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# Food fraud in selected sub-Saharan Africa countries: a wake-up call to national regulatory bodies to support enforcement and food safety

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Africa is projected to have 2.4 billion people by 2050 and provision of healthy and nutritious diets is one of the challenges facing food systems. Food fraud is an act of deliberate adulteration and counterfeiting of food ingredients and commodities at all stages of supply chains with the aim of economic gain. Food fraud in Africa is a menace both in public health and for the economic development. Food fraud is perpetuated at all stages of the food supply chain to alter the quality of food products for economic gain or financial advantage thus threatening food safety. In addition, limited information is available on food fraud monitoring/manifestation in Africa thus hindering the prevention efforts. The standard bodies in sub-Saharan Africa countries play a vital role in combating food fraud. However, weak reporting mechanisms and regulatory systems in Africa remains a challenge in controlling food fraud. This current review explores food fraud in Africa and stakeholder (consumers, industries and regulators) challenges in the supply chain in attempt to combat food fraud. The recommendations of the review will be helpful to policymakers and scientists in improving the quality and safety of food along the supply chain, and in reducing fraud. Quality testing infrastructure and technical know-how are very important for frequent and rigorous quality control of food products and food fraud prevention. The standard and regulatory bodies in African governments need to strengthen and comply with the regulations that govern food fraud and support enforcement and food safety.

KEYWORDS

**food fraud, food safety, public health, regulatory agencies, Africa**

## 1 Introduction

Food fraud is a contemporary issue in global trade and it poses advance health risks to consumers. Spink et al. (2019) describe food fraud as intentional and deliberate addition, tampering, substitution, or misrepresentation of food, food ingredients or food packaging; or false or misleading statements made about a product for economic gain. Food fraud is committed by counterfeit descriptions of products in terms of their details of origin,

TABLE 1 Types of foods with their adulterants and effects on human health in Africa.

| Types of foods | Adulterants | Effects on human health | Countries | References |
|---|---|---|---|---|
| Milk and dairy products – Yoghurt, Condensed milk, Ice cream | Melamine, urea, Starch, salt, Detergent, Products of other milk in sheep or cow's milk | Kidneys - Formation of melamine, Cyanurate Cocrystals (Kidney stones) | Kenya, Egypt, Ethiopia | Nyokabi et al. (2021); El-Loly et al. (2013); Ayza and Yilma (2014); Wanjala et al. (2018) |
| Meat products – Poultry meat, Pork, Beef | Nitrite, Dopamine, Meat of one animal adulterated with meat of the other animal | Cardiac damage, cancer Salmonellosis, Food poisoning | Kenya, South Africa | Njaramba et al. (2021); Cawthorn et al. (2013); Abuelnaga et al. (2021) |
| Fruit products – Bananas, Apples, Mangoes, water- melons | Methyl parathion, Calcium carbide, Wax coatings | Anemia (Low red blood cell count), Cardiac damage Liver damage Stomach, intestine – Diarrhoea, Constipation | Algeria, Nigeria, Zimbambwe, Kenya, Uganda, Rwanda | Islam et al. (2016); Odewale et al. (2021); Sharma et al. (2010); Gaouar et al. (2021) |
| Oils – Mustard oil, Sunflower oil, Extra-virgin, Ghee, Peanut oil | Palm oil, Olive oil, Papaya seeds, Mineral oil, Butter yellow Argemone oil, Cyanide | Epidemic dropsy, glaucoma, blindness, cardiopulmonary arrest, diarrhea, vomiting, cancer, etc. | Ghana, Nigeria, Ethiopia | Andoh et al. (2019); Andoh et al. (2020); (Assefa et al., 2013) |
| Dals and vegetables - Turmeric, Green chillies, Toor dal, Green peas, Mustard seeds, Cereals and pulses | Rhodamine B, Rhodamine 6G, Metanil yellow, Malachite green, Kesari dal, Argemone seeds, Metallic adulterants | Brain damage, Paralysis of legs Anemia (Low red blood cell count), Cardiac damage Liver damage Stomach, intestine – Diarrhoea, Constipation, Food Drop, Lead Poisoning | Nigeria, Ghana, Egypt | Anozie et al. (2018); Abayase and Mohammed, 2022; Youssef et al. (2017) |
| Drinks and beverages - Beers, juices, water, other alcoholic beverages | Ketamine, Metamizole, Midazolam, Paracetamol and other Sedatives | Liver damage, Brain damage | Kenya, Nigeria, Ghana | Bansal et al. (2017); Lakshmi, (2012); Darkwah et al. (2020) |

weights, types of processing and constituents (Spink and Moyer, 2011). The acts of food fraud include forged food labels, substitution of food or ingredients with cheaper alternatives, adulteration, and fraudulent permits (Manning and Soon, 2019). Food fraud has been reported in value chains including meat and vegetables (Cawthorn et al., 2015), milk (Handford et al., 2015; Sakaridis et al., 2013), edible oils (Yadav, 2018), honey (Soares et al., 2018), fish (Cawthorn et al., 2015; Fernandes et al., 2017a), shellfish and shrimp (Fernandes et al., 2017a; Fernandes et al., 2017b), cereals (Nasreen and Ahmed, 2014; Martín-Fernández et al., 2016), spices (Silvis et al., 2017; Villa et al., 2016) and rice (Vemireddy et al., 2015).

