

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

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11 **Abstract**

12 Multiple food fraud vulnerability assessment (FFVA) tools have been developed and refined
13 to capture and quantify food fraud issues in the supply chain. The aim of this research is to
14 review existing FFVA tools and the databases that underpin them and consider the challenges,
15 limitations and opportunities in their use. The databases considered include: the Rapid Alert
16 for Food and Feed Safety (RASFF) database, the Food Fraud Risk Information, Decernis Food
17 Fraud Database, FoodSHIELD, and HorizonScan. Four FFVA tools, Safe Supply of Affordable
18 Food Everywhere (SSAFE), the two Food Fraud Advisor's vulnerability assessment tools and
19 EMAAlert, are also critiqued in this paper from the viewpoint of the tools available and their
20 efficacy for food fraud vulnerability assessment.

21 **Keywords:** food fraud, vulnerability, intentional, adulteration, database

22 **Highlights**

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

28 **1. Introduction**

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

44 **Take in Table 1**

45 For perpetrators, successful modes of food fraud are measured in terms of the degree of
46 financial gain when compared with the risk of detection (Manning & Soon, 2014). As
47 opportunities arise, and the risk of detection decreases, the effort required to commit crime for
48 the benefit derived is reduced. In contrast, the higher the probability of being detected or
49 caught, the lower the returns for the fraudster (Spink & Moyer, 2011a). From an anti-fraud
50 perspective, it is difficult to predict where fraud may occur as fraudsters, if their modus
51 operandi is to remain undiscovered, are constantly required to identify new opportunities and
52 channels for committing fraud (Kingston, 2017). The key to preventing food fraud is the

53 development of measures to assess, detect, mitigate and where possible prevent it from
54 occurring. However, Everstine, Spink & Kennedy (2013) assert that economically motivated
55 adulteration (EMA) differs from other food threats as it is not readily predicted through food
56 safety risk assessments and intervention strategies. Instead food fraud vulnerability assessment
57 (FFVA) systematically considers the factors that create vulnerabilities in a supply chain, *i.e.*
58 where food fraud is more likely to occur (Nestle, n.d.).

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

74 **2. Risk assessment versus vulnerability assessment**

75 **2.1 Risk assessment**

76 Risk assessment is the overall process of risk identification, risk analysis and risk
77 evaluation. International Standardisation Organisation (ISO) Guide 73 (2009) states risk

78 assessment (finding, recognising and describing risk) leads into **risk analysis**, (the process to
79 understand the risk and determine its likelihood), and **risk evaluation**. The Guide highlights
80 that risk evaluation is the process of comparing the results of risk analysis with risk criteria to
81 determine firstly the significance of the risk and whether that degree of risk is acceptable i.e. it
82 is a risk identification and quantification process. This approach is thus a separate activity from
83 **risk management**. Risk management is situated to an organisation's activities and drives an
84 approach that leads to continuous improvement in seeking to eliminate or reduce risk. Risk
85 management is integrated into all organisational activities; involves a structured and
86 comprehensive focus that is dynamic and reflects internal and external risk factors; is inclusive
87 and ensures appropriate and timely involvement of necessary stakeholders and considers the
88 degree of uncertainty in the data available; and uses a holistic approach that considers the social
89 (human and cultural) factors that influence risk (ISO 31000, 2018).

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

101 The PAS 96 (2017) Guide highlights the process of undertaking risk assessment for food
102 crime including food fraud throughout a food business. The risk assessment process requires

103 the semi-quantitative determination of likelihood and impact, deriving a risk score and then
104 prioritising a risk management process to reduce risk. The process is supported by a risk matrix
105 leading to the development of a threat identification matrix that at each process step identifies
106 threats, vulnerabilities, access, mitigation, and testing programmes. TACCP is thus a risk
107 assessment and a risk management methodology that uses a risk matrix to prioritise internal
108 and external risk associated with fraud in order to prioritise the allocation of resources and the
109 weighting can be arbitrary.

