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Food fraud and mitigating strategies of UK food supply chain during COVID-19

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ABSTRACT

Covid-19 had shown the vulnerability of the food supply chain and fraudsters may take advantage of the pandemic whilst the population needed a continuous supply of safe and quality food. The lack of monitoring and policing in the food supply chain may encourage fraudsters to upscale their operations. Previous studies had warned of a surge in fraudulent products due to COVID-19. This raised the question on whether food fraud had increased during the pandemic? This study aims to investigate food fraud during COVID-19 and how the food supply chain develops mitigating strategies against fraudulent activities. A mixed-method approach including survey and semi-structured interviews were conducted among UK food businesses. Two hundred and two agri-food businesses responded to the survey and 15 semi-structured interviews were conducted. The majority of the food businesses did not experience an increase of food fraud activities during COVID-19. Two thematic domains and ten sub-themes were identified from the data set. There was a heightened sense of anticipation and preparation for increased fraudulent activities during the pandemic. The main risk mitigating strategies included horizon scanning; developing and maintaining supplier relationship and assurance; understanding product characteristics, testing capabilities, conducting vulnerability assessments and training. Practical and cost-effective strategies for small and medium food businesses were recommended. This is the first empirical study on food fraud and mitigating strategies of the UK food supply chain during the pandemic. Our findings provide evidence for informing the policies and practices of the food regulatory authorities as well as best practices to protect the UK food supply chain against food fraud during exogenous shocks like COVID-19.

1. Introduction

The supply and demand for food were significantly affected by COVID-19 (Aday & Aday, 2020). Lockdowns resulted in unstable market prices and rapid changes in the food distribution systems. There was a surge in demand for food and drink products, and the global food supply chain had been under immense pressure due to reduced production capacity and disruptions to labour and transportation. This created a supply gap during COVID-19 (Ma et al., 2021; Rizou et al., 2020). Consequently, new suppliers emerged to fulfil the supply gap and may have not been audited or assessed to the same level as established and/or approved suppliers. The lack of monitoring and policing in the food supply chain were potentially attractive to fraudsters (Elliott, 2020). During the first half of the pandemic period (December 2019–June 2020), the Europol INTERPOL joint operation (including UK) - OPERATION OPSON IX seized £28 million worth of illegal and sub-standard food and drinks, carried out 26,000 checks and dismantled 19 organised crime groups (Europol, 2022). This shows the scale and extent of food fraud in the global food system during this critical period. Onyeaka et al. (2022a; 2022b) also highlighted that food smuggling, production of counterfeit alcohol products and artificial enhancement of fish and meat using formalin were frequently reported in Africa.

Resilience in food systems is defined as the capacity or recovery of the food systems (e.g., food producers, distributors and consumers) to cope with interacting and cumulative forces that undermine food access and equity (Oliver et al., 2018; Pimm et al., 2019; Schipanski et al., 2016). Within the context of food fraud + COVID-19, the pandemic served as an enabler (due to lack of food monitoring, over-reliance on new or un-approved suppliers) of food fraud. Both factors were examples of interacting forces that affected the food systems. Resilience is measured by recovery time, degree of impacts and degree of recovery (Wu et al., 2021). An example of a high performing resilient food

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producer includes the ability to detect adulterated food, rapid removal of affected products and source alternative safe products from their suppliers.

Reports had warned of a surge in fraudulent products due to COVID-19. Worldwide, food regulatory authorities, food industry and researchers had raised concerns for food fraud during the pandemic (Brooks et al., 2021; Onyeaka et al., 2022b; Panghal et al., 2021). Criminals trading in counterfeit goods including food and pharmaceutical products had been quick to exploit the COVID-19 pandemic. Counterfeiters worked hard to profit from the pandemic and to exploit shortages of genuine products and the anxieties of consumers (Anti--Counterfeiting Group, 2020; Europol, 2021). Counterfeiting and sale of questionable products were seen in hand sanitisers (Korsten & de Bruin, 2020), personal protective equipment (Proffitt, 2020), counterfeit pharmaceuticals (Tesfaye et al., 2020), immunity-boosting treatments, testing kits and pharmaceutical products that had not been approved for COVID-19 treatments (Mackey et al., 2020) and counterfeit COVID-19 vaccines (Jarrett et al., 2020). Similarly, has food fraud increased during the pandemic?

Researchers reported that to date there was insufficient evidence of significant increases in specific COVID-19 related food fraud incidents (Crew, 2021; Frera et al., 2021; Points & Manning, 2020). The studies reviewed food safety and food fraud databases to compare reported incidences of fraud in the period between January–June 2019 and January–June 2020. The data showed a small increase in official food fraud alerts at the start of the pandemic. During the pandemic, global regulatory monitoring, sampling and testing were reduced due to staff working from home, illness and travel restrictions. Given the small increase in food fraud incidents in 2020, compared to 2019 despite the reduced workforce, it is possible that COVID-19 played a role in the increased number of reported incidents. However, the increase was small within the global context, and there was insufficient evidence to link significant increases of food fraud incidents to the pandemic (Frera et al., 2021). Similarly, Points and Manning (2020) cautioned against the lack of root cause information in food fraud databases making it difficult to identify the motivation behind the fraud. For example, in 2020, there was an increased report of melamine used to adulterate soy and pea protein in China. The increase was likely to be caused by demand for composite vegan products and not spurred by COVID-19 (Points & Manning, 2020).

