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Feeding fiction: Fraud vulnerability in the food service industry

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ABSTRACT

This study examines fraud vulnerability in the food service industry; identifies underlying fraud vulnerability factors; and studies the differences in fraud vulnerability between casual dining restaurants, fine dining restaurants and mass caterers for four product groups. Vulnerability was assessed by an adapted SSAFE food fraud vulnerability assessment, tailored to the food service sector situation. The 15 food service operators rated high vulnerability for 40% of the fraud indicators. This is considerably more than food manufacturers, wholesalers and retailers did previously. In particular, more opportunities and fewer controls were noted. Overall fraud vulnerability was more determined by the type of food service operator than by the type of food product. Casual dining restaurants appeared most vulnerable, followed by fine dining restaurants. Mass caterers seemed the least vulnerable operators, because they had more adequate food fraud controls in place. Considering its high vulnerability, reinforcement of mitigation measures in the food service industry is urgently recommended.

1. Introduction

On a windy and wet evening in November 2012, Ms X went to the cosy steak restaurant 'Piet de Leeuw' in the centre of Amsterdam. It was renowned for its excellent beef steak. When she stepped through the door, she noticed the authentic interior, wooden furniture, a shiny beer tap, wrought-iron lamps, a few paintings and many photos of guests who had a great time at the restaurant. She was enthusiastically welcomed by the waitress and ordered the beef steak the restaurant was famous for. It was delicious, and she was happy that she walked in. So far so good. It was only a few months later when the restaurant became front-page news and she felt hugely deceived. The steaks 'Piet' served were horse meat rather than beef. This practice was uncovered by a cunning journalist in the heyday of the European horsemeat scandal (Parool, , 2013). Actually, it appeared a family tradition since they had been serving horse instead of beef over three generations of owners.

In contrast with the above, sometimes restaurants are not the offenders themselves but they are victimized by fraudsters earlier in the chain and pass on the illicit products to their customers unknowingly. This happened for instance, when a large international furniture store served Swedish meatballs in their restaurants that consisted of horsemeat (NRC, 2013). Knowingly or not, many fraud cases in which the food service sector was involved have emerged and particularly fish species have been examined. Mislabelling of fish species was discovered in ~30% of the Brussels' restaurants and canteens examined and the extent of mislabelling depended on the type of catering business. Sushi bars presented, for instance, a considerably higher rate (45%) than regular restaurants (28%) (Christiansen, Fournier, Hellemans, & Volckaert, 2018). In Madrid, in 37% of the sampled restaurants mislabelled fish was found (Horreo, Fitze, Jiménez-Valverde, Nroiega, & Palaez, 2019) and 50% of sole fish samples purchased in German restaurants were cheaper species (Kappel & Schröder, 2016). This kind of food fraud has been observed in ~30% of mass catering outlets across Europe as well (Pardo et al., 2018). Obviously, the problem reaches far beyond Europe, food fraud in food service outlets occurs anywhere in the world. In the US 22% of grouper samples appeared to be in fact the cheaper species pangasius (Wang & Hsieh, 2016). Furthermore, Oceana conducted one of the largest seafood fraud investigations to date and collected 1215 seafood samples world-wide (Warner, Timme, Lowell, & Hirshfield, 2013). Species testing revealed that one-third of the samples analysed were mislabelled. Again, seafood mislabelling levels varied with the type of catering business: sushi venues ranked the highest (74%) and this was followed by restaurants (38%). Food fraud in China has been reported to occur in restaurants as well. A review of media reports by Zhang and Xue (2016) revealed that 7% of the cases had occurred in restaurants, 4% with street vendors and 2% in fast food

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service outlets. Another study showed that in Kenya used, highly degraded cooking oil was commonly re-sold to food service outlets. As a consequence 55% of the cooking oils was in the fresh state already unfit for consumption (Karimi, Wawire, & Mathooko, 2017).