110 **2.2 Vulnerability assessment**

111 Vulnerability is a measure of a system's susceptibility, or conversely resilience, to threat
112 scenarios whereas the level of risk focuses on the consequences and their severity should a
113 threat be realised (Ezell, 2007). Zio (2016) suggests there are multiple perceptions of
114 vulnerability and this will ultimately affect how individuals or teams assess vulnerability.

115 Vulnerability can be considered as a product, technical or system attribute namely:

- 116 a. The extent to which vulnerability is a *weakness or flaw* i.e. vulnerability as a “gap or
117 an element of the system that is missing”. An organisation can apply vulnerability
118 assessment internally or externally to a whole supply chain in order to identify the weak
119 areas or **hotspots** that are vulnerable to food fraud. An internal vulnerability assessment
120 aids understanding of the weaknesses, criticalities and access points within a specific
121 manufacturing environment where there are food fraud vulnerabilities;
- 122 b. By seeing vulnerability as a *risk* i.e. the degree of exposure (likelihood x severity)
123 through the use of tools such as HACCP, TACCP or VACCP;
- 124 c. Through considering vulnerability in terms of the *consequences* i.e. the degree of loss
125 or damages;

126

- 127 d. By assessing vulnerability in terms of it reducing the *capacity of an organisation or*
128 *supply chain to return to a steady state* i.e. determining vulnerability in terms of ability
129 to return to the status quo; or
- 130 e. *As failure to be resilient* where resilience is seen as continuous improvement into the
131 long term i.e. determining vulnerability as a failure to be sustainable.

132 As previously explored in this paper, vulnerability can also be assessed at the micro, meso
133 and macro level of a food system with the resultant challenge that vulnerability assessment
134 requires systems rather than linear (cause and effect) thinking. Vulnerability assessment, if
135 undertaken appropriately, can define the actions required to eliminate weak points, or
136 vulnerability points, and reduce the potential for food fraud to a level the organisation deems
137 acceptable. The GFSI Position Statement on Mitigating the Public Health Risk of Food Fraud
138 (GFSI, 2014) defines FFVA as a two-stage approach. Firstly, “ information is collected at the
139 appropriate points along the supply chain (including raw materials, ingredients, products,
140 packaging) and evaluated to identify and prioritise significant vulnerabilities for food fraud”
141 and then secondly, appropriate control measures need to be in place to reduce the risk arising
142 from these vulnerabilities. (GFSI, 2014). Thus, a relevant FFVA informs the development of a
143 control plan. Four years later, the GFSI develop this rationale further into two elements a
144 FFVA, and then a food fraud mitigation plan (GFSI, 2018). Therefore, vulnerability assessment
145 considers the strength, or weakness, of an organisation’s food fraud mitigation strategy (Cavin,
146 Cottenet, Blancpain, Bessaire, Frank, & Zbinden, 2016).

147 Marvin et al. (2016) drew together a set of variables that influence an organisation’s
148 vulnerability to food fraud. These criteria including **economic factors** (*e.g.* price, supply and
149 demand); **national factors** associated with the country of origin (*e.g.* governance) and **specific**
150 **incident related factors** such as fraud type, complexity and the potential for fraud detection
151 to then be able to identify headline predictors of food fraud. Price Waterhouse Cooper (PwC,

152 2016) differentiates between economic and market factors such as economic conditions, value
153 attributes, financial strains, level of competition and associated strategies, and supply/demand
154 and pricing and **cultural and behavioral factors** such as personal gain or desperation,
155 corruption level, blackmail, victimisation and ethical business culture. As well as the
156 determination of what vulnerability is and how vulnerability is articulated within FFVA tools,
157 the other factor that influences the effectiveness of these tools is the source, situational
158 applicability, quality and validity of the data and then the type of methodological assessment
159 approach in which the data is used. A typology of sampling has been synthesized in this
160 research that is utilised within this paper to differentiate between data and information sources
161 used for a given FFVA (Table 2).

162 **Take in Table 2**

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

172 **3. Food information databases**

173 This section compares a series of databases that contain information that can be used
174 by an organisation in assessing their internal or external vulnerability to food fraud. Five
175 databases critiqued here are either open access platforms e.g. the European Union (EU) Rapid
176 Alert for Food and Feed Safety Portal (RASFF) and others are commercial databases that

177 require a subscription payment for access or have some free to access components and other
178 pay to download elements.