The issue of food fraud has been often been overlooked or inadequately addressed especially in Africa due to factors such as complex food systems, weak regulations and competition from cheaper products, which create opportunities for fraud (Andoh et al., 2018). Food fraud has significant impact to public health and international trade (Spink and Moyer, 2011; World Trade Organization, 2017). The health risks associated with food fraud can be direct/immediate or indirect/chronic. Consumers are exposed to numerous adverse health effects and conditions including diarrhea, nausea, headache, insomnia, cancer, anemia, eye-sight problems, muscular paralysis, brain damage, vomiting, and abdominal pains (Table 1). Gastrointestinal, kidney and liver infections have also been reported (McGrath et al., 2021; Mohammadi and Jafari, 2020). Consumption of adulterated foods has also been associated with muscular convulsions, paralysis, cardiac disturbances, neurological, skeletal and gastrointestinal organ impairment (Bansal et al., 2017). Previous studies have reported human health risks associated with food fraud such as the use of harmful ripening agents (calcium carbide) on various fruits, toxic preservatives to milk, harvest of fruits and vegetables immediately after spraying with chemicals and lead in spices (Choudhary et al., 2020). The impact on public health due to food fraud activities can also compromise the nutritional quality of food denying the consumer the nutritional benefits to be accrued by utilization of the food products (Gizaw, 2019).

Food fraud along the value chains has gained prominence due to the interlinked nature of the international trade and global supply chains (van Ruth and Nillesen, 2021). Globally, the economic loss of food fraud has been predicted to be between $10 billion and $15 billion, which is estimated to $10 billion of foods sold commercially worldwide (Owolabi and Olayinka, 2021). However, the lack of documentation and information on food fraud cases in Africa especially weak traceability systems and concealment practices is a significant challenge. The European Union has a food and feed safety alert portal for alerts on food fraud cases in order to ensure safe, accessible and affordable food (Owolabi and Olayinka, 2021). In Asia, the Association of Southeast Asian Nations (ASEAN) have developed a similar portal akin to the European Union's for reporting food fraud and traceability (Owolabi and Olayinka, 2021). In Africa, surveillance, reporting and management of food fraud alerts remain decentralized with no available databases. This article reviews the current state of food safety vis-à-vis food fraud in Africa, the challenge for 78 policymakers, regulators and governments in combating the malpractice of food fraud.

Preventing food adulteration is a complex task that requires a multifaceted approach (McGrath et al., 2018; Theolier et al., 2021). The following measures can prevent and mitigate the adulteration of food products: strengthening regulations and enforcement, enhancing testing and quality control, promoting public awareness and consumer education, strengthening supply chain

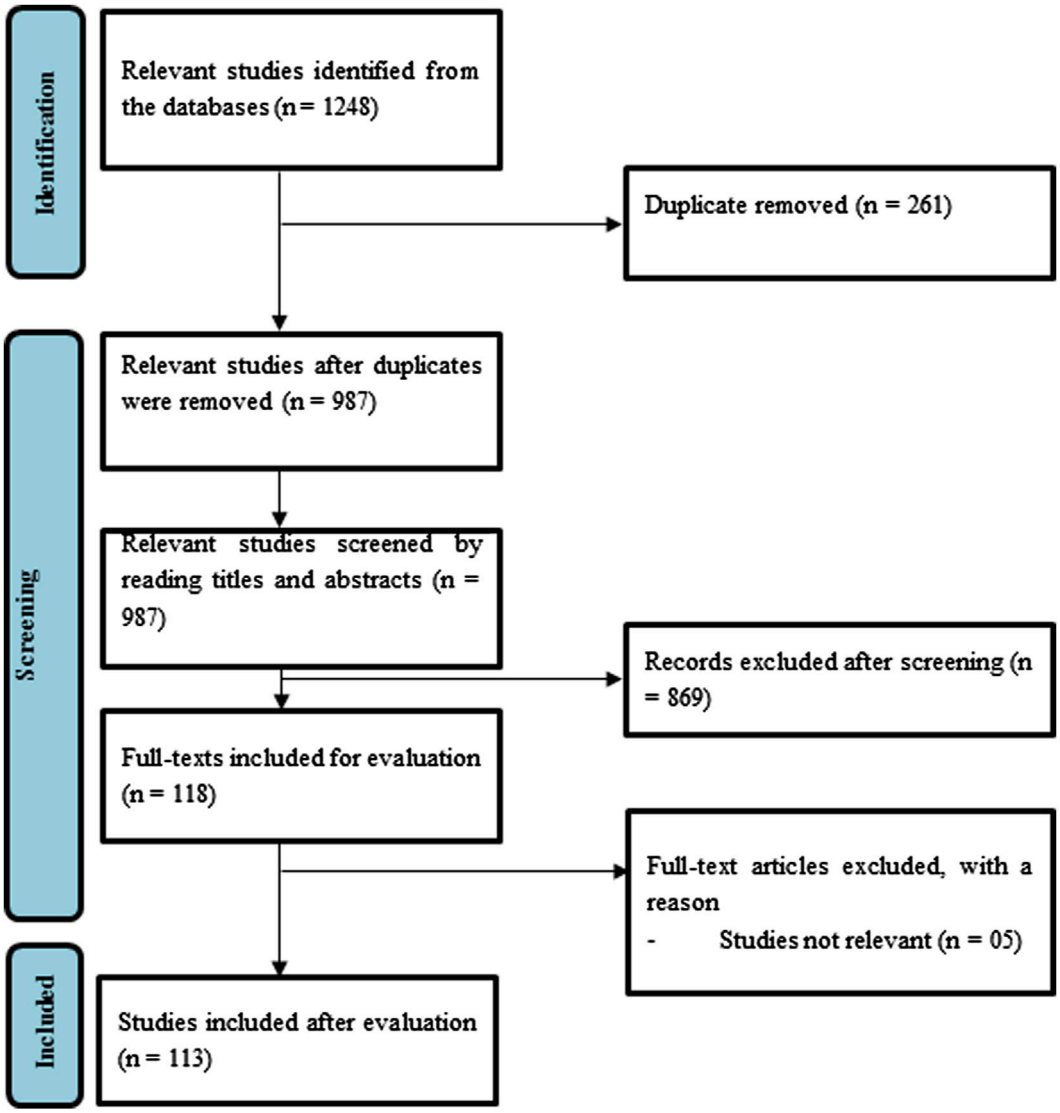


FIGURE 1
Overview of PRISMA procedure used in this study.

