




Agri-food fraud in Africa vis-à-vis global health

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Abstract

This paper reports on the extent of agri-food fraud in Africa, its occurrence across the Africa-EU trade borders, and associated implications for global health. It revealed that agri-food fraud in Africa and across Africa-EU trade borders may be a concern. Meanwhile, a few suspected cases have been reported, there may be more unchecked/unnoticed agri-food fraud practices ongoing in Africa requiring food trade border checks and rapid decisions making processes to reduce exposures. Exposure to adulterants can have significant implications for global health, as consumers unknowingly pay for, and consume, products that may be adulterated with substances which constitute a risk factor to one or more unchecked hazards against consumers' health protection. As global trade in agri-food products expands, the supply chain vulnerability to fraudulent activities becomes increasingly evident. This may be worse partly due to the inadequate food safety laws in African countries or poor enforcement. There is a need for food safety regulations in Africa that aim to ensure the safety and authenticity of food products, protect public health, and maintain consumer confidence. Finally, there is a need for rapid detection tools to make quick decisions on the field and agri-food traceability systems.

Keywords: Africa-EU trade border, Agri-Food fraud, Authenticity, Consumers' health, Traceability, Global health.

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Contribution of this paper to the literature

The agri-food fraud situation in Africa and incidence across trade boarders – a scenario which may be largely unchecked requiring authenticity assessment and fraud detection studies in Africa. The potential bearing of agri-food fraud in Africa on consumers health globally as per the food supply chains.

1. Introduction

As the world population grows exponentially, nowadays, consumers can hardly ascertain the origin or authenticity of the several scarce and long-supply chain agricultural commodities or foods we pay for. The rate of agri-food fraud is alarming as many sellers, retailers, and individuals nationally and internationally have indulged in this deceiving practice for economic gain. Agri-food fraud poses a significant challenge to the integrity of the global food supply chain, with potentially severe consequences for human health. According to the European Commission [1] agri-food fraud is “a non-compliance concerning any suspected intentional action by some fraudsters to deceive purchasers and gain an undue advantage thereof, in violation of the rules referred to in Article 1(2) of Regulation (EU) 2017/625” [2]. The repercussions of agri-food fraud extend far beyond economic losses to profound concerns for consumers’ health [3]. Agri-food fraud, encompassing a range of deceptive practices within the agricultural and food sectors, jeopardizes the safety and authenticity of food products [4]. The consequences of consuming adulterated or misrepresented food items can be severe, leading to adverse health effects and compromised nutritional value [5]. However, there is inadequate information on suspicious agricultural commodities or food products crossing the African trade borders.

2. Methodology

This scoping review paper has reviewed and summarized evidence from existing literature on agri-food fraud in Africa and across the Africa-European Union borders. The quality of each existing study of interest was not rigorously assessed. The search was based on agri-food fraud speculations involving any agri-food commodities, and cases of suspicions whether in Africa or abroad as long as the origin of the commodities could be confirmed to have originated from Africa. Additionally, this review probed into potential associated health implications that may arise should consumers consume such manipulated agri-food commodities. Keywords such as agri-food fraud, Africa, exposure, and health were used to search for relevant datasets on various search engines such as Google. The review was conducted using data obtained from online publications such as Google Scholar, Web of Science, and Scopus. In addition, a manual search for relevant literature was carried out using reference lists to include relevant studies, published in the English Language, and published between 2000 and 2024. When necessary, tables and figures were added to the narrative presentation of the results.