179 **3.1 Rapid Alert for Food and Feed Safety (RASFF) Portal - Information Exchange**

180 **Forum**

181 The RASFF provides an information exchange forum for member states and regulatory
182 bodies to provide food and feed control authorities with information about the measures taken
183 to respond to serious problems either detected in relation to food or feed being imported into
184 the EU or being transferred within the EU (RASFF, 2017). These problems include food safety
185 issues and instances of food fraud. The EU RASFF database is a centralised and searchable
186 database where urgent notifications can be sent, received and responded to (RASFF, 2018).
187 Members, including the European Commission, EU members, the European Food Safety
188 Authority (EFSA), the European Free Trade Association (EFTA) Surveillance Authority, (i.e.
189 Iceland, Liechtenstein and Norway) and Switzerland (RASFF, 2018).

190 The EU Administrative Assistance and Cooperation (AAC) system operates alongside
191 the RASFF system with the aim of effective information sharing to ensure a swift reaction
192 following detection of public health risks in the food chain and the EU Food Fraud
193 Network (FFN) exchanges information within this system (EC, 2019a). However, data is not
194 freely available except in the form of historic reports. The FFN was established to manage
195 requests for cross-border cooperation and to ensure the rapid exchange of information between
196 the Commission and national authorities in the event of suspected fraudulent practices
197 (Bouzembrak et al. 2018). The use of the RASFF database, either solely or in conjunction with
198 data from national databases has informed research into the types of incidents as well as the
199 value of such databases in informing risk or vulnerability assessment (Tähkääpää, Maijala,
200 Korkeala & Nevas, 2015; Bouzembrak & Marvin, 2016; Marvin et al. 2016). However it should
201 be noted that the data comes from a variety of sources and whilst some standardisation of food

202 classifications has taken place these classifications do not replicate those in other databases
203 which limits the drawing of inference from the pooling of information from multiple datasets

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

- 211 • **Beginners:** in the early stages of transition to an open data policy;
- 212 • **Followers:** with a basic open data policy and some advanced features on their portal,
213 but there are limitations for the public use/reuse of datasets;
- 214 • **Fast trackers:** greater advancement in their open data journey than followers; and
- 215 • **Leaders:** who have implemented an advanced open data policy with extensive portal
216 features (Foster et al. 2019).

217 These criteria will be used to determine the maturity of the databases considered in this paper
218 in the critique in Table 3.

219 **Take in Table 3**

220 **3.2 Food Fraud Risk Information Database**

221 Food Fraud Risk Information (<https://trello.com/b/aoFO1UEf/food-fraud-risk->
222 [information](https://trello.com/b/aoFO1UEf/food-fraud-risk-information)) is a free and accessible database on incidences of food fraud and emerging threats
223 (Food Fraud Advisors, 2017; Food Fraud Risk Information, n.d.). The site is designed in an
224 easy to navigate manner with highlights of the most recent food fraud incidences by month or
225 by product category. The site allows users to view incidences according to food and drink
226 categories including packaging materials and marketing claims. There is an internal risk rating

227 (low through to high), but the criteria for how risk has been determined is not outlined.
228 Individual incidents can be accessed for free but there is no free downloadable reporting
229 function. A static off-line historic database can be downloaded as an Excel spreadsheet for a
230 on-off fee. The source of information is important here especially in terms of its validity and
231 representativeness. Through exposing incidents, the media plays an increasingly important role
232 in providing the evidence that underpins food fraud governance, influencing the behaviour and
233 attitudes of government, food producers and consumers. However, Zhu, Huang and Manning
234 (2019) highlight there is a difference between the number and type of incident being reported
235 by government reports and those by the media as the media tends to report incidents that have
236 a public interest element and outline more of a “story” associated with the problem (see also
237 the work of Bouzembrak et al. 2018). In essence, developing databases through the use of
238 media material as a source of evidence means that such databases are socially rather than an
239 objectively constructed, thus the evidence is not independent of the social norms that frame it.

