

284

285 **3.5 Food Integrity Network (FIN)**

286 The Food Integrity (FI) Network (FIN, 2019) is a platform for stakeholders and experts to
287 exchange knowledge and expertise in food authenticity, safety and quality; and to rapidly
288 share information and intelligence about suspected and actual incidents to protect consumers
289 and food products from damaging effects of food misdescription (Source:
290 <https://secure.fera.defra.gov.uk/foodintegrity/expertdb/index.cfm>). HorizonScan is an
291 associated global database that monitors commodity safety (more than 500 commodities),
292 tracks over 22,000 suppliers and scans the official sites of over 180 countries and more than
293 100 independent sources daily. The database is searchable by commodity. It is a subscriber
294 only service (FERA, 2019). Email alerts can be tailored to the commodities and issues
295 important to the food business.

296

297 **3.6 European Commission's Joint Research Centre Europe Media Monitor (EMM)**

298 **System**

299 The EMM allows users to explore current news items reported by the world's online
300 media in 70 languages over 20000 RSS feeds and HTML pages sites from 7000 generic news
301 portals and 20 commercial news wires (EMM, 2019). The Medical Information System or
302 Medisys is a subset of this dataset that seeks to identify potential threats to public health e.g.
303 communicable disease, terrorist attacks or chemical or nuclear accidents (EMM, 2019).
304 Medisys (Source: <http://medisys.newsbrief.eu/>) continuously monitors about 900 specialist
305 medical sites plus all the generic EMM news on the main site. The open access site but
306 requires specific searching to access information on food fraud issues. The JRC provide a
307 monthly news report which is freely available online about food fraud incidents.

308 Researchers have used the Medisys database in their research. An Early Warning
309 System (EWS) was developed that can detect potential food fraud (Mojtahed, 2018). EWS
310 harvests data from the EMM that analyses, curates and aggregates information from
311 traditional and social media globally (EU Science Hub, 2017). The EWS has been further
312 refined and developed into a food fraud tool (MedISys-FF) that collects, analyses and presents

313 food fraud reports published in worldwide media (Bouzembrak et al. 2018). The tool was
314 benchmarked against RASFF, EMA (now FAIR) and HorizonScan and the MedISys-FF
315 system collected food fraud information with high relevance (>75%).

316

317 **3.7 The US Food And Drug Administration (FDA) Recalls, Market Withdrawals** 318 **and Safety Alerts Database**

319 The US FDA Recalls, Market Withdrawals and Safety Alerts Database is the US
320 regulators database of recalls (older information is archived but available). The database is
321 searchable and the data can be filtered using key words (see
322 <https://www.fda.gov/safety/recalls/>). This database has a wider scope than food fraud as it
323 includes all incidents that required a regulatory recall.

324

325 **3.8 UK Food Surveillance System (UKFSS) Database**

326 The UKFSS is a UK regulatory database that records the analytical and examination
327 results for all food and feed samples, submitted for analysis and/or examination by official
328 control laboratories on behalf of UK local authorities and port health authorities (Food
329 Standards Agency (FSA), 2019). In Scotland, the food sampling data is held separately in the
330 Scottish Food Sampling Database. This public analysis data is not available to the public as
331 an open source.

332

333 **3.9 Private laboratory databases**

334 Major private laboratories that provide analytical testing and services could contribute
335 formally or informally to the creation, validation and sharing of the data. In the UK such
336 organisations including Campden BRI. Campden BRI have also established with their food
337 company members the Food Industry Intelligence Network (FIIN). The objectives of FIIN are:

- 338 • To help ensure the integrity of food supply chains and protect the interests of the
339 consumer;

- 340 • To address the recommendations from “The Elliott Report” (Elliott, 2014) for industry
341 to establish a ‘safe haven’ to collect, collate, analyse and disseminate information and
342 intelligence;
- 343 • To share intelligence with governmental bodies to better understand where risks may
344 sit in the UK Food Industry from food fraud, and
- 345 • To help divert, detect, deter and disrupt those activities and in doing so, further
346 enhance the reputation of the UK Food Industry (CBRI, 2019).

347 Other private testing laboratories also hold data on food fraud incidents that may, or may
348 not, be openly available.

349

350 **3.10 Summary**

351 This section has highlighted the range of databases that can be used to identify historic levels
352 of a particular kind of food fraud associated with a particular food, country or company. The
353 databases are mostly subscribe to view which makes it difficult for small and medium sized
354 companies (SMEs) to access this data in order to be better informed when undertaking FFVA.
355 Spink, Moyer and Speier-Pero (2016) differentiate between four sources of data that ultimately
356 inform FFVA for a given organisation: static external databases, dynamic external internet
357 searches and automated keyword alerts (e.g. Google Alerts); internal datasets on known food
358 fraud incidents within the organisation and lastly subject matter expert insight databases e.g.
359 through groups such as FIIN. Spink, Moyer and Speier-Pero (2016) also developed a four
360 stage food fraud risk assessment. The first stage was a Food Fraud Initial Screening (FFIS)
361 step as a precursor to a FFVA leading to a Corporate Risk Map and then a Resource Allocation
362 Decision. The FFIS approach is divided into 4 steps:

- 363 (i) define the assessment scope (e.g. specify supply chain and region) and qualitative
364 risk ranking terminologies (e.g. very high / high / medium / low / very low);
- 365 (ii) (ii) review incidents and suspicious activities (e.g. derived from internal sources,
366 expert opinion or external databases);

- 367 (iii) (iii) screen for health hazards and enterprise risks (e.g. risk assess and rank health
368 hazard and enterprise [financial] risks and post the screening phase, and then to
369 (iv) (iv) plot the food fraud risks on a risk matrix.

370 Once completed, the business can then prioritise risks and make informed decisions on the
371 application of resources to mitigate the risk. Spink et al. (2016) conclude that the main
372 advantage of FFIS is that the initial screening will allow for product groups with lower risks or
373 with established controls to be removed from a following FFVA thus allowing subsequent
374 vulnerability assessment to focus more specifically on higher risks. In order to undertake FFIS
375 and the FFVA effectively, the assessment team needs to have access to appropriate data that
376 can inform their decision-making. The tools that are available for FFVA are now considered.

