

1 **Food fraud in insecure times: Challenges and opportunities for reducing food fraud in Africa**

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19 **Abstract**

20 **Background**

21 Food fraud describes deceptive acts that occur at all stages of the food supply chain for  
22 economic gain. The COVID-19 pandemic has had devastating impacts on individuals, institutions,  
23 and economies. Disruptions in supply chains and regulatory oversight have led to concerns  
24 about potential increases in food fraud-related incidents. In addition, the pandemic further  
25 exacerbated the issue of widespread and severe food insecurity in Africa, providing optimal  
26 conditions for fraudulent agents in the supply chain to perpetrate fraud. However, little is  
27 known about how food fraud manifests on the continent.

28 **Scope and Approach**

29 This review explores food fraud in the African context, emphasising the impact of COVID-19.  
30 The study provides examples of food fraud and challenges of critical stakeholders in the supply  
31 chain, including consumers, industry, and regulators in combating food fraud. It also discusses  
32 recommendations for researchers and policymakers to reduce fraud and improve the quality  
33 and safety of food along the supply chain.

34 **Key Findings and Conclusions**

35 There is consensus that the pandemic has created an environment that makes consumers more  
36 vulnerable to food fraud. However, there are significant data gaps on the incidence of food  
37 fraud, making statistical comparisons difficult. The monitoring of food fraud incidents,  
38 especially in Africa, remains in its early stages, limiting food fraud prevention efforts. Improved  
39 data collection and significant investments in testing infrastructure and technical know-how are

40 required for developing evidence-based action plans to combat fraud at both national and  
41 intra-continent levels to safeguard consumer health.

42 **Keywords:** Africa; Food adulteration; Food fraud; Food security; Food safety

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## 44 1. Introduction

45 Food fraud describes a wide range of intentional acts carried out by various agents across the  
46 food supply chain with the ultimate goal of financial gain (Spink & Moyer, 2011). The Food and  
47 Drug Administration (FDA) of the United States of America defines food fraud as “the  
48 fraudulent and intentional addition or substitution of a substance in a product or a product  
49 itself with the aim of increasing its apparent financial value or a reduction in the cost of  
50 production of such products” (Spink et al., 2019). These acts include adulteration, substituting  
51 food or ingredients with cheaper alternatives, forging food labels, and working with fraudulent  
52 permits (Points & Manning, 2020). Fraudulent activities in the food supply chain range from  
53 global coordinated corruption to small business decisions to mislabelling products or  
54 substituting an ingredient with cheaper options.

55 Food fraud has far-reaching implications. The health risks associated with food fraud can be  
56 direct/immediate or indirect/chronic. An immediate or direct health impact of food fraud is  
57 usually due to a single exposure to adulterated food. For example, an allergic reaction where  
58 food contains unlabelled ingredients such as nuts. Indirect/chronic health impacts of food fraud  
59 affect the consumer through long term exposure or consumption of adulterated food resulting  
60 in the build-up of adulterants within the body over a long time due to the ingestion of low  
61 doses of these contaminants (Spink & Moyer, 2011). Another health impact of food fraud is  
62 malnutrition, whereby the consumers do not gain the full nutritional benefits associated with  
63 foods or food products such as vitamins and minerals due to the substitution of these or  
64 modifications which the foods have received which makes these essential nutrients unavailable  
65 to the consumer (Munekata et al., 2020; Spink & Moyer, 2011).

66 In addition, food fraud has financial consequences and undermines consumer confidence in the  
67 food industry (Li et al., 2021). It has been estimated to cost the food industry 40 billion dollars  
68 each year, with reputational damage to food-producing and distributing companies and  
69 countries (Agnoli et al., 2016; PwC, 2017). Food fraud undermines profit margins for legitimate  
70 traders and creates an immense financial burden for the establishments responsible for  
71 regulating food systems.

72 Food fraud has existed since antiquity and is a growing global problem (Spink et al., 2019).  
73 However, it manifests within a local context that must be better understood to detect and thus  
74 prevent it. High profile food fraud incidents frequently reported in the literature include the  
75 addition of melamine to milk products in China, the 'horsemeat scandal' first detected in British  
76 and Irish markets, and dilution of extra virgin olive oil across Europe (Gossner et al., 2009;  
77 O'Mahoney, 2013; Taylor, 2019a). However, less is known about the nature and scale of food  
78 fraud in Africa.

