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A comprehensive review of food fraud terminologies and food fraud mitigation guides

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1 **Title: A comprehensive review of food fraud terminologies and food fraud mitigation**
2 **guides**

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4 **Authors names and affiliations:**

5 **1. Miss Kelsey Robson^{1,2}**

6 Krobson02@qub.ac.uk

7 **2. Professor Moira Dean ¹**

8 Moira.dean@qub.ac.uk

9 **3. Dr. Simon Haughey ¹**

10 s.a.haughey@qub.ac.uk

11 **4. Professor Christopher Elliott ¹**

12 Chris.elliott@qub.ac.uk

13

14

15 ¹Queens University Belfast, Institute for Global Food Security, Biological Sciences Building, 19
16 Chlorine Gardens, Belfast BT9 5DL, United Kingdom

17 ²ABP Food Group, John St, Mulladrillen, Ardee, Co. Louth, A92 C92H, Ireland

18

19

20 **Corresponding Author:**

21 Christopher Elliott

22 Chris.elliott@qub.ac.uk

23

24

25 **Highlights:**

- 26 • Food fraud definitions share common themes of intentional acts and economic motivation.
27 • Lack of consistent ‘types’ of food fraud creates confusion over how fraud is described.
28 • Of the twelve food fraud mitigation documents found none focused on the beef supply
29 chain.

30

31 **Abstract:**

32 Due to constant integrity challenges, ambiguous definitions, and lack of specific guidance, the food

33 industry has been left vulnerable to food fraud. Food fraud is undefined by the EU, resulting in the

34 creation of varying definitions from researchers and regulatory bodies. Not having a definition of

35 food fraud and related terms makes it challenging to comprehend, communicate and ideate on how

36 to prevent it. Furthermore, the food industry is lacking clear guidance on the prevention and

37 mitigation of food fraud. Several documents are available to help guide the food industry; however,

38 they are nonspecific to supply chains, which has left a substantial gap in knowledge that is necessary

39 to protect the food supply. This review analyzed definitions for food fraud and related terms, as well
40 as current guidance on food fraud prevention and mitigation, which can be utilized by the food
41 industry to find commonality and assess where more information is needed. An abundance of
42 literature describing food fraud was found, and although definitions varied, the common themes of
43 intentional acts and economic motivation were widespread. Additionally, general guidance
44 documents for food fraud mitigation and prevention shared general ideas of supply chain
45 transparency, supplier audits, horizon scanning, and vulnerability assessment, which could be
46 utilized throughout the food industry.

47 **Keywords**

48 Food fraud, Prevention, Mitigation

49

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52 R6603GFS) and ABP Food Group.*

53

54 **1. Introduction**

55 Food fraud dates back to ancient Rome and Athens where there were laws regarding the
56 adulteration of wines with flavours and colours (Sumar & Ismail, 1995). Even though food fraud is an
57 old problem it is still occurring. Although the true extent cannot be known food fraud is undoubtedly
58 cheating hundreds of millions of pounds from the food industry as well as from the consumers each
59 year in the UK alone (Shears, 2010). Food fraud is an issue affecting all food supply chains and
60 therefore the entire food industry, customers and consumers. Food supply chains are increasing
61 vulnerable due to globalisation and lengthening of supply chains (Lotta & Bogue, 2015; Trivedi et al.,

62 2016). Therefore, the need for sophisticated food fraud prevention and mitigation is greater than
63 ever. However, the fight against food fraud is hindered by ambiguity concerning the term
64 (Wisniewski & Buschulte, 2019). The European Union (EU) has not set a legal definition for what
65 food fraud is and this has led to inconsistencies among researchers and regulatory bodies, confusing
66 the understanding of food fraud and related terms (Wisniewski & Buschulte, 2019; Lotta & Bogue,
67 2015; Spink et al., 2015).

68

69 The food industry is in the unique position of being a victim of food fraud and also largely liable for
70 food fraud incidents (Wisniewski & Buschulte, 2019). Therefore, the food industry is in need of a
71 clear understanding of food fraud, as well as guidance on food fraud prevention and mitigation. A
72 range of academic literature, government publications, stakeholders have defined food fraud and
73 offered guidance on and mitigation strategies. However, within these documents definitions of food
74 fraud often differ, as well as on the types of food fraud that can occur. Therefore, prevention and
75 mitigations strategies are generalized and not specific to a particular supply chain which adds to the
76 ambiguity.

77

78 This literature review deconstructed the definitions of food fraud and related terminology, and
79 examined current guidance for food fraud prevention and mitigation. By determining the current
80 state of available guidance and understanding surrounding food fraud, this review aimed to point
81 out gaps that need to be filled. This will identify future works needed to protect food products from
82 fraud.

83

84 2. Defining food fraud

85 In this literature review searches were carried out to define food fraud and related terms.
86 Databases (Science Direct, Scopus, Web of Science) were searched for definitions of food fraud,
87 economically motivated adulteration (EMA), food integrity, food crime and food authenticity. The
88 searches found 231 articles, of which 107 duplicates were removed and abstracts read to determine
89 relevance. A total of 35 articles of interest were taken forward.

90
91 The searches revealed twelve definitions for food fraud in peer-reviewed literature. These
92 definitions are shown in **Table 1**. A majority of definitions agree that food fraud is an intentional
93 deception for economic gain using food. Within the definitions for food fraud, the motivation or
94 driving factor for economic gain is generally agreed. This is seen in all definitions except for Manning
95 (2016) which instead stated the motivation as “encourage[ing] another individual erroneously to
96 part with something of intrinsic value”. Although gain due to fraudulent behaviour is not explicitly
97 mentioned in Manning (2016) the objective to exploit an unsuspecting party is still indicated. Cruse
98 (2019) states that economic benefit is one motivation for food fraud, however, one can also be
99 motivated by an intent to cause harm. This point of view is not supported by other definitions,
100 although malicious contamination is considered a type of fraud, which will be discussed in section 9.
101 Many articles state that food fraud may cause unintentional harm, however this is generally a
102 ramification of product substitution or cheap, unhygienic processing, leading to food safety issues
103 (Manning & Soon, 2016; Spink, Moyer & Speirer- Pero, 2016; Zhang & Xue, 2016). All of the
104 definitions described in **Table 1** state that food fraud is intentional or deliberate and if
105 contamination occurs unintentionally this is not an act of fraud but a food safety incident.

106

107 **Table 1. Food fraud definitions form academic literature**

Source	Food fraud Definition
--------	-----------------------

Spink and Moyer, 2011	Food fraud is a collective term used to encompasses the deliberate and intentional substitution, addition, tampering or misrepresentation of food, food ingredients or food packaging: of false or misleading statements made about a product, for economic gain.
Everstine, Spink & Kennedy, 2013	The intentional adulteration of food for financial advantage.
Ellis Muhamadali, Haughey, Elliott, & Goodacre, 2015	Committed when food is deliberately placed on the market for financial gain, with the intent of deception of consumers. Referred to in the USA and occasionally elsewhere as economically motivated adulteration (EMA). Two of the main types include: trading of food which is unfit for consumption or harmful, or deliberately misdescribing or mislabelling food. The latter can include false statements regarding geographical origin, ingredients, or substitution with lower value (i.e. myrtle instead of oregano), or sometimes even dangerous contents not intended for human consumption (i.e. industrial dyes). The terms food fraud and food adulteration can be used to mean the same thing, when adulteration is intentional.
Spink et al., 2015	An international act with motivation for economic gain.
Charlebois, Schwab, Henn, & Huck, 2016	The deliberate intent to deceive, motivated by the prospect of financial gain.
Manning, 2016	The intentional misrepresentation of fact by one person solely, or acting on behalf of an organization, in order to encourage another individual erroneously to part with something of intrinsic value.
Moyer, DeVries & Spink, 2017	Food fraud (including the subcategory the US Food and Drug Administration (FDA) defined as <i>Economically Motivated Adulteration</i> (EMA)) is illegal deception for economic gain using food.
Spink et al., 2017	Illegal intentional deception for economic gain using food- can occur in all stages of the supply chain and often cross international borders.
Bouzembrak, Steen, Neslo, Linge, Mojtahed, & Marvin., 2018	Food fraud covers cases where there is a violation of EU food law, which is committed intentionally to pursue an economic or financial gain through consumer deception. Food fraud in the food supply chain can arise as a result of misrepresentation associated with: product integrity (e.g. counterfeit product, expiration date), process integrity (e.g. diversion of products outside of intended markets), people integrity (e.g. characterizations such as the cyber criminals and hacktivist) and data integrity (e.g. improper, expired, fraudulent or missing common entry documents or health certificates) of information accompanying the food item throughout the supply chain.
Cruse, 2019	An intentional change in a food product that a consumer is unaware of with their purpose to deceive consumers- whether to cause harm or to economically benefit.
Manning and Soon, 2019	Intentional modification of food products and/or associated documentation for economic gain and may lead to issues of food safety, legality and/or quality depending on the activities undertaken or the agent(s) used.
Spink et al., 2019a	Long Definition: Illegal deception for economic gain using food encompasses deliberate and intentional substitution, addition, tampering, or misrepresentation of food, food ingredients, or food packaging; or false or misleading statements made about a product for economic gain. The types of fraud include adulteration, tampering, product overrun, theft, diversion, simulation, and counterfeiting.
Spink, 2019; Spink et al., 2019a; Spink, Chen, Zhang, & Speier-Pero, 2019b	Short Definition: Illegal deception for economic gain using food

109

110 Further definitions of food fraud exist in the grey literature which includes publications from
 111 government bodies, regulatory standards, and stakeholders (**Table 2**). Similar to the definitions
 112 found in the academic literature, definitions of food fraud in the grey literature largely include
 113 intentional deception for economic gain. The motivation of economic or financial gain is seen in ten
 114 of the thirteen definitions as shown in **Table 2**. *PAS 96: 2017* does not directly state financial gain as
 115 a motive, but instead states that personal gain is one motive for food fraud, which may include
 116 financial gain. *PAS 96: 2017* also states that another motivation for food fraud may be to cause
 117 another party financial loss. The *Food Fraud Mitigation Guidance from USP (2016)* does not give
 118 motivation in its definition of food fraud but does say that one type of food fraud-EMA is intentional
 119 and motivated by financial gain. Additionally, the *Counter fraud good practice for food and drink*
 120 *businesses (2016)* does not state motivation. That maybe because *Counter fraud good practice for*
 121 *food and drink businesses* applies the definition of fraud, as seen in the Fraud Act 2006 to food fraud,
 122 instead of creating a specific definition for food fraud. *CWA 17369 (2019)* does not limit the
 123 motivation of food fraud to economic gain only. Therefore, motivations could include intent to harm,
 124 the ethical reason of a business, or individual or market pressure (van Ruth, Huisman & Luning,
 125 2017). However, *CWA 17369 (2019)* does note that "financial gain is the most common motivation
 126 for food fraud", and argues that intention can be hard to prove. Therefore, the inclusion of
 127 motivation in a definition of food fraud may be problematic, as it will be difficult to establish.
 128 However, most definitions found in **Tables 1 and 2** agree that food fraud is an intentional and
 129 deceptive act for economic gain in food.