377

378 **4.0 Food fraud vulnerability assessment (FFVA) tools**

379 The development of FFVA tools and the extent of their usage is now critiqued. The Wolfe
380 and Hermanson (2004) seminal “fraud diamond” model proposes that four factors influence
381 the potential for fraud: motivation, pressure, capability, and opportunity. Capability depends
382 on the individual perpetrators and their ability to undertake fraudulent activities and opportunity
383 to commit the activity, and also the degree of deterrence (Kowalska, Soon, & Manning, 2018).
384 Pressure in this context can be considered to be regulatory or political pressure or alternatively
385 supply chain pressure which can be influenced by market dynamics such as supply and
386 demand gaps, cost pressures, and increasing pressure to meet supply chain standards.
387 Motivation to commit fraud can be simply economic gain, other forms of self-interest or a wish
388 to cause disruption or chaos. The FFVA concept by van Ruth, Huisman & Luning (2017)
389 consists of three key elements and six groups of factors: two elements of the fraud diamond:
390 *opportunities* (in time and place), *motivations* (economic drivers, culture and behaviour), and
391 also *vulnerability reduction* in terms of implementing effective control measures (technical and
392 managerial measures). The FFVA tool was developed and made available as a free
393 downloadable app (van Ruth, Luning, Silvis, Yang, & Huisman, 2018).

394

395 **4.1 Safe Supply of Affordable Food Everywhere (SSAFE)**

396 Safe Supply of Affordable Food Everywhere (SSAFE) is a not for profit organisation
397 supported by a range of multi-national corporations that has developed a free, science-based
398 online FFVA tool (Excel spreadsheet, online or a phone app) that could be used across the
399 food supply chain (<http://www.ssafefood.org/our-projects/?proj=365#>) (SSAFE, 2019).
400 SSAFE developed the FFVA tool with Price Waterhouse Cooper (PwC), Wageningen
401 University, VU University Amsterdam and following consultation with global food industry
402 leaders (PwC, 2019). The use of this tool is advocated by the GFSI (2014). The advantage of
403 the tool is its flexibility and applicability to different products, business size and region. Other
404 key strengths associated with this tool is its versatility (available in 11 languages and maximise
405 tool accessibility), and its online and offline usage capability. The tool is built upon the
406 principles of HACCP as the FFVA also requires a team approach (e.g. security, finance, quality
407 assurance). Users are guided by an initial decision tree analysis to determine the scope of
408 assessment and then are taken through a series of questions (n=50). Each question contains
409 3 fixed answers. This tool uses a systematic approach where users are provided with an
410 explanation of why the question is important and each fixed answer contains information to
411 assist users in selecting the most appropriate answer. Once completed, users will be able to
412 assess the level of food fraud vulnerability and the means for its control (SSAFE, 2019). This
413 tool is designed to be a practical vulnerability assessment tool suited to guiding manufacturers
414 who may not have detailed and specific knowledge on food fraud and vulnerability. SSAFE
415 can be used as both an intrinsic and extrinsic vulnerability assessment tool. Examples of
416 intrinsic vulnerability assessed by SSAFE are internal processing activities, ethical business
417 culture and business strategies. Extrinsic vulnerability can include the price of raw materials,
418 corruption level of countries where suppliers are located and the level of competition across a
419 selected food sector. The tool does not provide for developing specific mitigation techniques
420 for a given vulnerability, but instead users can refer to information sources and references
421 provided in the tool for further guidance.

422

423 **4.2 Food Fraud Advisor's Vulnerability Assessment Tool**

424 Food Fraud Advisors have designed two types of vulnerability assessment tool one being
425 the generic FFVA (now version 3) and the other based on the method recommended by the
426 British Retail Consortium (Food Fraud Advisors, 2018). The tools are based on Excel
427 spreadsheets that develop a vulnerability assessment for each raw material and ultimately a
428 report that can be used for management and third party audits (see Table 4). The tool is not
429 free a fee is payable for its use.

430 **Take in Table 4**

431 The FFVA BRC Method tool allows the user to assess their raw materials and ingredients
432 only for vulnerability to EMA, substitution and dilution. A series of questions are used to assess
433 the likelihood of occurrence (e.g. historic incidents, price fluctuations, complexity of supply
434 chain) and likelihood of detection (e.g. direct sourcing, supply chain audits, routine testing) by
435 answering simple yes / no questions. Answers and user's comments are generated in the
436 results page providing food businesses with the scope, vulnerability rating and description of
437 the characteristics of the raw materials / ingredients. The extrinsic vulnerability rating is based
438 on a semi-quantitative 5 x 5 matrix of likelihood of occurrence x likelihood of detection which
439 generates three levels of risks (high, medium and low). The questions do address elements
440 of the fraud diamond including pressure, capability and detection.

441 The other conventional FFVA is designed to meet the requirements of GFSI food safety
442 standards such as FSSC 22000 and has a wider scope in terms of the types of food fraud
443 addressed (see Table 1) and the scope includes processing aids and packaging. There is also
444 the option of the pre-screening method. This approach can then inform the controls required
445 to reduce vulnerability.

446

447 **4.3 EMAlert – Economically Motivated Adulteration – Vulnerability Assessment Tool**

448 The Grocery Manufacturers Association (GMA) and Battelle have worked in partnership to
449 develop EMAlert, a software tool that enables food manufacturers to analyse and understand
450 EMA vulnerabilities (EMAlert, 2019). This tool is different to the others in that it includes a

451 behavioural model to consider fraudster decision making and how this impacts on food fraud
452 vulnerability. The tool is a pay for use subscription based system. The advantage of this
453 system is that it can assess a greater number of commodities (50) in one analysis compared
454 with SSAFE and EMAlert considers economic (motivation, pressure, opportunity), ease
455 (capability) and historical drivers.