Thus, food fraud is a widespread, a global problem and also the food service industry is infected. However, to what extent this industry is vulnerable to fraud and whether this varies across businesses is unknown. Although a variety of tools exist for other nodes in the chain (Soon, Krzyzaniak, Shuttlewood, Smith, & Jack, 2019)), none have been dedicated to the food service section. Therefore, it is timely to deliver such a food fraud vulnerability checklist that allows businesses to gauge their vulnerability to food fraud both for research purposes and as the first step towards fraud prevention. A food fraud theoretical framework was previously developed which defines the three key elements of food fraud according to the criminological Routine Activities Theory: opportunities, motivations and control measures (van Ruth, Huisman, & Luning, 2017). After all, fraud is the result of the interaction between the opportunities presented by victims and by those entrusted with controlling risks and motivated offenders (Levi, 2012). Based on this concept a food fraud vulnerability assessment tool (FFVA) was developed for the food supply chain (SSAFE, 2017). This tool suited particularly actors in the food manufacturing industry. Since the characteristics of food service operators differ from those of that part of the chain, we adjusted the tool to suit the food service industry's circumstances and needs in the current study. For instance, in the food service industry many actors are relatively small-scale businesses, they deal with a very large number of ingredients and products, but often have a limited number of suppliers (Luning, Chinchilla, Jacxsens, Kirezieva, & Rovira, 2013). In contrary, e.g. an olive oil producer is usually at least a medium sized enterprise and deals with a single product and many olive suppliers.

The aim of the current study is to analyse fraud vulnerability in the food service industry in comparison to the vulnerability of other nodes in the chain; to identify the underlying fraud vulnerability factors; and to examine the differences between casual dining restaurants (CD), fine dining restaurants (FD) and mass caterers (MC). The four product groups bananas (BN), black pepper (BP), extra virgin olive oil (OO) and sandwich ingredients (SW) were selected for the assessments since they vary in their ease of manipulation. They represent a whole product (BN), a ground product (BP), a liquid product (OO) and complex product (SW). Obviously, they are also products quite commonly present in food service businesses. Vulnerabilities were assessed for five operators in each of the three food service operator groups using the new, tailored to the food service industry, fraud vulnerability assessment tool (FS-FFVA). To obtain an impression of the actual fraud prevalence and for comparison with the vulnerability assessments, OO samples were requested from the premises of the operators and these were authenticated.

2. Methodology

2.1. Principles of the food service food fraud vulnerability assessment (FS-FFVA)

The principal structure of the FS-FFVA is based on the routine activities theory (Cohen & Felson, 1979). This criminological theory defines the three key elements leading to crime as: a suitable target, a motivated offender, and the absence of guardianship. Crime occurs on the convergence of these three elements in time and space. These key elements were modified to suit food fraud and are the centre of the FFVA: i.e. opportunities, motivations and control measures. Fraud factors (indicators) have been identified to analyse crucial aspects (van Ruth, Luning, Silvis, Yang, & Huisman, 2018). In the current study these fraud factors were checked for their relevance in a focus group session of food service operators comprising representatives of CD, FD and MC. For instance, some of the original fraud factors do not apply because food service operators are the last tier in the food supply chain and their customers have no practical opportunity to adulterate a product. Therefore, factors regarding the customer were omitted. In the focus group a few additional fraud factors were identified, which are specific for the food service industry. They were added if they could be underpinned scientifically. To avoid unnecessary repetitions, the factors of the FS-FFVA to be assessed were divided into three main subject groups: those focusing on the own company, the supplier and the product. The factors regarding the own company could be assessed once for all products and suppliers, and since food service operators appeared to have many products delivered by the same supplier, unnecessary repetition of the supplier's factors was avoided too. The assessment was developed and tested through an interactive and iterative process with CD, FD and MC representatives of the Dutch food service industry.

Table 1
Division of the factors of the food service food fraud vulnerability assessment according to the routine activities theory categories (horizontally) and subject focus (vertically). Number of key vulnerability factors, i.e. factors with high frequency of high vulnerability (> 50%) or medium + high vulnerability (> 75%) responses in brackets.

	Own company	Supplier	Product	Total
Opportunities	0 (0)	2 (0)	8 (6)	10 (6)
Motivations	6 (2)	8 (2)	4 (1)	18 (5)
Control measures	11 (6)	10 (3)	1 (0)	22 (9)
Total	17 (8)	20 (5)	13 (7)	50 (20)

The FS-FFVA consisted of 50 factors, the division of which is listed in Table 1. The assessment was developed in Dutch. The translated individual factors are detailed in Supplementary material S1. The assessment was formulated in statements and the assessor was requested to indicate whether this statement applied to their company, supplier or product under investigation (correct/incorrect) by selecting the yes or no option. We included also a middle option which had to be selected in case of uncertainty. This resulted in three answering options representing low, medium and high vulnerability levels.