79 Several factors make African food systems susceptible to fraudulent agents (Figure 1). The  
80 number of people living on the continent is projected to double by 2050. In addition, about 60%  
81 of this population will live in urban areas, placing Africa as the location of the fastest rate of  
82 urbanisation in the world (OECD & SWAC, 2020). Consequently, the food industry is adapting to  
83 increased demands for more processed products to complement indigenous staples in the diet,  
84 relying on imports to supplement production (Cockx et al., 2018; Colen et al., 2018). It has been  
85 estimated that between 2016 and 2018, 85% of the food consumed in Africa, valued at \$35  
86 billion per year, was imported from outside the continent (Akiwumi, 2020). An increasingly long

87 and complex global food supply chain provides an optimal environment where fraud is easier to  
88 perpetrate and more complicated to detect (Everstine et al., 2013).

89 At the same time, the bulk of the domestic food trade in Africa occurs via informal supply  
90 chains. This is characterised by low compliance with international standards, absence or non-  
91 enforcement of government regulations and limitations in technical expertise and  
92 infrastructure for food testing (Aworh, 2021; Morse et al., 2018). Subsequently, there is poor  
93 oversight over the quality and safety of food consumed by over 1.2 billion people in Africa.

94 Food fraud is linked to food safety, and Africa already bears a significant food safety burden  
95 with the highest per capita incidence of foodborne illness (WHO, 2015). The call to address food  
96 safety issues in Africa has gained significant momentum from researchers, policymakers,  
97 regulators, and consumers (Anyogu et al., 2021; Jaffee et al., 2019). However, food fraud has  
98 received less attention.

99 The COVID-19 pandemic has had far-reaching consequences, affecting almost all facets of life.  
100 Production lines, labour availability, working conditions, and transportation networks have all  
101 been negatively impacted by the COVID-19 pandemic (Onyeaka et al., 2021). The cumulative  
102 effect is a severe disruption to the seamless distribution of lawfully manufactured food.

103 Regrettably, this has provided additional opportunities for fraudulent actors to fill the supply  
104 gap with inferior or counterfeit food (van Ruth, 2020). Recently, an international investigation  
105 led by Interpol, Opson IX, involving 77 countries, led to the seizure of more than 40 million  
106 dollars worth of food and drink. Of particular interest was the observation of an increased  
107 amount of foods with forged expiry dates compared to pre-pandemic times (Interpol, 2021).

108 The pandemic has led to severe and widespread food insecurity in Africa (Akiwumi, 2020). In  
109 addition, increased food prices due to limited supplies and reduced incomes make consumers  
110 more vulnerable to food fraud as they seek less expensive alternatives. Not surprisingly, the  
111 food fraud problem in Africa has been considered alarming. The aim of this review is to bring  
112 attention to the status of food fraud in Africa, particularly as impacted by the COVID-19  
113 pandemic. We also discuss challenges impeding the detection and reduction of food fraud and  
114 share some long-term recommendations for Africa's local food systems to become more  
115 resilient and vibrant.

## 116 2. The situation of food fraud before the COVID-19 pandemic in Africa

117 Africa shares in the global burden of food fraud where foods are adulterated, substituted and  
118 counterfeited for financial gain. Although it is generally agreed that food fraud is widespread on  
119 the continent, this is primarily based on anecdotal evidence or from sketchy social or print  
120 media reports without any retrospective data or official reports to rely on. Several factors make  
121 it difficult to track food origins, including extended supply chains, porous borders and varying  
122 levels of monitoring and standardisation. Other reasons contributing to the rise in food fraud in  
123 Africa include local manufacturers' use of substandard ingredients to reduce manufacturing  
124 costs and lax regulatory enforcement, which have allowed fraudsters to thrive. Both imported  
125 and locally produced foods are involved in food fraud. Research findings from an investigation  
126 commissioned by the Confederation of Tanzanian Industries (CTI) reported that as much as 50%  
127 of imported goods into Tanzania, including food, were counterfeited. However, seizure data  
128 from the study period suggested a more conservative figure of 10% (CTI, 2017).