240 **3.3 Decernis Food Fraud Database**

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

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

254 **3.4 Food Adulteration Incidents Registry (FAIR)**

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

264 **3.5 Food Integrity Network (FIN)**

265 The Food Integrity (FI) Network (FIN, 2019) is a platform for stakeholders and experts to
266 exchange knowledge and expertise in food authenticity, safety and quality; and to rapidly share
267 information and intelligence about suspected and actual incidents to protect consumers and
268 food products from damaging effects of food misdescription (Source:
269 <https://secure.fera.defra.gov.uk/foodintegrity/expertdb/index.cfm>). HorizonScan is an
270 associated global database that monitors commodity safety (more than 500 commodities),
271 tracks over 22,000 suppliers and scans the official sites of over 180 countries and more than
272 100 independent sources daily. The database is searchable by commodity. It is a subscriber
273 only service (FERA, 2019). Email alerts can be tailored to the commodities and issues
274 important to the food business.

275 **3.6 European Commission's Joint Research Centre Europe Media Monitor** 276 **(EMM) System**

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

286 Researchers have used the Medisys database in their research. An Early Warning
287 System (EWS) was developed that can detect potential food fraud (Mojtahed, 2018). EWS
288 harvests data from the EMM that analyses, curates and aggregates information from traditional
289 and social media globally (EU Science Hub, 2017). The EWS has been further refined and
290 developed into a food fraud tool (MedISys-FF) that collects, analyses and presents food fraud
291 reports published in worldwide media (Bouzembrak et al. 2018). The tool was benchmarked
292 against RASFF, EMA (now FAIR) and HorizonScan and the MedISys-FF system collected
293 food fraud information with high relevance (>75%).

294 **3.7 The US Food And Drug Administration (FDA) Recalls, Market Withdrawals** 295 **and Safety Alerts Database**

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

301 **3.8 UK Food Surveillance System (UKFSS) Database**

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

308 **3.9 Private laboratory databases**

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

- 313 • To help ensure the integrity of food supply chains and protect the interests of the
314 consumer;
- 315 • To address the recommendations from “The Elliott Report” (Elliott, 2014) for industry
316 to establish a ‘safe haven’ to collect, collate, analyse and disseminate information and
317 intelligence;
- 318 • To share intelligence with governmental bodies to better understand where risks may
319 sit in the UK Food Industry from food fraud, and
- 320 • To help divert, detect, deter and disrupt those activities and in doing so, further enhance
321 the reputation of the UK Food Industry (CBRI, 2019).

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

324 **3.10 Summary**

325 This section has highlighted the range of databases that can be used to identify historic levels
326 of a particular kind of food fraud associated with a particular food, country or company. The

327 databases are mostly subscribe to view which makes it difficult for small and medium sized
328 companies (SMEs) to access this data in order to be better informed when undertaking FFVA.
329 Spink, Moyer and Speier-Pero (2016) differentiate between four sources of data that ultimately
330 inform FFVA for a given organisation: static external databases, dynamic external internet
331 searches and automated keyword alerts (e.g. Google Alerts); internal datasets on known food
332 fraud incidents within the organisation and lastly subject matter expert insight databases e.g.
333 through groups such as FIIN. Spink, Moyer and Speier-Pero (2016) also developed a four stage
334 food fraud risk assessment. The first stage was a Food Fraud Initial Screening (FFIS) step as a
335 precursor to a FFVA leading to a Corporate Risk Map and then a Resource Allocation Decision.
336 The FFIS approach is divided into 4 steps:

- 337 (i) define the assessment scope (*e.g.* specify supply chain and region) and qualitative
338 risk ranking terminologies (*e.g.* very high / high / medium / low / very low);
- 339 (ii) (ii) review incidents and suspicious activities (*e.g.* derived from internal sources,
340 expert opinion or external databases);
- 341 (iii) (iii) screen for health hazards and enterprise risks (*e.g.* risk assess and rank health
342 hazard and enterprise [financial] risks and post the screening phase, and then to
- 343 (iv) (iv) plot the food fraud risks on a risk matrix.