456

457 **4.4 Challenges with FFVA**

458 The challenge with FFVA is that there is a risk of under or over predicting when using
459 the qualitative criteria developed within the assessment tools. Some tools as outlined use a
460 matrix approach. A risk matrix is a proven mechanism to semi-quantitatively characterise and
461 rank risks but the overall risk score obtained by categorising likelihood and severity can be
462 imprecise and vague (Markowski & Mannan, 2008). This semi-quantitative approach can
463 produce uncertainties in the risk category determined (Manning, 2013). Some tools may use
464 a summative approach to determining risk, others to use multiplier factors when this is
465 combined with overprediction or underprediction of some risk factors e.g. likelihood this will
466 lead to a lack of consistency across the tools that can be used. Lack of technical know-how,
467 failing to access appropriate databases, poor datasets or inappropriate use of databases will
468 also limit the efficacy of FFVA tools. The emerging nature of food fraud incidents with there
469 always being the potential for new actors, new agents being used means that the use of FFVA
470 should not be an annual activity that is static and historic, but needs to be real-time and
471 reactive if the process is going to provide a meaningful and relevant risk score.

472 As outlined in this paper there is multiple terminology being used to determine
473 vulnerability and risk which is a challenge in itself. This emerging terminology from evolving
474 definitions of authenticity (Sumar & Ismail, 1995) to consideration of types of fraud and the
475 lack of a harmonized definition of food fraud (Bouzemrak et al. 2018), human behavioral
476 science, motivation, methods, ethical problems and social and criminal implications (Spink and
477 Moyer, 2011; Manning & Soon, 2016; Lord, Elizondo, & Spencer, 2017). Specialists from social
478 science and criminology backgrounds tend to give more emphasis to the social, economic and

479 legal aspects of food fraud, while food scientists tend to focus on chemical characteristics of
480 food, economic gain and the impact in terms of public health concerns. More
481 collaborative work should be done, particularly with social science specialists, to achieve a
482 universal definition of food fraud. CODEX proposed an Electronic Working Group (EWG) to
483 review CODEX gaps and to create a definition and scope for food fraud, food integrity, food
484 authenticity and other food fraud related terms. This is a major step forward to potentially
485 incorporate food fraud into the formal Codex Alimentarius which can revamp the food supply
486 chain as food fraud countermeasures will become a requirement when conducting business
487 (Spink, 2017).

488 Undertaking a supply chain FFVA requires the collection of information at the appropriate
489 steps (points) along the supply chain including raw materials, ingredients, products,
490 packaging, dispatch; evaluating each step to identify and prioritizing significant vulnerabilities
491 for food fraud, and then developing appropriate countermeasures such as monitoring and
492 testing strategies, supplier audits and anti-counterfeit technologies (GFSI, 2014). Within a
493 manufacturing business, effective FFVA requires the collection and evaluation of information
494 on potential food fraud vulnerability associated with the products, processes and people
495 employed (SSAFE, 2019a). Spink and Moyer (2011a) argue that FFVA tools are not
496 holistically applicable to quantify or predict food fraud incidents because an understanding of
497 criminology and behavioural science is also required. However, FFVA will allow food
498 businesses to map possible fraud scenarios associated with the materials and products that
499 the organisation procures, produces and sells, in order to accurately identify the potential
500 threat, the controls required and the mechanisms for updating such assessments if the
501 evidence changes in the future. Therefore, vulnerability is specific to the supply base,
502 ingredients, product, processes and activities undertaken by a given food manufacturer,
503 processor or retailer. The vulnerability assessment process is dynamic and needs to be
504 revisited both routinely in line with formal procedures and also reactively in the event that
505 FFVA outputs are out of date, for example a vulnerability changes or appears because of a
506 new supplier, harvest failure associated with one particular material or an increase in demand

507 for a particular material when supply remains constant. Therefore, FFVA tools identify the
508 degree of food fraud vulnerability at a given time and in a given set of circumstances.

509

510 **5.0 Discussion**

511 Collaborative efforts between private and non-profit sector and governmental bodies
512 will help to grow food fraud networks to address and tackle food fraud at a landscape level are
513 hampered by the “pay to use” requirements of many incident databases and FFVA tools. A
514 lack of consistency in coding within databases and the lack of a universal definition of food
515 fraud needs to be addressed so it is possible to link, harmonise and connect multiple
516 databases to share information and intelligence within and between networks. Food fraud
517 assessment networks are developing. In the EU the FIN network is developing these
518 collaborative knowledge building as is the work of the JRC (EU Science Hub, 2016). To date
519 four EU wide coordinated control plans (horsemeat, fish, honey and online food supplements
520 and novel foods) had been developed to determine the extent of fraudulent practices in the
521 food sector (EC, 2018). These approaches are considering food fraud together with food and
522 feed safety in a concerted approach but there is no global, universal, central intelligence
523 database that is available to the food industry, regulators and investigators that brings together
524 all the intelligence and information that is currently available. This creases an inequity in the
525 food sector in that many SMEs cannot access such information. However some databases
526 and tools are free to download and if they have sufficient knowledge and understanding SMEs
527 can use this tools to start undertaking FFVA. Whilst some FFVA tools aid organisations to
528 develop a vulnerability profile or vulnerability register for the business, not all go to the next
529 step of developing a control plan. As social network analysis research develops with regard
530 to food fraud especially when combined with crime data mining and criminal network analysis
531 this will assist further in the development of FFVA tools. Emerging tools that use data mining
532 will take existing FFVA and detection approaches forward towards more predictive food fraud
533 modelling.

534 Manning and Soon (2014) sought to draw together the elements of both a predictive
535 and a reactive model for determining food fraud. This model included: determining the
536 situational and contributing factors for food fraud, identifying the databases that provided
537 information of interest in order to use FFVA tools and then to identify the factors that influence
538 the resultant risk ranking. This approach is underpinned by the use of intelligence from
539 industry, enforcement bodies, media and social network surveillance, economic trends,
540 unusual factors that could affect supply and demand dynamics and consider their effect. The
541 detect and react phase of the Manning and Soon (2014) model differentiates between passive
542 laboratory surveillance as part of routine testing programmes and active laboratory
543 surveillance which is targeted on known adulterants that is utilised when the risk ranking status
544 changes. This brings forward an important element of vulnerability assessment that is the use
545 of passive (static) systems and models or the use of reactive and smart systems that are
546 constantly evolving as new intelligence comes in. In these tools it can be shown that
547 vulnerability can be considered as a product, technical or system attribute: in terms of a
548 weakness or flaw. An internal vulnerability assessment can build understanding of the
549 weaknesses, criticalities and access points within a specific manufacturing environment where
550 there are food fraud vulnerabilities.