Food safety and food fraud databases are reliant on local media sources, food safety surveillance and inspections and scholarly literature to collate the data. It is likely that food fraud incidents were not being captured due to decreased regulatory oversight (Fera et al., 2020). As worldwide regulatory surveillance activities resumed, it is possible that more evidence concerning pandemic-related factors may emerge. This study aims to investigate the impact of COVID-19 on food fraud and the UK food supply chain's mitigating strategies against food fraud.

2. Methodology

2.1. Study design

A two-step study design was used to investigate food fraud during COVID-19 and mitigating strategies of the UK food supply chain. The first step involved an online survey followed by semi-structured interviews to further explore agri-food businesses' experiences and insights on their resilience strategies.

2.2. online survey

The questionnaire design was based on Brooks et al. (2021), Djekic et al. (2018) and Soon et al. (2019). It was divided into three sections (i) Characteristics of agri-food businesses (e.g., type of food business) (ii) Food fraud during COVID-19 and (iii) Strategies to mitigate food fraud during COVID-19. Sections (ii) and (iii) were assessed using Likert scale where 1 = Strongly disagree and 5 = Strongly agree. All questionnaires were reviewed by food safety and food fraud experts for content validity and pilot tested with several food industry representatives. The questionnaire (available in Appendix I) was hosted on the Online Survey (onlinesurvey.ac.uk) platform. Invitation to participate in the online survey was carried out through UK Food and Drink Federation, Food Authenticity Network, Food Industry Intelligence Network (FIIN), BRCGS registered list of food businesses and professional contacts. The criteria were agri-food businesses (i) operating in at least one part of the food supply chain such as farm, food processing, agents and brokers, distribution, wholesale, retail and technical support (e.g., food safety consultancy businesses); (ii) operating in the UK. Participants were provided with an explanation of the study and online consent was obtained before completing the survey.

2.3. Semi-structured interview

The semi-structured interview guide was developed based on literature sources named above. Additionally, the topic guide used Cox et al. (2020) on the Cost of Food Crime to supplement the questions. The protocol was pilot tested with a technical representative of a food manufacturing site in the UK to ensure clarity and relevance to the UK food industry. Ethical approval for the study was applied and approved by University of Central Lancashire (Reference Number: HEALTH 0227). The topic guide is available in Appendix II. Participants who completed the survey were invited to take part in the interviews. Interested participants were provided with an explanation of the interview and online consent was obtained prior to online interviews. Fifteen semi-structured interviews were conducted between May and October 2022 which varied in duration from 30 to 70 min.

2.4. Data analysis

Two-step cluster analysis was conducted to classify food businesses according to the strategies adopted to prevent food fraud. Log-likelihood was used as a distance measure and independent *t*-test uncovered statistically significant differences between clusters. The audio recordings of the interviews were transcribed and thematically analysed based on Braun and Clarke (2006) and Rosales et al. (2023). The transcripts were read and re-read to familiarise with the content followed by coding. The relationships between the initial codes were reviewed to identify broader patterns of sub-themes and themes (Table 1). An inductive approach was utilised because the coding and theme emerged from the content of the data.

Table 1
An example of coding and identification of themes.

Respondents' answers	Unit of analysis	Codes	Sub-theme	Theme
I'm continuously monitoring international **media**.	Media	Alerts	Information is key	Strategy to prevent food fraud
We would screen **RASFF** data every day.	RASFF	Horizon scanning tool		
We invest in **Decernis** Food Fraud Database.	Decernis	Horizon scanning tool		
We join FIIN and **share** our data anonymously.	Share	Active sharing		
Research as much as possible into the **history** of your products.	History	Historical data		

3. Results

Two hundred and two food businesses responded to the survey of which 2.5% were farms, 35.6% were processors and 62% post-processors (Table 2). Labour shortage was identified as the biggest impact of COVID-19 on agri-food businesses. Other areas were not deemed as disruptive compared to shortage of employees (Fig. 1). An overwhelming 78.2% of respondents reported that they did not experience an increase of fraudulent activities during COVID-19 while 15.8% were unsure and only 6% reported an increase of food fraud.

Most participants reported that they did not experience food fraud during the pandemic. This is reflected in food businesses' responses about their experiences of fraud during COVID-19 where all mean values were less than 2.00 (Table 3). Respondents trust that their suppliers were monitoring food fraud during the pandemic and would take necessary measures to counter food fraud. There was general agreement that using new, unverified food suppliers and lack of regulatory monitoring may increase food fraud. However, COVID-19 was not reported as a main trigger for food fraud (Table 3).

Cluster 1 was made up mostly of mixed food businesses (more than 1 type of food or drink categories), post-processing stage and operated in more than 1 country. Most participants in Cluster 1 were categorised as small (less than 50 employees) and large enterprises (more than 250 employees). Cluster 2 consisted of animal and plant-based food businesses and operated within farm and processing stages. Majority of the agri-food businesses (Cluster 1, n = 65; Cluster 2, n = 93) did not experience an increase of fraudulent activities during COVID-19. There were significant differences in the strategies employed by food businesses in Clusters 1 and 2. Food businesses in Cluster 1 were more likely to carry out preventative strategies such as increased testing, vulnerability assessments, surveillance and remote food safety audits and participate in food community support networks to mitigate food fraud (Table 4).