management, strengthening international cooperation, and encouraging responsible business practices; collaborative development of codes of conduct; implementation of best practice guidelines; monitoring and compliance mechanisms; capacity building and knowledge sharing; public–private partnerships and consumer engagement; and research and development (McGrath et al., 2018; Theolier et al., 2021; Selamat and Iqbal, 2016; Fung et al., 2018). By implementing these measures, we can safeguard public health, protect consumers' rights, and ensure the availability of safe and nutritious food (Fung et al., 2018). There is a need for adequate precautions to be taken by the consumer at the time of purchasing adulterated food, which can make consumers alert to avoid procuring such food (Gahukar, 2014). It is the collective responsibility of governments, regulatory bodies, industry stakeholders, and consumers to work together to combat food adulteration and establish a robust food safety ecosystem (Johnson, 2014; Stadler et al., 2016)

# 2 Methodology

## 2.1 Study design

The study employed a mixed research method as described by Robson and McCartan (2016). Electronic literature search and literature appraisal was done from published articles and book chapters on the occurrence of food fraud in Africa.

## 2.2 Literature search

Scientific databases provided by Science Direct, Scopus, Google Scholar, PubMed, Cochrane Library and Web of Science (SCIE) were used to perform electronic literature search. The literature search was systematically conducted in accordance to the recommendations of Preferred Reporting Items for Systematic

Reviews and Meta-Analyses (PRISMA) protocol (Moher et al., 2009). Key words "food fraud", "food products fraud", "food authentication", "adulteration", "tampering" "origin fraud", "mislabeling", "substitution", "misrepresentation", "economically motivated adulteration", "counterfeiting" "unapproved enhancement", and "health impact of food adulteration" were used to conduct scientific literature search for the period 1988 to 2022.

Five different searches were done capturing articles published in English language. Searches 1, 2 and 3 were done in 2021, whereas, searches 4 and 5 were done in 2022. Search 4 was done in the first month of 2022, while search 5 was done in April 2022. Searches 1 and 2 were done 3 months apart. Search 3 was conducted 2 months after search 2. Initial literature search yielded 1248 articles and reports, out of which 113 were more relevant and reviewed extensively and included in the review. Figure 1 below presents a summary of the search.

## 2.3 Eligibility criteria

All studies relating to food and food products with focus on fraud were included in the study. All other studies which had no concrete connection with food fraud were excluded in the study. Moreover, studies published in other sources such as editorials and conference abstracts were excluded in the study.

## 2.4 Study selection

A total of 1208 relevant studies were identified from the databases. After removal of 261 duplicate reference materials, 987 reference items were subjected to manual screening. The titles and abstracts or complete texts of the 987 reference items were read and 869 reference items did not meet the eligibility for inclusion in the study and therefore were rejected. Full text copies of relevant articles that matched the criteria for inclusion (113 references) were evaluated.

# 3 Food fraud situation in Africa

Significant incidents of food fraud have been reported in Africa where foods are substituted, counterfeited and adulterated for dishonest financial gain (Mensah et al., 2012; Cawthorn et al., 2015; Handfod et al., 2015; Visciano and Schirone, 2021). Food fraud in Africa involves both imported and local food products. Some of the factors that contribute to the increase in food fraud in Africa include extended supply chains and porous borders making it difficult to trace the food origins, use of substandard raw materials by local manufacturers to reduce costs, and varying levels of monitoring and standardization (Mbazima et al., 2022). In Africa adulteration is compounded due to lack of sufficient regulatory oversight to detect food fraud hence almost no protection for unwary consumers (Onyeaka et al., 2022). Regulatory agencies are more focused on the microbial safety of foods and not their authenticity (Onyeaka et al., 2021). This creates an environment where dishonest food businesses can thrive and engage in food adulteration with impunity (Momtaz et al., 2023). Various food products are prone to food fraud in Africa. This review provide an overview of the cases of food fraud focused on specific groups of food including meat products, milk and dairy products, honey, fruits and vegetables, fruit juices, edible oils and fats, cereals and cereal products, and fish and seafood.

The most common types of food fraud are adulteration, dilution, substitution, concealment, tampering (including date-code tampering), mislabeling or misrepresentation, unapproved enhancement, counterfeiting (including intellectual property rights counterfeiting), grey market product/theft/diversion (Spink et al., 2017; 2019; Global Food Safety Initiative, 2018). Mislabeling is the most common type of food fraud in agricultural food markets. Fraudulent food practices can be divided to two groups: the first group, there is no harmful to human health and is represented by a food or drink quality concern such as the dilution of spirits with water. The second group describes the type of food fraud, which can negatively impact health or cause dead (Kendall et al., 2019).

Food fraud is a significant challenge in sub-Saharan Africa (SSA) that threatens food safety and public health. The highest number of food fraud cases in 2022 was observed in Nigeria, specifically grain-based food (cereals and bakery products), oils and fats. Based on the study by Visciano and Schirone (2021), Ghana 42.4%, Nigeria 11.9%, Guinea, and Senegal 10.2% were the countries with the highest number of registered cases. The most adulterated commodities in sub-Saharan Africa were alcohol, grain-based food (cereals, bakery products), milk and dairy products, oils and fats. Cawthorn et al. (2013), and Manning and Soon (2019) also found that unconventional species like donkey, goat, and water buffalo were identified as substitutes in processed meats, indicating widespread mislabelingman in South Africa. Not only breaching the food labeling regulations, this type of adulteration also raises concerns about economic, religious, ethical, and health consequences (Cawthorn et al., 2013; Manning and Soon, 2019). The hygienic aspects of vending operations and the safety of these foods are problematic for food safety regulators in Africa (Mensah et al., 2012). Aworh (2021) demonstrated that animal-source foods and fresh fruits and vegetables are the leading cause of foodborne diseases in Africa region. Strict food safety and the application of good agricultural practices and good hygienic practices in Africa will reduce fresh products contamination and would serve as an important factor in prevention of adulteration, food fraud, and ensure food safety.