3. Results and Discussion

3.1. Agri-Food Fraud Suspicious Incidence Across the Africa-EU Trade Borders

Of Agri-food fraud in Africa have revealed the magnitude of deceptive practices that span from the farm (production) to the market (processing and trade) making food susceptible to fraud at any stage’ [6]. For example, at the primary production stage, instances such as apiculture demonstrate how adulteration can occur. For example, a finished product of apiculture, honey, which is a highly valued product consumed worldwide as a sweetener and medicine has had a decreased rate of interest and trust because of its vulnerability to adulteration. Honey is easily manipulated by illegally mixing it with syrups or sugars to increase volume and profitability [7, 8]. This not only diminishes the quality and nutritional value of the honey but also poses health risks to consumers who may unknowingly ingest substandard products. As products move from the farm to the market, fraud extends to finished goods, thus the longer the food supply chain, the higher the risk of fraud occurring. An example is the mislabeling of olive oil, wherein lower-grade oil is labeled as premium "extra virgin" olive oil [9]. This misrepresentation not only deceives consumers but also undermines the reputation of genuine producers and affects trade relations [8]. Similarly, herbal medicine and spices are susceptible to substitution, with inferior or cheaper herbal medicine and spices being presented as premium variants [10, 11]. Moreover, counterfeiting of dairy products - where fake versions of branded items are sold [12] not only jeopardizes consumer health but tarnishes the reputation of business brands. As the world population grows exponentially, the pressure to meet food demand may serve as a motivation for perpetrators of food fraud practices. Furthermore, mislabeling, a prevalent form of food fraud, has increased from 33% in 2015 to 47% in 2019 globally’ [13]. As predicted by the Consumers Brand Association, food fraud may cost between 10 - 15 billion USD loss to the global food industry, hence affecting 10% of all world food products that are being commercially sold [14].

There is little evidence of agri-food fraud across the African and European trade borders. This fraudulent activity encompasses a range of practices, including mislabeling, adulteration, counterfeiting, and misrepresentation of food products (Table 1 and 2). Some food categories particularly vulnerable to fraud in cross-border trades were identified (Table 1 and 2). Notably, dairy products, seafood, spices and herbs, olive oil, honey, and fresh produce emerged as high-risk categories, with documented fraud incidents. Generally, several common agricultural commodities or foods are vulnerable to fraud, each with a spectrum of potentially fraudulent practices (Table 1). Additionally, some instances of manipulated agri-food products have been detected in some African markets/countries (Table 2), some of which might have been destined to cross the trade borders between Africa and Europe. These incidents involve mislabeling seafood species, adulteration of olive oil with lower-grade oils, and the presence of contaminants in spices and herbs.

Table 1. Incidence of agri-food fraud in farm and market settings in Africa.

Stage	Fraudulent Practices	Total	Percentage (%)	Examples	Citations
Farm	Adulteration in apiculture	111	2.2	Mixing honey with syrups or sugars	Fakhlaei, et al. [7]; Handford, et al. [12] and Marvin, et al. [15]
Production site	Adulteration of beer and alcoholic beverages	nd	nd	Addition of illegal substances like strychnine	Shears [16]
Market	Adulteration of milk and milk product	526	10.5	Addition of urea, formalin, detergents, ammonium sulphate, boric acid, caustic soda, benzoic acid, salicylic acid, hydrogen peroxide, sugars and melamine in milk	Marvin, et al. [15] and Azad and Ahmed [17]
	Mislabeled olive oil			Labeling lower-grade oil as extra virgin olive oil	Girelli, et al. [9]
	Substitution of spices and herbal Medicine	99	2.0	Substituting cheaper spices and herbs for premium ones	
	Counterfeit dairy products (poultry meat and poultry product)	384	7.6	Selling fake versions of branded dairy products	Osman, et al. [11]; Kamboj [10]; Handford, et al. [12] and Marvin, et al. [15]
	Red palm oil			Addition of Sudan dye IV (a carcinogenic compound / azo dye)	
	Eggs and egg products	63	1.6	Contains harmful substances such as benzoic acid, sodium alginate	Handford, et al. [12] and Marvin, et al. [15]

Table 2. Reported Agri-food fraud incidents in some African countries and speculated health implications.

Country, Sub-African region	Food type	Agri-food fraud practice	Potential health implications	Citations
Cameroon, Central Africa	Red palm oil	-Use of azo coloring dye (Sudan dye IV)	Sudan dye IV is well known as a carcinogen	Toukap and Abia [18]
Nigeria, West Africa	Fat and oil, Alcoholic and Non-alcoholic drinks, Honey, sugar, Milk	Honey being diluted with syrup and milk counterfeited with no animal protein	Loss of consumers' trust in the product.	Opia [19] and Nagel [20]
Ghana, West Africa	Red palm oil	Sudan dye IV is being mixed in palm oil	Sudan dye iv is a carcinogen. It has the potential to cause cancer	
Kenya, East Africa	Vegetable oil	Vegetable oil made from recycled oil which is harmful to humans	Deceive consumers and give less confidence to the brand.	Nagel [20]
Egypt, North Africa	Wheat	Illegal addition of wrong or bad amount of wheat	Deceive consumers of the choices they want	Mabrouk, et al. [21]
Morocco	Olive oil	Olive oil counterfeiting by adulteration with cheaper oils		Ellyat [22]
Nigeria and Ethiopia	Honey	Substandard honey diluted with sugar syrup		Orina [23]
African nations (such as Ghana, Morocco, Senegal, The Gambia, Egypt, Kenya, Togo, Madagascar, Uganda)	Shrimps, sole (fish product), vegetables (e.g. spinach leaves) and fruits (e.g. oranges), etc	Shrimps to which sulphites (E 220 – E 228) were added as additives, and non-compliance in cases of vegetables and fruits e.g. being tainted with pesticide residues		European Commission (EC) [24]