129 Some common examples of fraud occurring in African food systems are summarised in Table 1.  
130 Fraudulent practices occur across all African regions and involve all aspects of food fraud  
131 (Figure 2). This includes the addition of unknown and undeclared compounds to enhance the  
132 quality attributes of food, counterfeiting, dilution, substitution, and mislabelling. Examples of  
133 unapproved enhancements include the use of chlorine bleach and detergent in the processing  
134 of cassava to *fufu* to improve its appearance (Igomu, 2020), the addition of the embalming  
135 agent formaldehyde to preserve fish and meat between capture or slaughter and sale has been  
136 reported in Nigeria, Ethiopia, Uganda and Cameroon (Deudjui et al., 2020; Idris 2021; Ssali,  
137 2020). Similarly, the adulteration of palm oil with the carcinogenic dye Sudan red to deepen the  
138 colour of the product is a common practice in Ghana (Andoh et al., 2019; Andoh et al., 2020). In  
139 Cameroon, fishers have been observed to add the pesticide Gamalin to water bodies to kill fish  
140 which subsequently float and are collected by the fishers and enter the supply chain (Deudjui et  
141 al., 2020). In addition to health risks associated with consuming these products, the  
142 unregulated use of pesticides can lead to the destruction of the ecosystem, as other biological  
143 organisms will be affected. Some other reported food fraud cases involve the use of legally  
144 permitted chemicals above recommended limits. Examples include the indiscriminate use of  
145 the preservative sodium benzoate to extend the shelf life of *injera* and plant hormones to ripen  
146 plantain and pineapples (Deudjui et al., 2020).

147 There are several reports of counterfeiting in the milk, rice, and sugar supply chains. This  
148 usually involves repackaging these products as known brands, a common practice in the rice  
149 supply chain in Nigeria, where locally produced rice is presented as the more expensive, foreign  
150 brands perceived to be of superior value (Onyenuecha, 2017; Taylor, 2019b). Honey is a high-



151 value product and is considered among the most common foods affected by fraud (Moore et  
152 al., 2012). In South Africa, the dilution of honey with cheaper substitutes such as fructose, rice  
153 or beet syrup and labelling imported honey as local honey is widespread (Knowler, 2021). In  
154 Ethiopia, increasingly sophisticated methods for adulterating butter along the supply chain have  
155 also been noted (Gemechu et al., 2021).

156 Food fraud has severe consequences for the health of African consumers. For example, an  
157 outbreak of epidemic dropsy in Ethiopia was linked to the adulteration of edible oils with  
158 argemone oil. One hundred and eighty cases were reported, and twelve people died (Assefa et  
159 al., 2013). Similarly, in Nigeria, two teenagers were reported to have died after consuming  
160 contaminated biscuits whilst their classmates were hospitalised (AgroNigeria, 2018). However,  
161 this report was disputed by the school authorities, and although this incident occurred in 2018,  
162 no investigations have been undertaken. Three outbreaks of methanol poisoning occurred in  
163 Libya and Kenya between 2013 and 2014. Over 2000 people fell ill after consuming alcoholic  
164 drinks diluted with methanol and an average case fatality ratio of 10% was recorded (Rostrup et  
165 al., 2016). Other cases abound; however, documentation of the health impact of food fraud  
166 and adulteration by regulatory agencies within Africa is lacking. Systematic data collation is not  
167 undertaken, with information filtering through unofficial channels and social media. There are  
168 also economic consequences for food fraud. Palm oil is an essential source of foreign exchange  
169 for Ghana. However, to protect the health of EU consumers, import restrictions continue to be  
170 in place for palm oil of Ghanaian origin (FSA, 2021).

### 171 **3. Burden and Current Status of food fraud in Africa during the COVID-19 pandemic**

172 The observation of an increase of fraudulent activities in critical supply chains such as personal  
173 protective equipment (PPE) associated with the COVID-19 pandemic has raised concerns about  
174 similar occurrences within the food industry (Proffitt, 2020). However, it has been challenging  
175 to ascertain the true impact of COVID-19 on the incidence of food fraud. This has become a  
176 topic of increasing interest to the food industry, policymakers, regulators, and researchers.  
177 An initial review of food fraud incidents occurring during the pandemic in Africa has highlighted  
178 that seizures of diverted goods were frequently reported. For example, smuggled rice,  
179 vegetable oil and spaghetti in Nigeria, illegal seafood products caught during the closed season  
180 in Mozambique, contraband soft wheat flour in Algeria, and smuggled rice in Mauritania (Club  
181 of Mozambique, 2021; Cridem, 2021; Isenyo, 2021, Premium Times, 2021). Counterfeiting has  
182 also been rife. The South African authorities confiscated 70,000 litres of alcohol collected from  
183 illegal establishments between October and December 2021 (Bhengu, 2021). Moroccan  
184 authorities impounded over 5000 bottles of counterfeit beer and whisky (Bladi, 2021). In Kenya,  
185 the police dismantled a criminal organisation producing and selling counterfeit condiments to  
186 hotels. A mixture of chemicals, sugar, water, and preservatives was sold as branded tomato  
187 sauce even though it contained no tomatoes (The Standard, 2021). The Rwandan Food and  
188 Drug Authority issued a nationwide recall of a honey product diluted with cheaper sweeteners  
189 but was labelled as pure honey (Ntirenganya, 2021). The Egyptian authorities raided a factory  
190 where white paint and illegal flavouring ingredients were used to produce cheese. 37 tonnes of  
191 products including 15 tonnes of cheese were seized (Archyde, 2021). There are several reported  
192 cases of seizures of illicit food products in Africa, yet the effort is insignificant considering the  
193 scale of food fraud.