2.2. The food service industry assessment

2.2.1. The respondents

In the Netherlands, the food service sector comprises approximately 50,000 businesses with 400,000 employees. Most of these businesses are small scale, only about 10% has 10 employees or over (CBS, 2019). Annual turnover of this sector amounts approximately € 20 billion, which is about one-third of the expenditure on food in the Netherlands. The restaurant sector contributes with € 5.9 billion, catering with € 3.3 billion and fast food service with € 1.4 billion (Foodstep, , 2018). In the current study we focus on the restaurant sector and in particular on three key types of restaurants: CD, FD and MC because they have different business characteristics. CD and FD are for instance small scale restaurants, whereas MC actors are large sized. On the other hand, CD and MC operators offer lower-medium cost meals, whereas the FD operators aim for the higher price segment. CD and MC operators usually purchase their raw materials from larger distributors, but FD operators try to work with short, transparent supply chains where feasible. Five actors in each of the three food service operator groups (CD, FD, MC) in the Netherlands were assessed for their fraud vulnerabilities. This was conducted for four food products (BN, BP, OO, SW) in the first six months of 2019. The characteristics of the operators are listed in Table 2.

2.2.2. The vulnerability assessments

The questionnaire was sent in Excel format by e-mail prior to the date of the meeting of the respondent and the researcher. They had, therefore, time to consult additional documents and ask experts in their organisation about certain questions. The food service operator

Table 2
Details of food service operators assessed in the study and samples collected. Price range of a 3-course menu was € 30–40 for casual dining restaurants and € 60–80 for fine dining restaurants. Mass caterers served different types of meals in the lower price range. Extra virgin olive oil samples were supplied on a voluntary basis, NS indicates operators that did not supply samples. NA - Not applicable.

Operator code	Type of food service operator	Location	Additional characteristics[a]	Extra virgin olive oil sample
CD1	Casual dining restaurant	Boxtel	NA	X
CD2	Casual dining restaurant	Den Bosch	NA	X
CD3	Casual dining restaurant	Well	NA	NS
CD4	Casual dining restaurant	Venlo	NA	X
CD5	Casual dining restaurant	Rosmalen	NA	NS
FD1	Fine dining restaurant	Amsterdam	1 Michelin star	X
FD2	Fine dining restaurant	Amsterdam	1 Michelin star	X
FD3	Fine dining restaurant	Blokzijl	1 Michelin star	NS
FD4	Fine dining restaurant	Bennekom	1 Michelin star	NS
FD5	Fine dining restaurant	Heelsum	1 Michelin star	X
MC1	Mass caterer	De Meern	MVO certified; corporate, campus, hospital/care facilities, leisure/events catering	X
MC2	Mass caterer	Hoofddorp	Corporate catering	NS
MC3	Mass caterer	Doesburg	HACCP implemented; corporate, institutional, school catering	NS
MC4	Mass caterer	Schijndel	ISO 9001 certified; corporate, campus, hospital, leisure catering	NS
MC5	Mass caterer	Rijswijk	FSSC 22,000 certified, leisure/events catering, specialised in Asian food	X

[a] MVO = maatschappelijk verantwoord ondernemen (business considering corporate social responsibility); HACCP = Hazard Analysis of Critical Control Points; ISO = International Standardisation Organiation; FSSC =.

respondent answered all questions of the questionnaire in the presence of the researcher, who was available to clarify questions. The 50 questions were answered one by one. The interviewer interpreted the answers and allocated the answer to one of the options in the grid, which was discussed with the respondent. The duration of the interview was between 1.5 and 2 h. All assessments were conducted between November 2018 and April 2019.

2.2.3. Data analysis

The responses, as determined by the businesses, were transferred to a scoring system. A score of 1, 2 or 3 was assigned to low, medium (uncertain) or high vulnerability responses, respectively. The frequencies of low, medium and high vulnerability scores for each fraud factor were calculated for each type of operator and food product. For instance, 80% of the CD operators selected the low vulnerability response, 0% the medium vulnerability response and 20% the high vulnerability response for the first own company factor for the first product. Similarly, frequencies were calculated over the own company, supplier and product factors for each food service operator group and for each food product. Key fraud factors were identified based on their medium and high vulnerability score frequencies, i.e. they were considered key factors if the high vulnerability score frequency exceeded 50% or cumulated medium and high vulnerability score frequencies exceeded 75% of the responses. Significance of differences in scores and frequencies between groups were assessed by multi-factor analysis of variance (MANOVA: type of food operator × product) with post-hoc Fisher's Least Significant Difference tests. Although the scores are ordinal data, MANOVA was applied to get insights into the influence of the two individual factors as well as their interactions. It allowed also a direct comparison with previous data from other nodes in the chain (van Ruth et al., 2018). Comparison with a non-parametric test for differences between operator groups or between food products resulted in similar results (Supplementary data S2), but the MANOVA provided more information. Throughout the study $P = .05$ was considered.