130 **Table 2. Food fraud definitions in standards and publications from government bodies and**
 131 **stakeholders**

Source	Definition
Elliott review into the integrity and assurance of food	Deliberately placing food on the market, for financial gain, with the intention of deceiving the consumer. Although there are many kinds of food fraud, the two main types are: • Sale of food which is unfit and potentially harmful, such as: -recycling of animal by-products back into the food chain -packing and selling of beef and poultry with an

supply networks (DEFRA, 2014)	unknown origin -knowingly selling goods which are past their 'use by' date. • Deliberate misdescription of food such as: -products substituted with a cheaper alternative, for example farmed salmon sold as wild, and Basmati rice adulterated with cheaper varieties. -making false statements about the source of ingredients, i.e. their geographic, plant or animal origin. Food fraud may also involve the sale of meat from animals that have been stolen and/or illegally slaughtered, as well as wild game animals like deer that may have been poached.
Food authenticity five steps to help protect your business (FDF, 2014)	Food fraud is committed when food is deliberately placed on the market for financial gain, with the intention of deceiving consumers or customers.
Food fraud and “Economically Motivated Adulteration” of food and food ingredient (CRS, 2014)	The act of defrauding buyers of food and food ingredients for economic gain.
GFSI Position on mitigating the public health risk of food fraud (GFSI, 2014)	Food fraud, including the subcategory of economically motivated adulteration, is of growing concern. It is deception of consumers using food products, ingredients and packaging for economic gain and includes substitution, unapproved enhancements, misbranding, counterfeiting, stolen goods or other.
Counter fraud good practice for food and drink businesses (CIEH, 2016)	The criminal law in England & Wales concerning fraud is primarily derived from the Fraud Act 2006. There are three ways to commit fraud under the Fraud Act 2006: <ul style="list-style-type: none"> • By false representation. • By failing to disclose information. • By abusing a position of trust.
Food fraud Mitigation Guidance (USP, 2016)	Food fraud encompasses a wide range of deliberate fraudulent acts to food.
Food fraud vulnerability assessment and mitigation (PwC, 2016)	Food fraud is simply defined as intentional deception using food for economic gain.
PAS 96:2017 - Guide to protecting and defending food and drink from deliberate attack (BSI, 2017)	Dishonest act or omission relation to the production or supply of food, which is intended for personal gain or to cause loss to another party.
Process manual for the GFSI benchmarking process v7.2 (GFSI, 2017)	Food fraud: A collective term encompassing the deliberate and intentional substitution, addition, tampering or misrepresentation of food, food ingredients or food packaging, labelling, product information or false or misleading statements made about a product for economic gain that could impact consumer health.
Global standards food safety issue 8 (BRC, 2018)	Fraudulent and intentional substitution, dilution or addition to a product or raw material, or misrepresentation of the product or material, for the purpose of financial gain, by increasing the apparent value of the product or reducing the cost of its production.
The EU food fraud network and the system for	Food fraud is about intentional actions taken by businesses or individuals for the purpose of deceiving purchasers and gaining an undue advantage therefrom, in violation of the EU agri-food chain legislation. These intentional infringements may also constitute a risk to

administrative assistance - food fraud (EC, 2018)	human, animal or plant health, or to animal welfare or to the environment as regards GMOs and plant protection products. The EU Food Fraud Network refers to four key operative criteria to distinguish whether a case should be reported as a suspicion of fraud or as a non-compliance: 1. Violation of EU law codified in the EU agri-food chain legislation. 2. Intention 3. Economic gain 4. Deception of Customers
CWA 17369 (CEN, 2019)	Intentionally causing a mismatch between food product claims and food product characteristics.
FSSC 22000 (FSSC, 2019)	A collective term encompassing the deliberate and intentional substitution, addition, tampering or misrepresentation of food, food ingredients or food packaging, labelling, product information or false or misleading statements made about a product for economic gain that could impact consumer health (GFSI v7.2:2018).

132

133 3. Defining economically motivated adulteration (EMA)

134 In some instances, the term EMA has been used interchangeably with food fraud (Everstine, Spink &
135 Kennedy, 2013; CRS, 2013). Alternately, EMA has been classified as a subcategory of food fraud
136 (Spink & Harte, 2008; FDA, 2009; Spink 2009; Spink & Moyer, 2011; van Ruth, Huisman & Luniong,
137 2017; Galvin-King, Haughey & Elliott, 2018). The FDA defined EMA as "fraudulent, intentional
138 substitution or addition of a substance in a product for the purpose of increasing the apparent value
139 of the product or reducing the cost of its production, i.e., for economic gain." The FDA noted that
140 "EMA includes dilution of products with increased quantities of an already-present substance (e.g.,
141 increasing inactive ingredients of a drug with a resulting reduction in strength of the finished
142 product, or watering down of juice) to the extent that such dilution poses a known or possible health
143 risk to consumers, as well as the addition or substitution of substances in order to mask dilution"
144 (FDA, 2009). More recently, EMA has been called a "substance of economic gain with potential
145 health risk" (Spink et al., 2019a). Cruse has defined it as "an intentional change in a food product
146 that a consumer is unaware of for economic gain" (Cruse, 2019). Cruse also noted that there is little
147 distinction between EMA and food fraud. Definitions found in this literature review indicate EMA has
148 become near synonymous with the term food fraud.

150 4. Defining food authenticity

151 Food authenticity is defined as food being authentic (CEN, 2019). Authentic food is described as a
152 “match between the food product characteristics and the corresponding food product claims” (CEN,
153 2019). In short, food is authentic when, “food is what it says it is” (DEFRA, 2014; Spink et al., 2019a).
154 The Elliott Review expands on this definition by stating that, “food authenticity is about ensuring
155 that food offered for sale or sold is of nature, substance, and quality expected by the purchaser
156 (Section 14 Food Safety Act 1990).” (DEFRA, 2014). Food authenticity is referred to as a state rather
157 than an act. Therefore, no motivation or intention has been described in literature. Hence, food
158 authenticity is not an intentional or unintentional act, such as food quality or food fraud, but rather
159 is affect by both intentional and unintentional doings.

160

161 5. Defining food integrity

162 Food integrity had been defined by the EU Food Integrity Project (2017) as, “the state of being
163 whole, entire, or undiminished or in perfect condition.” This project regards integrity as going
164 beyond food fraud, including aspects of food such as the safety and quality of the product (EU FIP,
165 2017). Similarly, the Elliott Review states that food integrity is defined by food that is, “not only safe
166 and of the nature, substance and quality expected by the purchaser but also captures other aspects
167 of food production, such as the way it has been sourced, procured and distributed and being honest
168 about those elements to consumers.” (DEFRA, 2014). Manning (2016) expands on the definition
169 given in the Elliott Review, and describes four types of food integrity issues: (1) product integrity
170 (authenticity) — the inherent quality attribute of totality or completeness; (2) process integrity —
171 the activities undertaken to produce the food item encompassing the design, assurance, monitoring

172 and verification of processes within the product life-cycle to ensure that they remain authentic and
173 intact; (3) people integrity - described as the honesty and morals exhibited by an individual and (4)
174 data integrity - information accompanying the food item throughout the supply chain that is the
175 consistency and accuracy of data through the food product life-cycle. Broadly stated, Manning
176 (2016) would argue that food integrity would include all aspects of the food product, if the people
177 producing the product were treated ethically, if all data and traceability are accurate, and if
178 processes follow the legal standard and adherence to any claims made. While Spink et al. (2019a)
179 have summarized food integrity as “the product is of the specification defined such as quality and
180 label claims” (EU FIP, 2017).

181

182 6. Defining food crime

183 Van Ruth et al. (2018) states that "all food fraud is a form of criminal behaviour no matter the
184 definition of crime," asking the question, whether the terms food fraud and food crime are
185 synonymous? According to Kulling et al. (2019), the term food crime is a form of deceptive criminal
186 behaviour identical to the term food fraud. Likewise, the United Kingdom (UK) National Food Crime
187 Unit (NFCU) (2019) states that food crime "is serious fraud that impacts the safety or the
188 authenticity of food, drink, or animal feed. It can be seriously harmful to consumers, food
189 businesses, and the wider food industry". This definition is vague as it does not clarify what
190 constitutes as 'seriously harmful'. NFCU does go on to give examples of food crime as the “use of
191 stolen food in the supply chain, unlawful slaughter, diversion of unsafe food, adulteration,
192 substitution or misrepresentation of food, and document fraud” (NFCU, 2019). However, all
193 examples given here, could also be examples of food fraud. Therefore, food crime may be
194 described as a subset of food fraud. Spink et al. (2019b) gave two definitions of food crime which
195 are " the violation of a criminal statute using food," and a "serious food fraud incident” (Manning &

196 Soon, 2016; Spink et al., 2019a). Again, these definitions do not clarify how food crime and food
197 fraud differ. However, a violation of criminal statute using food could include the use of food to
198 cause harm, which would not be a subset of food fraud as food fraud has been defined as an act
199 motivated by economic gain (section 4). A distinction is made by Spink et al. (2019a), where food
200 crime is defined as "all types of food fraud which is conducted on a large scale." More specifically, this
201 publication states that, "Food fraud becomes food crime when the scale and potential impact of the
202 activity is considered to be serious. This might mean that the criminal activity has cross-regional,
203 national or international reach, that there is a significant risk to public safety, or that there is a
204 substantial financial loss to consumers or businesses." (Spink et al., 2019a). Elliott Review defines
205 food crime stating, "Food fraud becomes food crime when it no longer involves random acts by
206 'rogues' within the food industry but becomes an organized activity by groups which knowingly set
207 out to deceive, and or injure, those purchasing food" (DEFRA 2014). Definitions found in this review
208 described food crime as both a subset of food fraud that occurs on a large scale and the use of food
209 in criminal acts intended to harm.

210

211 7. Food defense, food safety, food quality and food fraud

212 Other terms that may further complicate the understanding of food fraud are: food defense, food
213 safety, and food quality. The main differences between these terms is the intention, whether the act
214 was intentional or unintentional, and the motivation, whether the act is for economic gain or intends
215 to harm to public health, the economy, or create terror (Spink & Moyer, 2011). The intention and
216 motivation of food fraud, food defense, food safety and food quality are illustrated in Spink and
217 Moyers' food protection risk matrix seen below (**Figure 1**).

218

219

220 **Figure 1. Food protection risk matrix** (Spink & Moyer, 2011)

		Motivation
Food Quality	Food Fraud	Gain : Economic
Food Safety	Food Defense	Harm: Public Health, Economic, or Terror
Unintentional	Intentional	
Action		

221

222 Manning and Soon (2016) defined food defense as the active steps taken, i.e., the procedures,
 223 processes, and countermeasures used to achieve product safety in response to intentional acts of
 224 adulteration meant to cause harm. Similarly, the Global Food Safety Initiative (GFSI) describes food
 225 defense as procedures adapted to ensure the safety of products' intentional malicious attack,
 226 malicious tampering, or terrorism (BRC, 2018; GFSI, 2014; GFSI, 2017; Manning, 2019). While PAS 96:
 227 2017 defines food defense as procedures that protect food and drinks from "maliciously and
 228 ideologically motivated attack," which leads to contamination of a product or supply disruptions as
 229 food defense. The US Food and Drug Administration (FDA) describes food defense as "the effort to
 230 protect food from intentional acts of adulteration where there is an intent to cause wide-scale public
 231 health harm." (FDA, 2018 as seen in Manning, 2019). All definition agrees that food defense is
 232 countermeasures to protect against act using food which intend harm. However, neither Manning
 233 and Soon (2016), PAS 96:2017 nor GFSI state that harms must be widespread as specified in US
 234 regulations. The principal differences between food fraud and food defense are that in food fraud
 235 are acts of adulterations that do not intend to harm and are motivated by greed, while food defense
 236 protects against acts that intend to harm (GFSI, 2017). Acts that intend harm could be an act of food
 237 crime (seen in section 6) or food terrorism, a subcategory of bioterrorism which is defined by the
 238 World Health Organization (WHO) as, "an act or threat of deliberate contamination of food for

239 human consumption with chemical, biological or radio-nuclear agents for the purpose of causing
240 injury or death to civilian populations and/or disrupting social, economic or political stability" (WHO,
241 2002). Although food defense acts against food terrorism, the terms are often used interchangeably.

242

243 The GFSI and the Food and Agriculture Organization of the United Nations (FAO) define food safety
244 as an, "assurance food will not cause harm to the consumer which is prepared and/or eaten
245 according to its intended use" (BRC, 2018; FAO, 2017). Food safety issues are described as
246 unintentional contamination of food that makes food injurious to health (Manning & Soon, 2016).
247 Unlike food fraud and food defense, food safety issues are unintentional. Nevertheless, intentional
248 acts, such as food fraud and food defense, may create food safety issues (Spink, 2019).