Recently, according to the European Commission's first (January 2024) monthly agri-food fraud suspicions report on the EU Agri-Food Fraud Suspicions [24] majority of suspicions were at border control followed by market control. Several suspicious commodities were from Africa. For example, shrimps from Senegal were suspected to be tampered with using sulphites (E 220 – E 228) (471 mg/Kg) as notified by Spain and classified as Additives not compliant with EU Maximum limits (MLs). Likewise, sole (fish product) from Gambia was manipulated using *Cynoglossus senegalensis* instead of *Synaptura* spp as notified by Italy and classified as Adulteration (ingredient substitution) [24]. Furthermore, a series of non-compliances (implicit claim violations) classified as Residues of pesticides not compliant with EU Maximum Residue Limits (MRLs) mainly involving fruits and vegetables originating from Africa specifically, Egypt (vine leaves, carrots, mandarins, oranges, and strawberries), Kenya (mangetout peas and peppers), Ghana (pineapples), Madagascar (cowpeas), Togo (spinach leaves), and or Uganda (peppers) were suspected in Europe as notified by Belgium, Netherlands, Slovenia, Romania, Italy or Germany [24]. Meanwhile, there may be more unchecked and unnoticed food fraud situations, these further emphasize the need for food trade border checks for rapid decisions toward reducing exposures and protecting consumers' health [25]. Therefore, "one fraud anywhere may equate to several consumers in one world – the One Fraud to Consumers in One World concept – Abia 2024". This further complements the relevance of the potential agri-food fraud across Africa-EU trade borders and calls for action.

The trade relationship between Africa and the European Union (EU) is a pivotal nexus in the global food supply chain, facilitating the exchange of agricultural and food products. This trade corridor does not only support economic growth but also presents opportunities for cross-cultural cooperation and development. Agriculture commodities or foods are traded across the Africa-EU trade borders from African countries to the European markets or from the European countries to the African nations, thus constituting an import-export traffic situation. African countries export a diverse range of products to the EU, including fruits, vegetables, coffee, cocoa, nuts, and various processed foods while European countries also export products to Africa such as machinery, pharmaceuticals, and industrial goods [26, 27]. However, within this trade relationship, vulnerabilities to agri-food fraud emerge, as products traverse complex supply chains, diverse regulatory frameworks, and varying economic conditions.

Agri-food fraud, a multifaceted issue characterized by deceptive practices in the food supply chain, has emerged as a critical challenge in the global trade of agricultural commodities and food products [28]. The rate of agri-food fraud has become an increasing problem globally in the food industry and for consumers with sellers seeking to capitalize on financial gains [29]. In this context, the trade relationships between Africa and the European Union (Africa-EU) have garnered attention as a hotspot for agri-food fraud. These trade borders form a critical juncture in the global food trade, where products navigate complex supply chains, regulatory variations, and socio-economic disparities. This dynamic trade relationship presents opportunities and challenges, making it an important focal point for understanding the intricacies of agri-food fraud and its implications.

Given that agricultural commodities and food products are traded commonly across the Africa-EU trade borders, certain food categories are particularly susceptible to fraudulent activities in this trade relationship. This may partly be due to factors such as high demand, diverse supply sources, and challenges in traceability [13]. For instance, in the export of fruits and vegetables, mislabeling or substitution can occur, leading to the misrepresentation of origin or variety. Commodities like coffee and cocoa, where quality and origin play a crucial role, may also face adulteration or false labeling, affecting the authenticity and value of the products [30]. Additionally, processed foods, such as olive oil and spices, may be susceptible to mislabeling, substitution, or dilution, impacting both consumer health and the reputation of producers.