2.3. Authentication of extra virgin olive oil samples

Eight OO samples (Table 2) were supplied by the operators and these were subjected to 2-monochloropropanediol (2-MCPD) ester and 3-MPCD ester analysis using the methodology described previously (Yan, Oey, van Leeuwen, & van Ruth, 2018). These compounds are contaminants, formed during the refining process of oils. Their presence at higher concentration levels is, therefore, a strong indication of admixture or full replacement of extra virgin olive oil with refined olive oil or other refined vegetable oils. Admixture with refined olive oils or other refined vegetable oils can be detected at 5% admixture level using the 2-MCPD ester concentration and at 2% using the 3-MCPD ester concentration as indicator with 95% confidence (Yan et al., 2018).

3. Results and discussion

3.1. Key fraud factors

The food fraud factor responses of all food service operators of the FS-FFVA are presented in a tiling diagram in Fig. 1. Table 1 provides a high level overview of the division of the key fraud factors over subjects (own company, supplier, product) and categories (opportunities, motivations, control measures). The individual key factors are presented below, and those that were also identified as key fraud factors in the same manner for other types of food businesses in six supply chains (van Ruth et al., 2018) are underlined. Eight key fraud factors were identified for the own company including two motivations related factors, i.e. the level of competition (OCM3; see for more information about factor codes the questionnaire in Supplementary data S1) and other illegal gain options available (OCM6). They concern also six controls related factors: the lack of a fraud monitoring system (OCC1), lack of a track and trace system (OCC3), lack of a contingency plan (OCC7), lack of sufficient fraud coverage of the national food policy (OCC8), lack of law enforcement (OCC9) and lack of industry guidelines (OCC10).

The five key fraud factors at the supplier's level concern two motivations related and three controls related factors: the level of competition (SM3), financial strains imposed on the supplier (SM4), lack of an adequate fraud monitoring system (SC1), lack of integrity screening of employees (SC4) and lack of a contingency plan (SC7).

Key fraud factors regarding the products examined are the ease of adulteration (P02), historical evidence of fraud (P03), accessibility to the product (P04), the availability of technology and knowledge to adulterate (P05), lack of transparency in the chain (P06), difficulty of general detectability of frauds with these products (P08) and valuable components or attributes of the products assessed (PM1).

There appears to be considerable overlap in key fraud factors between the food service sector and the wholesalers, food manufacturers and retailers examined previously (van Ruth et al., 2018). The latter group presented only one additional key fraud factor, i.e. social control in the supply chain. However, the above shows nine additional key

Fig. 1. Tiling of raw data of the food service food fraud vulnerability assessments. The results of the various restaurant/product combinations presented in rows, the 50 factors in columns. Green colour represents a low vulnerability, orange a medium vulnerability and red a high vulnerability response. Blank boxes indicate that a particular product was not used/served in the food service operator's business.

vulnerability factors for the food service industry in comparison with the other nodes, which points at an increased general fraud vulnerability in this industry. The additional key fraud factors concern in particular additional opportunities and lack of adequate controls in comparison to other nodes in the chain.

Only a limited number of studies are available on a direct comparison of food fraud prevalence in the food service industry and retail. Two surveys allowed comparisons of the point of purchase. The Dutch consumers' organization carried out a food fraud survey for a variety of products, one of which was lamb meat purchased from 22CD operators and 8 smaller sized retail outlets (butchers, etc.) in Amsterdam (Polderman, Cammelbeeck, Uitslag, & de Gouw, 2016). Fifty percent of the restaurants served 'lamb meat' dishes which consisted partially or fully of meat of other species. In the retail outlets this kind of adulteration was discovered in 38% of the shops. In a large US study, mislabelled fish was detected more often in general CD restaurants (52% of the restaurants) and sushi venues (95%) than in outlets of large retailers (27%) (Warner et al., 2013). Both the Dutch and US findings confirm the higher vulnerability in the food service sector compared to retail, but we acknowledge that there are very few studies available.

When it comes to non-compliant or dishonest behaviour, the hospitality sector has, unfortunately, a dubious track record. Rule breaking is very common in this industry, e.g. 95% of all US operators are challenged with it (Henle, Giacalone, & Jurkiewicz, 2005). It has been estimated that 75% of employees steal at least once at work which results in losses of billions of dollars for the US food service industry (Shum, Ghosh, & Gatling, 2019). Moral issues in this industry have also been reported as a cause of non-compliance with regard to sanitation practices, which in turn may result in food safety hazards in this industry (Ridderstaat & Okumus, 2019). These moral issues together with extensive opportunities and the lack of efficient controls may aggravate food fraud occurrence in this industry.