551 Other tools, or stages within tool application see vulnerability as a *risk* i.e. the degree of
552 exposure (likelihood x severity) reflect on vulnerability in terms of the *consequences* i.e. the
553 degree of loss or damages should the incident occur. The other two elements of vulnerability
554 described in this paper are: the ability or capacity of an organisation or supply chain to return
555 to a steady state i.e. determining vulnerability in terms of ability to return to the status quo;
556 and the need for resilience and for the organisation or supply chain to drive continuous
557 improvement in the medium to long term. This needs to be addressed in further iterations of
558 models that drive effective vulnerability reduction action plans.

559

560 **6. Conclusion**

561 The databases considered here both complement and underpin the various FFVA tools
562 described, but due to multiple types of food fraud issue, a lack of skills and understanding by
563 people of how to use FFVA and variable scopes of assessments means that inconsistency in
564 vulnerability scoring can occur. There is a clear requirement for more industry level
565 cohesiveness and consistency in how FFVA is undertaken to address both intrinsic and
566 extrinsic food fraud vulnerability.

567 FFVA tools differ from conventional purely food safety hazard analysis or risk assessment
568 tools as FFVA also requires consideration of a number of socio-economic factors. These
569 include: economic conditions, social and opportunistic issues, knowledge levels of
570 organization that might make them more vulnerable to fraud, as well as an understanding of
571 criminal behavior. The impact of fluctuations in market conditions that influence both
572 perpetrator opportunity, level of economic gain derived and thus the rationalization of whether
573 to commit fraud, or not are also of importance in assessing vulnerability. The challenge for
574 policy makers and the industry is therefore to develop FFVA tools so that they can support
575 assessment of existing vulnerabilities and also overcome knowledge gaps in where and how
576 fraud might occur. Further, the situational vulnerabilities for a given organization or food supply
577 chain is of importance to effectively inform the appropriate options for food fraud control and
578 mitigation at the organization and supply chain level.

579

580 **References**

- 581
- 582 Ali, M. H., Tan, K. H., & Ismail, M. D. (2017). A supply chain integrity framework for halal
583 food. *British Food Journal*, 119(1), 20-38.
- 584
- 585 BRC Global Standards (2018). Food safety. Available at:
586 <https://www.brcglobalstandards.com/brc-global-standards/food-safety/> [Accessed 19 August
587 2018]
- 588
- 589 Bouzembrak, Y., Steen, B., Neslo, R., Linge, J., Mojtahed, V. & Marvin, H. J. P. (2018).
590 Development of food fraud media monitoring system based on text mining. *Food Control*, 93,
591 283-296.
- 592
- 593 Bouzembrak, Y., & Marvin, H. J. (2016). Prediction of food fraud type using data from Rapid
594 Alert System for Food and Feed (RASFF) and Bayesian network modelling. *Food Control*,
595 61, 180-187.
- 596
- 597 Brucker (2018). FT-NIR for targeted and non-targeted adulterant screening. Available at:
598 <https://www.brucker.com/applications/food-agriculture/food-safety/food-fraud.html> [Accessed
599 3 June 2018]
- 600
- 601 Campden BRI (2019). Food Industry Intelligence Network (FIIN). Available at:
602 <https://www.campdenbri.co.uk/news/fiin.php> [Accessed 20 April 2019]
- 603
- 604 Cavin, C., Cottenet, G., Blancpain, C., Bessaire, T., Frank, N., & Zbinden, P. (2016). Food
605 adulteration: from vulnerability assessment to new analytical solutions. *CHIMIA International*
606 *Journal for Chemistry*, 70(5), 329-333.
- 607
- 608 CWA 17369:2019 – “Authenticity and fraud in the feed and food chain – Concepts, terms,
609 and definitions” Available at:
610 <https://shop.bsigroup.com/ProductDetail?pid=000000000030390716> [Accessed 3 June
611 2019]
- 612
- 613 Davidson, R. K., Antunes, W., Madslie, E. H., Belenguer, J., Gerevini, M., Torroba Perez,
614 T., & Prugger, R. 2017. From food defence to food supply chain integrity. *British Food*
615 *Journal*, 119(1), 52-66
- 616
- 617 Decernis (2019). Food Fraud Database. Available at: [https://decernis.com/solutions/food-](https://decernis.com/solutions/food-fraud-database/)
618 [fraud-database/](https://decernis.com/solutions/food-fraud-database/) [Accessed 14 April 2019]
- 619
- 620 de Kieffer, D. E. (2010). Chapter 10: Where is the gray market? Underground economies
621 and illegal imports. Legal and business strategies to address illegitimate commerce. Oxford
622 University Press, Oxford.
- 623
- 624 Dennis, M.J (1998). Recent developments in food authentication. *Analyst*, 123(9), R151-
625 R156.
- 626
- 627 EMAlert (2019). EMAlert Vulnerability Assessment Tool. Available at:
628 <https://www.emalert.org/> [Accessed 19 April 2019]
- 629
- 630 European Commission (EC) (2014). Horsemeat: one year after – Actions announced and
631 delivered! Available at: http://europa.eu/rapid/press-release_MEMO-14-113_en.htm
632 [Accessed August 2018].
- 633