249

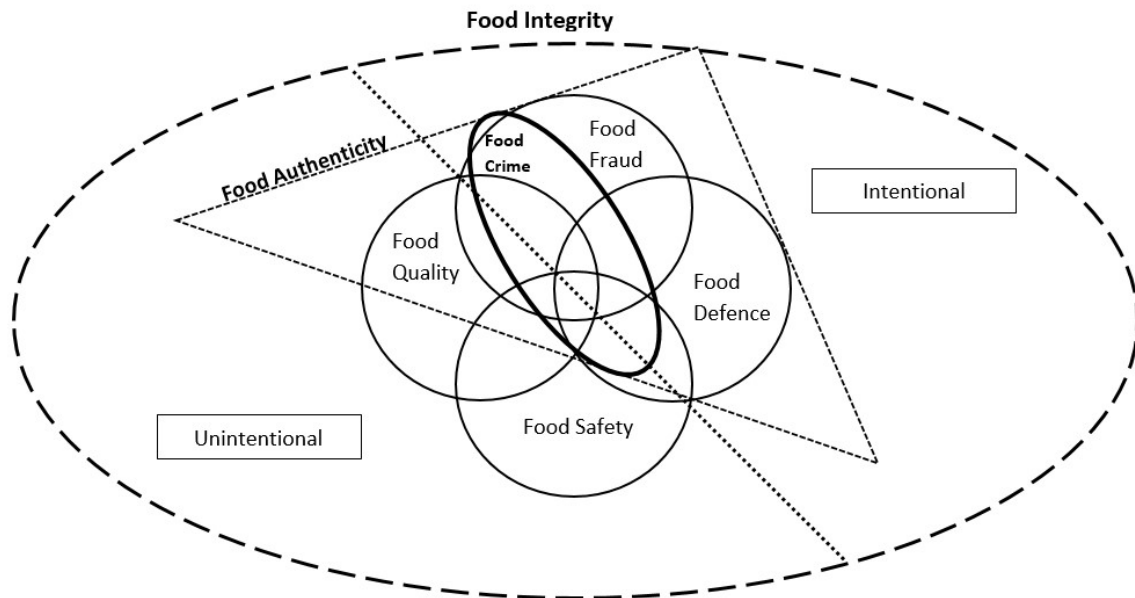
250 As in the case of food safety, food quality issues are unintentional that can be affected by intentional
251 doings. The FAO states that food quality "includes all the attributes that influence a product's value
252 to the consumer. This includes negative attributes such as spoilage, contamination with filth,
253 discoloration, off-odours and positive attributes such as the origin, colour, flavour, texture and
254 processing method of the food" (FAO, 2017; Spink et al., 2019). This definition has been summarized
255 by Manning and Soon (2016) as the "deliverability of attributes that influence a products value to a
256 consumer". Both definitions agree that food quality refers to attributes that affect the acceptability
257 of products and brand equity. Although food quality issues are not the same as food safety issues,
258 food quality may affect food safety (Spink and Moyer, 2011).

259 8. Understating interactions in terminology

260 Overlapping terminology associated with food integrity, food authenticity, food fraud, food defense,
261 food safety, food quality and food crime creates confusion. **Figure 2** adapted from Spink and Moyer

262 (2011) and Manning and Soon (2016) illustrates how the terms interact with each other. This
263 modification includes food integrity, which was not included in previous publications. Food integrity
264 is shown as an overarching term that is related to intentional and unintentional acts that includes
265 food fraud and the safety, quality, and authenticity of a food product. It also includes the way a
266 product was produced and procured; therefore, if a product was produced in an unethical or illegal
267 way, product integrity is lost. Food integrity is compromised if an intentional or unintentional issue
268 occurs. Issues that can occur in the form of contaminants are any substance not intentionally added
269 to food, which is present in food as a result of production; or adulterants which are any substance
270 intentionally added to food, which is not present in food as a result of production (Spink, 2019).
271 Modifications also include food authenticity centered around whether a product was adulterated or
272 contaminated, in intentional or unintentional acts. Intentional acts fall under the definitions of food
273 fraud and food defense. However, the motivation behind food fraud and food defense differs. Acts
274 of food crime such as food fraud do not intend to cause harm but is committed on a large scale.
275

276 **Figure 2. Intentional and unintentional modifications of food (modified from Spink and Moyer,**
 277 **2011; Manning and Soon, 2016)**



278
 279

280 9. Defining types of food fraud

281 Food fraud has been further categorised into types of fraud (GAO, 2009; Spink & Moyer, 2011;
 282 Manning & Soon, 2016; GFSI, 2017; Bouzembrak et al., 2018; Manning & Soon, 2019; CEN, 2019;
 283 NFCU, 2019a). Determining types of food fraud helps to decide how fraud might occur in the food
 284 supply. The most frequently referred to types of food fraud found in this data were defined by Spink
 285 and Moyer (2011), **Table 4**. Spink and Moyer’s (2011) fraud types have been cited 377 times (at time
 286 of manuscript submission) and has been cited in numerous articles found in literature searches
 287 conducted for this review (Cawthorn, Stainman & Hoffman 2013; Galvin-King, Haughey & Elliott,
 288 2018; Manning, 2016; Manning & Soon, 2014; Sentandreu & Sentandreu 2014; Soon et al.,
 289 2019). These and other types of food fraud found through literature searches in this review are
 290 outlined in **Table 3**. All of the listed types of food fraud describe those which could occur in any food
 291 supply chain.

292 Table 3. Types of Food Fraud

	GAO, 2009	Spink & Moyer, 2011	Manning and Soon, 2016	Manning, 2016	Spink, Moyer and Whelan, 2016	GFSI, 2017	RASFF (Bouzembrak et al., 2018)	HorizonScan (Bouzembrak et al., 2018)	Manning and Soon, 2019	CWA 17369 (CEN, 2019)	NFCU, 2019a
Addition				X	X				X	X	
Additional of illegal/unapproved or undeclared additives				X	X						
Adulterant-substances				X	X						
Adulteration		X	X					X	X	X	X
Breaches of Protected Designation of Origin (PDO), Protected Geographical Indication (PGI) and Traditional Specialties Guaranteed (TSG) Requirements				X	X						
Claim violation									X	X	
Concealment				X	X	X					
Counterfit		X	X			X		X	X		
Dilution				X	X	X				X	
Diversion		X	X	X	X	X		X	X		
Document fraud											X
Duplication									X		
Expiration date							X				
Extension				X	X						

False declaration of — geographical region, species, botanical or varietal origin, masking, introduction of animal by-products to the food chain		X	X					
False health claims		X	X					
False or misleading statements made about a product for economic gain								X
Grey market production					X			
Illegal and unapproved slaughter		X	X					
Illegal importation						X		
Illegal processing								X
Illegal sale of unauthorized food supplement		X	X					
Improper, expired, fraudulent or missing common entry documents						X		
Improper, fraudulent, missing or absent health certificates						X		
Intellectual property rights counterfeiting		X	X					
Introduction of food waste to the food supply chain		X	X					
Malicious poisoning, bioterrorism or sabotage	X	X					X	
Misbranding		X	X					
Misdescription								X X
Mislabelling	X	X	X	X	X			
Misleading indications(works/pictures)	X	X					X	

Misleading use on product of quality assurance scheme branding which the producer is not accredited to				X	X				
Misrepresentation	X			X	X			X	X
Mixing of adulterants				X	X				
Modification				X	X				
Non-disclosure of changes made to the nature				X	X				
Over-run		X	X	X	X		X	X	
Over-treating	X			X	X			X	
Packaging size			X						
Product tampering								X	X
Production from unapproved and unsuitable food premises				X	X				
Records tampering								X	X
Removal				X	X			X	X
Replacement				X	X				
Selling non organic food as organic				X	X				
Short weighing	X			X	X			X	
Simulation		X		X	X			X	
Smuggling				X	X			X	
Species Substitution	X								
Substance and quality of a product				X	X				
Substitution				X	X	X		X	X
Tampering		X	X	X	X		X	X	
Tax avoidance/Gray market product				X	X				
Theft		X	X	X	X	X		X	X

Transshipment	X	X	X				
Unapproved enhancements					X		
Unapproved pesticides		X	X				
Unapproved processes						X	X
Use of illegal food contact material and packaging		X	X				
Waste diversion							X

293

294 The specificity of food fraud types given in publications shown in **Table 3** varies between being very
295 generalized to extremely precise. The GAO (2009) defines five general types of food fraud. All other
296 publications have expanded from this. For example, Spink, Moyer, and Whelan (2016) described 38
297 types of food fraud, which they state could be summarized into the seven types given by Spink and
298 Moyer (2011). This same range is seen in the most recent publications; Manning and Soon (2019) are
299 very specific and described 20 types of food fraud, while the NFCU (2019) is more generalized and
300 described seven types of fraud. It seems researchers are still determining the level of specificity
301 needed to best communicate how fraud can be committed in food supply chains. By being overly
302 specific researchers may leave gaps and fraud types may be left out, however if types are too
303 general there may be ambiguity concerning how a fraud type is defined and how it appears in the
304 food supply chain as indicated in sections 2-6 and can lead to inconstant terms.

305

306 As seen, types of fraud presented by researchers are not consistent; however, it appears that
307 researchers have built on previous research. For example, types of fraud used in HorizonScan
308 (Bouzembrak et al., 2018) are the same as those defined by Manning and Soon (2016), excluding
309 “Packing size.” Manning and Soon (2016) agreed with the seven types of fraud described by Spink
310 and Moyer (2011) with the addition of “Malicious poisoning, bioterrorism or sabotage,” “Misleading
311 indications (works/pictures),” and “Package size.” Then again in 2016, types of fraud described by
312 Manning are almost the same as Spink, Moyer, and Whelan (2016) but Spink, Moyer, and Whelan
313 (2016) did not include “Malicious poisoning, bioterrorism or sabotage” and “Misleading indications
314 (works/pictures).” In 2017 the GFSI described nine broad fraud types using language, which
315 seemingly tried to include the list of types described by Manning and Soon and Spink, Moyer, and
316 Whelan in 2016—again showing a struggle between over-generalizing and over-specifying types of
317 fraud.

318 As researchers specify and generalize types of fraud, terminology used may be the same yet
319 definitions of these terms may differ. For example, eight of the ten document sources name
320 tampering as a type of food fraud. The European Committee for Standardization (CEN) (2019) is the
321 only source which described two kinds of tampering by differencing between record tampering, that
322 is the "deliberate changing of explicit food products claims so that they do no longer match the
323 known characteristics", and product tampering; "the deliberate changing of food product
324 characteristics so that they no longer match the implicit or explicit claims associated with the
325 product." Spink and Moyer (2011) do not distinguish between record and product tampering. They
326 define tampering as "Legitimate product and packaging used in a fraudulent way" (Spink & Moyer,
327 2011). This definition is comparable to the CEN definition of record tampering, but not product
328 tampering. Instead of product tampering, Spink and Moyer (2011) use the term adulteration to
329 describe when "a component of the finished product is fraudulent." The CEN (2019) notes that, in
330 some cases, adulteration "means the same things as" how they define tampering. However, the CEN
331 (2019) differentiates the two by stating, "adulteration according to most definitions includes the
332 addition of a foreign or inferior substance to the food product, whereas tampering as defined here
333 can also include subjecting the product to an undeclared process, or removing something that
334 should have been present in the product." To further complicate types of fraud, the NFCU (2019)
335 doesn't use the term tampering or record tampering, but instead used the title 'misrepresentation'
336 to define the act of "marketing or labelling a product to wrongly portray its quality, safety, origin or
337 freshness."