# 4 Fraud in selected types of food

Based on research articles and various local news reports, food fraud is rife in Africa and some common examples of fraud occurring in African food systems are summarized in (Table 2).

## 4.1 Meat products

Meat and meat products provide dietary protein to majority of people worldwide. The adulteration of meat has become a growing food safety threat in recent years, especially processed meat products. The processed meat value was at $714 billion globally

TABLE 2 Some food fraud cases/examples in sub-Saharan African Countries.

| Food product | Category/Type of adulteration[a] | Adulterant | Country | References |
|---|---|---|---|---|
| Meat | Concealment, Mislabelling | Red and white meat without proper labels to confirm origin | Algeria | Oussama (2018) |
| Meat | Substitution | Goat meat substituted with beef and mutton | Kenya | Njaramba et al. (2021) |
| Meat | Concealment, Mislabelling | Undeclared beef meet in processed sausages and beef patties contaminated with chicken and pork meat | South Africa | Tembe et al. (2018) |
| Meat | Concealment, Mislabelling | *Kofta* and *Hawawshy* dishes were found to be adulterated with chicken rather than the proclaimed beef or mutton meat | Egypt | Abd El-Aziz (2018) |
| Fish, Meat, Milk | Unapproved enhancement | Use of embalming agents, e.g., formaldehyde to extend shelf life | Cameroon, Uganda, Ethiopia, Nigeria | Deudjui et al. (2020); Ahmadu (2021); Ssali (2018) |
| Milk | Counterfeit | Repackaging milk powder in fake branded packaging | Nigeria | Onyenuyecha (2017) |
| Milk, Injera (Flatbread) | Unapproved enhancement | Use of preservatives above recommended concentrations to extend shelf life | Ethiopia | Deudjui et al. (2020) |
| Milk | Unapproved enhancement | Use of formaldehyde, hydrogen peroxide sodium carbonate and bicarbonate to extend shelf life of raw milk | Sudan, Kenya | Wanjala et al. (2018); Ongarora and Karwimbo, (2019); Nyokabi et al. (2021) |
| Milk | Unapproved enhancement | Adulteration of milk with vegetable oil, water and defatted milk | Ethiopia | Ayza and Yilma (2014) |
| Honey | Dilution | Adulteration with fructose, rice, or beet syrup | South Africa | Knowler (2021) |
| Honey | Counterfeit | Production of fake honey using boiled water and sugar products | Ethiopia | Gebremariam and Brhane (2014) |
| Honey | Dilution | Production of fake honey using boiled water | Nigeria | Igwe et al. (2012) |
| Honey | Mislabelling | Importing cheap "bulk" honey and passing this off as local, more expensive honey | South Africa | Knowler (2021) |
| Honey | Adulteration | Honey adulterated with sugar syrup and crushed yellow bananas | Rwanda | Kagire (2021) |
| Bananas, Plantains | Unapproved enhancement | Use of plant hormones above approved recommended doses for fruit ripening | Cameroon | Deudjui et al. (2020) |
| Fruit juices | Unapproved enhancement | Addition of sugar and dilution with water to processed fruit juices | Nigeria, Ghana | Anozie et al. (2018); Abayase and Mohammed et al. (2022) |
| Guava juices | Unapproved enhancement | Adulteration of Guava juices with sugars | Egypt | Youssef et al. (2017) |
| Grape juices | Concealment, Mislabelling | Adulterated with apple juice | South Africa | Stander et al. (2013) |
| Palm oil | Unapproved enhancement | Addition of Sudan IV dyes to enhance the colour | Ghana | Andoh et al. (2019) |
| Edible oils | Adulteration | Edible oils adulterated with argemone oil | Ethiopia | Assefa et al. (2013) |
| Rice | Dilution, Substitution, Unapproved enhancement | "Plastic rice" scandal. Sweet potatoes and synthetic resin mixed to form rice grains | Nigeria | The Sun (2016) |
| Cereals and nuts | Illegal export | Seized up to 600 tonnes of grains, maize, and nuts for illegal export | Burkina Faso | European Parliament (2012) |
| Fish | Unapproved enhancement | Use of insecticides to catch fish | Cameroon | Deudjui et al. (2020) |
| Fish | Unapproved enhancement | Formaldehyde used to preserve fish between capture and sale | Ethiopia, Uganda, Nigeria and Cameroon | Deudjui et al. (2020); Ssali (2018); Ahmadu (2021) |

[a]Based on the food fraud categories as recognized by the European Commission (EC), 2021 and the Global Food Safety Initiative (GFSI, 2018).

in 2017, and current projections put the value of the industry to reach $1567 billion in 2022 (Black et al., 2019). Therefore, the growing demand for meat and meat products attracting unscrupulous folks in the value chain to be involved in adulteration and other malpractices (Tembe et al., 2018). Meat processors substitute meats of high quality with cheaper or undesirable ones (Alamprese et al., 2016). The substituted meat species may expose consumers to zoonotic and foodborne diseases of public health concern and can also cause allergenic reactions (Ouso et al., 2020; Zaukuu et al., 2021).