194 While these recent events indicate that despite the pandemic, it remains business as usual for  
195 fraudsters, it has been more challenging to ascertain if the pandemic has led to a significant  
196 increase in food fraud occurrence not only in Africa but globally. A recent study by the Food  
197 Authenticity Network (FAN) compared the number of global food fraud incidents in the Safety  
198 HUD database (Merieux Nutriscience) before (January to June 2019) and during (January to  
199 June 2020) the pandemic. The authors reported an increase of 90 fraud-related incidents during  
200 the study period, which possibly indicate the first signs of the effect of the pandemic on food  
201 fraud (Frera et al. 2021). The report also noted that 22 countries had recorded an increased  
202 number of food fraud incidents, including 14 countries that had not recorded any food fraud  
203 incidents at all in 2019. For example, Ghana was identified as a country of origin associated with  
204 14 food fraud incidents in 2020 compared to only four times in 2019.

205 A similar investigation by Points & Manning (2020) noted an increase in adulteration incidents  
206 in the HorizonScan database (Fera Science) between April and June 2020 compared to the same  
207 period in 2019. This increase was attributed to reports of melamine adulteration of soy-based  
208 products to improve the protein content. However, the authors emphasised the need to caveat  
209 interpretations of food fraud incidence data when discussing the influence of the pandemic on  
210 food fraud. They concluded that there was no evidence based on the data available in  
211 HorizonScan that the pandemic had led to an increase in food fraud.

212 Global monitoring of food fraud incidents is in its early stages, and although database tools  
213 exist, they contain relatively small amounts of food fraud compared to food safety data. There  
214 are few to no official reporting systems for food fraud-related incidents across Africa. In  
215 addition, most food fraud databases that aggregate food fraud incidents are behind paywalls,

216 limiting their accessibility. This makes it challenging to monitor trends in food fraud at a  
217 regional level and is a considerable obstacle to designing interventions to protect consumers  
218 and global trade efforts. Geographical location has been recognised as a factor influencing food  
219 fraud vulnerability (van Ruth & Nillesen, 2021). Therefore, better quality evidence on incidents  
220 of food fraud in Africa are required.

221 There is consensus that COVID-19 has emphasised weaknesses in Africa's food production and  
222 control systems, particularly the challenge of regulating what is primarily an informal food  
223 economy. In addition, economic hardship has been linked to an increase in food fraud, as  
224 disruptions to the food supply chain provides opportunities for criminal elements to introduce  
225 fraudulent foods into legitimate supplies. This is in addition to reducing the limited government  
226 oversight as more emphasis is placed on the health sector. COVID-19 has already had a severe  
227 impact on food security in Africa. For example, some parts of Nigeria and South Sudan have  
228 been identified as requiring urgent action to prevent widespread death and collapse of  
229 livelihoods (FAO, 2021a). However, availability and access are not the only challenges Africa  
230 faces where food is concerned. Urgent action is also needed to respond to the challenge of  
231 food fraud, and consequently safety, in Africa.