3.2. Type of food service operator and fraud vulnerability

Comparison of the results of the food service operator groups reveals that the CD group has the most high vulnerability responses (Fig. 1). Cumulated responses for the own company fraud factors, show the higher vulnerability of CD in comparison to FD and MC too (Fig. 2). The supplier's fraud factors present a lower vulnerability for MC in comparison to the other two groups. For BN and BP, CD presents higher vulnerability levels, whereas for EVOO and SW the order of the latter two is reversed. The difference in responses between the type of operators for individual factors was examined for their significance using a two factor evaluation (i.e. type of operator × product) (Table 3). The operator groups showed significant differences in responses for ten out of the 17 own company factors and for seven of the 20 suppliers' factors. Most of them were controls related (11), some were related to motivations (five) and only one was opportunities related. Hence, the food service operator groups differ primarily in fraud vulnerability in regard to motivational factors and differ in the level of adequacy of control measures. Comparing the three types of operators, MC clearly presents lower fraud vulnerability according to these distinguishing factors than the other two groups. CD and FD are found to present a significantly higher vulnerability level for a similar number of factors compared to MC, half of these factors overlap but the other half present significant differences between CD and FD.

Many more vulnerability factors show significant differences between operator groups than previously found among wholesalers, food manufacturers and retailers. For the latter, only one opportunities related factor, two motivations related factors and four controls related factors presented significant differences (van Ruth et al., 2018). It appears that differences over a larger range of fraud factors exist between the three food service operator groups (17 of the 50 factors) in comparison to the different nodes in the chain (7 of the 50 factors) indicating more inter-operator group variations, especially when it comes to motivational drivers and controls.

There are a number of potential differences in characteristics and practices between the food service operator groups that may affect their fraud vulnerability. For instance, the size and type of the operator in relation to ethical behaviour, rivalry, limited choice of suppliers and implementation of extensive food safety management measures (Peeters, Denkers, & Huisman, 2019). The CD and FD businesses are smaller sized than the MC, which may affect ethics in those companies. Small owner-managed businesses are very different in organisation from large corporations where ownership and management are separated. However, previous studies have not shown that these differences result in different degrees of ethical behaviour. On the other hand, the ethical values and inclinations of the small business owner will have far more direct consequences on the practices of the business as a whole (Longenecker, Moore, Petty, Palich, & McKinney, 2006).

Competition in the food service industry is fierce. Although the food service sector in the Netherlands has seen considerable growth over the last few years after the latest economic crisis, this growth varies with the type of operator. Restaurants in the Netherlands have benefited more from the growth than café's or MC (CBS, 2017).

In the current study it appeared that the food service operators dealt with a fairly limited number of suppliers in comparison to retailers.