There are several reports of adulteration in meat and meat products value chains in Africa. In Kenya, cases of substitution of

beef and chevron with bushmeats remain a growing food fraud threat in the meat value chain (Njaramba et al., 2021). Njaramba et al. (2021) found high levels of meat species substitution, with goat meat substituted with beef and mutton based on high-resolution melting analysis of mitochondrial products. There are also reports of bad meat treated with preservatives and resold to unsuspecting consumers. The report was aired in a July 2019 news segment by Nation Television (NTV), called #RedAlert described the unscrupulous nature of use of preservatives on meat and meat products (Nation Newspaper in Kenya, 15 July 2019). A study by Tembe et al. (2018) analyzed processed meats authenticity in Kwa Zulu Natal Province, South Africa and found undeclared beef meet in processed sausages and beef patties contaminated with chicken and pork meat. In Egypt, *kofta* and *hawawshy* dishes were found to be adulterated with chicken rather than the proclaimed beef or mutton meat (Abd El-Aziz, 2018). Use of minced meats has gained prominence in preparation of hamburgers, meatballs, sausages and patties, as they are easily prone to substitution (Alamprese et al., 2016). In Ethiopia, Uganda, Nigeria and Cameroon, formal dehyde has been used to preserve meat between slaughter and sale (Deudjui et al., 2020; Ssali, 2028; Ahmadu, 2021).

A rampant food safety hazard involves slaughtering animals soon after administering vaccines and medication without allowing the recommended time limit for reduction to the recommended levels (Birgen et al., 2020). This practice has been aided by weak public health and veterinary inspection routines that has allowed slaughter of animals with residues in them. Food additives, heavy metals, mycotoxins, pesticide residues and veterinary drug residues are some of the reported chemical contaminants rampant meat value chain sectors in sub-Saharan Africa. Past reports have shown that microbial contamination especially in the informal meat sector remains a potential public health risk. Birgen et al. (2020) confirmed that pathogens of *campylobacter* and *staphylococcus aureus* are prevalent due to poor slaughter and post-slaughter handling practices, exposing consumers to contamination risks.

Based on our findings, mislabeling of processed meats is common in Africa and not only violates food labelling regulations, but also poses economic, religious, ethical and health impacts. Therefore there is need for improved meat labelling practices by governments in sub-Saharan Africa are important to combat fraud and protect consumers. The practices should include clear labelling, classification and compositional specifications of meats and meat products to combat fraud in processed meat and meat products in order to protect consumers.

## 4.2 Milk and dairy products

Milk is consumed either in its natural form or through dairy products because of its rich macronutrient composition (Roncada et al., 2012; Ayza and Yilma, 2014). By 2050, the milk and dairy products demand in sub-Saharan Africa is expected to triple (Gülzari et al., 2020). Fraud in the dairy industry has been rampant due to its increased consumption and demand coupled with predicted low supply (Poonia et al., 2017; Baptista et al., 2021). Common fraudulent operations in dairy industry include milk fat and/or milk protein substitution, dilution with water, addition of preservatives, addition of fillers, substitution of milk from a superior species to a less superior one, addition of whey rennet, application of undeclared processing methods and mislabeling (Baptista et al., 2021; Kamal and Karoui, 2015; Wanjala et al., 2018; Ongarora and Karwimbo, 2019; Nyokabi et al., 2021). The type of animal from which the milk come influences the price and availability of the milk and therefore folks are always tempted to adulterate for financial gains (Baptista et al., 2021).

Therefore, quality control at all stages of milk and milk products manufacture is required. In order to increase the shelf life of milk at room temperature, chemical additives are deliberately added to raw milk (Kamal and Karoui, 2015). This is illegal and a major adulteration practice. Chemical additives such as formaldehyde, hydrogen peroxide sodium carbonate and bicarbonate have been reported in raw milk in Sudan and Kenya (Wanjala et al., 2018; Ongarora and Karwimbo, 2019). This indicates that there is need to adopt mechanisms for quality control to improve the quality of milk. This can be done through proper monitoring of the dairy value chain. Dairy products consumers may also be educated on the dangers of consuming unsafe dairy products.

The acts of interference of milk components in the informal sector are rampant and lower the hygiene and nutritional quality of the milk therefore resulting in loss of value for money (Gülzari et al., 2020). Milk quality survey in three ecological zones of Kenya (Laikipia, Nakuru and Nyandarua), confirmed that milk was adulterated with sterile water (Nyokabi et al., 2021). The reported also noted contamination of the adulterated milk with *Brucella abortus*, a major concern and health risks to consumers. Therefore, there is an urgent need for regulation framework and monitoring due to high health risks posed to consumers. A study by Ayza and Yilma (2014) on patterns of milk adulteration in Southern Ethiopia found that 95% of respondents are aware of milk adulteration practices. In the study, the respondents indicated that common adulterants in milk were vegetable oil, water and defatted milk. A majority of respondents noted that milk adulteration was motivated to increase profit margins and noted weak regulatory framework in place.

## 4.3 Honey adulteration

Honey is a high sugar product naturally produced by bees sucking on the living parts of plants (De Beer et al., 2021). Honeybees collect pollen and nectar from a variety of flowering plants and convert it into the wax and honey (De Beer et al., 2021). Only worker honeybees forage for food, consuming as much nectar from each flower as they can. After foraging, worker honeybees return to the hive/comb and pass the collected nectar to the other worker honeybees. This worker holds the nectar on her tongue until the liquid evaporates, creating honey and then stored in a cell within the hive/comb. Honey is composed of water, fructose, glucose, sucrose, minerals, phytochemicals, and proteins which are responsible for its sensory characteristics such as smell, aroma, taste and color (Padiso et al., 2021). Honey has been historically used by mankind for brewing and medicinal purposes (Siddiqui et al., 2017), with current usage in confectionery, baking, medical drugs among others. The importance of honey and its commercial value has been increasing over the years due to its multiple uses in alleviating food and nutrition security. Addition of foreign

substances such as molasses or elimination of substances such as pollen is prohibited due to the overall effect on quality (Sobrino-Gregorio et al., 2019).