634 European Commission (EC) (2018). EU coordinated control programmes. Available at:
635 https://ec.europa.eu/food/safety/official_controls/eu-co-ordinated-control-plans_en
636 [Accessed 3 June 2018]
637
638 European Commission (EC) (2019a). Administrative Assistance and Cooperation System
639 Available at: https://ec.europa.eu/food/safety/food-fraud/aas_en [Accessed 20 April 2019]
640
641 EC Regulation 882/2004. Regulation (EC) No 882/2004 of the European Parliament and of
642 the Council. Official Journal of the European Communities L165/1. Available at: <https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32004R0882> [Accessed 3 June 2018]
643
644
645 ECHA (European Chemicals Agency) (2016), Forum methodology for recommending
646 analytical methods to check compliance with REACH Annex XVII restrictions. European
647 Chemicals Agency, 2016 Helsinki, Finland. doi: 10.2823/904598
648
649 EFSA (European Food Safety Authority) (nd) Data standardization. Available at:
650 <https://www.efsa.europa.eu/en/data/data-standardisation> [Accessed 16 March 2019]
651
652 Elliott, C. (2014). Elliot review into the integrity and assurance of food supply chain networks
653 – final report, a national food crime prevention framework report. HM Government, London.
654
655 Europe Media Monitor (EMM) (2019). European Commission's Joint Research Centre.
656 Competence Centre on Text Mining and Analysis. Europe Media Monitor Available at:
657 <http://emm.newsbrief.eu/overview.html> [Accessed 19 April 2019]
658
659 EU Food Fraud Network (2018). EU Food fraud network. Available at:
660 https://ec.europa.eu/food/safety/food-fraud/ffn_en [Accessed 3 June 2018]
661
662 Eurofins (2018). Food authenticity. Available at: <https://www.eurofinsus.com/food-testing/testing-services/authenticity/> [Accessed 3 June 2018]
663
664
665 Eurostat (2010). Typology of sampling strategies. Eurostat European Commission. Working
666 group "Food Safety Statistics". May 2010. Available at:
667 [https://circabc.europa.eu/sd/d/2fc47bd9-237a-4c79-93e0-](https://circabc.europa.eu/sd/d/2fc47bd9-237a-4c79-93e0-6a4665cf3591/201_Typology_sampling_strategies.pdf)
668 [6a4665cf3591/201_Typology_sampling_strategies.pdf](https://circabc.europa.eu/sd/d/2fc47bd9-237a-4c79-93e0-6a4665cf3591/201_Typology_sampling_strategies.pdf). [Accessed 16 March 2019]
669
670 EU Science Hub (2016). The JRC in Geel (Belgium). Available at:
671 <https://ec.europa.eu/jrc/en/about/jrc-site/geel> [Accessed 3 June 2018].
672
673 EU Science Hub (2017). Europe media monitor – Newsbrief. Available at:
674 <https://ec.europa.eu/jrc/en/scientific-tool/europe-media-monitor-newsbrief> [Accessed 3 June
675 2018]
676
677
678 Everstine, K. Spink, J., & Kennedy, S. (2013). Economically motivated adulteration (EMA) of
679 food: common characteristics of EMA incidents. *Journal of Food Protection*, 4, 560-735.
680
681 Ezell, B. C. (2007). Infrastructure vulnerability assessment model (I-VAM). *Risk Analysis: An*
682 *International Journal*, 27(3), 571-583.
683
684 FAIR (2019). Food Adulteration Incidents Registry. Available at:
685 <https://foodprotection.umn.edu/tools-services/food-adulteration-incidents-registry-fair>
686 [Accessed 18 April 2019]
687
688

689 FERA (2019). HorizonScan. Available at: [https://www.fera.co.uk/food-safety/support-](https://www.fera.co.uk/food-safety/support-tools/horizon-scan)
690 [tools/horizon-scan](https://www.fera.co.uk/food-safety/support-tools/horizon-scan) [Accessed 20 June 2019]
691
692 FIN (Food Integrity Network) (2019). Food Integrity Network. Available at:
693 <https://secure.fera.defra.gov.uk/foodintegrity/expertdb/index.cfm> [Accessed 19 April 2019]
694
695 Fiorino, G. M., Garino, C., Arlorio, M., Logrieco, A. F., Losito, I., & Monaci, L. (2018).
696 Overview on untargeted methods to combat food frauds: A focus on fishery products.
697 *Journal of Food Quality*, doi.org/10.1155/2018/1581746
698
699 Food Fraud Advisors (2017). Food fraud risk database. Available at:
700 <https://www.foodfraudadvisors.com/food-fraud-risk-information/> [Accessed 3 June 2017]
701
702 Food Fraud Advisors (2018). Vulnerability assessment tools. Available at:
703 <https://www.foodfraudadvisors.com/vulnerability-assessment-tools/> [Accessed 19 August
704 2018]
705
706 Food Fraud Risk Information (n.d.). Recent food fraud incidents. Available at:
707 <https://trello.com/b/aoFO1UEf/food-fraud-risk-information> [Accessed 3 June 2018]
708
709 Food Standards Agency (2019a) Privacy Notice. UK Food Surveillance System. Available at:
710 <https://www.food.gov.uk/about-us/privacy-notice-uk-food-surveillance-system> [Accessed 19
711 April 2019]
712
713 Foster, D., Locker, A., Maldonado, A., O'Dea, E., Llorente, J.S., Sögel, J. Tapanainen, H
714 Thomas, S., Tirian, A. Richardson, J., Marsic, I., Pintado, C. Czomba, B., Ringwald, F., &
715 Gabbi, S. (2019). Publication of scientific data from EU-coordinated monitoring programmes
716 and surveys. European Food Safety Authority (EFSA). EN-1544 Available at:
717 http://www.efsa.europa.eu/sites/default/files/scientific_output/EN-1544.pdf [Accessed 16
718 March 2019]
719
720 GFSI. (Global Food Safety Initiative). (2014). GFSI Position on mitigating the public health
721 risk of food fraud July 2014. Available from: [http://www.mygfsi.com/news-](http://www.mygfsi.com/news-resources/news/295-gfsi-position-paper-on-mitigating-the-public-health-risk-of-food-fraud.html)
722 [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)
723 [mitigating-the-public-health-risk-of-food-](http://www.mygfsi.com/news-resources/news/295-gfsi-position-paper-on-mitigating-the-public-health-risk-of-food-fraud.html)
724 [fraud.html](http://www.mygfsi.com/news-resources/news/295-gfsi-position-paper-on-mitigating-the-public-health-risk-of-food-fraud.html). [Accessed 4 April 2019].
725
726 GFSI (Global Food Safety Initiative). (2018). Tackling food fraud through food safety
727 management systems. Available at:
728 [https://www.mygfsi.com/files/Technical_Documents/201805-food-fraud-technical-document-](https://www.mygfsi.com/files/Technical_Documents/201805-food-fraud-technical-document-final.pdf)
729 [final.pdf](https://www.mygfsi.com/files/Technical_Documents/201805-food-fraud-technical-document-final.pdf) [Accessed 4 April 2019].
730
731 Huddersfield University (nd) Glossary of terms, Available at:
732 <http://onlineqda.hud.ac.uk/glossary.php> [Accessed 16 March 2019]
733
734 ISO 31000: 2018 Risk management. Guidelines ISO. Paris
735
736 ISO Guide 73:2009 Risk management vocabulary ISO. Paris
737
738 Kendall H, Naughton P, Kuznesof S, Raley M, Dean M, Clark B, et al. (2018) Food fraud and
739 the perceived integrity of European food imports into China. *PLoS ONE* 13(5): e0195817.
740
741 Kingston, J. K. C. (2017). Representing, reasoning and predicting fraud using fraud plans.
742 *11th International Conference on Research Challenges in Information Science (RCIS)*, doi:
743 10.1109/RCIS.2017.7956528