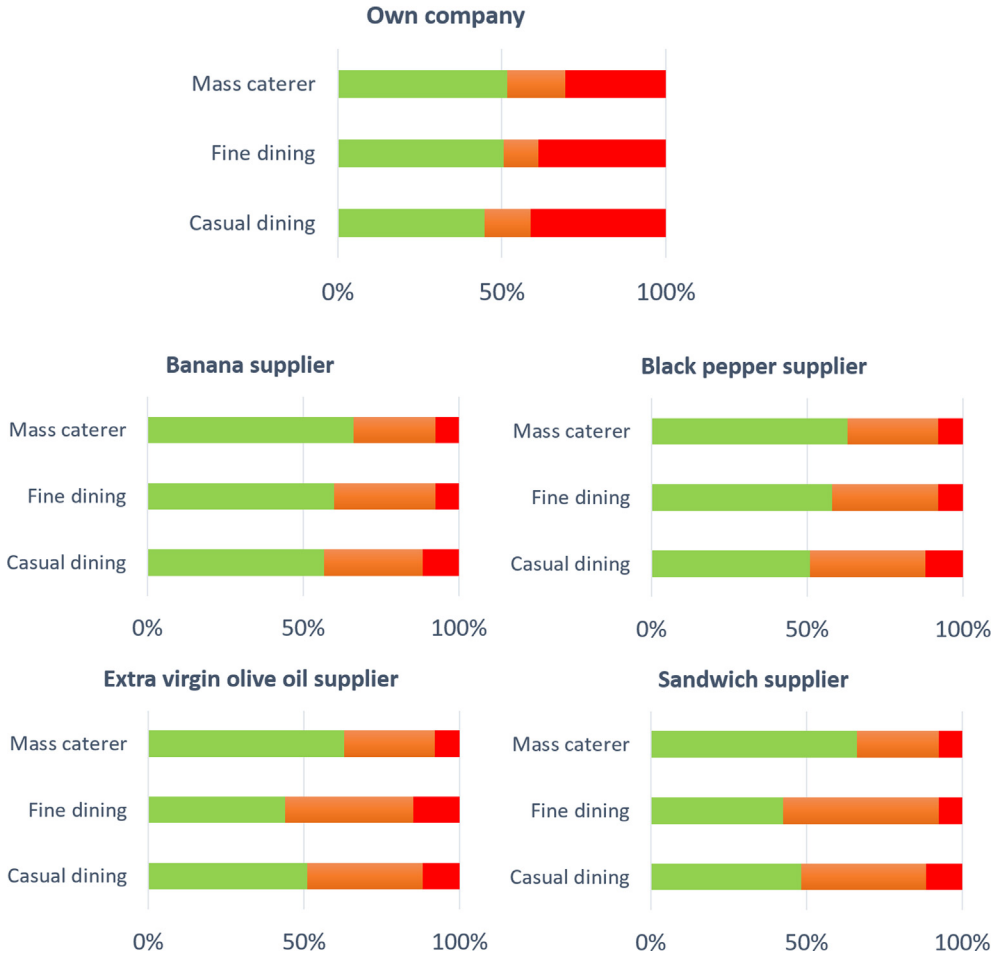

Fig. 2. Frequency bar diagrams for cumulated responses. Green colour represents low vulnerability, orange medium vulnerability and red high vulnerability responses. For instance (top diagram): the five mass caterers selected for the own company factors the low vulnerability option (green) in 52% of the cases, the medium vulnerability option (orange bar) in 18% and high vulnerability option (red bar) in 31% of the cases. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

Table 3
Own company and supplier-related fraud factors of the fraud vulnerability assessment with significantly different responses by the three food service operator groups and for the food product groups (two way analysis of variance: type of food service operator × food product with post-hoc Fisher's Least Significant Difference tests, $P < .05$).[a]

Own company related factors					Supplier-related factors				
Factor code	Fraud factor	Casual dining	Fine dining	Mass catering	Factor code	Fraud factor	Casual dining	Fine dining	Mass catering
OCM1	Economic health	A	B	AB	SO1*	Location supplier	B	A	B
OCM3	**Level of competition**	B	B	A	**SM3**	**Level of competition**	A	A	B
OCM4	Financial strains	AB	B	A	SM8*	Country's corruption level	B	A	B
OCC1	**Fraud monitoring system**	AB	A	B	SC3	Track and trace system	A	AB	B
OCC2	Information system	B	A	AB	SC8	General supplier requirements	A	AB	B
OCC3	**Track & trace system**	A	A	B	SC9	Internal/external audits	A	A	B
OCC4	Employee integrity screening	B	A	B	SC10	Certification	A	B	AB
OCC7	**Contingency plan**	A	A	B					
OCC8	**National food policy**	A	A	B					
OCC11	General supplier requirements	A	B	B					

[a] Different letters in a row in the section of the own company or the supplier indicate significant differences between type of food service operator groups, with A reflecting higher vulnerability scores than B. Key fraud factors are presented in bold letter type (see Table 1 for definition). Factor codes and factor descriptions are listed in Supplementary material S1. An asterisk indicates a significant effect of the factor product.

They usually obtain many of their ingredients and products from the same wholesaler. There are also only a limited number of wholesalers available that supply these products. This results in dependency and impose certain strains on the food service operators. FD operators also obtain some of their ingredients from small local producers with short, visible chains. The smaller businesses are too small to present power over their suppliers, MC operators are much more powerful because of their size and purchase volumes.

In terms of controls, the MC stood out in the current study. In general, larger operators in the food supply chain have more extensive food safety management systems, which may also cover food fraud to some extent. Smaller sized businesses have significantly more troubles with implementing food safety management systems (Luning et al., 2015). This also holds for food service operators: the MC have more advanced systems in place than the CD and FD operators and are, therefore, in a better position to mitigate their fraud vulnerabilities.

3.3. Type of food product and fraud vulnerability

The product-related factors indicate that for the single ingredient products, BN is least vulnerable to fraud, followed by BP and OO, respectively (Fig. 3 and Table 4). SW is a different kind of product because of its more multi-ingredient composition, and appears also more vulnerable to fraud than BN. The products differ in response to six factors, mostly in regard to ease of adulteration, valuable components, historical evidence, location of supplier and corruption level of the country the supplier is based in. The differences in vulnerability are in agreement with the previous study in which other nodes in various supply chains were examined (van Ruth et al., 2018). It is also in agreement with perceptions of stakeholders on the ease of adulteration, in which liquid products are considered easier to tamper with, and they are closely followed by ground products and much later by solids (NSF Safety and Quality UK, 2014). In practice, BP fraud vulnerability can obviously be reduced tremendously if restaurants grind pepper from whole peppercorns themselves, which may suit smaller sized businesses. A few of the businesses interviewed indeed ground peppercorns in their kitchens.