Honey is a common target for food fraud, with common adulterants including sugar syrups, molasses/jaggery, beet sugar, use of natural syrups such as maple syrup, corn syrup with aim of increasing yield and economic gain (De Beer et al., 2021). The honey composition and quality varies according to the botanical origin, geographical area and harvesting season (Çinar et al., 2014). Confusing labeling such as masking of the botanical and geographical origins is a major problem in honey adulteration (De Beer et al., 2021). In this respect, the product only fulfills some quality parameters to satisfy consumer acceptability but fails the authenticity test (De Beer et al., 2021). Some reported practices of honey adulteration include adding honey flavors to caramel so as to mimic natural honey, some farmers feed their bee colony with a mixture of sucrose so as to increase the volume produced, and such practices are economically motivated and done with minimal regard to quality of the product or the end user (consumer) (Nwalor et al., 2018). It is imperative to maintain the purity of honey, lower the adulterants and develop testing procedures to detect adulterants in honey (Sobrino-Gregorio et al., 2019).

In South Africa, the quality parameters of imported honey vis-à-vis locally produced honey were analyzed and found that both sources complied with the regulatory framework (De Beer et al., 2021), including the Agricultural Product Standards (APS) Act 119 of 1990, 2000 (DAFF, 2000) and legislations, International Honey Commission (IHC) and Codex Alimentarius Honey standards (Bogdanov et al., 1999; AOAC, 1995). However, the study noted that the global decrease in bees due to climate change, has resulted to rampant honey adulteration and thus stricter regulatory enforcement need to be enhanced to combat the vice. This has resulted in blending of local and imported honey and mislabeling the same as "South African" which is misleading to consumers. Padiso et al. (2021) reported that concentration of inherent sugars, i.e., sucrose, fructose and glucose in natural and commercial honey from Botswana and Zambia had no sign of adulterations or added sugar content. However, in the same study the authors opine that comparative data in most African countries is lacking on the state of honey production and adulteration practices. A study by Gebremariam and Brhane, (2014) on honey quality in Ethiopia found some varying differences in sugar content of the commercial honey sold suggesting a form of adulteration, despite the product meeting national quality standards. Igwe et al. (2012) assessed quality attributes of honey in Nigeria and detected adulteration (20% water) using match-lighting test, but not with caramel-based adulterants.

The International Honey Commission is tasked with developing analytical tools and methods for determining the physicochemical parameters and quality of honey globally. Sobrino-Gregorio et al. (2019) compared two methods of detecting adulteration in honey by conventional and PCR methods. The study showed that use of DNA techniques can detect molasses at lower levels thus offering a better tool in detecting sugar-based adulterants in honey. Siddiqui et al. (2017) advocates for use of NMR spectroscopy due to its 319 powerful nature of detecting substances at the molecular level, however, it's costly in terms of equipment and reagents. Near Infrared Spectroscopy has been successfully applied to detect adulterants in honey (Kumaravelu and Gopal, 2015). Use of SPME-GC-MS methods are ideal in detecting honey quality and authenticity based on botanical and geographical region, as the practice has been rampant to actors involved in honey adulteration (Sotiropoulou et al., 2021). The quality of honey varies with 325 geographical and botanical variations globally. Olawode et al. (2018) used $^{1}$H-NMR methods to assess quality parameters of honey from South Africa, Zambia and Slovakia with the aim of establishing specific chemical markers for detection of adulterants and establishment of quality controls. The analyzed samples from the three countries showed their physicochemical parameters to be within limits albeit with slight concentration levels. These are necessary so as to have a common referral for quality parameters of honey in Africa and globally.

## 4.4 Fruits and vegetables

Fruits and vegetables are highly valued for their nutritional superiority and high economic returns to stakeholders along the value chain (Sharma et al., 2010). Recent consumer focus on the nutrition value has led to an increased demand in fresh fruit and vegetables; however, the demand remains unmet. This has led to prevalence of increased use of ripening agents for commercial reasons, aimed at meeting fruit demand in the off seasons (Islam et al., 2016). Artificial ripening agents such as ethylene, ethephon and calcium carbide, mimic natural ripening process of fruits. Their use has raised serious global public health concerns, with reports suggesting associated health hazards to human health (Islam et al., 2016). Calcium carbide has been reported to cause stomach disorder by altering the mucosal tissue pH balance due to its alkaline nature. Acetylene induce hypoxia by reducing oxygen supply to the brain, while ethephon use should be limited to 1–50 ppm depending on fruit used (Islam et al., 2016).

The irregular use of pesticides in fruits and vegetables has presented a serious public health debate in Africa (Narenderan et al., 2020). Some unscrupulous farmers and traders spray crops with pesticides and harvest them without allowing the lapse for residue elimination time. The increase in use of pesticides in farming has been influenced by population increase, urbanization and thus huge demand for food crops (Narenderan et al., 2020), thus encouraging some misuse in these substances by actors along the value chain. Odewale et al. (2021) reported concentrations of DDT and HCH residues on carrots, cucumber, tomato and watermelon in Nigeria to be above the maximum residue limits of European Commission. These residues are carcinogenic and their continued use continues to pose significant public health risks. Pesticide residues have been reported in tomatoes, eggplant and pepper with Malathion, monocrotophos, Omethioate and Methyl parathion (Sharma et al., 2010). Tomatoes are the ubiquitous vegetable used in most culinary dishes in African households, and reports by Gaouar et al. (2021) from Western Algeria showed high residue levels for the fungicides difenoconazole and triadimenol and the pesticide methomyl with high concentrations of up to 0.045 mg/kg. Therefore, household interventions such as trimming, soaking, blanching of various fruits and vegetables as a

form of lowering the inherent residue levels needs to be adopted by the consumers. The overuse of agrochemicals in production of fruits and vegetables is a global problem which requires enforcement of strict regulations in regional and global food supply systems (Philippe et al., 2021).

