THE NIGERIAN MEAT INDUSTRY: AN OVERVIEW OF PRODUCTS' MARKET, FRAUD SITUATIONS, AND POTENTIAL WAYS OUT

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ABSTRACT

Meat is an integral part of the human diet worldwide and plays a central role in the world's culinary traditions. Meat serves as a vital source of essential nutrients, including amino acids, vitamins, and minerals. In Nigeria, it occupies a unique place in the social fabric of the nation and promotes unity and tradition. The meat industry in Nigeria encompasses a range of sources, with beef taking precedence, yet also including options like chicken, chevon, mutton, pork, and more. However, despite its importance, the industry faces multiple challenges, encompassing environmental, socio-economic, and governance issues. The Nigerian government has actively contributed to enhancing meat production through various policies, investments, and modernization efforts. Nevertheless, challenges such as disease outbreaks and inefficient value chains persist. Surprisingly, meat fraud and adulteration have received limited attention despite these issues significantly impacting consumer welfare, public health, and the economy. This article provides an overview of the Nigerian meat industry, explores specific cases of meat fraud, and discusses authentication methods used in neighboring African countries, offering insights for Nigerian researchers and the government.

Keywords: meat authentication, meat industry, meat processing, meat market, food frauds, analytical methods

INTRODUCTION

Meat has been a fundamental part of the human diet for millions of years, occupying a prominent place in many global culinary traditions, with annual consumption and production worldwide reaching up to 350 metric million tons (Hannah et al., 2017). In addition to its cultural importance, meat serves as a vital source of essential amino acids, vitamins, and minerals such as iron, zinc, and selenium (Klurfeld, 2018). These nutrients are essential for growth, development, and overall health. In Nigeria, meat is an integral part of most meals, and its significance extends beyond its role as a source of nutrients: it plays a central role in the social fabric of the country, fostering a sense of unity and tradition among the people. One such tradition is the custom of eating meat only after finishing a meal – a ritual with which many Nigerians can identify. The various reasons attributed to this custom were tradition/upbringing, rewarding the completion of a meal, budget, or financial limitations (Vanguard, 2017).

In Nigeria, a wide spectrum of meat sources plays a crucial role in influencing the nation's preferences for animal protein, with beef reigning as the predominant choice. Complementing this preference are options such as chicken, chevon (goat meat), mutton, pork, venison, and an array of other animal meats. The prevalence of beef can be attributed to the substantial cattle population in Nigeria, surpassing that of other animal species. Meat production predominantly occurs within

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modest households and small-scale farms, particularly concentrated in the northern regions. As reported by Flanders Investment & Trade Market Survey (2020), approximately 60% of Nigeria's cattle population thrives in the semi-arid zones, under the care of nomadic herders. However, it is essential to acknowledge that domestic livestock production significantly falls short of the country's overall demand, a fact underscored by the Food and Agriculture Organization (2023). On average, per capita meat consumption is estimated at approximately 6.4 kilograms annually per person (Akinsulu et al., 2019).

The meat industry is an important economic factor in Nigeria. But despite its contributions to one-third of the nation's agricultural GDP (Kwaghe et al., 2016), the industry remains relatively modest and is growing slowly, compared to the burgeoning population that depends on it for sustenance (Ogbeide, 2015). The sector faces a variety of challenges that include environmental, socioeconomic, and regulatory issues, which will be explored in depth in this article. The Nigerian government has taken a central role in promoting meat production in the country. One notable policy implemented by the government was a strict ban on the importation of meat and meat products. This strategic move was aimed at curtailing the influence of foreign companies in the Nigerian meat market while providing incentives for domestic production. In addition, governments have made significant investments in livestock production, established research institutes dedicated to the advancement of livestock production, and promoted modern practices in the sector. However, the meat industry faces some unique challenges, including disease outbreaks and inefficient value chains. Addressing these complex issues is urgently needed to ensure the longevity of the industry, meet the growing demand for meat, and improve the livelihoods of those deeply involved in the meat production process.