#### 232 **4. Current efforts and challenges facing responses to food fraud during the COVID-19** 233 **pandemic**

234 Food security has been of significant concern in Africa even before the COVID-19 pandemic  
235 broke out (FAO, ECA, AUC, 2021). Contributory factors such as supply crises, poverty, and  
236 conflict, have contributed to the persistent food crisis. The COVID-19 pandemic has further  
237 complicated the food situation of Africa in terms of food security, safety, and fraud by posing

238 more profound challenges. To begin with, border restrictions, lockdowns, and curfews designed  
239 to halt the spread of infection have interrupted supply systems that were already struggling to  
240 meet market demands under normal circumstances. Not surprisingly, these disruptions have  
241 allowed fraudsters to close supply gaps with fake and low-quality foods, which consumers  
242 rapidly purchase in panic-buying and stockpiling observed at the initial stages of the COVID-19  
243 pandemic lockdown (Hall et al., 2021; Islam et al., 2021). In addition, the financial pressure on  
244 businesses to reduce material inputs and production costs to avoid laying off staff and break-  
245 even economically have made fraudulent activities more appealing (Manning & Soon, 2019).  
246 Concerted and coordinated efforts have been established to minimise the impact of COVID-19  
247 on the food industry, ensuring consumers are less vulnerable to food fraud. For example, the  
248 Food and Agriculture Organisation (FAO) has pursued initiatives such as extending emergency  
249 food aid programs and offering urgent help to smallholder agricultural production through the  
250 expansion of e-commerce to avert severe food shortages and support nations in maintaining  
251 their food supply chains (Galanakis, 2020). At a regional level, steps are also being taken to  
252 build more sustainable and resilient food supply chains. The Feed Africa Response to COVID-19  
253 (FAREC) from the African Development Bank has supported 23 African countries with capital for  
254 funding farm input, replenishing food stocks and stabilising food prices (Ali Mohammed et al.,  
255 2021). The COVID-19 Recovery and Resilience Agri-finance Project (CORRAP) in Senegal is  
256 supporting the recovery of the cereal and legume value chains by providing sustainable access  
257 to quality inputs, training for capacity building and the use of digital services for improving  
258 market access (Reliefweb, 2020). In Kenya, digital technologies are being used to improve the

259 regulated supply of food commodities, market connections, and regulatory monitoring via  
260 ongoing collaborations with agri-tech businesses (Prause et al., 2021).  
261 More efforts are also being made by regulatory agencies to identify fraudulent behaviour. An  
262 indefinite closure of butchers was mandated in Kampala, Uganda, following reports that many  
263 butchers were using an embalming substance called formalin to dispel flies and make meat  
264 seem deceptively fresh (Independent, 2021). In Ethiopia, the Ethiopian Food and Drug Authority  
265 (EFDA) has stepped up regulatory measures on the illegal use of sodium benzoate to extend the  
266 shelf life of a staple food product, *injera*, from three to ten days. Though the safety of the  
267 chemical was initially supported by the EFDA, traders were using this chemical unlawfully and  
268 unprofessionally by adding excess amounts to the detriment of consumers' health (Sinla, 2020).  
269 Through these steps, some African countries are taking the proper steps to establish more  
270 resilient and efficient food supply and regulatory systems in Africa, reducing food fraud and  
271 improving food security and safety during and beyond the pandemic. However, these are  
272 preliminary steps and capacity building, including access to relevant technology, policy overhaul  
273 and further legislative backing is still required to sanitise Africa's food supply chains.

## 274 **5. Conclusion and recommendations**

275 Food fraud is a growing global threat with public health and economic consequences. The  
276 examples of food fraud highlighted in this commentary confirm that food fraud is widespread in  
277 Africa, has severe health implications, and warrants urgent attention. Addressing the threat of  
278 food fraud requires innovative and accessible solutions driven by collaborations between the  
279 food industry, researchers, and government agencies. The scale of the informal food trade,  
280 where many food sellers have no registered addresses or certifications, remains a significant

281 challenge. Here, policymakers and regulators have an essential role as it is easier to prevent  
282 food fraud than it is to detect it (FAO, 2021b). African governments can articulate and adopt a  
283 standard legal definition for food fraud and leverage customs and border protection agencies to  
284 prevent counterfeit goods from entering the supply chain. The African Continental Free Trade  
285 Area (AfCFTA) agreement could provide a platform for harmonising food quality and safety  
286 standards, cooperating on border control, and facilitating inter-country trade (WorldBank,  
287 2020). The increasing participation of African countries in international collaborative  
288 enforcement efforts, such as the recent Operation Opson IX campaign, should be encouraged  
289 (Interpol, 2021).

290 This report also highlights severe data gaps on food fraud-related incidents and the need for  
291 increased consumer awareness of food fraud in Africa. A situation where regulators cannot  
292 monitor or enforce existing regulations and producers know the quality of the food product on  
293 offer, but the consumer does not, creates an optimal environment for fraud to persist  
294 (Charlebois et al., 2016; Meerza et al., 2018; van Ruth, 2017). In the long term, at the country  
295 and continent level, food fraud databases such as the RASFF database developed by the EU will  
296 be required. However, more studies that aggregate food fraud incidents occurring across the  
297 continent are required as these can be useful for identifying trends, target areas for regulation  
298 and developing risk assessments (Zhang and Xue, 2016).