3.2. Agri-Food Fraud and Global Health

Agri-food fraud is a potential threat to consumers' health, wherever globally a consumer consumes manipulated agri-food, jeopardizing global health [25]. Global health mainly focuses on worldwide health improvement (including mental health), reduction of disparities, and protection against global threats that disregard national borders, including the most common causes of human death and years of life lost from a worldwide perspective [31]. Exposure to agri-food fraud can have significant implications for global health, as consumers unknowingly pay for, and consume products that may be illegally adulterated with substances (or that are being mislabeled) which constitute a risk factor to one or more unchecked hazards against consumers' health protection [8, 25]. These fraudulent practices compromise the integrity of the food supply chain and can lead to adverse health effects. For instance, adulterating foods with inferior ingredients or contaminants exposes consumers to potential allergens, toxins, or harmful chemicals that can trigger allergic reactions, foodborne illnesses, or long-term health issues [32]. Mislabeling or substitution may lead to inadequate nutrient intake, impacting overall health and exacerbating nutritional deficiencies. Moreover, introducing fraudulent products into the market erodes consumer trust, hindering their ability to make informed dietary choices.

Global health is intricately linked to food authenticity and safety. Exposure to inauthentic (presumably unsafe) food otherwise known as manipulated food is a threat to public health, as consumers may unknowingly consume sub-standard or adulterated products, exposing themselves to contaminants [2, 8] allergens, and nutritional deficiencies [1, 33]. Furthermore, the health consequences of agri-food fraud can lead to increased healthcare costs, decreased productivity, and economic losses for both consumers and governments since it increases health risks adding to the national burden [34]. This can affect economic development and exacerbate existing health disparities. Therefore, comprehending the extent of agri-food fraud and its health implications within the context of African-European trade becomes imperative for safeguarding public health and ensuring the integrity of the food supply chain.

To combat the growing threat of agri-food fraud and food safety by extension, the African national regulatory agencies e.g. Nigeria (National Agency for Food and Drug Administration and Control, NAFDAC), South African (South African Health Products Regulatory Authority, SAHPRA), Ethiopia (Ethiopian Food and Drug Authority, EFDA), and Cameroon (Cameroon Food Safety Framework Law) may need to make more provisions for food compliance and inspections. These regulations aim to ensure the safety and authenticity of food products, protect public health, and maintain consumer confidence. As global trade in agriculture commodities and food products expands, the supply chain vulnerability to fraudulent activities becomes increasingly evident. This may be worse partly due to the inadequate food safety laws in African countries or poor enforcement. Finally, there is a need for

rapid detection tools to make quick decisions on the field, and a need for supply chain traceability systems [25]. This article has provided relevant information on the extent of food fraud practice across the Africa-European trade border and highlighted a potential association with consumers' health in different geographic locations around the globe.

4. Conclusion

Agri-food fraud is a growing syndrome in Africa which may unfortunately largely be unchecked. Agri-food fraud may be common across the Africa-EU borders, with speculated unprecedented implications on consumer health globally. This may partly be due to the absence or inadequate enforcement of food safety-related legislation in some African countries. When speculating that the variety and severity of sicknesses in Africa may be associated with fraud, agri-food fraud in Africa may require more attention. The need for efficient and effective systems for agri-food fraud prevention, vulnerability assessment, and authorities to track suspicious foods in the market or trade borders and trace them back to their origin/producers cannot be emphasized. There is a need for the producers/industries to devise strategies of not only authenticating their products but also being capable of distinguishing their products in the market from fake copies as a means of protecting their brands and maintaining consumers' trust. Safeguarding the genuineness and safety of agri-food commodities or products strengthens consumers' health protection and global trade connections. Overall, the road ahead requires unwavering commitment, constant vigilance, and a united effort to ensure that the food consumed worldwide is safe and wholesome.