Numerous authors have examined these problems in various studies on the Nigerian meat industry (Table 1). These studies have examined issues such as inadequate handling and packaging in slaughterhouses as discussed by Oluwafemi et al. (2013) and Nwanta et al. (2008), constraints in the poultry sector, and factors hindering commercial and economic development as explored by Anosike et al. (2018). Olaoye and Ntuen (2011) identified the role of infrastructure in meat

spoilage as a limiting factor for the industry, while Otu and Okon (2019) and Usman et al. (2015) research examined possible fraudulent practices by butchers, including soaking meat in water and neglecting proper measurement standards. It's worth noting, however, that intentional adulteration of meat and meat products in the Nigerian meat industry has received little attention in these discussions.

Meat product authenticity remains a relatively underexplored subject, primarily due to the fact that, in contrast to many other food products, meat is commonly retailed in a fresh state at open markets across the country, with limited availability of packaged meat in a select number of supermarkets (Osazuwa--Peters, 2021). This underdeveloped and disorganized meat sales system in Nigeria may account for the lack of attention given to product fraud. As Otu and Okon (2019) noted in their study, fraud is deeply ingrained in Nigerian society and has been rationalized through various arguments, including the belief that "everyone in Nigeria is a cheat" or that it represents a morally less deviant offense compared to other more heinous crimes. These factors, among others, emphasize the significance of shedding light on fraud within the Nigerian meat sector as a pivotal issue impacting consumer welfare, public health, the meat industry, and the broader Nigerian economy. In this article, we provide an overview of the Nigerian meat industry, highlight some specific cases of meat fraud, and discuss methods used in surrounding African countries to authenticate meat and how these can be adopted by Nigerian researchers.

SOME POPULAR MEAT PRODUCTS/DISHES IN NIGERIA

In terms of popularity, beef is the most consumed meat in Nigeria, followed by chicken, mutton, turkey, pork, chevon, etc. (Akinsulu et al., 2019; Ogbeide, 2015; Anyiro et al., 2014; Ogunwole and Adedeji, 2014) but not necessarily in that order. As a result, the most popular meat products and meat dishes are made from beef. There are more meat products such as *tsire-suya*, *dambu*, *kilishi*, etc. in northern Nigeria than in the south. This is probably because of the larger populations of these animals there, whereas meat dishes such as *nkwobi* and *isi-ewu* are more common in the south.

Table 1. Some selected reviews and research on the Nigerian meat industry

Authors	Objectives	Findings	Conclusions
Nwanta et al., 2008	Assessment of the situations in abattoirs and meat processing plants in association with unwholesome consumption.	Improper state of abattoirs across the country Lack of proper waste management system	A coordinated and sustained effort is essential to enhance the quality and safety of meat production in Nigeria.
Nwoga et al., n.d.	Exploration of alternative reproductive technology to improve assisted reproductive technologies (ARTs) to improve cattle production.	Low cattle production and breeding efficiency during dry season Insufficient technical knowledge, limited funding, and fund misuse limit ARTs adoption	ARTs have the potential to revolutionize the Nigerian meat industry by improving the productivity and quality of cattle despite high cost and need for special training.
Anosike et al., 2018	To analyze the challenges of poultry production in Nigeria and suggest possible solution for the purpose of increased production.	Small-scale poultry production offers opportunities for saving, investment, and risk security, constituting around 90% of total poultry production in Nigeria	Several significant challenges that have hindered its growth and productivity. proposed solutions, including veterinary intervention, knowledge dissemination, and financial support.
Usman et al., 2015	To estimate the effect of water-soaking on the minerals and nutritional compositions of beef.	Soaking was found to significantly reduce the nutritional quality of beef with great effects on its mineral element contents	Meat processing managers must ensure that all meat sold complies with health and food safety regulations through testing and quality assurance systems.
Oluwafemi et al., 2013	To highlight and identify areas that should be addressed to improve the quality of fresh beef at the retail point for human consumption.	Beef or meat products are not well processed and cared for in many parts of Nigeria	Government parastatal should use their good offices to enforce strict compliance to standard food safety regulations.
Kwaghe et al., 2016	To assess the current status of livestock production, management systems, and existing policies in Nigeria, with a focus on understanding the challenges.	Livestock production challenges such as inadequate grazing reserves, poor disease management, and substandard meat processing lead to low-quality meat and economic issues	Proper hygiene and effective management of livestock is the only way to achieve success in livestock production which could lead to agricultural development, better international trade, and an increase in the nation's GDP.
Olaoye & Ntuen, 2011	Evaluation of meat spoilage, potential of lactic acid bacteria as a bio-preservative and ways to manage wastage associated with meat due to spoilage.	Lack of standard facilities for handling and processing meat exposes the product to high risk of contamination and spoilage by pathogens and microorganisms	Lactic acid bacteria as biological preservatives could be used to supplement existing traditional preservation techniques.
Kubkomawa et al., 2018	To encourage entrepreneurship in animal agriculture by exploring the current systems and dynamics of beef production and marketing in the country.	Beef Production and Marketing Dynamics	The dominance of middlemen in the beef industry, with their disproportionate profits compared to producers and consumers, underscores the need for a holistic approach that incorporates socioeconomic factors to provide reliable data for effective interventions.
Ogbeide, 2015	To determine compositional quality preferences of consumers and to use the outcome of the objectives to advance improvement in the livestock industry.	A higher proportion of consumers preferred lean meat	Farmers and meat producers can utilize consumer preference as guide toward livestock and meat production.