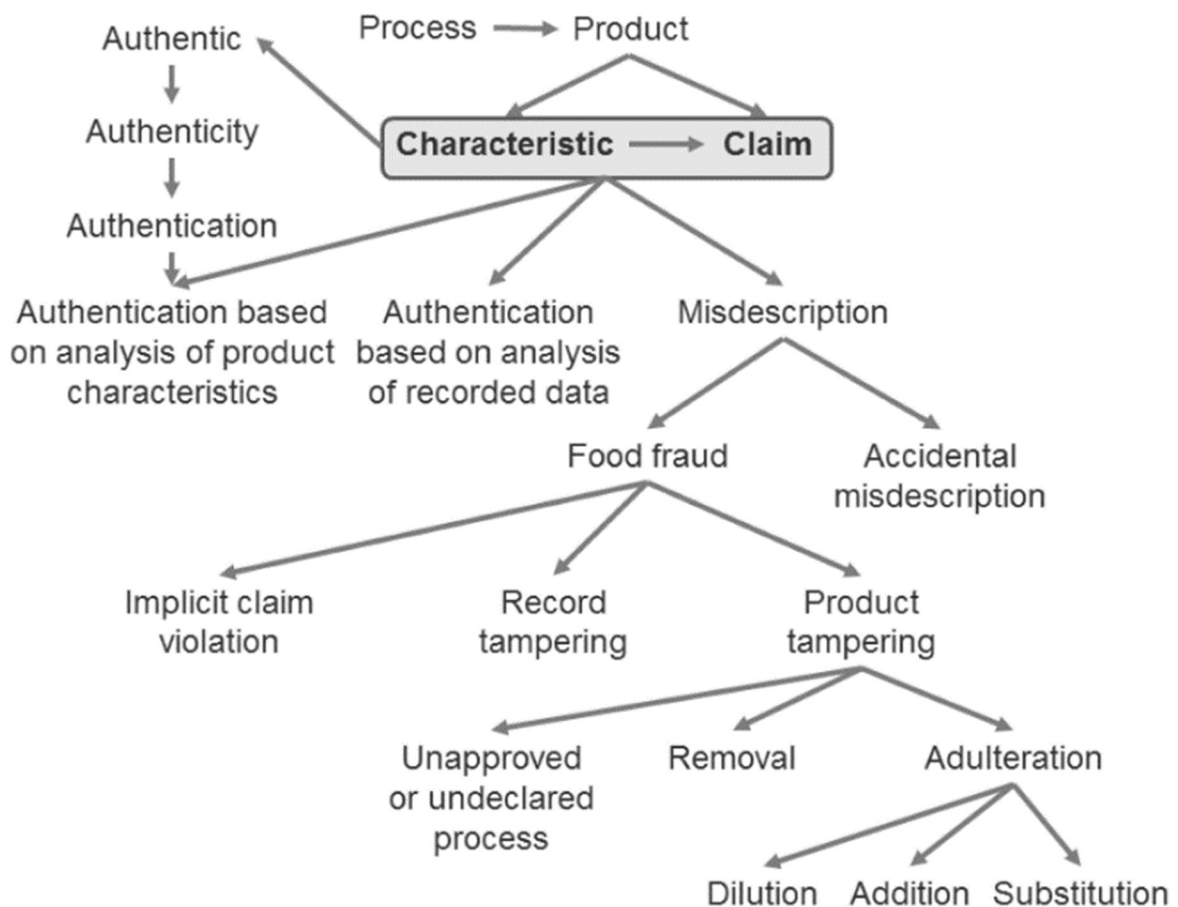
338

339 Confusion can be caused by multiple types of fraud described and differing terminology used. A
340 number of publications have created images to illustrate a hierarchy of terms and how fraud types
341 interact to create more clarity. CEN (2019) describes product tampering (defined above) as a type of
342 food fraud. It then describes adulteration, "intentionally adding an unapproved, undeclared, or
343 inactive ingredient to the food product, or substituting a declared ingredient with another

344 ingredient,” as a type of product tampering. Following on it states that adulteration includes all
 345 forms of addition, that is “intentionally adding an unapproved or undeclared ingredient to the food
 346 product”; dilution, “intentionally increasing the quality of an inactive or already-present substance,”
 347 and substitution, “intentionally replacing a declared ingredient in a food product with another
 348 ingredient” (CEN, 2019). To help clarify the interactions between fraud types, the CEN (2019)
 349 created a hierarchy of terms (Figure 3). Similarly, Ballin (2010) shows four main types of fraud in
 350 meat (meat origin, meat substitution, meat processing treatment, and non-meat ingredient
 351 additives), then sub-divided these into 20 types of food fraud (Figure 4). These figures provide a
 352 visual representation of interactions between types of food fraud, which can aid in creating a better
 353 understanding.

354

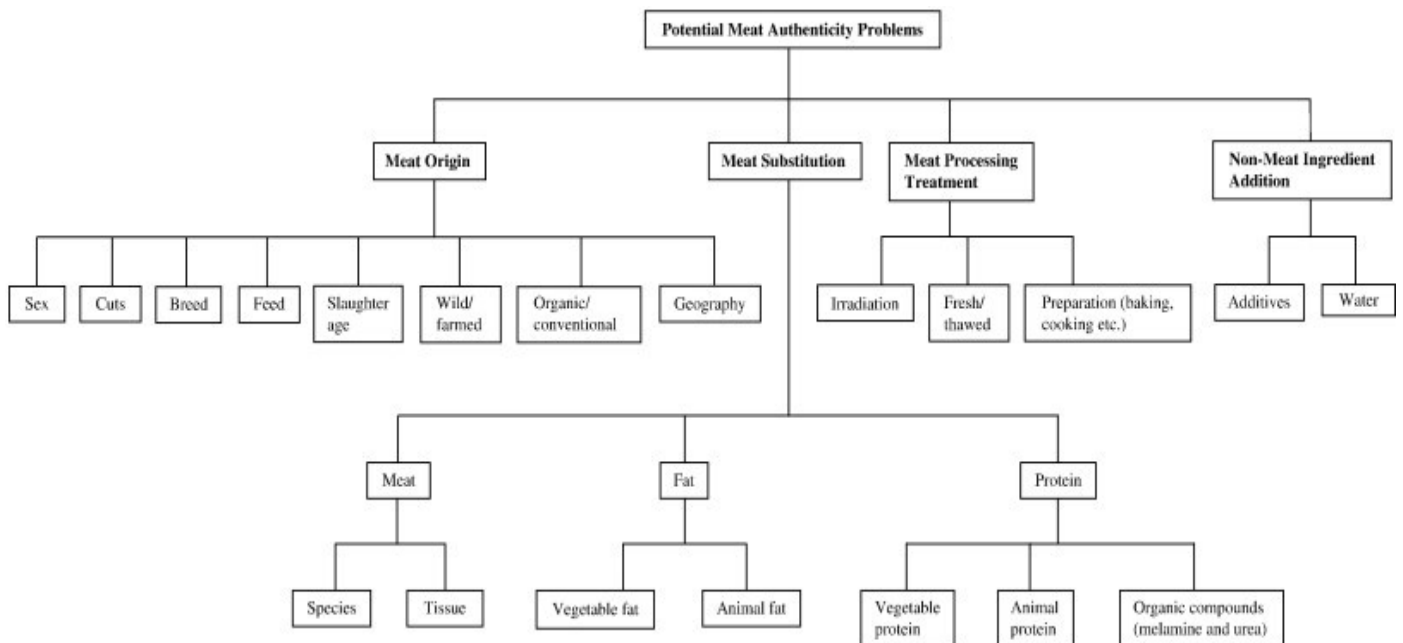
355 **Figure 3. Hierarchy of terms and definitions (CEN, 2019)**



356

357 **Figure 4. Types of fraud specific to meat** (Ballin, 2010)

358



359

360 The publications in **Table 3** list types of fraud which can occur in all kinds of food supply chains,
361 alternatively Ballin (2010) determined types of food fraud specific to meat (**Figure 3**). Ballin (2010)
362 shows four main types of fraud in meat, which were then sub-divided into 20 types. By specifying
363 types of fraud to a particular supply chain the author was able to more accurately communicate
364 different types of food fraud which may be seen in this sector.

365

366 Determining types of food fraud can help create a better understanding of how fraud occurs and aid
367 communication. Identifying types of food fraud is an ongoing effort; recent research building on
368 previous publications to create clear descriptions of how fraud is occurring. Currently, there is a lack
369 of clarity due to multiple descriptions of types of food fraud and the use of the same terms with
370 varying meanings.

371 10. Legislation on food fraud in the EU

372 Lack of consistent definitions for food fraud in the EU is a barrier to creating legislation that
373 influences the creation of a collective approach in addressing food fraud (Kowalska, Soon &
374 Manning, 2019). Therefore, food fraud is not addressed in any single EU law but is indirectly
375 addressed through the violation of food law (Spink et al., 2019c). This creates an obstacle in
376 combatting food fraud. Depending on the type of fraud and the type of product that is involved in
377 the fraudulent act, different legislation relates to food fraud, including:

- 378 • Regulation (EC) No 178/2002 on general food law on imports and exports, traceability,
379 labeling, and product recalls.
- 380 • Regulation (EC) No 1924/2006 on nutrition and health claims
- 381 • Regulation (EU) No 1169/2011 on the provision of food information to and the ban on
382 misleading advertising and labeling practices.
- 383 • Regulation (EU) 2017/625 the official controls regulation has been a step in the right
384 direction considering food fraud legislation. This legislation empowers national authorities
385 and the European Commission by giving them the necessary powers to ensure effective
386 enforcement of regulatory requirements concerning food and feed law, animal health and
387 welfare, and plant health and plant protection products (EC, 2019). Also, this legislation
388 holds more focus on the authenticity and integrity of the agri-food chain, then previous
389 legislation such as (EC) No 172/2002 (EC, 2017).

390

391 Another challenge in the creation of food fraud legislation and regulations is that food fraud acts are
392 committed outside of authorized or legitimate supply chains (Primrose, Woolfe & Rollinson, 2010).
393 Therefore, to help defend against food fraud, the EU has established the EU Food Fraud Network,
394 which empowers member states to exchange information and to collaborate voluntarily in matters

395 of food fraud (EC, 2020). Furthermore, member states have individually set up regulatory bodies to
396 defend against food fraud. An example of this is the NFCU established in the UK in 2015 in response
397 to the 2013 horse meat scandal as a law enforcement arm of the Food Standards Agency (FSA)
398 focusing on food crime (NFCU, 2019b).

399

400 11. Food fraud mitigation and prevention

401 In addition to understanding food fraud, this review aimed to review prevention and mitigation
402 countermeasures used to protect the food supply chain from food fraud (Spink et al., 2017).
403 Prevention and mitigation both aim to control food fraud. Mitigation assumes food fraud events will
404 frequently occur and focus on trying to mitigate or reduce the negative consequence (Spink et al.,
405 2017; 2019a). Prevention assumes that the root cause of the event could be eliminated or at least
406 significantly reduced in the likelihood of occurrence (Spink et al., 2017; 2019a). Food fraud
407 prevention aims at reducing food fraud before it occurs (Moyer, DeVries, & Spink, 2017). Achieving
408 food fraud prevention and mitigation depends on identifying, reducing or eliminating vulnerability. A
409 vulnerability is a weakness or flaw that creates opportunities; or susceptibility to the system for food
410 fraud (Spink et al., 2017). This differs from risk which is the potential for an unwanted outcome
411 resulting from an incident, event, occurrence, as determined by its likelihood and the associated
412 consequence (Spink et al., 2019a).

413 The food industry is liable for the quality and safety of its products and therefore is also liable for
414 food fraud even if they were a victim of the fraud themselves (Wisniewski & Buschulte, 2019).
415 Therefore, the responsibility of food fraud mitigation and prevention primarily falls on the food
416 industry (Wisniewski & Buschulte, 2019). The food industry includes primary processors who turn
417 raw materials into a form which is safe for human consumption, manufacturers who produce
418 products into raw material or components into retail units or supplier products, retailers who sell

419 product to the consumer and any business or operator who carries out the processing,
420 manufacturing, packaging, storage, transports, import, distribution or sale of food (Nestle, 2016;
421 BRC, 2018; EIT Food and Queens University Belfast, 2020). Lack of understanding of where fraud may
422 be occurring and what types of fraud are happening has left the food industry vulnerable (Spink et
423 al., 2019). Van Ruth, Huisman, and Luning (2017) assess a company's food fraud vulnerability
424 through determining the motivation of fraudsters, opportunity for fraud, and control measures to
425 detect fraud. The food industry can use this knowledge to look out for economic drivers and
426 business culture, which may motive fraud, identify areas of opportunity, and implement measures to
427 detect incoming fraud. Furthermore, van Ruth (2018) describes 50 specific fraud factors which can
428 help a company determine vulnerability, such as the complexity of adulteration of raw materials,
429 supply, and pricing raw material and tracking and tracing system supplier. These factors can help a
430 company assess its vulnerability and the vulnerability of different commodities within their supply
431 base.