Table 2
Characteristics of agri-food businesses (n = 202).

Type of food business	n (%)	Type of food business	n (%)
Alcoholic and fermented drinks	3 (1.5)	Herbs, spices and seasoning	2 (1.0)
Baked goods	9 (4.5)	Poultry and poultry products	2 (1.0)
Beverages (non-alcoholic)	4 (2.0)	Meat and meat products	20 (9.9)
Cans and jars	1 (0.5)	Ready-to-eat meals	2 (1.0)
Cereals and nuts	3 (1.5)	Savoury snacks	1 (0.5)
Confectionary	7 (3.5)	Seafood and seafood products	4 (2.0)
Dairy	7 (3.5)	Packaging materials	18 (8.9)
Dried foods	3 (1.5)	Storage and distribution	13 (6.4)
Eggs and egg products	2 (1.0)	Agents and brokers	7 (3.5)
Fats and oils	1 (0.5)	Others (e.g., mixed food products; food additives; frozen food; pre-mixes; dairy free food)	71 (35.1)
Fruits, vegetables and nuts	22 (10.9)		
Country		**Type of supply chain**	
England	169 (83.7)	Farm	5 (2.5)
Northern Ireland	4 (2.0)	Primary processing	34 (16.8)
Scotland	11 (5.4)	Secondary processing	38 (18.8)
Wales	4 (2.0)	Wholesale	3 (1.5)
More than 1 country	14 (6.9)	Storage and distribution	12 (5.9)
		Retail	3 (1.5)
Number of employees		Catering	2 (1.0)
Less than 50	64 (31.7)	Packaging	87 (43.1)
51–250	89 (44.1)	Others	18 (8.9)
More than 250	49 (24.3)		

3.1. Agri-food businesses' insights of food fraud during COVID-19 and mitigating strategies

Fifteen participants took part in the semi-structured interviews between May–October 2022 (Appendix III). The semi-structured interviews provided deeper understanding of food fraud during the pandemic and the mitigating strategies adopted by food businesses in the UK. All participants reported that they did not experience food fraud during COVID-19. The main risk mitigating strategies included horizon scanning; developing and maintaining supplier relationship and assurance; understanding product characteristics, testing capabilities, conducting vulnerability assessments and training. One food business (Participant [P14], food importer) was able to circumvent food fraud during the pandemic due to strategies adopted at their establishment.

3.2. Experiences of food fraud

Some participants shared their experiences of food fraud during their careers (not during COVID-19) as lessons for other agri-food businesses. Incidents included adulteration of garlic puree with water and onion, addition of chalk to garlic powder and adulteration of buffalo mozzarella with cow's milk. There were also incidences where soy lecithin was substituted with peanut lecithin and where a forged BRCGS certificate was detected. Due to horizon scanning, P14 (food importer) was aware that ethylene oxide products were being diverted into the food supply chain and was able to circumvent the incident. Below were examples of food fraud incidents which were detected as a result of mitigating strategies and due diligence.

> 'When you look at standard garlic and even when you puree it, you should get moisture content of around I would say 65–70%, but we will find moisture content all the way up to 96%. Through volatile analysis, we found other spikes on the volatile chromatograms and we tie that back into onion.' (P6, Poultry supply chain)

> 'We did a trace back to source with one of our suppliers and their supplier in China had actually falsified their BRCGS accreditation certificate. It was an incredible, incredibly well forged document.' (P7, ready meal manufacturer)

3.3. Food fraud during COVID-19

3.3.1. Anticipation and sense of preparedness

Most participating companies reported to the best of their knowledge that they were not affected by food fraud during COVID-19. In fact, there was a heightened sense of preparation and anticipation of increased incidents during the pandemic. Organisations rely on multi-strategies to assess, detect, deter or prevent food fraud.

> 'We were fully preparing ourselves for the fact that there could be more potential for food adulteration. It hasn't transpired.' (P4, Dried ingredients manufacturer)

> 'Not that we know of. We expect, you now, I think there is an element on one being worried about availability, but weren't affected. (P5, ready meal manufacturer)

> 'During COVID-19, there was ethylene oxide products coming out of India, but luckily we had predicted that in terms of horizon scanning.' (P14, food importer)