Table 2. Some meat products and dishes in Nigeria

Meat product	Originating region	Key ingredients	Cooking method
Suya/Tsire-suya	Northern Nigeria but found in all Nigerian states	cow, goat, ram, or chicken meat, *yaji-kuli kuli* (defatted groundnut cake), dried herbs, chili pepper, spices, cloves, salt, ginger, etc.	grilled over an open charcoal fire
Kilishi	Northern Nigeria	beef and *yaji* slurry	oven-dried and slowly roasted
Dambu	Northern Nigeria	cow, goat, ram, chicken or camel meat, *yaji* slurry	pounded and fried in a shallow vegetable oil
Balangu	Northern Nigeria	beef, groundnut oil, spices, and salt	roasted over an open fire
Kundi, Banda or Tinko	Northern Nigeria	meat animals such as horses, donkeys, camels, or even elephants	boiled, sun-dried, or smoked
Nkwobi	Eastern Nigeria	cow foot, palm oil and potash, crayfish, pepper, spices, some herbs, *utazi* leaves and onions	slowly cooked
Asun	Western Nigeria	beef, chicken or mutton, peppers, onions, ginger, and various spices	grilled or roasted and marinated
Meat pepper soup	Western Nigeria	goat, ram, or cow intestines	boiled
Meat pie	throughout the country	minced or ground beef, pastry dough, diced potatoes, and carrots	oven-baked

Many of these products are regional and are traditionally produced, meaning that their production methods are based on ancient techniques and technologies. *Kilishi* for instance, is said to have been historically preserved for emirs and their soldiers as battle food supply. In the preparation of these meat products, care is taken to ensure a long shelf life, and preservation after production is minimal. Some of these products' information is summarized in Table 2.

THE NIGERIAN MEAT INDUSTRY

The meat industry is a segment of the food industry that includes all persons, enterprises, and activities involved in the production, processing, packaging, storage, and marketing of meat on a large scale. The meat industry in Nigeria is less structured and developed than the rest of the world and is plagued by many challenges such as insecurity, inadequate power supply, fuel shortage, etc., which limit its potential and growth. Despite this, the food industry in Nigeria is the largest in Africa with a national revenue of $191.40 billion in 2022 and is expected to grow at an annual

rate of 8.68% by 2027 (Statista, 2022). The National Bureau of Statistics classified 122 food items into 15 major food groups to represent the main food items consumed in the Nigerian food market. In this classification, meat, poultry products, and seafood accounted for the largest expenditure on specific food items after cereals, roots, and starchy foods (Fig. 1) (National Bureau of Statistics, 2020). The Nigerian meat industry consists of the livestock industry, the meat processing sector, and the market.