744
745 Kowalska, A., Soon, J. M., & Manning, L. (2018). A study on adulteration in cereals and
746 bakery products from Poland including a review of definitions *Food Control*, 92, 348-356
747
748
749 Lord, N., Elizondo, C. J. F., Spencer, J. (2017). The dynamics of food fraud: The interactions
750 between criminal opportunity and market (dys)functionality in legitimate business.
751 *Criminology & Criminal Justice*, 17(5), 605-623.
752
753 Lotta, F., & Bogue, J. (2015). Defining food fraud in the modern supply chain. *European*
754 *Food and Feed Law Review*, 114-122.
755
756 López, M. I., Trullols, E., Callao, M. P., & Ruisánchez, I. (2014). Multivariate screening in
757 food adulteration: Untargeted versus targeted modelling. *Food chemistry*, 147, 177-181.
758
759 Manning L. (2019), Food defence: refining the taxonomy of food defence threats, *Trends in*
760 *Food Science and Technology*, 85, 107-115,
761
762 Manning, L., & Soon, J.M., (2016). Food safety, food fraud and food defense: a fast evolving
763 literature, *Journal of Food Science*, 81(4) R823–R834
764
765 Manning, L., & Soon, J. M. (2014). Developing systems to control food adulteration. *Food*
766 *Policy*, 49, 23-32.
767
768 Manning, L., (2013). Development of a food safety verification risk model. *British Food*
769 *Journal*, 115 (4) 575-589
770
771 Manning, L. (2016). Food fraud: policy and food chain. *Current Opinion in Food Science*, 10,
772 16-21.
773
774 Markowski, A. S. & Mannan, M. S. (2008). Fuzzy risk matrix. *Journal of Hazardous*
775 *Materials*,
776 159(2008), 152-7.
777
778 Marvin, H. J., Bouzembrak, Y., Janssen, E. M., van der Fels-Klerx, H. J., van Asselt, E. D., &
779 Kleter, G.A. (2016). A holistic approach to food safety risks: Food fraud as an example. *Food*
780 *Research International*, 89, 463-470.
781
782 Mojtahed, V. (2018). Early warning system for food fraud detection: Machine learning
783 applied to food big data. Food Integrity. Available at:
784 https://www.fera.co.uk/media/wysiwyg/events/Food_Integrity_WP8-Fera.pdf [Accessed 3
785 June 2018]
786
787 Nestle (n.d.). Food Fraud Prevention, Economically Motivated Adulteration, Available at:
788 [http://www.nestle.com/asset-library/documents/library/documents/suppliers/food-fraud-](http://www.nestle.com/asset-library/documents/library/documents/suppliers/food-fraud-prevention.pdf)
789 [prevention.pdf](http://www.nestle.com/asset-library/documents/library/documents/suppliers/food-fraud-prevention.pdf) [Accessed on 28 August 2018].
790
791 PAS 96 (2017). Guide to protecting and defending food and drink from deliberate attack.
792 Available at: <https://www.food.gov.uk/sites/default/files/pas962017.pdf> [Accessed on 28
793 August 2018].
794
795 PwC (Price Waterhouse Cooper) (2019) Food fraud vulnerability assessment. Available at:
796 <https://www.pwc.com/foodfraud> [Accessed 20 April 2019]
797

798 PwC (Price Waterhouse Cooper) (2016). Food Fraud Vulnerability Assessment and
799 Mitigation: Are you doing enough to prevent food fraud? Available at:
800 [https://www.pwc.com/gx/en/services/food-supply-integrity-services/assets/pwc-food-fraud-](https://www.pwc.com/gx/en/services/food-supply-integrity-services/assets/pwc-food-fraud-vulnerability-assessment-and-mitigation-november.pdf)
801 [vulnerability-assessment-and-mitigation-november.pdf](https://www.pwc.com/gx/en/services/food-supply-integrity-services/assets/pwc-food-fraud-vulnerability-assessment-and-mitigation-november.pdf) [Accessed 25 August 2018]
802

803 RASFF (2018). The Rapid Alert System for Food and Feed. Available at
804 https://ec.europa.eu/food/safety/rasff_en [Accessed 28 August 2018]
805

806 RASFF (2017) The Rapid Alert System for Food and Feed: 2017 Annual Report. Available
807 at: https://ec.europa.eu/food/sites/food/files/safety/docs/rasff_annual_report_2017.pdf
808 [Accessed 16 March 2019]
809

810 Silvis, I. C. J., van Ruth, S. M., van der Fels-Klerx, H. J. & Luning, P. A. (2017). Assessment
811 of food fraud vulnerability in the spices chain: An explorative study. *Food Control*, 81, 80-87.
812

813 Slovic, P. (1999). Trust, emotion, sex, politics, and science: Surveying the risk-assessment
814 battlefield. *Risk analysis*, 19(4), 689-701.
815