Some participants however, cautioned that food fraud incidents may

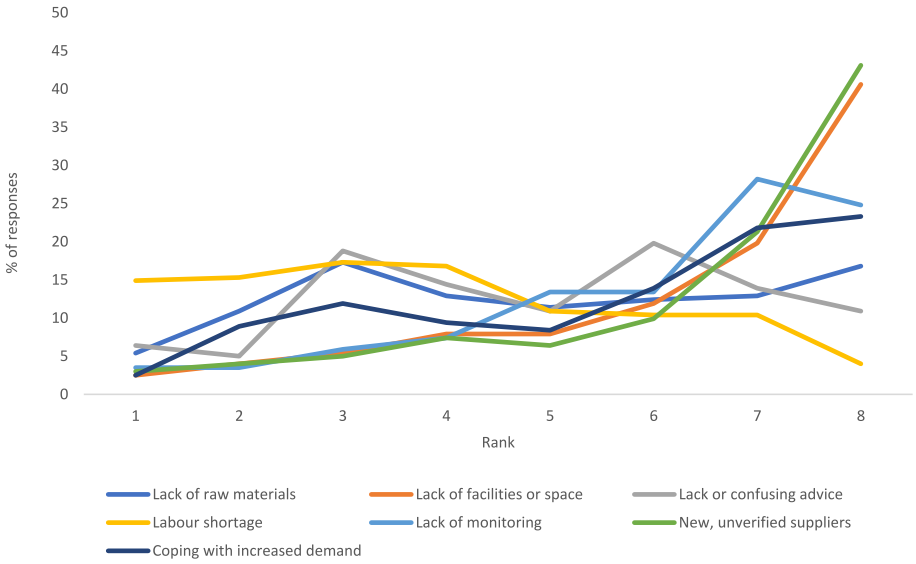

Fig. 1. Impact of COVID-19 on food business (1 = severe impact; 8 = least impact).

Table 3
Food fraud during COVID-19 (n = 202).

No.	Items	[a]Mean ± SD	Mode
1)	During COVID-19, my business experienced:		
a	*improper, fraudulent, missing, or absent health certificate from suppliers*	1.55 ± 0.89	1.00
b	*illegal or unauthorised import, trade, or transit from suppliers*	1.52 ± 0.92	1.00
c	*adulteration, tampering, substitution, or dilution from suppliers*	1.55 ± 1.00	1.00
d	*improper, expired, or missing import declaration/ documentation from suppliers*	1.60 ± 0.94	1.00
e	*mislabelling from suppliers*	1.62 ± 0.98	1.00
f	*theft and resale from suppliers*	1.43 ± 0.83	1.00
2)	My suppliers can be trusted to		
a	*monitor food fraud during COVID-19*	3.82 ± 1.23	4.00
b	*take effective measures against food fraud during COVID-19*	3.88 ± 1.17	4.00
3)	Regulatory authorities can be trusted to		
a	*monitor food fraud during COVID-19*	3.30 ± 1.10	3.00
b	*take effective measures against food fraud during COVID-19*	3.34 ± 1.13	3.00
4)	Using new, unverified food suppliers may increase likelihood of fraud during COVID-19	3.80 ± 1.12	4.00
5)	Lack of regulatory monitoring during COVID-19 may increase likelihood of fraud	3.70 ± 1.06	4.00
6)	Competition for raw materials/ingredients may increase likelihood of fraud during COVID-19	3.73 ± 1.05	4.00
7)	COVID-19 is a main trigger for food fraud	2.42 ± 1.02	3.00

[a] Where 1 = strongly disagree; 5 = strongly agree.

not have been reported during the pandemic, but incidents could arise at a later stage. Small and medium food businesses were potentially more vulnerable to food fraud during COVID-19.

> 'We were pleased as an industry to see there wasn't an uptick in our supply chain yet, and I say yet because it might, it might follow because dried ingredients have quite long shelf-life, they can be in warehouses and storage for a long period of time, so it could be, you know, 18 months on, two years on from COVID when you start to see the problem.' (P4, Dried ingredients manufacturer)

3.3.2. *Other pressure points helped to prepare food supply chain*

The sense of preparedness was also due to other pressures or incidents that occurred in the UK food supply chain. The Horsegate scandal shook the food industry and led to the implementation of the strategies proposed by Elliott (2014) in his report on the integrity and assurance of food supply networks. Some food companies also felt that they were more prepared due to Brexit as products and processes were simplified. Respondents also commented that the food supply chain was always under constant pressure over the past few years. They had to deal with issues associated with the Suez Canal, geopolitical threats, climate change and its effects on food availability, cost of living crisis and inflation. The constant pressures drove food businesses to be more prepared in dealing with uncertainties and crises.

> 'Although we didn't have the threat (of horsemeat), the incident itself cost a lot of time and a lot of money because we had to do constant DNA sampling. I think the Horsegate scandal along with Elliott report made the huge fundamental shift and change our attitude towards food fraud.' (P12, Dairy product manufacturer)

> 'Yeah, maybe we were better prepared because of Brexit. We've switched our approach to using dedicated clearance agents and shipping agents.' (P10, Storage and distribution)

> 'Because of Brexit, members had been, um, shall we say, simplifying their product ranges so that we're not relying on as far as possible on European sources because we knew that the supply chain would be damaged by Brexit as it has. So that meant, you know, less variety and then even less opportunity for anything to go wrong.' (P1, Trade Association)

3.3.3. *Adaptive and resilient in between lockdowns*

Most participants revealed that there were very little differences in strategies between the first (March to June 2020) and second lockdown (November 2020). The existing strategies assisted food businesses to assess risks and vulnerabilities and potentially prevent food fraud incidents. Over the two national lockdowns, food businesses adapted to the restrictions and changes that occurred during the pandemic. Although there were increased lead times, shortage of supply, reduced staff and increased demand for specific food items, the participating food businesses demonstrated resilience at times of uncertainties.

> 'So, in the second lockdown, people were much more ready if you see what I mean. The first lockdown actually made people challenge,

Table 4
Strategies adopted by food businesses to mitigate food fraud during COVID-19 (n = 202).