Livestock industry

The meat industry is composed of several main players and the livestock industry is primarily at the base, which produces animals for the other production chains. The main livestock in Nigeria are cattle, goats, sheep, pigs, and poultry. Northern Nigeria has the highest number of cattle, goats, and sheep, most of which are nomadic or extensively raised. Based on October 2022 statistics from the Federal Ministry of Agriculture and Rural Development (Nkechi, 2022), the current livestock population in Nigeria is estimated at 22.4 million cattle, 53 million sheep, 99.9 million goats, 9 million pigs,
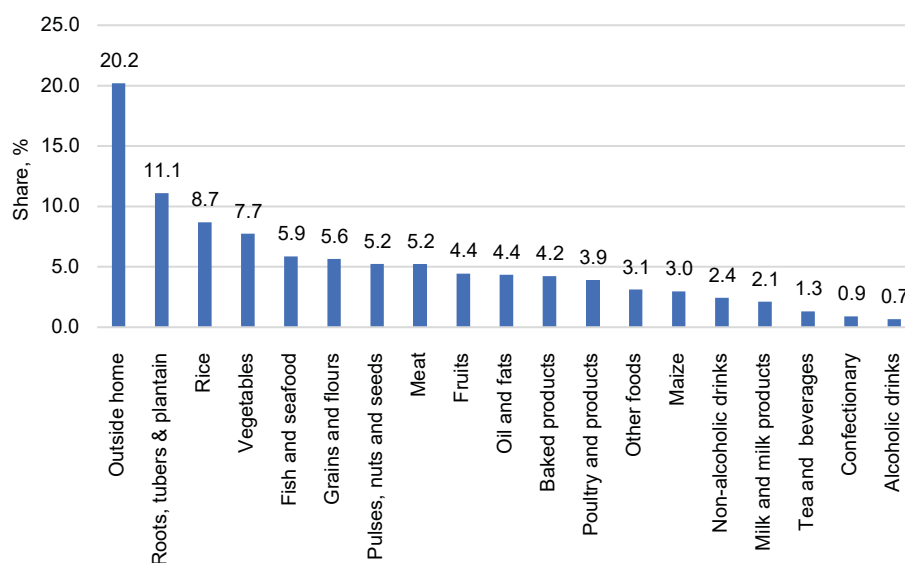
Fig. 1. Categories of food items consumed in Nigeria
Source: National Bureau of Statistics, 2020.

and over 425.8 million poultry. However, this number is still too low to meet the country's needs. As a result, Nigeria relies on its neighboring countries of Chad, Cameroon, and Niger for imports of live cattle, most of which are brought into the country by nomadic herders. The National Bureau of Statistics (NBS) findings on foreign trade showed a significant 68.4% increase in national spending on live cattle imports between 2015 and 2021 (Ibemere, 2021). The perennial plague of Nigeria's livestock sector is gross underproduction, despite an annual growth rate of 22.7% and a net value of 30 trillion naira. This is largely owing to the fact that 70% of beef and 25% of poultry consumed in Nigeria is imported (Iyayi, 2020).

In addition to cattle, an important source of meat in Nigeria is sheep and goats. The indigenous breeds of sheep and goats are raised in households in semi-intensive or free-range systems. They are mostly kept as a quick and available source of income, and their sales may not be sufficient to meet the demand for large-scale processing, so their demand is also supplemented by imports. On the other hand, sheep rearing in Nigeria is usually optimized for the Eid-al Adha festival period, when sales of live sheep and consumption of mutton are highest. Sheep are fattened about 3 to 4 months before the Islamic festival and sold at a substantial profit.

Recently, modern farmers have begun to intensively expand the production of these small ruminants and market their products to meet the growing demand.

Poultry farming is the most widespread livestock production in Nigeria. Traditionally, animals are raised in free-range systems, accounting for 45% of total national production, while semi-intensive and intensive poultry farming account for 33% and 22%, respectively (Herrero, 2020). Relatively, poultry is consumed less by Nigerians than beef and other red meat products because they are considered more expensive and unaffordable to the average citizen (Abegunrin et al., 2021). Poultry meat is consumed most during the Christmas season and some poor Nigerians even save up to afford a live chicken. This limited consumption of poultry meat in the pre-Christmas period by the average Nigerian probably contributes to the fact that domestic production in the country is just enough and the importation rate of poultry meat and products is not that high.