432

433 **Table 5** lists 12 guidance documents designed to aid the prevention and mitigation of food fraud.
434 Most of these documents are aimed at large business food operators, which are organizations that
435 carrying out activities related to processing, manufacture, packaging, storage, transportation, import
436 and distribution of food (Nestle, 2016). These types of businesses have staff and resources available
437 to follow the advice given in the guidance documents found in this review. *Food authenticity five*
438 *steps to help protect your business from food fraud* did offer a number for small businesses to
439 contact and get advice on fraud mitigation (FDF, 2014). Still, there is a gap in knowledge and
440 available support for small producers, manufactures and retailers who may not have the resource
441 available to dedicate to practices shared in the guidance documents below, which leaves the food
442 supply vulnerable to fraud.

443

444 *Guidance on Authenticity of Herbs and Spices* was the only guidance document found which focused
445 on a specific supply chain (FDF, 2016). All others guidance documents provided general direction
446 which could be applied to all supply chains. Tools and concepts given for non-specific supply chains
447 is beneficial as they can be adapted for individual supply chain needs and used for all differencing
448 supply chains. However, there are advantages to having specified information. Even with general
449 tools given business are left with a large amount of work to determine risks and vulnerabilities
450 bespoke to their specific supply chain. Having specified guidance available individual supply chains
451 would provide businesses with more in-depth information and allow for more holistic food
452 prevention and mitigations plans to be developed. For example, *Guidance on Authenticity of Herbs
453 and Spices* (FDF,2016) includes flow charts and harvest information specific to herbs and spices,
454 allowing companies to take into account risks posed by seasonal changes in supply.

455

456 **Table 5. Comparison of Food Fraud Mitigation Guides**

Title	Description	Nature of Business	Supply Chain	Mitigation Measures
Food authenticity five steps to help protect your business from food fraud (FDF, 2014)	This simple guide, which follows on from FDF's Guide on 'Sustainable Sourcing: Five Steps Towards Managing Supply Chain Risk', sets out a step-by-step process to help food and drink manufacturing businesses of all sizes protect their businesses from food fraud by helping them to identify, priorities and manage upstream supply chain food authenticity risks	Large Scale Operators	General guidance for all supply chains	<ul style="list-style-type: none"> ✓ Map Your Supply Chain ✓ Identify Impacts, Risks and Opportunities ✓ Assess and Priorities Your Findings ✓ Create a Plan of Action ✓ Implement , Track, Review & Communicate
GFSI position on mitigating the public health risk of food fraud (GFSI, 2014)	The GFSI Board decided to follow the recommendations of the Food Fraud Think Tank and proposes to incorporate the two food fraud mitigation steps in the form of two new key elements in the GFSI Guidance Document to; 1. Require a company to perform a food fraud vulnerability assessment 2. Have a control plan in place. The vision is that, like the introduction of food defense into the Guidance document a few years ago, the mitigation of food fraud and the potential impact on consumers' health becomes an integral part of a company's food safety management system.	Large Scale Operators	General guidance for all supply chains	<ul style="list-style-type: none"> ✓ GFSI position ✓ Proposed key elements for food fraud mitigation
Counter Fraud Good Practice Guide for Food and Drink Businesses (CIEH, 2016)	The purpose of this guide is to outline how food and drink business can apply established counter fraud good practice to improve fraud resilience and reduce its financial and reputational cost	Large scale food operators	General guidance for all supply chains	<ul style="list-style-type: none"> ✓ The impact of fraud ✓ Fraud affects food businesses ✓ The advantage of focusing on fraud reliance ✓ The role of government in detecting and addressing fraud ✓ The modern strategic approach to counter fraud ✓ Summary of counter fraud good practice ✓ Counter fraud good practice for food and drink businesses ✓ Establish the nature and scale of the problem ✓ Develop a strategy ✓ Establish an implementation structure ✓ Design and implement fraud prevention measures ✓ Design and implement fraud detection measures

<p>Food Fraud Mitigation Guidance (USP, 2016)</p>	<p>USP's Food Fraud Mitigation Guidance provides a practical framework to help your organization develop a system for identifying vulnerabilities in your ingredient supply chain and developing a control plan to mitigate risks.</p>	<p>Large scale food operators</p>	<p>General guidance for all supply chains</p>	<ul style="list-style-type: none"> ✓ Design and implement investigative processes ✓ Monitor outcomes ✓ Terminology ✓ Contributing factors assessment <ul style="list-style-type: none"> ○ Supply chain ○ Audit strategy ○ Supplier relationship ○ History of suppliers ○ Testing frequency ○ Geopolitical considerations ○ Fraud history ○ Economic anomalies ✓ Potential impact assessment <ul style="list-style-type: none"> ○ Public health impact ○ Economic impact ✓ Overall vulnerabilities ✓ Mitigation strategies development
<p>Food Fraud Prevention (Nestle, 2016)</p>	<p>The purpose of this booklet is to guide food operators through approaches and processes to improve the resilience of supply chains to food fraud. It provides guidance on how to assure the authenticity of food by minimising vulnerability to fraud and mitigating the consequences of food fraud. This booklet Describes a process for food fraud prevention and the principles of the vulnerability assessment; Outlines measures that can deter fraudsters, or give early detection of food fraud and provides sources of information and intelligence that may help to identify emerging threats.</p>	<p>Large Scale Operators</p>	<p>General guidance for all supply chains</p>	<ul style="list-style-type: none"> ✓ What is food fraud ✓ Raw Material Specifications ✓ Analytical surveillance ✓ Supplier relationship ✓ Supplier audit
<p>Food fraud vulnerability assessment and mitigation (PwC,2016)</p>	<p>PwC has the expertise in risk assessment, forensic services, supplier management and internal controls required to help companies assess their vulnerability to food fraud, then design and implement measures to mitigate food fraud risk. Along with the SAFEE tool PwC has published a sort mitigation guide offering information on food fraud.</p>	<p>Large Scale Operators</p>	<p>General guidance for all supply chains</p>	<ul style="list-style-type: none"> ✓ Are you doing enough to prevent food fraud? ✓ A few things you may want to know ✓ Food fraud and food safety: What is the connection? ✓ A science-based framework for understanding food fraud risk ✓ Opportunities ✓ Motivations ✓ Control Measures

				<ul style="list-style-type: none"> ✓ The war on food fraud ✓ Ready to get started a few things you should know ✓ Food fraud Challenges ✓ New GFSI food fraud requirements ✓ We can provide greater insight and management of fraud risk
<p>Food Supply Chain Vulnerability: A Ti whitepaper in partnership with RQA Group (RQA Group,2016)</p>	<p>Vulnerability of the food supply chain is one of the hottest topics in the international food industry. Those vulnerabilities are not limited to breaches of physical security, theft and malicious contamination by ideologues, extortionists, criminals or terrorists. In this whitepaper, Ti's CEO, Professor John Manners-Bell, and Managing Director, RQA Group, Vince Shiers Ph.D., offers insight into the vulnerability of the food supply chain by highlighting the threats and offering analysis of the best practice for securing the supply chain.</p>	Large scale food operators	General guidance for all supply chains	<ul style="list-style-type: none"> ✓ Threats to the food supply chain <ul style="list-style-type: none"> ○ Malicious tampering ○ Theft ○ Food Safety and temperature control ✓ Securing the supply chain
<p>Guidance on Authenticity of Herbs and Spices: Industry best practice on assessing and protecting culinary dried herbs and spices (FDF, 2016)</p>	<p>This guidance was developed by a Joint Industry Working Group comprised of representatives of the British Retail Consortium, Food and Drink Federation and Seasoning and Spice Association, in liaison with the Food Standards Agency and Food Standards Scotland to provide Industry Best Practice Guidance on vulnerability assessment for culinary dried herbs and spices (including blends), in order to mitigate against potential adulteration and substitution.</p>	Large scale food operators	Herbs and spices	<ul style="list-style-type: none"> ✓ Decision tree to protect herbs and spices against supply chain vulnerabilities ✓ Product Specifications ✓ Supplier Assurance ✓ Product type ✓ Knowing your Market Understanding Vulnerabilities in Your Supply Chain ✓ Verification and detection measures ✓ Sampling and inspection programmes ✓ Selection a Test Method and Laboratory ✓ Supply Chain Verification Measures ✓ Receipt of Material ✓ Devising Testing Strategy ✓ Types and Methods of Adulteration ✓ Generic Supply Map for Herbs and Spices with Examples of Fraud Vulnerabilities ✓ Typical Harvest Charts
<p>Working Together to Tackle the Threat From Food Crime (NFCU, 2016)</p>	<p>The UK National Food Crime Unit (NFCU) has produced a guide for working in partnership with the food industry to respond to the challenge of food crime. The guide explains the role of the NFCU in the fight against food crime, how the NFCU can support industry, and how in turn industry can</p>	Large Scale Operators	General guidance for all supply chains	<ul style="list-style-type: none"> ✓ What is the National Food Crime Unit? ✓ What is the Threat from Food Crime? ✓ Tackling Food Crime, a Shared Objective ✓ Looking After Your Information

	support the NFCU to enhance the UK's resilience and response to food crime in its many forms.			
PAS 96:2017, Guide to protecting and defending food and drink from deliberate attack (BSI, 2017)	The purpose of PAS 96 is to guide food businesses through approaches and procedures to improve resilience of the supply chain from fraud and other forms of attack. PAS aims to assure food authenticity and safety, and minimize chance of attack.	Large Scale Operators	General guidance for all supply chains	<ul style="list-style-type: none"> ✓ Terms and definitions ✓ Types of threats ✓ Understanding the attacker ✓ Threat Assessment Critical Control Point (TACCP) ✓ Assessment ✓ Critical Controls ✓ Response to an incident ✓ Review of food protection arrangements ✓ TACCP Case Studies
Guidance on Food fraud Mitigation (FSSC 22000, 2018)	Following the GFSI benchmarking requirements, FSSC 22000 has introduced a chapter on Food fraud mitigation in the latest version of the Scheme (v4.1). This has become mandatory from January 1, 2018 and includes requirements for a Food fraud Vulnerability Assessment and a Food fraud Prevention Plan applicable to all products.	Large Scale Operators	General guidance for all supply chains	<ul style="list-style-type: none"> ✓ Definition ✓ FSSC 22000 scheme Requirements ✓ Food fraud Mitigation Team Training ✓ Implementation ✓ Auditing
Tackling food fraud through food safety management systems (GFSI, 2018)	Builds off GFSI, 2014. To offer more insight on types of food fraud and food fraud vulnerability.	Large Scale Operators	General guidance for all supply chains	<ul style="list-style-type: none"> ✓ What is food fraud and is it a challenge for food safety and management systems ✓ The GFSI requirements on food fraud ✓ The implementation ✓ Auditing a vulnerability assessment and a food fraud mitigation plan ✓ Detail of types of fraud, and examples

457

458

459

460

461

462 Although, all documents listed in **Table 5** provide beneficial information on food fraud prevention
463 and mitigation for food business operators, guidance is still lacking. Many of the documents give
464 companies the same advice digested and presented in various ways. The core advice given include:
465 (i) the development a system to check and approve suppliers, (ii) supplier audits, (iii) creating open
466 and transport relationships with suppliers, (ix) horizon scanning, the act of looking for and
467 analysing external threats and opportunities that will emerge, including economic anomalies,
468 geographical considerations, political unrest and climate change (Food Fraud Advisors, 2020); (x)
469 identification of vulnerabilities, and (xi) risk assessment. All of the above advice is agreed as being
470 essential in food fraud prevention and mitigation plans. However, each document offers bespoke
471 information. *PAS 96:2017* is an extensive document which offers thorough guidance, however, it
472 focuses on food defense rather than food fraud (BSI, 2017). Still *PAS 96:2017* offers detailed plans
473 for vulnerability identification and prioritization (BSI, 2017). *Nestlé's Food Fraud Prevention*
474 document focuses on determining the inherit vulnerabilities of a raw material, supplier relationship
475 and supplier audit, but does not provide specific information about how to determine raw material
476 vulnerabilities or information on developing prevention, mitigation or detection plans (BSI, 2017).
477 *Nestlé's Food Fraud Prevention* plan does note the importance of self- assessment and the
478 importance of companies working proactively toward food fraud mitigation (Nestle, 2016). *Food*
479 *Supply Chain Vulnerability: A Ti whitepaper in partnership with RQA Group* gives ideas on what
480 threats and vulneraries in the supply chain might look like though the use of cases studies, and
481 provides questions that businesses should ask to ensure they have proper food fraud mitigation
482 measures in place (RQA Group,2016). *Food Fraud Mitigation Guidance* provided by the USP provides
483 factors which contribute to vulnerably as well as matrixes to determine the contribution to
484 vulnerability which applies to each factor, an unlike many of the other documents *Food Fraud*
485 *Mitigation Guidance* takes testing frequency into account when assessing vulnerability (FSSC 22000,
486 2018). *Guidance on Food Fraud Mitigation* from FSSC 22000 (2018) focuses on conducting a food
487 fraud vulnerability assessment and auditing. Additionally, this document states the importance of a

488 business establishing a food fraud mitigation team, to manage and update mitigation plans. While
489 these guidance documents offer generalized insight on food fraud mitigation and prevention, they
490 do not offer specific insight on food fraud to individual product supply chains. By providing product
491 chain specific information documents could offer more insight on threats and vulnerabilities
492 bespoke to a single food supply chain as well as inherent vulnerabilities associated with different raw
493 materials, as well as testing methods available that could be used for fraud detection. This
494 information would give the food industry specific information needed to build holistic prevention
495 and mitigation plans.