No.	Items	Cluster 1 (Post-processors) Frequency (%)	Cluster 2 (Primary and secondary processors) Frequency (%)
1	**Type of food business**		
a	Plant-based	0 (0)	34 (100)
b	Animal-based	8 (16.0)	42 (84.0)
c	Mixed	86 (72.9)	32 (27.1)
2	**Stage of food business**		
a	Farm	0 (0)	5 (100)
b	Processing	9 (12.5)	63 (87.5)
c	Post-processing	85 (68.0)	40 (32.0)
3	**Increase in fraudulent activities**		
a	Yes	9 (75.0)	3 (25.0)
b	**No**	**65 (41.1)**	**93 (58.9)**
c	Unsure	20 (62.5)	12 (37.5)
4	**Location**		
a	England	79 (46.7)	90 (53.3)
b	Northern Ireland	3 (75.0)	1 (25.0)
c	Scotland	1 (9.1)	10 (90.9)
d	Wales	0 (0)	4 (100.0)
5	More than one country	11 (78.6)	3 (21.4)
a	**Number of employees**		
b	Less than 50	37 (57.8)	27 (42.2)
c	51–250	30 (33.7)	59 (66.3)
d	More than 250	27 (55.1)	22 (44.9)

No.	Items	Cluster 1 (Post-processors) (n = 94)		Cluster 2 (Primary and secondary processors) (n = 108)		Clusters 1 and 2 (t-value)	Overall (n = 202)	
		[a]Mean ± SD	Mode	Mean ± SD	Mode	t	Mean ± SD	Mode
1	My business:							
a	increases the number of sampling and testing to verify food authenticity	3.26 ± 1.08	3.00	2.35 ± 0.99	3.00	6.28**	2.78 ± 1.13	3.00
b	increases monitoring and surveillance of the food supply chain	3.85 ± 0.89	4.00	2.82 ± 1.20	4.00	6.96**	3.30 ± 1.18	4.00
c	conducts vulnerability assessments in the food supply chain	4.35 ± 0.65	4.00	3.92 ± 1.06	4.00	3.45**	4.12 ± 0.92	4.00
d	conducts remote food safety audits	3.90 ± 1.05	5.00	2.81 ± 1.35	4.00	6.45**	3.32 ± 1.33	4.00
e	uses Blockchain technology to secure documentation and transactions	2.21 ± 1.13	1.00	1.80 ± 1.03	1.00	2.73*	1.99 ± 1.10	1.00
f	uses forensic accounting to mitigate financial fraud in food trade	2.32 ± 1.12	3.00	1.69 ± 0.92	1.00	4.29**	1.99 ± 1.06	1.00
g	joins the food community support network for updates	3.84 ± 1.06	4.00	3.16 ± 1.42	3.00	3.91**	3.48 ± 1.31	4.00

[a] Where 1 = strongly disagree; 5 = strongly agree; **p < 0.001; *p < 0.05.

actually how quickly can we do this? How can we simplify it? Can we reduce what we ask for? So yeah, well the second lockdown people were much more prepared because they've done it all before.' (P3, Food manufacturer)

'There was an element of panic buying, there was disruption to supply chains. Therefore, there was a need to access other supply chains, maybe a little bit more. It's a blip and the industry has proved itself, particularly the food industry in the UK. I think we've got great standards and you can see that from food safety BRC, the way that the industry has adopted that. It's probably global leader in that area.' (P6, Poultry supply chain)

3.3.4. *Geopolitical tensions were more concerning than COVID-19*

Geopolitical tensions were identified as more threatening compared to COVID-19 as conflicts may escalate food fraud vulnerabilities. Several food businesses revealed that dealing with the implications of Brexit, war in Ukraine, China's repressions of Uyghurs and possibility of Chinese invasion of Taiwan were more challenging. Such issues posed challenges in sourcing for raw materials and finding alternative supplies whilst ensuring food integrity. Food integrity does not only assure the safety, authenticity and quality of food; it should encompass all aspects of food production including the way it has been sourced, procured, distributed and being honest about the claims to consumers (Elliott, 2014). A participant shared experiences of their food industry in reducing their sources from China which led to possible misrepresentation of food origins due to the change.

'The industry has pulled away from China, from Chinese paprika, especially paprika coming from Xinjiang province due to the treatment of the and I can't pronounce this … Uyghur people? Yeah, so there has been a lot of noise around human rights violations. Retailers jumped on it immediately and said we don't want to buy from here. So, when all of a sudden, this source needs to be removed, supply chain started to buckle under the pressure. So, of course the price went up and everyone was struggling to source outside of that area, and what we found was that, so everyone pretty much switched to Indian supply. However, what transpired was that paprika was moved from China to India and then used as Indian one.' (P8, Ambient low risk food manufacturer)

'So, if you look at a map, we will look at it from a geopolitical point, which is probably one of our weakest areas. Because you know what happens if China does invade Taiwan? What's the impact? Do we sanction, throw the same sanctions at China as we have done at Russia? Because we're all in big trouble if we do that.' (P6, Poultry supply chain)

3.3.5. Can't put a price on preventing food fraud

Although participants' companies invested in food safety and food fraud prevention strategies, the overall costs were difficult to estimate or were never estimated. What was clear from the interviews was that one can't put a price on preventing food fraud. Typical costs included testing, auditing, costs of accreditation, training, culture change and implementing extra controls upon risk and vulnerability assessments and staff time. Participants agreed that there were also costs associated with buying from certified manufacturers. Some food businesses dedicated a significant budget to investing in new tools such as horizon scanning, blockchain technology and advanced laboratory and molecular analysis. Some quoted costs ranged from £5,000 - £10,000 on DNA testing to an overall technical budget in excess of £500,000 per year.