The poultry sector of the Nigerian livestock industry is consistently the most active and thriving sector within the livestock industry. It is the sector where individuals and companies are most actively engaged in livestock production and has more intensive production activities. This growth can be attributed to

the availability of information on poultry production to novice and veteran farmers. It has also contributed to the affordability and ease of acquiring livestock for production. Farmers have quick access to inputs such as medicines, vaccines, and feeds. The year-round availability of the market for poultry products for restaurants and processing plants has also had a very positive impact on the growth of the sector.

On the other hand, the red meat animal sector is largely dominated by small-scale farmers and there are very few commercial farms for intensive production of these animals. Some of the challenges responsible for the low participation and performance of this sector are the high cost of production, inaccessibility of credit, and illiteracy, to name a few. The Nigerian livestock sector is not without hope. The ways recommended to harness the imminent potential are *i*) genetic improvement of indigenous livestock breeds, *ii*) adoption of intensive but sustainable production systems to maximize productivity, *iii*) availability of cheap inputs to reduce production costs, and *iv*) value chain development (Iyayi, 2020).

Meat processing industry

Meat processing is the set of activities performed on raw meat to change the form of the meat to meet the needs of the final consumer. In Nigeria, meat processing includes, at its simplest, the slaughter of live animals, evisceration, cutting of the carcass, and preparation of large portions for retail sale (open stalls). However, these activities are limited to public slaughterhouses or local slaughterhouses where butchers or open-stall meat vendors purchase and slaughter their animals individually (Adeyemo et al., 2009). Private slaughterhouses go beyond these basic activities of slaughtering and cutting large portions by thoroughly washing animals, cutting them into small portions, packaging, sealing, branding, labelling, and storing fresh meat. Cattle, sheep, goats, and pigs are predominantly slaughtered in government slaughterhouses, while chickens and other less popular meat animals are processed in private establishments.

Currently, the processing of meat for retail is done in extremely dirty conditions with no regard for health and safety. Animals are transported to slaughterhouses in inhumane conditions, kept in filthy pens, slaughtered, and processed on the bare floor in open spaces
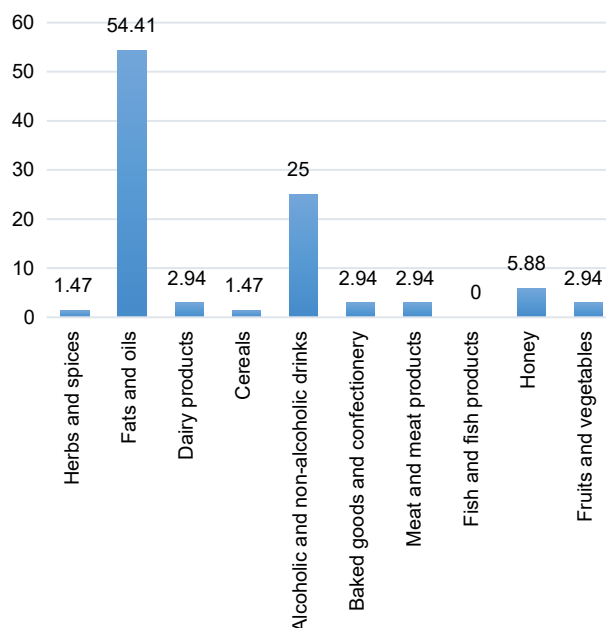

Fig. 2. Adulteration frequency of common food items consumed in Nigeria based on a survey response from 68 respondents
Source: Opia, 2020.

(Adeyemo et al., 2009; Tekki et al., 2012). The dirty conditions of retail meat production have led many health-conscious Nigerians to become active in the meat processing business, which was otherwise in the hands of uneducated and less safety- and health-conscious people. These businesses are small-scale operations that slaughter an average of 8–10 cattle, 15–20 goats, rams, pigs, and thousands of poultry per day. They operate in a hygienic environment and ensure that meat processing standards are met (Fig. 2).