816 Soon, J. M., & Manning, L. (2017). Whistleblowing as a countermeasure strategy against
817 food crime. *British Food Journal*, 119(12), 2630-2652.
818

819 Spink, J. (2017). Review – CODEX CCFICS23 Meeting summary – Action to define food
820 fraud and related terms. Available at: [http://foodfraud.msu.edu/2017/05/05/review-codex-](http://foodfraud.msu.edu/2017/05/05/review-codex-ccfics23-meeting-summary-action-to-define-food-fraud-and-related-terms/)
821 [ccfics23-meeting-summary-action-to-define-food-fraud-and-related-terms/](http://foodfraud.msu.edu/2017/05/05/review-codex-ccfics23-meeting-summary-action-to-define-food-fraud-and-related-terms/) [Accessed 23
822 June 2018]
823

824 Spink, J., & Moyer, D. C. (2011a). Defining the public health threat of food fraud. *Journal of*
825 *Food Science*, 76(9), R157–R162.
826

827 Spink, J., & Moyer, D. C. (2011b). Backgrounder: Defining the public health threat of food
828 fraud, in research grants. Minneapolis, MN: National Center for Food Protection and
829 Defense (NCFPD) (pp. 7). Minneapolis, MN: National Center for Food Protection and
830 Defense (NCFPD). <http://www.ncfpd.umn.edu>
831

832 Spink, J., Moyer, D. C., & Speier-Pero, C. (2016). Introducing the Food Fraud Initial
833 Screening model (FFIS). *Food Control*, 69, 306-314.
834

835 SSAFE (2019). Introduction to SSAFE Food Fraud Vulnerability Assessment tool. Available
836 at: <http://www.ssafe-food.org/our-projects/?proj=365#> [Accessed 20 April 2019].
837

838 Sumar, S., & Ismail, H. (1995). Adulteration of foods – past and present. *Nutrition & Food*
839 *Science*, 95(4), 11-15.
840

841 Tähkääpää, S., Maijala, R., Korkeala, H., & Nevas, M. (2015). Patterns of food frauds and
842 adulterations reported in the EU rapid alert system for food and feed and in Finland. *Food*
843 *Control*, 47, 175–184.
844

845 U.S. Food and Drug Administration, U.S. FDA (n.d.). Vulnerability assessment resources.
846 Available at:
847 [https://www.accessdata.fda.gov/scripts/FDTraining/course_01/module_03/lesson_04/FD01_](https://www.accessdata.fda.gov/scripts/FDTraining/course_01/module_03/lesson_04/FD01_03_04_030.cfm)
848 [03_04_030.cfm](https://www.accessdata.fda.gov/scripts/FDTraining/course_01/module_03/lesson_04/FD01_03_04_030.cfm) [Accessed 17 August 18]
849

850 U.S. Food and Drug Administration, U.S. FDA (2017). Food defense plan builder download.
851 Available at: www.accessdata.fda.gov/scripts/fdplanbuilder/download.cfm [Accessed 17
852 August 18]

853
854 Van Ruth, S. M., Luning, P. A., Silvis, I. C. J., Yang, Y., & Huisman, W. (2018). Differences
855 in fraud vulnerability in various food supply chains and their tiers. *Food control*, 84, 375-381.
856
857 Van Ruth, S. M., Huisman, W. & Luning, P. A. (2017). Food fraud vulnerability and its key
858 factors. *Trends in Food Science & Technology*, 67, 70-75.
859
860 Wang, C.-S., Van Fleet, D. D. & Mishra, A. K. (2017). Food integrity: a market-based
861 Solution. *British Food Journal*, 119(1), pp.7-19,
862
863 Wolfe, D. T., and Hermanson. D.R. 2004. The Fraud Diamond: Considering the Four
864 Elements of Fraud. *CPA Journal*, 74(12), 38-42.

865 Wright, M., Ibrahim, F., Manning, L. & McKellar, D. (2014). Research to explore the current
866 and historic trends in food sampling with particular reference to sampling and surveillance
867 undertaken by Local Authorities and Port Health Authorities. Report for the Food Standards
868 Agency. Available at: [Accessed 16 March 2019]
869
870 WHO (World Health Organization) (2008), *Terrorist threats to food. Guidance for establishing
871 and strengthening prevention and response systems*. World Health Organization. Food Safety
872 Issues Series. WHO, Geneva.
873
874 Xiu, C., & Klein, K. K. (2010). Melamine in milk products in China: Examining the factors that
875 led to deliberate use of the contaminant. *Food Policy*, 35, 463-470.
876
877 Zhu, X., Huang, I.Y & Manning, L. (2019). The role of media reporting in food safety
878 governance in China: a dairy case study, *Food Control* 96, 165-179
879
880 Zio, E. (2016). Challenges in the vulnerability and risk analysis of critical
881 infrastructures. *Reliability Engineering & System Safety*, 152, 137-150.
882
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884 **Table 1. Types of food fraud. (Adapted from Spink & Moyer, 2011a; 2011b; Lotta &
885 Bogue, 2015; Spink et al., 2016: CWA,17369:2019).**
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Types of food fraud
Deception during manufacture Overrun (intentional overproduction, sometimes called the “third shift” Overtreating (including adding more water than allowed by regulation),
Diversion into illicit supply chains Diversion, Smuggling Theft
Duplication Simulation, Counterfeiting
Interventions with the food product Adulteration Addition Substitution, Product tampering Removal Unapproved processes

Misrepresentation

Misdescription

Record tampering

Misrepresentation of food characteristics, country of origin, food ingredients or food packaging,