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

351 **4.0 Food fraud vulnerability assessment (FFVA) tools**

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

367 **4.1 Safe Supply of Affordable Food Everywhere (SSAFE)**

368 Safe Supply of Affordable Food Everywhere (SSAFE) is a not for profit organisation
369 supported by a range of multi-national corporations that has developed a free, science-based
370 online FFVA tool (Excel spreadsheet, online or a phone app) that could be used across the food
371 supply chain (<http://www.ssafe-food.org/our-projects/?proj=365#>) (SSAFE, 2019). SSAFE
372 developed the FFVA tool with Price Waterhouse Cooper (PwC), Wageningen University, VU
373 University Amsterdam and following consultation with global food industry leaders (PwC,
374 2019). The use of this tool is advocated by the GFSI (2014). The advantage of the tool is its
375 flexibility and applicability to different products, business size and region. Other key strengths
376 associated with this tool is its versatility (available in 11 languages and maximise tool

377 accessibility), and its online and offline usage capability. The tool is built upon the principles
378 of HACCP as the FFVA also requires a team approach (*e.g.* security, finance, quality
379 assurance). Users are guided by an initial decision tree analysis to determine the scope of
380 assessment and then are taken through a series of questions (n=50). Each question contains 3
381 fixed answers. This tool uses a systematic approach where users are provided with an
382 explanation of why the question is important and each fixed answer contains information to
383 assist users in selecting the most appropriate answer. Once completed, users will be able to
384 assess the level of food fraud vulnerability and the means for its control (SSAFE, 2019). This
385 tool is designed to be a practical vulnerability assessment tool suited to guiding manufacturers
386 who may not have detailed and specific knowledge on food fraud and vulnerability. SSAFE
387 can be used as both an intrinsic and extrinsic vulnerability assessment tool. Examples of
388 intrinsic vulnerability assessed by SSAFE are internal processing activities, ethical business
389 culture and business strategies. Extrinsic vulnerability can include the price of raw materials,
390 corruption level of countries where suppliers are located and the level of competition across a
391 selected food sector. The tool does not provide for developing specific mitigation techniques
392 for a given vulnerability, but instead users can refer to information sources and references
393 provided in the tool for further guidance.

394 **4.2 Food Fraud Advisor's Vulnerability Assessment Tool**

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

401 **Take in Table 4**

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

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

417 **4.3 EMAlert – Economically Motivated Adulteration – Vulnerability Assessment Tool**

418 The Grocery Manufacturers Association (GMA) and Battelle have worked in partnership to
419 develop EMAlert, a software tool that enables food manufacturers to analyse and understand
420 EMA vulnerabilities (EMAlert, 2019). This tool is different to the others in that it includes a
421 behavioural model to consider fraudster decision making and how this impacts on food fraud
422 vulnerability. The tool is a pay for use subscription based system. The advantage of this system
423 is that it can assess a greater number of commodities (50) in one analysis compared with
424 SSafe and EMAlert considers economic (motivation, pressure, opportunity), ease (capability)
425 and historical drivers.

426 **4.4 Challenges with FFVA**

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

441 As outlined in this paper there is multiple terminology being used to determine
442 vulnerability and risk which is a challenge in itself. This emerging terminology from evolving
443 definitions of authenticity (Sumar & Ismail, 1995) to consideration of types of fraud and the
444 lack of a harmonized definition of food fraud (Bouzembrak et al. 2018), human behavioral
445 science, motivation, methods, ethical problems and social and criminal implications (Spink and
446 Moyer, 2011; Manning & Soon, 2016; Lord, Elizondo, & Spencer, 2017). Specialists from
447 social science and criminology backgrounds tend to give more emphasis to the social, economic
448 and legal aspects of food fraud, while food scientists tend to focus on chemical characteristics
449 of food, economic gain and the impact in terms of public health concerns. More
450 collaborative work should be done, particularly with social science specialists, to achieve a
451 universal definition of food fraud. CODEX proposed an Electronic Working Group (EWG) to

452 review CODEX gaps and to create a definition and scope for food fraud, food integrity, food
453 authenticity and other food fraud related terms. This is a major step forward to potentially
454 incorporate food fraud into the formal Codex Alimentarius which can revamp the food supply
455 chain as food fraud countermeasures will become a requirement when conducting business
456 (Spink, 2017).