The largest percentage of red meat eaten in Nigerian homes and *bukatarias* (local restaurants) comes from public abattoirs while few and more informed elites patronize the new emerging businesses of the small-scaled processors (Osazuwa-Peters, 2021). However, this does not imply the absence of industrial-sized meat processors – they just happen to be more established in poultry meat production e.g., Zartech Farms and Obasanjo farms. Similarly, there are more small- and medium-size poultry meat processors than there are for red meat, and they account for 80% of poultry meat products in the Nigerian market.

Meat market

Meat markets describe designated places where meat is offered for sale. Meat outlets are usually butcher stores, supermarkets, hypermarkets, grocery stores, online stores, and wet markets. In Nigeria, prominent meat markets are located in close proximity to the city's central slaughterhouse, such as the Oko-Oba meat market in Lagos and the Bodija meat market in Ibadan. The strategic location facilitates the transportation of meat from the slaughterhouse to the point of sale. The system of selling meat in Nigeria is very unorganized, lacks price regulation, and is unhygienic. Adesokan et al. (2021) described this system of meat marketing as an informal system of food marketing common in developing countries because of their poor economic conditions and because of its unsanitary and untaxed disorganization, supplying meat products at affordable prices to equally poor consumers.

Fresh red meat is sold on the basis of standardized cuts and regulated prices per kilo in an extremely hygienic and refrigerated environment in developed nations around the world. What comprises the sale of fresh red meat in Nigeria is the direct opposite of everything enumerated. The meat is offered on wooden boards in open-air stalls where dust, dirt, and flies abound (Fig. 3). Consumers buying the meat are also in the habit of touching the meat to physically assess it or get a feel for the weight so they can set an appropriate price to haggle with the vendor/butcher.

Fig. 3. Hygienically processed and packed fresh meat cut from a meat processing company in Nigeria (phot. Bukola Adenuga)

While some meat vendors are stationary in the market, some vendors hawk their meat in small wooden crates, sometimes with only a flimsy piece of netting to protect the meat from the elements (dust, flies, sunlight, etc.). Refrigeration of meat for sale is virtually nonexistent in the Nigerian meat market, as electricity is also non-existent. Many butchers suffer losses when their meat is not sold in full every day because the price of a second day's meat drops drastically, especially if it has been out in the open all day and its fresh red colour from the day before is now a dull brown colour. In the worst case, this meat goes bad and must be disposed of.

In the poultry meat market, on the other hand, there is a higher level of hygiene in the sale and handling of meat. Throughout Nigeria, a high percentage of fresh poultry meat is sold frozen. It is sold in small or large stores, supermarkets, or even in open-air stalls. The system of selling poultry suggests that Nigerians can adopt a sanitary system of processing and distributing red meat. However, decades of unregulated acts in public slaughterhouses and the sale of meat in the open, which has resulted in cheap and affordable meat, have conditioned people to see this as the norm. It is therefore not surprising that more and more informed Nigerians are no longer buying this type of unhealthy meat as a new generation of red meat markets grows. This new generation of markets offers hygienically treated meat for sale, with a regulated pricing system that assures consumers that they are getting quality meat at a good price. Many of these new meat sellers are available online and offer online catalogues where consumers can shop and have a purchase delivered to their homes.

The bushmeat market is another thriving segment in the Nigerian meat industry. This market contributes significantly to total meat consumption in Nigeria annually. In WildAid's study, which surveyed 2000 people, it was found that over 70% of Nigerians living in urban areas have eaten game meat at least once in their lives (Unah and Knights, 2021). There are markets dedicated to the sale of bushmeat, such as the Oluwo market in Lagos, where all kinds of wildlife are offered for sale. Bushmeat can also be found hanging on poles along highways to be sold fresh or processed through hard smoking to motorists. Similar to the red meat market, less attention is paid to hygiene in these

markets. Carcasses of dead game with bullet holes or cuts from the snare are offered for sale unprocessed on wooden tables. Some vendors, however, process meats such as antelope and snakes by smoking them. To date, there is no standard commercial processing for bush meat despite its significant consumption in Nigeria.