496

497 In addition to the guidance documents, there are also a variety of tools available to the food industry
498 to aid in food fraud mitigations, including tools to determine food fraud vulnerability, and identify
499 what is susceptibility to food fraud within a company or supply chain (Spink et al., 2017). Identified
500 vulnerabilities are then used as a basis for food fraud prevention and mitigation programs. Another
501 tool often issued is horizon scanning, which refers to the act of proactively looking for and analysing
502 threats and opportunities that may emerge in the medium to long term (Food Fraud Advisers, 2020;
503 Ulberth, 2016). Manning and Soon (2019) and Ulberth (2020) have summarized vulnerability
504 assessment tools in recent publications, several of these are summarized below:

505

- 506 • **SSAFE Food Fraud Vulnerability Assessment (FFVA) tool-** SSAFE is a non-profit organization
507 that aims to set up a globally accepted internationally recognized food protection systems
508 and standards (SSAFE, 2017). SSAFE, in collaboration with PwC, and Wageningen University,
509 have developed the SSAFE FFVA, an online tool that is free of charge and can be used by
510 food operators across the food supply chain of any size, geographical location, or type of
511 food business. This tool helps companies identify food fraud vulnerability in their business.

512 However, it does not provide specific fraud prevention or mitigation techniques or fraud
513 detection plans (PwC, 2020).

514

515 • **EMAlert** – This software tool was developed by The Grocery Manufacturers Association
516 (GMA), and Battelle enables food manufacturers to analyse and understand EMA
517 vulnerabilities (Manning & Soon, 2019; EMAlert, 2019). This tool estimates an organization’s
518 vulnerability to EMA, then prioritize mitigation efforts associated with EMA threats.
519 Manning and Soon (2019) highlight an advantage this system provides to the food industry
520 as it can assess a large number (50) of commodities in one analysis.

521

522 **The Rapid Alert System for Food and Feed (RASFF) portal** – RASFF is a free resource
523 database which is open to anyone, maintained by the European Commission (EC) under
524 regulation EC/178/2002. Under this legislation, member states are legally required to report
525 information concerning direct and indirect risks to human health from food or feed
526 (European Food Safety Authority (EFSA), 2010). Reports on RASFF include the type and date
527 of notification, the reason for notification, the hazard(s), the nature of the product involved,
528 the country of notification, and the country of origin (EFSA, 2010; Djekic, Jankovic &
529 Rajkovic, 2017). Although this is a database used to record and food safety incidents, it has
530 been used as a horizon scanning tool in multiple academic publications (Tähtkääpää et al.,
531 2015; Marvin et al., 2016; Robson et al., 2020).

532

533 • **HorizonScan** - HorizonScan is a privatized subscription-based system operated by the Food
534 and Environment Research Agency (Fera) in the UK. It is a popular tool used by the food
535 industry throughout the EU. HorizonScan monitors the safety and integrity issues of food
536 commodities globally by collecting data from over 100 sources daily (FERA, 2020).

537 HorizonScan risk assesses and analyses trends in reports to identify potential food safety
538 issues before they escalate to more significant threats within the food supply chain (FERA,
539 2020).

540

541 • **Decernis** – The Decernis Food Fraud database (formerly The US Pharmacopeial (USP) Food
542 Fraud Database) is available through subscription. This database focuses solely on food fraud
543 and provides records of potential food fraud incidents from government, media, and
544 academic sources. Decernis provides a list of potential adulterants, as well as information
545 on testing techniques for each product in the database (Everstine, 2018).

546

547 • **Food Industry Intelligence Network (Fiin)** – Fiin was created in 2015 by industry leaders. Its
548 development was the result of recommendations made in the Elliott Review (DEFRA, 2014).
549 Fiin started with 21 founding member which has since grown to 46 members (as of 2019);
550 these members include retailers, manufacturers, and foodservice companies (DEFRA, 2020;
551 Campden BRI, 2019). Campden BRI is responsible for creating a database to collect
552 anonymized industry data from Fiin members on food authenticity testing. This data is
553 analyzed to produce quarterly reports for the Fiin members and is the only such scheme that
554 exists globally.

555

556 • **The Food Protection and Defense Institute’s World Factbook of Food**- The World Factbook
557 of Food was created by the Food Protection and Defense Institute (FPDI). For each product
558 in the World Factbook of Food, information is provided on the production, trade,
559 seasonality, processing steps, supply chain structure, food safety concerns, and past food

560 fraud incidents (FPDI, 2017). The database was designed to serve as a central reference
561 database for food and is available on a subscription basis (DEFRA, 2020).

562

563 A combination of the tools listed above could be utilized to create a holistic prevention plan for food
564 fraud. All businesses can use SSAFE in order to get a baseline of where they may be vulnerable. Then
565 RASFF, HorizonScan, and Decernis can be used individually or in combination with each other to
566 horizon scan for current and potential threats in supply chains. Fiin is a tool that should be utilized
567 by larger companies that have the capability to do so. Unlike RASFF, HorizonScan, and Decernis, Fiin
568 provides data concerning testing which is on-going in the food industry—giving greater insight into
569 where the food chain is protected and where information is lacking and supply chains may be
570 vulnerable. World Factbook can give information on product seasonality and trade, which can
571 contribute to when a commodity is most likely to be adulterated, while Decernis gives information
572 on testing, which is carried out to determine the adulterants. Together the World Factbook and
573 Decernis could be used to create a food fraud detection program. Other research can be used in
574 place of the aforementioned tools to determine vulnerabilities and created food fraud prevention
575 plans. However, these tools can be used to save time and give quick and accurate information, which
576 could be particularly useful for companies with numerous types of food products and supply chains.

577

578 In addition to these tools, there are a wide variety of traceability technologies available to ensure
579 the authenticity of a commodity/product. Traceability technologies aim to create more transparency
580 in the supply chain, making it impossible for fraudulent products to enter (van Ruth et al.,2018;
581 Yiannas, 2018). Technologies such as blockchain and other forms of digitized technologies can trace
582 products back to processors and even back to the farm rapidly and create a chain of transactions
583 concerning products which have to date been to date un-hackable (Charlebois 2017; Yiannas, 2018).
584 Another traceability tool designed for food industry supply chain management is Muddy Boots

585 Software which passes data up and down supply chains and provides instant viewing, management,
586 and reports on the quality, traceability, and compliance of their products and suppliers (Muddy
587 Boots, 2020).

588 12. Conclusion

589 Food fraud is undefined by the EU, leading to the creation of numerous definitions from researchers
590 and regulatory bodies, which has confused the understanding of food fraud and related terms. This
591 makes it challenging to fully comprehend and form clear communication surrounding food fraud and
592 how to prevent it. Through this review, commonalities between definitions of food fraud have been
593 identified as intentionally deceptive acts for economic gain using food. Additionally, types of food
594 fraud have been identified by multiple researchers in an ongoing effort to describe how food fraud
595 might occur. Research in this area is built from previous publications and is still evolving. Some
596 research name particular types of fraud, while others define it more in general terms. However,
597 clarity on how food fraud can occur in specific supply chains would provide the food industry with
598 the knowledge to help with prevention and mitigate fraud.

599

600 Food fraud prevention and mitigation has become a focus of researchers, legislators, and the food
601 industry. Several documents are available to help guide the industry in food fraud prevention and
602 mitigation methods. However, only one document found in this review is bespoke to a specific
603 supply chain (*Guidance on Authenticity of Herbs and Spices*). Therefore there is a substantial gap in
604 knowledge in this area. This paper argues that to help the food industry develop better food fraud
605 prevention and mitigation methodologies guidance should be developed for individual supply
606 chains. Supply chain specific guidance will help clarify any ambiguity in how fraud may be occurring
607 and where specific prevention and mitigation efforts should focus.

608

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613

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619

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631 15. References

632 Bosley, C. (2007). German kebab sales slump after rotten meat scandal. Reuters. Retrieved January
633 31, 2010 from <http://www.reuters.com/article/idUSLA76533220070903>

634 Bouzembrak, Y., Steen, B., Neslo, R., Linge, J., Mojtahed, V., & Marvin, H. J. P. (2018). Development
635 of food fraud media monitoring system based on text mining. *Food Control*, *93*, 283-296.
636 <https://doi.org/10.1016/j.foodcont.2018.06.003>

637 BRC, British Retail Consortium. (2018). *Global Food Safety Standard (Issue 8)*. British Retail
638 Consortium

639 Brooks, S., Elliott, C. T., Spence, M., Walsh, C., & Dean, M. (2017). Four years post-horsegate: an
640 update of measures and actions put in place following the horsemeat incident of 2013. *npj*
641 *Science of Food*, *1*(1), 1-7. <https://doi.org/10.1038/s41538-017-0007-z>

642 BSI, British Standards institution. (2020). *PAS 96- Food and Drink Defence*. BSIgroup. Retrieved
643 January 23, 2020, from <https://www.bsigroup.com/en-GB/PAS-96/>

644 Campden BRI. (2019). Food industry intelligence network (fiin) final report quarter 3 2019. Campden
645 BRI.

646 Cawthorn, D. M., Steinman, H. A., & Hoffman, L. C. (2013). A high incidence of species substitution
647 and mislabelling detected in meat products sold in South Africa. *Food Control*, *32*(2), 440-
648 449. <https://doi.org/10.1016/j.foodcont.2013.01.008>

649 CEIN, Chartered Institute of Environmental Health (2016). Counter fraud good practice for food and
650 drinks businesses. Chartered Institute of Environmental Health. Retrieved February 18, 2020,
651 from, [https://www.cieh.org/media/1240/counter-fraud-good-practice-for-food-and-drink-](https://www.cieh.org/media/1240/counter-fraud-good-practice-for-food-and-drink-businesses.pdf)
652 [businesses.pdf](https://www.cieh.org/media/1240/counter-fraud-good-practice-for-food-and-drink-businesses.pdf)

653 CEN, European Committee for Standardization. (2018). CEN/CW 86 - Project Plan for the CEN
654 Workshop - Authenticity in the feed and food chain – General principles and basic
655 requirements – Workshop (approved during the kick-off meeting on 2017-05-11), Retrieved
656 February 2, 2020 from
657 <ftp://ftp.cencenelec.eu/CEN/WhatWeDo/Fields/Food/WS/86/ProjectPlan.pdf>

658 CEN, European Committee for Standardization. (2019). CWA 17369: Authentic and fraud in the feed
659 and food chain- Concepts, terms and definitions. CEN-CENELEC Management Centre.