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

476 when supply remains constant. Therefore, FFVA tools identify the degree of food fraud
477 vulnerability at a given time and in a given set of circumstances.

478 **5.0 Discussion**

479 Collaborative efforts between private and non-profit sector and governmental bodies
480 will help to grow food fraud networks to address and tackle food fraud at a landscape level are
481 hampered by the “pay to use” requirements of many incident databases and FFVA tools. A lack
482 of consistency in coding within databases and the lack of a universal definition of food fraud
483 needs to be addressed so it is possible to link, harmonise and connect multiple databases to
484 share information and intelligence within and between networks. Food fraud assessment
485 networks are developing. In the EU the FIN network is developing these collaborative
486 knowledge building as is the work of the JRC (EU Science Hub, 2016). To date four EU wide
487 coordinated control plans (horsemeat, fish, honey and online food supplements and novel
488 foods) had been developed to determine the extent of fraudulent practices in the food sector
489 (EC, 2018). These approaches are considering food fraud together with food and feed safety
490 in a concerted approach but there is no global, universal, central intelligence database that is
491 available to the food industry, regulators and investigators that brings together all the
492 intelligence and information that is currently available. This creases an inequity in the food
493 sector in that many SMEs cannot access such information. However some databases and tools
494 are free to download and if they have sufficient knowledge and understanding SMEs can use
495 this tools to start undertaking FFVA. Whilst some FFVA tools aid organisations to develop a
496 vulnerability profile or vulnerability register for the business, not all go to the next step of
497 developing a control plan. As social network analysis research develops with regard to food
498 fraud especially when combined with crime data mining and criminal network analysis this
499 will assist further in the development of FFVA tools. Emerging tools that use data mining will

500 take existing FFVA and detection approaches forward towards more predictive food fraud
501 modelling.

502 Manning and Soon (2014) sought to draw together the elements of both a predictive
503 and a reactive model for determining food fraud. This model included: determining the
504 situational and contributing factors for food fraud, identifying the databases that provided
505 information of interest in order to use FFVA tools and then to identify the factors that influence
506 the resultant risk ranking. This approach is underpinned by the use of intelligence from
507 industry, enforcement bodies, media and social network surveillance, economic trends, unusual
508 factors that could affect supply and demand dynamics and consider their effect. The detect and
509 react phase of the Manning and Soon (2014) model differentiates between passive laboratory
510 surveillance as part of routine testing programmes and active laboratory surveillance which is
511 targeted on known adulterants that is utilised when the risk ranking status changes. This brings
512 forward an important element of vulnerability assessment that is the use of passive (static)
513 systems and models or the use of reactive and smart systems that are constantly evolving as
514 new intelligence comes in. In these tools it can be shown that vulnerability can be considered
515 as a product, technical or system attribute: in terms of a weakness or flaw. An internal
516 vulnerability assessment can build understanding of the weaknesses, criticalities and access
517 points within a specific manufacturing environment where there are food fraud vulnerabilities.
518 Other tools, or stages within tool application see vulnerability as a *risk* i.e. the degree of
519 exposure (likelihood x severity) reflect on vulnerability in terms of the *consequences* i.e. the
520 degree of loss or damages should the incident occur. The other two elements of vulnerability
521 described in this paper are: the ability or capacity of an organisation or supply chain to return
522 to a steady state i.e. determining vulnerability in terms of ability to return to the status quo;
523 and the need for resilience and for the organisation or supply chain to drive continuous

524 improvement in the medium to long term. This needs to be addressed in further iterations of
525 models that drive effective vulnerability reduction action plans.

526 **6. Conclusion**

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

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

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852 **Table 1. Types of food fraud. (Adapted from Spink & Moyer, 2011a; 2011b; Lotta &**
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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)

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 exchange forum	Searchable with classifications	Purposive, random or reactive, sampling from regulatory sampling	Free to download	Database only no additional vulnerability assessment tool.
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 a subscription only service	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.
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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866 **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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