Claim violation

False or misleading statements made about a product for economic gain

Underweight product

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Table 2. Types of sampling

Term	Description
Sampling	The process of selecting a subgroup of a population to represent the entire population.
Sampling strategy	A sampling strategy is the approach used to select the units of the target population subject to official controls e.g. businesses, foodstuffs, etc
Routine surveillance	Sampling strategy where samples are taken to check compliance levels and detect previously unidentified issues. Routine surveillance may be risk-based, with samples selected to match some form of risk rating. Surveillance may be planned and funded at a national level, such as through EU competent authorities through national sampling programmes, or locally determined. Local sampling plans may be informed by national priorities as well as local assessment of risks.
Types of sampling	
Availability sampling	See convenience sampling
Census sampling	Sampling strategy that samples the totality of the population on which the data is reported.
Convenience or convenient sampling	A non-probability sampling strategy that uses the most easily accessible people (or cases) to participate in a study. Also know as opportunity sampling and availability sampling or strategy based on the selection of a sample for which units are selected only on the basis of feasibility or ease of data collection. It's a not random sampling. The data reported refer themselves to units selected according to this strategy.
Judgmental sampling	See suspect sampling
Objective sampling	Selection of a <i>random sample</i> from a population on which the data are reported.
Opportunity sampling	See convenience sampling
Probability sampling	The probability sampling method gives each eligible element/unit a known (and commonly equal) chance of being selected in the sample; random procedures are employed to select a sample using a sampling frame. Also known as random sampling
Purposive sampling	A non-probability sampling strategy in which the researcher selects participants who are considered to be typical of the wider population (sometimes referred to as judgmental sampling)

Quota sampling	A non-probability sampling strategy where the researcher identifies the various strata of a population and ensures that all these strata are proportionately represented within the sample to increase its representativeness
Random sampling	See probability sampling
Selective sampling	Sampling strategy is based on the selection of a random sample from a subpopulation (or more frequently from subpopulations) of a population on which the data are reported. The subpopulations are can but are not always determined on a risk basis. The sampling from each subpopulation is not proportional: the sample size is proportionally bigger for instance in subpopulations considered at high risk. This sampling includes also the case when the data reported refer to censuses on subpopulations
Snowball sampling	A non-probability sampling strategy whereby referrals from earlier participants are used to gather the required number of participants
Statutory sampling	Official sampling undertaken where the products to be tested as well as frequency of the said testing is set out in law to control specific health risks.
Stratified sampling	Probability based sampling where the population is divided into specific groups (strata) and a sample is drawn from each group.
Suspect sampling	Suspect sampling or enforcement related sampling is a form of judgmental sampling where the selection of an individual product or establishment is done in order to confirm or reject a suspicion of non-conformity. Sampling strategy where samples are taken as part of enforcement investigations.

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Sources: (Huddersfield University, nd; Eurostat, 2010; Wright, Ibrahim, Manning & McKellar, 2014)

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Table 3. Comparison of databases that provide information that can be used in a food fraud vulnerability assessment.

Name	Accessibility	Openness Maturity Level	Purpose	Functionality	Source of data	Downloading of data	FFVA Capacity
RASFF System	Free to access	Leaders	Competent authority information	Searchable with classifications	Purposive, random or reactive, sampling from	Free to download	Database only no additional vulnerability assessment tool.

			exchange forum		regulatory sampling		
Food Fraud Risk Information Database	Free to access top level data – pay to view database	Followers	Information exchange forum	Categorised into lists by product type or time period. Ability to subscribe to a list or an individual card	On-line news items and alerts	Data lists are accessible but pay to download a historic database on a spreadsheet	Database with a risk rating (high, medium, low) risk assessment criteria not shown. No additional vulnerability assessment tool.
Decernis Food Fraud Database	Pay to access Annual subscription or 30 day subscription	Beginners	Database to enable FFVA	Categorised by ingredients with search capabilities and analytics	Scientific articles, media, regulatory and judicial reports and food industry and trade associations	No free data	Database and associated FFVA capability within the tool.
Food Adulteration Incident Registry (FAIR).	Pay to access annual subscription Information over five years old is free	Followers	Incident database	Categorised by incident	Publically available data	Data over five years old is freely accessible	Database and associated with FOODSHIELD a collaborative platform and the Intentional Adulteration Assessment Tool (IAAT) for food defence
Food Integrity Network (FIN)	Subscription based on personal credentials – Stakeholder or expert Horizonscan is	Beginners	Incident database	Categorised by incident	Suspected and actual incidents of adulteration	No free data	Database and knowledge network – linked to Horizon Scan. No FFVA capability.

	a subscription only service						
MediSys-FF	Open access	Leaders	European Commission database	Categorised by type of disease, food safety hazard or threat	Publically available media information	Freely available	Database. No FFVA capability.
The US FDA Recalls, Market Withdrawals and Safety Alerts Database	Open access	Leaders	Regulators database of issued alerts	Categorised by recall type by commodity e.g. food, cosmetics etc.	Regulatory data. Publically available database	Freely available	Database of alerts that is searchable. Older data is archived but available. No FFVA capability.
UKFSS Database	Private database	None	Incident and sampling database	Private system	Regulatory sampling	No freely available data	Database. No FFVA capability.
Private laboratory databases	Private databases	None	Sampling databases	Private system	Market sampling systems	No freely available data	Database. No FFVA capability.

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899 **Table 4. Comparison of the two FFVA tools provided by Food Fraud Advisors (2018)**

Vulnerability Assessment Tool v3.0s	Vulnerability Assessment Tool (BRC method)
Suitable for ingredients, raw materials such as processing aids, additives, packaging materials, finished products, dietary supplements, herbal remedies (oral), functional food additives and 'boosters'	Suitable for food ingredients
Addresses all aspects of food fraud	Addresses economically motivated adulteration, substitution and dilution

Based on the methodology recommended by Michigan State University Food Fraud Initiative	Based on the method recommended by the British Retail Consortium (BRC)
Generates a report containing: Purpose and scope Likelihood of food fraud and impact (severity) of food fraud The results of the vulnerability assessment in a risk matrix format Optional initial screening (pre-filter) step Optional controls report	Generates a report containing: Purpose and scope Likelihood of occurrence of food fraud for the material Likelihood of detection of food fraud The results of the vulnerability assessment in a risk matrix format
Suitable to meet the requirements of all major food safety standards and can be used by food businesses that do not operate a formal food safety management system	Designed to meet the requirements of BRC Food Safety Issue 8.
Easy to review and update	
Results and data can easily be copied and pasted into other documents	
Save, file and print the results for your next audit	

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