299 Combating fraud requires that industry and agents of regulatory agencies can access  
300 appropriate testing procedures to detect where fraud has occurred at various stages of the  
301 supply chain. A range of bioanalytical and molecular methods can be used to study a food's  
302 intrinsic signature, including its provenance and geographical origin, detect illegal adulterants,

303 or substituted ingredients (Gonzalez-Pereira et al., 2021; Hong et al., 2017). For example,  
304 Blanco-Fernandez et al. (2021) used molecular tools to investigate the prevalence of  
305 mislabelling in fish caught in African waters available for retail sale in Spain. Other DNA based  
306 methods have also been used as a reliable tool in detecting widespread substitution in the fish  
307 (Galal-Khallaf et al., 2014) and meat (Cawthorn et al., 2013) supply chains in Egypt and South  
308 Africa, respectively. Andoh et al. (2019) reported on the efficiency of spectroscopy coupled with  
309 chemometric methods in detecting the presence of Sudan IV dyes in adulterated palm oil  
310 samples.

311 However, these methods often require expensive equipment and expert technical skills, so they  
312 remain inaccessible to many food testing laboratories. International collaborations can play an  
313 important role in capacity building. Recently, a two-phased approach involving portable  
314 scanners for rapid, on-site screening supplemented with more sophisticated laboratory-based  
315 analytical methods has been trialled in the rice value chain in West Africa and has shown some  
316 promising results (McGrath et al., 2021). The establishment of the African Centre for Food  
317 Fraud and Safety is a welcome development for fostering future research collaborations that  
318 can drive innovation while taking the local context of the issues into account.

319 The pandemic has further highlighted the potential of Industry 4.0 technology to combat food  
320 fraud, loss, and waste trends. The collection of real-time data to increase communication  
321 between suppliers and purchasers and streamline food redistribution has been improved using  
322 Information and Communication Technologies (ICTs), Big Data, Internet of Things (IoT)  
323 platforms, and web-based applications. These applications based on artificial intelligence (AI)  
324 and Big Data have been used to link farmers and suppliers and provide immediate feedback on



325 changes in demand (Flanagan et al., 2019). These fraud combating efforts are considered to  
326 have played a key role in reducing the rate of food fraud during the pandemic (Galanakis et al.,  
327 2020). Many technologies for testing and verifying foods according to internationally  
328 recognised standards are increasingly sophisticated and, at present, are not accessible to many  
329 African countries due to cost, technology infrastructure and expertise.

330 Following the Covid 19 pandemic, the assurance of food security within the continent is of  
331 paramount importance to meet the nutritional and calorific demands of Africans and reduce  
332 vulnerability to food fraud (Boyacı-Gündüz et al., 2021). Current agricultural practices will not  
333 be sufficient to meet the food needs of a growing African population (Giller et al., 2021; Van  
334 Ittersum et al., 2016). Thus, there is a need to explore alternative approaches to meet the  
335 growing food needs of the continent, using transformational methods for food security  
336 assurance and resilience amid and post-pandemic (Boyacı-Gündüz et al., 2021).

337 Several approaches can be employed more actively to forestall a food crisis in the coming years.  
338 These include the use of single-cell proteins (SCP), which have been shown to be a veritable  
339 food source (Ritala et al., 2017) with proven nutritional values comparable to conventional food  
340 sources (Sharif et al., 2021) and can be employed as feed in aquaculture and livestock farming  
341 (Jones et al., 2020). Similarly, hydroponic farming has been shown to be practical in certain  
342 countries of Africa. It has the potential to boost agri-business profitability, offering a sustainable  
343 approach for food security (Gumisiriza et al., 2022) can be employed to increase food  
344 availability reducing the vulnerability of consumers to fraudulent agents. Also, the use of  
345 functional food ingredients (Galanakis et al., 2020) and employing agri-food innovation  
346 strategies including food valorisation, alternative plant-based “meat” products, bioactive

347 compounds, and smart agricultural ICT backend technologies (Galanakis et al., 2021) can  
348 improve the food environment, boosting food security and reducing the potential for food  
349 fraud in the continent.

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