Few factors showed interactions between the type of food service operator and the type of food products. Only the factor corruption level of the country of the supplier (SM8) showed interaction. FD operators are usually in favour of local sourcing which result in a different vulnerability level than for those that source ingredients from farther away. This aspect would explain this interaction. Otherwise, operators across the three groups obtained a wide range of ingredients often from the same suppliers.

3.4. Think like a criminal

Let us step into the shoes of the food criminal now, considering the identified vulnerabilities above, where would we attack? While the rationality of criminal decision making is strongly contested, fraud offenders are found to show at least some level of rationality (Huisman, 2016). They do not act in an erratic way, thoughts precede their actions. Since fraud offenders are expected to be mostly criminal professionals rather than professional criminals, they are also very familiar with practicalities in the business (Lord, Flores Elizondo, & Spencer, 2017). Generally, the food service sector is an interesting target because it is offering more opportunities and is more often lacking adequate controls than other nodes in the chain according to the assessments in the current study. Furthermore, there is a considerable variation in vulnerability among food service operators. As a criminal, we would be interested in the weakest among them. In this respect, CD and to some extent FD restaurants are the most interesting in the food service industry: more motivational drivers and fewer controls. Perhaps CD businesses have also fewer critical customers, but it will be very difficult to authenticate products as a consumer anyway.

Looking at the products, particularly BP and OO come to mind due to the ease of adulteration and, again, lack of specific controls. OO seems the more preferred target of the two because fraud with BP can be prevented by grinding whole peppercorns on-site in smaller sized businesses. This is not feasible for OO, and fairly advanced laboratory-based analytical tests are required to authenticate the product. Thus, extra virgin olive oil would be a key product for those with a criminal mindset. Extra virgin olive oil in a smaller sized business would be the most vulnerable situation.

3.5. Fraud detected in collected extra virgin olive oil samples

In order to sniff out some fraud in practice, the interviewed food service operators (Table 2) were asked to supply OO samples from OO used in their business, to which eight of them agreed: 3CD, 3 FD and 2 MC operators. To determine whether refined olive oil or other refined vegetable oils were mixed in, all samples were subjected to 2- and 3-MCPD analysis. Results show that the OO samples of the three CD operators were adulterated with refined oils (Table 5) since the samples exceeded the thresholds for both 2- and 3-MCPD esters. The OO samples from the FD and MC operators did not show anomalies. It is striking that all three CD operators worked with adulterated olive oil in their business. Of course, the number of samples is small, but the results are certainly food for thought and in line with the fraud vulnerability assessments.

4. Considerations

The food service industry appears more vulnerable to food fraud than their retail counterparts due to more extensive opportunities and lack of controls. Especially restaurants seem relatively easy targets. More insights in the food service's fraud vulnerability may be gained by evaluation of other groups of food service operators, for instance fast food operators, airline caterers, those that cater for institutions (e.g. prisons), and their direct suppliers. Increase of the number of operators per group is also recommended since it will help to cover more variation present in practice.

When it comes to mitigation of the established vulnerabilities, a first step should beraising awareness of food fraud among food service operators. Many food service operators do not give food fraud much

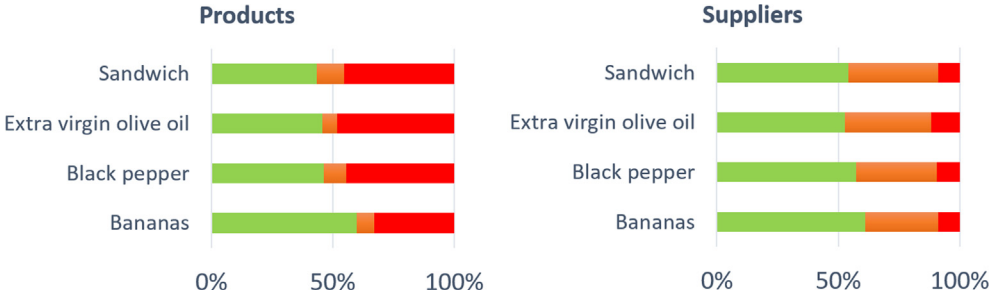

Fig. 3. Frequency bar diagrams for cumulated responses. Green colour represents low vulnerability, orange medium vulnerability and red high vulnerability responses. For further explanation see Fig. 2. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