References

- [1] European Commission, "Agri food fraud: What does it mean?," Retrieved: https://food.ec.europa.eu/safety/eu-agri-food-fraud-network/what-does-it-mean_en. [Accessed 12/08/2023], 2019.
- [2] European Commission (EC), "Regulation (EU) 2017/625 of the European parliament and of the council of 15 March 2017," Retrieved: <https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32017R0625;document=32017R0625.OfficialJournaloftheEuropeanUnion>. [Accessed 05/04/2024], 2017.
- [3] L. Niu, M. Chen, X. Chen, L. Wu, and F. S. Tsai, "Enterprise food fraud in China: Key factors identification from social co-governance perspective," *Front Public Health*, vol. 9, pp. 1-14, 2021. <https://doi.org/10.3389/fpubh.2021.752112>
- [4] M. E. Dasenaki and N. S. Thomaidis, "Quality and authenticity control of fruit juices-a review," *Molecules*, vol. 24, no. 6, p. 1014, 2019. <https://doi.org/10.3390/molecules24061014>
- [5] A. Ogunlade and M. Adeleke, *Food, technology and culture in Africa* (African Books Collective). Reamsworth Publishing. <https://muse.jhu.edu/book/98691>, 2021.
- [6] B. Winkler *et al.*, "Fighting fraudulent and deceptive practices in the agri-food chain," Retrieved: https://publications.jrc.ec.europa.eu/repository/bitstream/JRC131525/JRC131525_01.pdf. [Accessed 2023].
- [7] R. Fakhlaei *et al.*, "The toxic impact of honey adulteration: A review," *Foods*, vol. 9, no. 11, p. 1538, 2020. <https://doi.org/10.3390/foods9111538>
- [8] A. W. A. Abia, "Food fraud detection: The role of spectroscopy coupled with chemometrics," *Journal of Nutrition and Diet Management*, vol. 1, pp. 1-7, 2023. <https://doi.org/10.59462/jndm.1.1.103>
- [9] C. R. Girelli, L. Del Coco, and F. P. Fanizzi, "Tunisian extra virgin olive oil traceability in the EEC market: Tunisian/Italian (Coratina) EVOOs blend as a case study," *Sustainability*, vol. 9, no. 8, p. 1471, 2017. <https://doi.org/10.3390/su9081471>
- [10] A. Kamboj, "Analytical evaluation of herbal drugs drug discovery research in pharmacognosy," Retrieved: https://books.google.com/books?hl=en&lr=&id=hbqZDwAAQBAJ&oi=fnd&pg=PA23&dq=Similarly,+spices+are+susceptible+to+substitution,+with+inferior+or+cheaper+spices+being+presented+as+premium+variants&ots=uUqJwObdZP&sig=FBzmQT-Tn_ABBQ-tJWvzJihP1gIq. [Accessed 2012].
- [11] A. G. Osman, V. Raman, S. Haider, Z. Ali, A. G. Chittiboyina, and I. A. Khan, "Overview of analytical tools for the identification of adulterants in commonly traded herbs and spices," *Journal of AOAC International*, vol. 102, no. 2, pp. 376-385, 2019. <https://doi.org/10.5740/jaoacint.18-0389>
- [12] C. E. Handford, K. Campbell, and C. T. Elliott, "Impacts of milk fraud on food safety and nutrition with special emphasis on developing countries," *Comprehensive Reviews in Food Science and Food Safety*, vol. 15, no. 1, pp. 130-142, 2016. <https://doi.org/10.1111/1541-4337.12181>
- [13] P. Visciano and M. Schirone, "Food frauds: Global incidents and misleading situations," *Trends in Food Science & Technology*, vol. 114, pp. 424-442, 2021. <https://doi.org/10.1016/j.tifs.2021.06.010>
- [14] I. O. Owolabi and J. A. Olayinka, "Incidence of fraud and adulterations in ASEAN food/feed exports: A 20-year analysis of RASFF's notifications," *Plos One*, vol. 16, no. 11, p. e0259298, 2021. <https://doi.org/10.1371/journal.pone.0259298>
- [15] H. J. Marvin *et al.*, "Global media as an early warning tool for food fraud; an assessment of MedISys-FF," *Food Control*, vol. 137, p. 108961, 2022. <https://doi.org/10.1016/j.foodcont.2022.108961>
- [16] P. Shears, "Food fraud—a current issue but an old problem," *British Food Journal*, vol. 112, no. 2, pp. 198-213, 2010. <https://doi.org/10.1108/00070701011018879>
- [17] T. Azad and S. Ahmed, "Common milk adulteration and their detection techniques," *International Journal of Food Contamination*, vol. 3, pp. 1-9, 2016.
- [18] N. H. Toukap and W. A. Abia, "Red palm oil authenticity and fraud detection awareness, perceptions, and knowledge of producers, sellers and consumers in Cameroon," *International Journal of Advances in Engineering and Management*, vol. 6, pp. 670-675, 2024.
- [19] J. E. Opia, "Food fraud in Nigeria: Challenges, risks and solutions," Theses. <https://doi.org/10.21427/nm91-rk58>, 2020.
- [20] V. Nagel, "Food or foe – The rise of counterfeit food across Africa Insights into the law in South Africa | welcome to go legal," Retrieved: <https://www.golegal.co.za/counterfeit-food-africa/>. [Accessed 2020].
- [21] S. Mabrouk, A. Abdelmonsef, and A. Toman, "Smart grain storage monitor and control," *American Scientific Research Journal for Engineering, Technology, and Sciences*, vol. 31, no. 1, pp. 156-162, 2017.
- [22] H. Ellyat, "Italy's slippery 'extra virgin' olive oil scandal," Retrieved: <https://www.cnbc.com/2015/11/13/italys-slippery-extra-virgin-olive-oil-scandal.html>. [Accessed 2015].
- [23] I. N. Orina, "Quality and safety characteristics of honey produced in different regions of Kenya", Thesis, 2014.
- [24] European Commission (EC), "January 2024 report on EU agri-food fraud suspicions," Retrieved: https://food.ec.europa.eu/document/download/70e6460b-0a7c-4200-9757-77839407d903_en?filename=ff_ffn_monthly-report_202401.pdf.
- [25] W. A. Abia and T. B. Perkwang, "Agri-food fraud in a geographic area in relation to global health: A probe into the perceptions, knowledge, attitudes, practices, and concerns of cameronian," *Journal of Nutrition and Diet Management*, vol. 2, no. 2, pp. 1-11, 2024. <https://doi.org/10.59462/JHAN.2.2.113>
- [26] B. Akwei, "The dilemma of the process-oriented and spillover effects of regional economic integration of West Africa: ECOWAS intra-regional trade and trade with key," *South Asian Research Journal of Business and Management*, vol. 23, pp. 49-58, 2020.
- [27] A. Malik *et al.*, "Global environmental and social spillover effects of EU's food trade," *Global Sustainability*, vol. 6, p. e6, 2023. <https://doi.org/10.1017/sus.2023.4>
- [28] N. Friedman and J. Ormiston, "Blockchain as a sustainability-oriented innovation?: Opportunities for and resistance to Blockchain technology as a driver of sustainability in global food supply chains," *Technological Forecasting and Social Change*, vol. 175, p. 121403, 2022.