> 'It's not really a cost you associate with stability. We, you know, we as a retail manufacturer as I said before, you know, we care about food safety, we care about vulnerability etcetera. So, we insist on only buying products from manufacturers that have third party accreditation. There's a cost to that obviously but everyone in the industry who supplies retailers will also be bearing that cost.' (P5, Ready meal manufacturer)

> 'In terms of raw materials, do you pay a little bit more to get raw materials from certain supply chains? As an example, say spices, you could probably get the spices that we utilise a lot cheaper, but your risk is massively higher, so therefore actually do you pay a little bit more to give you confidence in quality, safety and authenticity? Yes, you do. But again, it's very difficult to put a price on that.' (P6, Poultry supply chain)

3.4. Strategies to mitigate food fraud

3.4.1. Information is power

Horizon scanning was identified as one of the key strategies to protect food businesses from food fraud. Tools ranged from open-source databases such as national and international governmental alerts, Rapid Alert System for Food and Feed (RASFF), European Commission's Joint Research Centre (JRC) Food Fraud Monthly summaries and media to paid databases such as Decernis Food Fraud Database and FERA HorizonScan. Some participating food businesses were also members of Food Industry Intelligence Network (FIIN), Leatherhead Food Research, Campden BRI or Food Authenticity Network (FAN). Being part of such networks was crucial in keeping updated with scientific and authenticity affairs. Information and data could be gathered from the procurement team, suppliers, Environmental Health Officers, customers and auditors. Having access to food authenticity tests, food fraud incidents, raw materials' availability and demand, political and environmental changes assisted food companies in spotting opportunities for food fraud.

> 'A lot of it has to do with having good sources of information and then having the resource to scan those sources and to act upon any issues that come up.' (P8, Ambient low risk food manufacturer)

> 'Very fortunately had been listening to Farming Today on the radio, and I drove to work at 5.30 in the morning and it was mentioned that tens of thousands of horses were missing Europe, I'm gonna believe, into the food chain. I got to work and I said to my boss, I'm gonna send some products off for DNA horse testing. They look at me like I was a raving lunatic. Five days later, the horsemeat scandal broke out. We were already ahead of the game.' (P7, Ready meal manufacturer)

3.4.2. Supply chain relationship and assurance

Having a robust Supplier Quality Assurance was a key strategy. The participants mentioned using reputable and trusted suppliers who were certified by the Global Food Safety Initiative (GFSI) scheme. GFSI certified businesses provided a high level of assurance within the food supply chain. Based on P7's (ready meal manufacturer) experience where their supplier falsified their BRC accreditation, P7 cautioned that one should always verify the suppliers' accreditation. All participants carried out risk and vulnerability assessments of their supply chain. Building trust and having an honest, open conversation with the supply chain during COVID-19 were essential. The dried ingredient manufacturer (P4) and dairy products manufacturer (P12) maintained short supply chains to reduce food fraud. Short supply chains increase visibility and strengthen their relationship.

> 'We have worked tirelessly to develop those supplier relationships so that we can get that sight back to farm as much as possible.' (P4, Dried ingredients manufacturer)

> 'I guess the worst thing you can do is go, I'm not gonna accept any changes. If the supplier goes, I haven't got any option, I'll just put a bit of that in, there you go. So, I suppose our strategy at that point was to make sure that we had a very open communication chain between our retailers and our supply chain.' (P5, Ready meal manufacturer)

3.4.3. Understand product characteristics, vulnerabilities and testing capabilities

Vulnerability assessments were conducted on raw materials and ingredients to identify areas of risks and to implement control measures. For example, P9 (food packaging printer) assessed for potential fraud in their raw materials such as packaging boards. Paper and carton boards may be substituted with different materials that may have a change in odour or not as hygienically safe. Soy lecithin that was adulterated with peanut lecithin also drove P8 (ambient low risk food manufacturer) to switch to sunflower lecithin.

> 'So, we, our solution was to switch to sunflower lecithin. We have been working on a project to remove soy lecithin entirely because the control is not there currently with our product.' (P8, Ambient low risk food manufacturer)

Raw materials and product specifications helped to define what they were buying. P6 (ready meal manufacturer) who purchased adulterated garlic puree (adulterated with water and onion) used the incident to define and establish volatile levels in their specifications. Thus, understanding product characteristics were identified as one of the key strategies. The physicochemical properties (e.g., particle size, gelatinisation point) and content of different chemical parameters (water, sugar composition and carbon content) were inherent characteristics, which makes it more difficult to adulterate the product. Product testing (e.g., DNA, physicochemical parameters, fatty acid profiles, isotopic analysis) was another strategy to verify the safety, quality and authenticity of their products.