Table 4
Product-related fraud factors of the fraud vulnerability assessment with significantly different responses by the food service operator groups and for the four product groups (two way analysis of variance: type of food service operator × food product with post-hoc Fisher's Least Significant Difference tests, $P < .05$).[a]

Factor code	Fraud factor	Type of food service operator			Food products			
		Casual dining	Fine dining	Mass caterer	Bananas	Black pepper	Extra virgin olive oil	Sandwich
PO1	Ease of adulteration A				B	B	B	A
PO2	**Ease of adulteration B**	A	A	B	C	A	A	B
PO3	Historical evidence	A	AB	B	C	A	A	B
PO4	**Accessibility**	A	B	A				
PO5	**Availability of technology and knowledge to adulterate**	A	B	A				
PO6	**Transparency in the chain A**	A	B	A				
PO7	Transparency in the chain B	A	B	A				
PM1	**Valuable components or attributes**	A	AB	B	A	B	A	A

[a] Different letters in a row in the section of the type of food service operator or the food products indicate significant differences, with A reflecting higher vulnerability scores than B. If no significant differences were observed, the box was left blank. Key fraud factors are presented in bold letter type (see Table 1 for definition). Factor codes and factor descriptions are listed in Supplementary material S1.

Table 5
Results of authentication analyses of extra virgin olive oil samples supplied by the food service operators.

Food service operator	Extra virgin olive oil[b]		
	2-MCPD ester [mg/kg oil]	3-MCPD ester [mg/kg oil]	Conclusion
Casual dining restaurant 1	0.19	0.40	Adulterated
Casual dining restaurant 2	0.08	0.21	Adulterated
Casual dining restaurant 4	0.53	1.40	Adulterated
Fine dining restaurant 1	< 0.07	< 0.10	Authentic
Fine dining restaurant 2	< 0.07	< 0.10	Authentic
Fine dining restaurant 5	< 0.07	< 0.10	Authentic
Mass caterer 1	< 0.07	< 0.10	Authentic
Mass caterer 5	< 0.07	< 0.10	Authentic

[a]Thresholds of monopropanediols are 0.028 mg 2-MCPD/kg and 0.036 mg 3-MCPD/kg oil (Yan et al., 2018); limit of detection of the procedure applied is < 0.07 mg 2-MCPD/kg oil and < 0.10 mg 3-MCPD/kg oil. Samples exceeding these values are considered adulterated.

thought, although it may considerably damage their reputation. Their customers pay the price for these activities, and they even sometimes pay with their health for them. Industry guidelines and social control will help to mitigate the vulnerabilities. Although MC operators have to some extent fraud monitoring programmes in place, these are fully lacking in the CD and FD restaurants. Many smaller sized businesses are probably also not able to invest in testing of incoming ingredients. In that case, they can protect themselves by purchasing food ingredients in whole form, a whole fish instead of a fillet, grinding spices themselves, etc. although this will not be feasible for all products. Short, visible supply chains will also reduce vulnerability. Furthermore, some self-detection may help to control the vulnerabilities or at least reduce the impact when fraud is detected at an early stage. In the last five years small, portable, cost-efficient analytical devices and smart phone applications have surfaced the market and some of them are suitable for citizen science. For instance for organic milk authentication such a low cost application was developed (van Ruth & Liu, 2019). This kind of rapidly developing tools provides operators with options to check the identity of their incoming ingredients. Bad apples in the food service industry that commit food fraud themselves or pass on illicit products knowingly can probably only be exposed by surveys conducted by authorities, consumer organisations and scientists with attention from the media. For legitimate businesses some mitigation is urgently needed, because it will only be a matter of time before the next food fraud scandal emerges. The group of food criminals never refrain from work, search for the weakest spots in supply chains, and unfortunately, the food service operators appear fairly vulnerable.

CRediT authorship contribution statement

Saskia M. van Ruth: Conceptualization, Data Curation, Formal analysis, Funding acquisition, Investigation, Methodology, Project administration, Resources, Supervision, Writing – original draft. **Joris van der Veeken:** Data curation, Formal analysis, Investigation, Writing – review & editing. **Pieter Dekker:** Methodology, Writing – review & editing. **Pieternel A. Luning:** Conceptualization, Methodology, Writing – review & editing. **Wim Huisman:** Conceptualization, Methodology, Writing – review & editing.

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Appendix A. Supplementary material

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