## 4.5 Fruit juices adulteration

Fresh and processed fruit juices have high nutritive and health benefits. As the demand for juices increases worldwide so their adulteration and decrease in product quality is becoming a growing problem. Fruit juices are among the top ten most targeted food products globally for adulteration. Fruit juice adulteration mainly occur through dilution with water reducing soluble solids, such as sugars or organic acids (Fry et al., 1999) or fragrance extracts, colorants and artificial flavors (Banti, 2020; Elkins et al., 1988). Adulteration of fruit juices can also occur through addition of cheaper fruit juices (Narenderan et al., 2020). Adulteration of fruit juices during processing directly affects vitamin C concentration in the final products.

African countries are in the fore-front of processedfruit juices production and these products are susceptible to adulterations. Unlike in Europe where the 2012/12 EU directive provided strict regulation on the quality of juices (European Parliament, 2012), Africa lacks strict regulations to regulate juice production. Anozie et al. (2018) confirmed diminishing quality of fruit juices in Nigeria due to increased concentration of toxic compounds in processed juices. The compounds in some of the sampled products included added sugar and other contaminating adulterants which jeopardize the quality of processed fruit juices raising the risk of health problems to consumers. In Ghana, the addition of sugar and dilution with water were the most used adulterant for fruit juice adulteration (Abayase and Mohammed, 2022). The most common forms of fruit juice adulterants were sugars used to make the juice sweeter and tastier to customers (Abayase and Mohammed, 2022). According to Youssef et al. (2017) adulteration of Guava juices with sugars is the most common in Egypt, resulting in its reduced vitamin C and antioxidant activity. In South Africa, grape juices have been reported to be adulterated with apple juice (Stander et al., 2013). This kind of adulterations causes majorly economic food fraud.

## 4.6 Edible oils adulteration

There has been an increasing demand for edible oils as a result of ever growing global population (O'Brien and Fats, 2004). Edible oils are mainly composed of triglycerides and are used for deep frying of foods (Yang et al., 2018). This high demand coupled with low supply of edible oils and greed for financial gains has resulted in adulteration of high-quality edible oils with inexpensive low-quality oils. The adulteration of fat and oil begins with admixing cold press oil with refined oil, which is used in the adulteration of cold press oil. During the refining process, trans-fatty acids which are absent in cold-press oil, are formed. Trans-fatty acids are not essential, and they do not promote good health. The potential intake of adulterated edible oils containing unhealthy oils and trans-fatty acids may result into cardiovascular diseases (Tavernise, 2018). In Ethiopia, twelve people died following adulteration of edible oils with argemone oil (Assefa et al., 2013). In Africa, regulatory agencies lack skilled inspectors, infrastructure, and/or finances thus adulteration of edible oils still remains a major challenge.

Efforts have been devoted to the development of analytical strategies to determine adulterated edible oils including the use of a high performance liquid chromatography (HPLC), mass spectrometry, electronic nose, isotopic dilution, biomarkers and sensors, nuclear magnetic resonance, deoxyribonucleic acid (DNA) barcoding, and electroanalytical techniques for quality control and assurance of consumable products and edible oils (Apetrei and Apetrei, 2014; Fang et al., 2013; Zhu et al., 2017; Zhang et al., 2014; Guillen and Cabo, 1997; Muik et al., 2007; Li et al., 2015). Raman and infrared spectroscopy are non-destructive and rapid techniques that require a small sample size and are capable of solid and liquid sample analysis with little or no sample preparation, making them ideal for fingerprinting, determination of authenticity, and quality assurance of consumable products including edible oils (Fang et al., 2013; Zhu et al., 2017; Zhang et al., 2014; Guillen and Cabo, 1997; Muik et al., 2007; Li et al., 2015).

## 4.7 Cereals and cereal products

Cereal grains and their products including maize, barley, sorghum, rice, wheat and oats are staple food for the majority globally (Food and Agriculture Organization of the United Nations Statistics Division, 2019). Increased demand of cereals in African countries due to increased population and urbanization, increases the incidences of fraud. Cereal grains and their products are used for human food, livestock feed and for industrial applications. The major form of adulteration experienced in the global market of cereals and cereal products is the substitution of more superior and expensive varieties with less superior and cheaper varieties (Food and Agriculture Organization of the United Nations Statistics Division, 2019).

Rice (*Oryza sativa* L.) is the most important cereal grain susceptible to adulteration (Food and Agriculture Organization of the United Nations Statistics Division, 2019). The many varieties of rice cultivated and commercialized are morphologically similar looking kernels with significant price variations and hence easily adulterated (Vemireddy et al., 2015). The existence of many rice varieties also limits the effectiveness of quality control efforts in the value chain of rice. Although there are several rice varieties in every country in Africa, each of the countries has a popular and preferred variety, for example, Jasmine and Pishori in Ghana and Kenya, respectively. This results to the high demand in these popular varieties exceeding the supply and thus creating a favorable environment for cheating leading to fraud in the case of substitution and adulteration of these varieties with other varieties which are not preferred.

## 4.8 Fish and seafood

Fish and other aquatic foods provide essential micronutrients proteins and lipids and are sources of income (Sriket et al., 2007). Demand by consumers towards healthier foods has led to increased

demand for fish and seafood products (Rehbein and Oehlenschläger, 2009). However, they are among the most easily adulterated food products during processing by altering the species' morphological characteristics. The increasing demand for processed fish products has hampered effective monitoring of fraud since the visual identification is impossible (FAO, 2018).