660 Charlebois, S. (2017). *How blockchain technology could transform the food industry*. Retrieved
661 February 18, 2020, [https://theconversation.com/how-blockchain-technology-could-](https://theconversation.com/how-blockchain-technology-could-transform-the-food-industry-89348)
662 [transform-the-food-industry-89348](https://theconversation.com/how-blockchain-technology-could-transform-the-food-industry-89348)

663 Charlebois, S., Schwab, A., Henn, R., & Huck, C. W. (2016). Food fraud: An exploratory study for
664 measuring consumer perception towards mislabeled food products and influence on self-
665 authentication intentions. *Trends in Food Science & Technology*, 50, 211-218.
666 <https://doi.org/10.1016/j.tifs.2016.02.003>

667 CRS, Congressional Research Service. (2014). *Food fraud and “Economically Motivated Adulteration”*
668 *of Food and Food Ingredients*. CRS. Retrieved February 18, 2020, from,
669 <https://fas.org/sgp/crs/misc/R43358.pdf>

670 Cruse, C. (2019). Food Fraud and the Food, Drug, and Cosmetic Act: Bridging a Disconnect. *Food &*
671 *Drug LJ*, 74, 322.

672 DEFRA DERFA, United Kingdom Department for Environment, Food & Rural Affairs. (2020). *Food*
673 *fraud Mitigation*. Food Authenticity Network. Retrieved February 18, 2020, from
674 <http://www.foodauthenticity.uk/food-fraud-mitigation-guides#g1>

675 DEFRA, United Kingdom Department for Environment, Food & Rural Affairs (2014). *Elliott review into*
676 *the integrity and assurance of food supply networks*. HM Government. Retrieved February 2,

677 2020 from
678 [https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/350726/el](https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/350726/eliot-review-final-report-july2014.pdf)
679 [liot-review-final-report-july2014.pdf](https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/350726/eliot-review-final-report-july2014.pdf)

680 Djekic, I., Jankovic, D., & Rajkovic, A. (2017). Analysis of foreign bodies present in European food
681 using data from Rapid Alert System for Food and Feed (RASFF). *Food control*, 79, 143-149.
682 <https://doi.org/10.1016/j.foodcont.2017.03.047>

683 EC, European Commission (2017). Questions & Answers on Commission Regulation (EC) No
684 2017/625 (Official Controls Regulation). Retrieved February 18, 2020, from
685 [https://ec.europa.eu/food/sites/food/files/safety/docs/oc_qa_ocregulation_20170407_en.p](https://ec.europa.eu/food/sites/food/files/safety/docs/oc_qa_ocregulation_20170407_en.pdf)
686 [df](https://ec.europa.eu/food/sites/food/files/safety/docs/oc_qa_ocregulation_20170407_en.pdf)

687 EC, European Commission (2020). The EU Food Fraud Network. Retrieved January 30, 2020, from
688 https://ec.europa.eu/food/safety/food-fraud/food%20fraudn_en

689 EC, European Commission. (2018). *The EU food fraud network and the system for administrative*
690 *assistance –food fraud*. Retrieved February 18, 2020, from
691 [https://ec.europa.eu/food/sites/food/files/safety/docs/food-](https://ec.europa.eu/food/sites/food/files/safety/docs/food-fraud_network_activity_report_2018.pdf)
692 [fraud_network_activity_report_2018.pdf](https://ec.europa.eu/food/sites/food/files/safety/docs/food-fraud_network_activity_report_2018.pdf)

693 EC, European Commission. (2019). Legislation on official controls. Retrieved February 18, 2020 from
694 https://ec.europa.eu/food/safety/official_controls/legislation_en

695 EFSA, European Food Safety Authority. (2010). Establishment and maintenance of routine analysis of
696 data from the Rapid Alert System on Food and Feed. *EFSA Journal*, 8(1),
697 1449.10.2903/j.efsa.2010.1449

698 EIT Food and Queens University Belfast. (2020). Mapping the Agri-Food Chain. *Panic-buying during a*
699 *crisis: how do food supply chains cope?*. Retrieved April 23, 2020, from
700 <https://www.futurelearn.com/courses/resilience-food-supply-chain/1/steps/754194>

701 Ellis, D. I., Brewster, V. L., Dunn, W. B., Allwood, J. W., Golovanov, A. P., & Goodacre, R. (2012).
702 Fingerprinting food: current technologies for the detection of food adulteration and
703 contamination. *Chemical Society Reviews*, 41(17), 5706-5727.
704 <https://doi.org/10.1039/C2CS35138B>

705 Ellis, D. I., Muhamadali, H., Haughey, S. A., Elliott, C. T., & Goodacre, R. (2015). Point-and-shoot:
706 rapid quantitative detection methods for on-site food fraud analysis—moving out of the
707 laboratory and into the food supply chain. *Analytical Methods*, 7(22), 9401-9414.
708 [10.1039/C5AY02048D](https://doi.org/10.1039/C5AY02048D)

709 EU FIP, European Union Food Integrity Project (2017). FoodIntegrity. Retrieved January 31, 2010
710 from <https://secure.fera.defra.gov.uk/foodintegrity/index.cfm>

711 Everstine, K., Spink, J., & Kennedy, S. (2013). Economically motivated adulteration (EMA) of food:
712 common characteristics of EMA incidents. *Journal of food protection*, 76(4), 723-735.
713 <https://doi.org/10.4315/0362-028X.JFP-12-399>

714 FDA, Food and Drug Administration. (2009). Economically Motivated Adulteration; Public Meeting;
715 Request for Comment [Docket No. FDA-2009-N-0166]. Federal Register, 74, 15497.
716 Retrieved February 2, 2020 from <http://edocket.access.gpo.gov/2009/pdf/E9--7843.pdf>

717 FDF, Food and Drink Federation. (2014). Food authenticity five steps to help protect your business
718 from food fraud. Retrieved February 18, 2020,
719 https://www.fdf.org.uk/corporate_pubs/Food-Authenticity-guide-2014.pdf

720 FDF, Food and Drink Federation. (2016). *Guidance on Authenticity of Herbs and Spice*. Retrieved
721 February 2, 2020 from [https://www.fdf.org.uk/corporate_pubs/guidance-](https://www.fdf.org.uk/corporate_pubs/guidance-herbsandspices.pdf)
722 [herbsandspices.pdf](https://www.fdf.org.uk/corporate_pubs/guidance-herbsandspices.pdf)

723 FERA, Food and Environment Research Agency. (2020). A technology-led solution for managing
724 complex supply chains. Retrieved June 1 2020, from [https://www.fera.co.uk/food-](https://www.fera.co.uk/food-safety/support-tools/horizon-scan)
725 [safety/support-tools/horizon-scan](https://www.fera.co.uk/food-safety/support-tools/horizon-scan)

726 Food Fraud Advisors. (2020). *Horizon scanning for food fraud*. Food fraud Advisors. Retrieved
727 February 2, 2020, from [https://www.foodfraudadvisors.com/horizon-scanning-for-food-](https://www.foodfraudadvisors.com/horizon-scanning-for-food-fraud/)
728 [fraud/](https://www.foodfraudadvisors.com/horizon-scanning-for-food-fraud/)

729 FPDI, Food Protection and Defense Institute. (2017). <https://facts.foodprotection.io/about>

730 FSSC 22000, Foundation Food Safety System Certification 22000. (2019). FSSC 22000 scheme version
731 5. Retrieved February 18, 2020, from [https://www.fssc22000.com/wp-](https://www.fssc22000.com/wp-content/uploads/19.0528-FSSC-22000-Scheme-Version-5.pdf)
732 [content/uploads/19.0528-FSSC-22000-Scheme-Version-5.pdf](https://www.fssc22000.com/wp-content/uploads/19.0528-FSSC-22000-Scheme-Version-5.pdf)

733 FSSC 22000. (2018). *Guidance on Food Fraud Mitigation*. FSSC 22000. Retrieved February 18, 2020,
734 from [https://www.fssc22000.com/wp-content/uploads/fssc-22000-guidance-on-food-fraud-](https://www.fssc22000.com/wp-content/uploads/fssc-22000-guidance-on-food-fraud-final-100418.pdf)
735 [final-100418.pdf](https://www.fssc22000.com/wp-content/uploads/fssc-22000-guidance-on-food-fraud-final-100418.pdf)

736 Galvin-King, P., Haughey, S. A., & Elliott, C. T. (2018). Herb and spice fraud; the drivers, challenges
737 and detection. *Food Control*, 88, 85-97. <https://doi.org/10.1016/j.foodcont.2017.12.031>

738 GFSI, Global Food Safety Initiative (2017). Process manual for the GFSI benchmarking process v7.2,
739 GFSI. Retrieved February 2, 2020 from [https://mygfsi.com/wp-](https://mygfsi.com/wp-content/uploads/2019/09/Benchmarking_Requirements_v7_2_Manual.pdf)
740 [content/uploads/2019/09/Benchmarking_Requirements_v7_2_Manual.pdf](https://mygfsi.com/wp-content/uploads/2019/09/Benchmarking_Requirements_v7_2_Manual.pdf)

741 GFSI, Global Food Safety Initiative. (2014). GFSI position on mitigating the public health risk of food
742 fraud. Retrieved April 27, 2020, from [https://mygfsi.com/wp-](https://mygfsi.com/wp-content/uploads/2019/09/Food-Fraud-GFSI-Position-Paper.pdf)
743 [content/uploads/2019/09/Food-Fraud-GFSI-Position-Paper.pdf](https://mygfsi.com/wp-content/uploads/2019/09/Food-Fraud-GFSI-Position-Paper.pdf)

744 GFSI, Global Food Safety Initiative. (2018). Tackling food fraud through food safety management
745 systems. GFSI. Retrieved February 20, 2020, from [https://mygfsi.com/wp-](https://mygfsi.com/wp-content/uploads/2019/09/Food-Fraud-GFSI-Technical-Document.pdf)
746 [content/uploads/2019/09/Food-Fraud-GFSI-Technical-Document.pdf](https://mygfsi.com/wp-content/uploads/2019/09/Food-Fraud-GFSI-Technical-Document.pdf)

747 Hayneys, B. & Spagnuolo, S. (2017). Brazil police raid BRF and JBS meat plants in bribery probe.
748 Retrieved 13 March, 2019, from [https://www.reuters.com/article/us-brazil-corruption-](https://www.reuters.com/article/us-brazil-corruption-food/brazil-police-raid-brf-and-jbs-meat-plants-in-bribery-probe-idUSKBN16O1LH)
749 [food/brazil-police-raid-brf-and-jbs-meat-plants-in-bribery-probe-idUSKBN16O1LH](https://www.reuters.com/article/us-brazil-corruption-food/brazil-police-raid-brf-and-jbs-meat-plants-in-bribery-probe-idUSKBN16O1LH).

750 Kowalska, A., Soon, J. M., & Manning, L. (2018). A study on adulteration in cereals and bakery
751 products from Poland including a review of definitions. *Food Control*, 92, 348-356.
752 <https://doi.org/10.1016/j.foodcont.2018.05.007>

753 Kulling, S., Bunzel, D., Frommherz, L., Molkentin, J., Lehmann, I., Engert, S., & Steinberg, P. (2019).
754 The Setup of the National Reference Centre for Authentic Food (NRZ-Authent) in Germany.
755 *European Journal of Lipid Science and Technology*, 121(12), 1900023.
756 <https://doi.org/10.1002/ejlt.201900023>

757 Lotta, F., & Bogue, J. (2015). Defining food fraud in the modern supply chain. *Eur. Food & Feed L.*
758 *Rev.*, 10, 114.

759 Manning, L. (2016). Food fraud: Policy and food chain. *Current Opinion in Food Science*, 10, 16-21.
760 <https://doi.org/10.1016/j.cofs.2016.07.001>

761 Manning, L., & Soon, J. M. (2014). Developing systems to control food adulteration. *Food Policy*, 49,
762 23-32. <https://doi.org/10.1016/j.foodpol.2014.06.005>

763 Manning, L., & Soon, J. M. (2016). Food safety, food fraud, and food defense: a fast evolving
764 literature. *Journal of food science*, 81(4), R823-R834. [https://doi.org/10.1111/1750-](https://doi.org/10.1111/1750-3841.13256)
765 [3841.13256](https://doi.org/10.1111/1750-3841.13256)

766 Manning, L. (2019). Food defence: Refining the taxonomy of food defence threats. *Trends in Food*
767 *Science & Technology*, 85, 107-115.