> 'If you are getting baobab from Southern Africa, you may get risk of the ingredients being in there like maize flour, but we do that by checking the presence of raffinose. It's a starch that you get in other starches as a sugar, but you don't get it in the baobab.' (P14, Food importer)

3.4.4. People-centred approach

The importance of training was widely acknowledged by all participants. Staff awareness and role competence act as the first line of defence against food fraud. Thus, investment in staff development was key. Several participants mentioned 'culture change' whilst maintaining good communication internally and with the supply chain formed part of their food fraud mitigating strategies.

> 'Are you in good communication with procurement team? Making sure that people in procurement know what they're buying and that they raise, you know, someone's coming up with something. We can

buy this raw material, but it's a lot cheaper.' (P3, Food manufacturer)

P4 (Dried ingredient manufacturer) was focused on building and maintaining an integrity culture. The food business also provided a whistleblowing platform for their staff and suppliers.

'And we also have whistleblowing provision. So, if somebody believes that they are, you know, under pressure to commit a food crime and they want to talk about it anonymously or even they suspect something like that, then we have a provision to report that anonymously.' (P4, Dried ingredients manufacturer)

3.4.5. Cost-effective strategies for SMEs

Participants proposed some cost-effective strategies to reduce or prevent food fraud in small and medium food enterprises (SMEs) as their existing strategies may not be applicable to SMEs. Buying from trusted, approved or local suppliers resonated among the participants. Asking questions, ensuring traceability is in place and simply verbalising that food fraud or food crime is not tolerated could act as deterrents. Understanding market tariffs and knowing the average price of raw materials could counter potential fraud. SMEs may have limited resources to test their products, hence risk and vulnerability assessments are key. Identification of high-risk products and using a targeted approach to implement control strategies would help to reduce costs. SMEs could seek advice or support from Food Authenticity Network (FAN) which is free to join, and it provides one-stop resources on how to mitigate food fraud.

'If you were in a position where you have choices over what raw materials you can use, go for low-risk ones. If you've got a high-risk raw material, then it would be around purchasing it from a recognised supplier. (P2, Technical consultant)

'If the price seems too good to be true for something they are paying for, then to go with their gut. It probably is too good to be true' (P4, Dried food ingredients manufacturer)

'Look at what your true risks are and put your focus in there because you won't be able to do everything. You're just scattering the wrong approach to it, and you'll never detect anything.' (P5, Ready meal manufacturer)

4. Discussion

COVID-19 was not identified as a main trigger for food fraud. Most food businesses reported that they did not experience food fraud during the pandemic. This study supports the findings from Crew (2021), Frera et al. (2021) and Points & Manning (2020). The preparedness and heightened sense of anticipation among food businesses could have been a potential deterrent during the COVID-19. It is possible that the food supply chain was focused on the impacts of COVID-19 and the lack of demand for certain foods (e.g., foods in catering services), due to closure of shops, which could have reduced the motivation for food fraud. Food fraud vulnerability increases when demand exceeds supply (van Ruth et al., 2017). Similarly, when supply exceeds demand, it diminishes the incentives to commit fraud (Wolfe & Hermanson, 2004). Although most participants reported that they did not experience food fraud during the pandemic, we cannot rule out the possibility of undetected and/or unreported food fraud incidents. It is possible that some businesses may not have been recording food fraud incidents before or after Covid, as they may have been treated as a Business-to-Business (B2B) 'incident' labelled as something else (Cox et al., Forthcoming). Some food businesses would prefer not to publicise a fraud that would damage their reputation or expose vulnerability in the system (Points & Manning, 2020). Additionally, 62% of the participants were post-processors and were less vulnerable to food fraud. Previous studies had identified primary and secondary processing as more vulnerable to fraudulent activities since these were the points where original food materials were altered (e.g., mincing, filleting, grinding) making them indistinguishable from other similar products (Robson et al., 2020; Soon & Abdul Wahab, 2022).

Previous pressure points that occurred in the supply chain taught the UK agri-food industry valuable lessons. The Horsegate crisis exposed the vulnerabilities of complex food supply chains and since the publication of The Elliott Review (2014), the UK agri-food industry has adopted the recommendations to mitigate and prevent food fraud (Brooks et al., 2017). The ability to adapt to national restrictions and changes that occurred during the pandemic were highlighted by the participants. Our findings reflected Moran et al. (2020) and Mitchell et al. (2020) that despite significant disruptions, the UK food system has remarkable adaptive capacity. Building trust and having open, effective communications (Sharma et al., 2022; Wulandhari et al., 2022) with suppliers and stakeholders (Kazancoglu et al., 2021) contributed to organisational resilience during the pandemic. Being risk aware and responsive, having the IT capabilities and flexibility were some of the enablers of resilience in food supply chains (Kazancoglu et al., 2021).

Geopolitical issues were identified as more concerning than COVID-19. Prior to the war, Russia and Ukraine accounted for roughly 30% of global wheat exports, 20% corn exports and more than half of the global sunflower oil (Burke, 2022; Osendarp et al., 2022). The conflict has interrupted supply chains, resulted in price hikes and threatened food provision in dependent countries. Such factors increase food fraud vulnerabilities in the food supply chain (Barrere et al., 2020). Thus Everstine et al. (2021, pp. 23–43) recommended to estimate the geopolitical risk of countries by reviewing information such as country risk classification (AMFORI, 2019) and corruption levels for ingredient sourcing countries (Transparency International, 2022).