In Ethiopia, Uganda, Nigeria and Cameroon, formaldehyde has been used to preserve fish between capture and sale (Deudjui et al., 2020; Ssali, 2018; Ahmadu, 2021). The most fraudulent practices in the fish and seafood industries include the false declaration of geographical origin or production method, mislabeling of cold-stored products as fresh and substitution of high priced fish products with cheaper alternatives. For these reasons, the European Parliament and European Council, Regulations (EU) No. 1379/2013), state that the label of seafood must include the commercialized name of the species, the type of methods used to produce it and the place where the fish or the seafood species was caught or farmed (Ortea et al., 2016). The fish and seafood industry in Africa needs to ensure fish product safety to consumers by ensuring fish authenticity.

## 5 Food safety governance in Africa

Ensuring food safety and quality is the responsibility of processors, producers, consumers and the government. Most countries in Africa have few ministries/agencies/departments to enforce food safety laws. In addition, the mandates of these ministries overlap in their regulatory oversights (Jaffee et al., 2020). The few agencies cannot effectively collect, collate and analyze data on food safety. Moreover, they cannot provide evidence-based food safety reports for action. Therefore, clear jurisdictions with no overlapping mandates but coordinated communications should be established (Jaffee et al., 2020). Food fraud prevention in Africa may be enhanced by proper education and awareness creation, institutional monitoring and penalization of food fraud crimes (Onyeaka et al., 2022).

Many sub-Saharan African (SSA) countries have fragmented food safety and fraud regulations that are not harmonized with international standards, which lead inconsistencies in enforcement and creates loopholes that fraudsters can exploit (GFSI, 2018; Grace, 2015). There is need for African governments to develop comprehensive, harmonized regulations aligned with international standards such as CODEX Alimentarius to ensure uniformity and improve enforcement efficiency (Nwuneli, 2018).

Many sub-Saharan countries, there are no specific laws targeting food fraud. Existing regulations often focus on food safety and hygiene but do not address fraud comprehensively. This lack of specific legislation makes it challenging to prosecute food fraud cases effectively. There is need to introduce dedicated food fraud laws that clearly define offenses, penalties, and enforcement mechanisms to provide a legal framework for tackling food fraud (Onyeaka et al., 2022).

The standard and regulatory bodies in Africa lack the resources, training, and technology needed to enforce existing regulations effectively. This result to weak enforcement allows fraudulent practices to persist, undermining consumer trust and public health. There is need to increase funding and capacity building for standards and regulatory bodies, including training programs for inspectors and investment in modern testing equipment.

## 6 Conclusion and recommendations

The prevalence of food fraud in sub-Saharan Africa is influenced by factors such as the complexity of the food supply chain, low consumer awareness, poverty, weak regulatory frameworks, and limited testing, inspection capabilities, outdated/irrelevant food fraud law not harmonized to the international standard and lack of awareness of the food regulators in order to identify and investigate the food fraud signal (Onyeaka et al., 2022). To ensure the integrity of the food supply chain, it is crucial to implement strategies such as food traceability analysis, food authenticity testing, vulnerability assessments, and the development of food fraud databases (Onyeaka et al., 2022). These strategies can help detect and mitigate fraud, ensuring the safety and authenticity of food for consumers. Collaboration between the public and private sectors is also essential in effectively combating food fraud (Spink et al., 2017; Unnevehr, 2022).

Food fraud in sub-Saharan Africa is rampant and has severe public health and economic implications. All actors in the food value chain are required to work closely to defeat food fraud in Africa. As food fraud is transnational, regulatory compliance and enforcement consistencies are required to effectively fight food fraud in African Countries. Practices such as increased level of risk-based inspections, established productive monitoring and implementation of food protection systems in the supply chain, and implementation of better ingredient control and certification, may help limit food fraud. Moreover, introduction of national and international police offices for food fraud may help with the enforcement of food fraud laws.

The weak reporting mechanisms and regulatory framework on food fraud in Africa remains a challenge as targeted actions to alleviate and inform policy decision is lacking. Food fraud eradication in Africa in the future requires concerted efforts between the consumers, food industries, scientific community/researchers, and government regulatory agencies (Onyeaka et al., 2022). Combating food fraud requires access to appropriate testing methods by departments of regulatory agencies. African governments can adopt standard regulations for prevention of food fraud by leveraging on customs and border protection agencies to prevent illegal adulterants into the supply chain. In addition, the African governments need to seek international aid and partnerships to fund the development of regulatory framework and training programs. Therefore, standard regulations on food fraud for the African continent similar to European Countries will be of value to the economic gain and public health of African citizens. In addition, fraud databases such as the Rapid Alert System for Food and Feed (RASFF) database developed by EU will be required in Africa, either at the country and continental levels. There is need for African governments to adopt innovative and modern technologies to prevent food from being adulterated or mislabeled (Aday and Aday, 2020; Samuel, 2021).

The limited financial resources in Africa restrict the ability of governments to invest in necessary infrastructure and technology for food fraud prevention. In addition, limited access to modern

technology and skilled personnel impedes the implementation of advanced food fraud detection methods (Edwards et al., 2020; Edwards et al., 2021). Therefore, there is need to seek international aid, technology transfer programs and partnerships with developed countries to fund the development of regulatory infrastructure and training programs.

## Author contributions

JN: Conceptualization, Writing – original draft, Writing – review and editing. ElN: Writing – review and editing. JK: Writing – review and editing. IL: Writing – review and editing. HR: Writing – review and editing. GM: Writing – review and editing. CT: Writing – review and editing. ENN: Conceptualization, Writing – original draft, Writing – review and editing.

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## Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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