- [29] Thermo Fisher Scientific, "Food adulteration analysis information," Retrieved: <https://www.thermofisher.com/us/en/home/industrial/food-beverage/food-beverage-learning-center/food-analytical-testing-information/food-adulteration-analysis-information.html>. [Accessed 2023].
- [30] S. Kamiloglu, "Authenticity and traceability in beverages," *Food Chemistry*, vol. 277, pp. 12-24, 2019. [Online]. Available: <https://doi.org/10.1016/j.foodchem.2018.10.091>
- [31] S. E. Fischer *et al.*, "Is it about the 'where' or the 'how'? Comment on defining global health as public health somewhere else," *BMJ Global Health*, vol. 5, no. 5, p. e002567, 2020. <https://doi.org/10.1136/bmjgh-2019-002172>
- [32] M. Momtaz, S. Y. Bubli, and M. S. Khan, "Mechanisms and health aspects of food adulteration: A comprehensive review," *Foods*, vol. 12, no. 1, p. 199, 2023. <https://doi.org/10.3390/foods12010199>
- [33] J. M. Ryan, *Food fraud*. Cambridge, USA: Academic Press, 2015.
- [34] A. Cox, A. Wohlschlegel, L. Jack, and E. Smart, "The cost of food crime, Food Standard Agency (Research Project code: FS 301065), 2020," Retrieved: <https://www.food.gov.uk/sites/default/files/media/document/the-cost-of-food-crime.pdf>. [Accessed 2020].