768 Manning, L., & Soon, J. M. (2019). Food Fraud Vulnerability assessment: reliable data sources and
769 effective assessment approaches. *Trends in Food Science & Technology*.
770 <https://doi.org/10.1016/j.tifs.2019.07.007>

771 McGrath, T. F., Haughey, S. A., Patterson, J., Fauhl-Hassek, C., Donarski, J., Alewijn, M., ... & Elliott, C.
772 T. (2018). What are the scientific challenges in moving from targeted to non-targeted
773 methods for food fraud testing and how can they be addressed?—Spectroscopy case study.
774 *Trends in food science & technology*, 76, 38-55. <https://doi.org/10.1016/j.tifs.2018.04.001>

775 Merriam-Webster. <https://www.merriam-webster.com/>

776 Mousavi, S. M., Khaniki, G. J., Eskandari, S., Rabiei, M., Samiee, S. M., & Mehdizadeh, M. (2015).
777 Applicability of species-specific polymerase chain reaction for fraud identification in raw
778 ground meat commercially sold in Iran. *Journal of Food Composition and Analysis*, 40, 47-51.
779 <https://doi.org/10.1016/j.jfca.2014.12.009>

780 Moyer, D. C., DeVries, J. W., & Spink, J. (2017). The economics of a food fraud incident—Case studies
781 and examples including Melamine in Wheat Gluten. *Food Control*, 71, 358-364.
782 <https://doi.org/10.1016/j.foodcont.2016.07.015>

783 Muddy Boots. (2020). *Home*. Retrieved April 13, 2020, from <https://en.muddyboots.com/>

784 Nestle. (2016). *Food fraud Prevention*. Nestec Ltd. Retrieved February 18, 2020, from
785 [https://www.nestle.com/sites/default/files/asset-](https://www.nestle.com/sites/default/files/asset-library/documents/library/documents/suppliers/food-fraud-prevention.pdf)
786 [library/documents/library/documents/suppliers/food-fraud-prevention.pdf](https://www.nestle.com/sites/default/files/asset-library/documents/library/documents/suppliers/food-fraud-prevention.pdf)

787 NFCU, National Food Crime Unit (2016). *Working Together to Tackle the Threat from Food Crime*.
788 NFCU. Retrieved February 18, 2020, from
789 <https://www.food.gov.uk/sites/default/files/media/document/tacklingfoodcrime-nfcu.pdf>

790 NFCU, UK National Food Crime Unit. (2019a). Food Crime. Retrieved January 31, 2010 from
791 <https://www.food.gov.uk/safety-hygiene/food-crime>

792 NFCU, UK National Food Crime Unit. (2019b). National Food Crime Unit. Retrieved May 1, 2010
793 from <https://www.food.gov.uk/about-us/national-food-crime-unit>.

794 Primrose, S., Woolfe, M., & Rollinson, S. (2010). Food forensics: methods for determining the
795 authenticity of foodstuffs. *Trends in Food Science & Technology*, 21(12), 582-590.
796 <https://doi.org/10.1016/j.tifs.2010.09.006>

797 PwC, PricewaterhouseCoopers. (2016). *Food fraud Vulnerability Assessment and Mitigation*. PwC
798 Retrieved February 18, 2020, from [https://www.pwc.com/gx/en/services/food-supply-](https://www.pwc.com/gx/en/services/food-supply-integrity-services/assets/pwc-food-fraud-vulnerability-assessment-and-mitigation-november.pdf)
799 [integrity-services/assets/pwc-food-fraud-vulnerability-assessment-and-mitigation-](https://www.pwc.com/gx/en/services/food-supply-integrity-services/assets/pwc-food-fraud-vulnerability-assessment-and-mitigation-november.pdf)
800 [november.pdf](https://www.pwc.com/gx/en/services/food-supply-integrity-services/assets/pwc-food-fraud-vulnerability-assessment-and-mitigation-november.pdf)

801 PwC, PricewaterhouseCoopers. (2020). *Food fraud vulnerability assessment*.
802 [https://www.pwc.com/gx/en/services/food-supply-integrity-services/food-fraud-](https://www.pwc.com/gx/en/services/food-supply-integrity-services/food-fraud-vulnerability-assessment.html)
803 [vulnerability-assessment.html](https://www.pwc.com/gx/en/services/food-supply-integrity-services/food-fraud-vulnerability-assessment.html)

804 Rahmati, S., Julkapli, N. M., Yehye, W. A., & Basirun, W. J. (2016). Identification of meat origin in food
805 products—A review. *Food Control*, 68, 379-390.
806 <https://doi.org/10.1016/j.foodcont.2016.04.013>

807 Robson, K., Dean, M., Brooks, S., Haughey, S., & Elliott, C. (2020). A 20-year analysis of reported food
808 fraud in the global beef supply chain. *Food Control*, 107310.
809 <https://doi.org/10.1016/j.foodcont.2020.107310>

810 RQA Group. (2016). *Food Supply Chain Vulnerability: A Ti whitepaper in partnership with RQA Group*.
811 Retrieved February 18, 2020, [http://www.rqa-group.com/wp-](http://www.rqa-group.com/wp-content/uploads/2016/12/RQA_Ti-Food-Supply-Chain-Vulnerability-Whitepaper.pdf)
812 [content/uploads/2016/12/RQA_Ti-Food-Supply-Chain-Vulnerability-Whitepaper.pdf](http://www.rqa-group.com/wp-content/uploads/2016/12/RQA_Ti-Food-Supply-Chain-Vulnerability-Whitepaper.pdf)

813 Sentandreu, M. Á., & Sentandreu, E. (2014). Authenticity of meat products: Tools against fraud. *Food*
814 *Research International*, 60, 19-29. <https://doi.org/10.1016/j.foodres.2014.03.030>

815 Shears, P. (2010). Food fraud—a current issue but an old problem. *British Food Journal*.

816 Soon, J. M., Krzyzaniak, S. C., Shuttlewood, Z., Smith, M., & Jack, L. (2019). Food fraud vulnerability
817 assessment tools used in food industry. *Food control*, *101*, 225-232.
818 <https://doi.org/10.1016/j.foodcont.2019.03.002>

819 Spink, J. & Harte, B. (2008). Academic food stuff, a strategy to combat economic food fraud.
820 *Packaging World Magazine*, 29. Retrieved February 2, 2020, from
821 <https://www.packworld.com/article-25733>

822 Spink, J. (2019). The current state of food fraud prevention: overview and requirements to address
823 “How to Start?” and “How Much is Enough?”. *Current Opinion in Food Science*.
824 <https://doi.org/10.1016/j.cofs.2019.06.001>

825 Spink, J., & Moyer, D. C. (2011). Defining the public health threat of food fraud. *Journal of food*
826 *science*, *76*(9), R157-R163. <https://doi.org/10.1111/j.1750-3841.2011.02417.x>

827 Spink, J., Bedard, B., Keogh, J., Moyer, D. C., Scimeca, J., & Vasan, A. (2019a). International Survey of
828 Food fraud and Related Terminology: Preliminary Results and Discussion. *Journal of food*
829 *science*, *84*(10), 2705-2718. <https://doi.org/10.1111/1750-3841.14705>

830 Spink, J., Chen, W., Zhang, G., & Speier-Pero, C. (2019b). Introducing the food fraud prevention cycle
831 (FOOD FRAUDPC): A dynamic information management and strategic roadmap. *Food*
832 *Control*, *105*, 233-241.

833 Spink, J., Hegarty, P. V., Fortin, N. D., Elliott, C. T., & Moyer, D. C. (2019c). The application of public
834 policy theory to the emerging food fraud risk: Next steps. *Trends in food science &*
835 *technology*, *85*, 116-128. <https://doi.org/10.1016/j.tifs.2019.01.002>

836 Spink, J., Moyer, D. C., & Speier-Pero, C. (2016). Introducing the food fraud initial screening model
837 (FFIS). *Food control*, *69*, 306-314. <https://doi.org/10.1016/j.foodcont.2016.03.016>

838 Spink, J., Moyer, D. C., & Whelan, P. (2016). The role of the public private partnership food fraud
839 prevention—includes implementing the strategy. *Current Opinion in Food Science*, 10, 68-75.
840 <https://doi.org/10.1016/j.cofs.2016.10.002>

841 Spink, J., Moyer, D. C., Park, H., Wu, Y., Fersht, V., Shao, B., ... & Edelev, D. (2015). Introducing Food
842 Fraud including translation and interpretation to Russian, Korean, and Chinese languages.
843 *Food chemistry*, 189, 102-107. <https://doi.org/10.1016/j.foodchem.2014.09.106>

844 Spink, J., Ortega, D. L., Chen, C., & Wu, F. (2017). Food fraud prevention shifts the food risk focus to
845 vulnerability. *Trends in Food Science & Technology*, 62, 215-220.
846 <https://doi.org/10.1016/j.tifs.2017.02.012>

847 SSAFE. (2017). *About SSAFE*. Retrieved February 2, 2020, from [http://www.ssafe-food.org/about-](http://www.ssafe-food.org/about-ssafe/)
848 [ssafe/](http://www.ssafe-food.org/about-ssafe/)

849 Sumar, S., & Ismail, H. (1995). Adulteration of foods—past and present. *Nutrition & Food Science*.
850 *System*. Retrieved 14 March, 2019, from [https://www.fera.co.uk/media](https://www.fera.co.uk/media/wysiwyg/HorizonScan_Leaflet.pdf)
851 [/wysiwyg/HorizonScan_Leaflet.pdf](https://www.fera.co.uk/media/wysiwyg/HorizonScan_Leaflet.pdf)

852 Tähkäpää, S., Maijala, R., Korkeala, H., & Nevas, M. (2015). Patterns of food frauds and adulterations
853 reported in the EU rapid alert system for food and feed and in Finland. *Food Control*, 47,
854 175-184. <https://doi.org/10.1016/j.foodcont.2014.07.007>

855 Trivedi, D. K., Hollywood, K. A., Rattray, N. J., Ward, H., Trivedi, D. K., Greenwood, J., ... & Goodacre,
856 R. (2016). Meat, the metabolites: an integrated metabolite profiling and lipidomics approach
857 for the detection of the adulteration of beef with pork. *Analyst*, 141(7), 2155-2164.
858 [10.1039/C6AN00108D](https://doi.org/10.1039/C6AN00108D)

859 Ulberth, F. (2016). Early warning systems for food safety and integrity need to be anticipative to be
860 useful for preventing food crisis situations. <https://doi.org/10.1007/s00003-016-1041-5>

861 Ulberth, F. (2020). Tools to combat food fraud—a gap analysis. *Food Chemistry*, 127044.
862 <https://doi.org/10.1016/j.foodchem.2020.127044>

863

864 USP, U.S Pharmacopeial Convention. (2016). *Food fraud mitigation guidance*. The United States
865 Pharmacopeial Convention. Retrieved February 18, 2020, from
866 [https://www.usp.org/sites/default/files/usp/document/our-work/Foods/food-fraud-](https://www.usp.org/sites/default/files/usp/document/our-work/Foods/food-fraud-mitigation-guidance.pdf)
867 [mitigation-guidance.pdf](https://www.usp.org/sites/default/files/usp/document/our-work/Foods/food-fraud-mitigation-guidance.pdf)

868 van Ruth, S. M., Huisman, W., & Luning, P. A. (2017). Food fraud vulnerability and its key factors.
869 *Trends in Food Science & Technology*, 67, 70-75. <https://doi.org/10.1016/j.tifs.2017.06.017>

870 van Ruth, S. M., Luning, P. A., Silvis, I. C. J., Yang, Y., & Huisman, W. (2018). Differences in fraud
871 vulnerability in various food supply chains and their tiers. *Food Control*, 84, 375-381.
872 <https://doi.org/10.1016/j.foodcont.2017.08.020>

873 Wisniewski, A., & Buschulte, A. (2019). How to tackle food fraud in official food control authorities in
874 Germany. *Journal of Consumer Protection and Food Safety*, 14(4), 319-328.
875 <https://doi.org/10.1007/s00003-019-01228-2>

876 Yiannas, F. (2018). A new era of food transparency powered by blockchain. *Innovations: Technology,*
877 *Governance, Globalization*, 12(1-2), 46-56. https://doi.org/10.1162/inov_a_00266

878 Zhang, W., & Xue, J. (2016). Economically motivated food fraud and adulteration in China: An
879 analysis based on 1553 media reports. *Food control*, 67, 192-198.
880 <https://doi.org/10.1016/j.foodcont.2016.03.004>

881