Costs of food fraud were estimated at £11.97 billion in the UK (Gee et al., 2017) and between US$10–15 billion per year in the global food and drink industry (GMA, 2010) to US$30–40 billion for global losses to food fraud (PwC, 2013). Such figures helped to encourage the global food industry to take risk mitigating strategies (Cox et al., 2020). It was evident that food businesses understood the significant threat of food fraud to public health and the economic costs associated with it. In fact, understanding the impact of food crime, including food fraud, on the UK economy and society is one of the key research priorities of the Food Standards Agency, UK (FSA, 2022). In addition to the economic impact of food crime, there are food crime prevention costs that are mentioned, and these include investments in technical expertise, horizon scanning tools, product authenticity tests, supplier quality assurance, training and risk mitigating protocols. Such prevention costs are needed to assure food integrity. Horizon scanning, models such as the Vulnerability Analysis and Critical Control Points (VACCP), reporting systems, human intelligence have all been proposed as measures used to prevent food crime (Cox et al., 2020; Steinberg, & Engert, 2019).

Food businesses agreed that they used food fraud vulnerability assessments as one of the key strategies against food fraud. This echoes Soon et al. (2019) where most food businesses utilised their own in-house food fraud vulnerability assessment tools or used the Campden Threat Assessment and Critical Control Point (TACCP). Larger food chains had also requested Vulnerability Assessment and Critical Control Point (VACCP) plans from suppliers demonstrating the value of such vulnerability assessment tools (Crew, 2021). As part of the TACCP assessments, food businesses conducted horizon scanning to scan for new or emerging threats (BSI, 2017). Horizon scanning had proven useful as early warning tools for food fraud as indicated by Bouzembrak and Marvin (2016) and Marvin et al. (2022). Thus, having the resources to scan information and act upon them is crucial. Overall, food businesses agreed that they joined food community networks to keep updated with food alerts and food safety information. An excellent example is the Food Authenticity Network which has created a COVID-19 resource base to tackle pandemic-related food fraud issues (Food Authenticity

Network, 2022). Alrobaish et al. (2022) revealed that both techno-managerial (control and assurance activities) and human factors affect the food integrity culture of a food establishment. The participants in our study were focused on building trust with their supply chain, invested in people-centred approaches and cultural change which could improve the integrity climate of the organisation. This has been demonstrated by Alrobaish et al. (2022) where having a high food integrity culture is associated with low fraud vulnerability.

5. Limitations

This study has several limitations including limited number of participants in the online survey, more than 80% of the responses were from England and findings were based on self-reports. The survey respondents were highly concentrated in packaging, followed by primary and secondary processing. Thus, the responses were less representative of the farm, retailing and catering services. Food fraud is a constant challenge due to the variety and diversity (often unknown and un-tested) of adulterants used in food. As the findings were based on experiences/opinions of participants and the use of vulnerability assessments as a management tool, there is a possibility that some fraudulent incidents remained undetected since the study excluded food authenticity testing. There is a possibility for optimistic bias where individuals believe they are less likely than others to experience negative events (da Cunha et al., 2014). All the participants in the semi-structured interviews were from large food establishments or were technical consultant(s) for large food companies that were GFSI accredited. It is likely that most interviewed participants were from Cluster 1 and had the technical expertise and resources to carry out mitigating strategies. Thus, the study was less able to capture views from small and medium enterprises. Participants who were interested and motivated in the topics were also more likely to participate in the study. This introduced selection bias among our participants. However, due to the mixed-method approach of the study, the quantitative and qualitative methods showed consistency between its findings and those from previous research.

6. Conclusion

Majority of food businesses did not experience food fraud during COVID-19. Large food businesses were more likely to carry out preventative strategies such as increased testing, vulnerability assessments, remote food safety audits and participated in food community support networks to mitigate food fraud. During the pandemic, food companies anticipated and prepared for increased fraudulent activities in the food supply chain, but food fraud incidents did not transpire. Previous incidents such as the Horsegate Scandal had revamped the UK food industry and as a result, the food supply chain was more prepared against fraudulent activities. Geopolitical tensions were identified as more concerning than COVID-19 and conflicts in regions to possibly escalate food fraud vulnerabilities. Participating food companies utilised a diverse range of risk mitigating strategies to assess, detect, deter and prevent food fraud. This included horizon scanning, building trust and maintaining an open and honest communication with the supply chain, vulnerability and risk assessments, training and staff awareness. However, it is possible that the lack of reported food fraud incidents was due to decreased regulatory oversight during the pandemic. Food supply chains should remain vigilant and adaptive in their risk mitigating strategies to prevent and/or deter food fraud. SMEs should be better supported to ensure they could adopt cost-effective strategies that are practical and feasible. SMEs have limited resources for testing; hence risk and vulnerability assessments are key. Identification of high-risk products and using a targeted approach to implement control strategies would help to reduce costs. Further research to explore the mitigating strategies of small and medium food businesses should be carried out.

CRediT authorship contribution statement

Jan Mei Soon-Sinclair: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Project administration, Writing, Data curation, Investigation, Writing. **Shingai Nyarugwe:** Data curation, Investigation, Writing. **Lisa Jack:** Conceptualization, Investigation, Writing.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

The data that has been used is confidential.

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Appendix A. Supplementary data

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