MEAT FRAUD INCIDENCES IN NIGERIA

Food fraud is any intentional or deliberate attempt by a company or individual to deceive the consumer and make an illicit profit from the sale of a product (Commission Regulation EU, 2019). Food fraud comes in several forms: substituting ingredients, adding undeclared substances, diluting, reducing, mislabeling, etc. Fraudulent activities in buying and selling are a common phenomenon in many modern markets and Nigeria is no exception (Otu and Okon, 2019). The concept of fraud in the Nigerian food industry is not foreign or unfamiliar to many Nigerians who shop in the local markets. Nigerians, more than any other nation, face food fraud that has become their reality in hindsight. Nearly 200,000 Nigerians die annually from food poisoning and more than 90,000 are hospitalized for foodborne illnesses (Oyefeso, 2019). Locally produced unbranded and unpackaged products are highly vulnerable and susceptible to fraud.

Meat is very susceptible to fraud, especially when it is processed. It can be difficult to determine the type of origin, cut, or even the quality of the meat. Although meat is relatively widely available in Nigeria, it is still not easily affordable, especially in a volatile economy like Nigeria, where the slightest change in production factors immediately leads to an increase in food prices. Recently, meat production, processing, and sales have been severely affected by additional factors such as increasing insecurity and insurgency in the northern region of Nigeria, where most red meat animals are produced or found in large numbers. Also, the continuous increase in fuel prices and ethnoreligious clashes between herdsmen and farmers, livestock traders, and butchers are some of the factors affecting the availability of meat in Nigerian markets (Ajulo, 2022). These factors have led to widespread fraudulent activities such as mislabeling of meat, sale of expired meat, sale of meat of questionable origin, and product smuggling in the Nigerian meat industry.

Cases of meat fraud have been reported in several countries around the world, including the European horsemeat scandal (Smith and McElwee, 2021), the Chinese rat meat scandal (Dai and Jiang, 2013), and the Brazilian rotten meat scandal (Oxford Analytica, 2017). The incidents have shaken the media wave and consumers' interest in the authenticity of meat products has been reawakened, making them no longer just passively interested in verifying the meat products they consume (Kendall et al., 2019). In Nigeria, however, cases of fraud in the meat sector were far too underreported (Fig. 4) and the media do not give them the attention they deserved in order to alert consumers to the dangers of meat fraud. One can only speculate about the reasons for this lack of attention. Oyekunle (2018) attributes this to poverty and consumer illiteracy while Onyeaka et al. (2021) observed that despite the increasing food safety problems that have led to the deaths of hundreds of thousands of Nigerians, many are unaware of these dangers in the food industry.

Fig. 4. Fresh meat cuts offered for sale on wooden boards with no sanitary measures in place (phot. Bukola Adenuga)

The sale of contaminated meat is a major challenge in the Nigerian meat sector. Meat products have been reported to contain unhealthy levels of bacterial loads (Adesokan et al., 2021), aspergillosis and mycotoxins (Atanda et al., 2013), high levels of metal deposits (Ekanem et al., 2020), and even antibiotic residues (Omeiza et al., 2012). On September 19, 2022, the Nigeria Security and Civil Defence Corps (NSCDC), Kwara State Command, arrested a butcher

for allegedly selling contaminated meat after receiving a tip-off from a concerned person. Further analysis of the meat by the State Department of Health confirmed that the meat was not fit for consumption (Rabiu, 2021). In Lagos, Nigeria's most populous metropolitan state, a news reporter uncovered the sale of toxic brown ponmo (cow skin, a product derived from cowhide) to unsuspecting consumers. The leather-like material of ponmo is repeatedly scorched by these processors with toxic materials such as old shoes, tires, old motor oil and plastics to remove hair on the hide. This results in harmful fumes and blackened products contaminated with toxic chemicals and carcinogenic heavy metals (Lambo, 2021).

Another common practice is the use of paracetamol tablets and soda drinks when cooking meat to make it softer or more tender. Paracetamol is a drug used to treat mild headaches or fevers and was never designed for cooking and is therefore not approved for food safety. This practice was devised to reduce production costs but comes at the expense of consumer health (liver and kidney failure). The National Agency for Food and Drugs Administration and Control (NAFDAC) has issued a warning to all food processors and sellers to refrain from using the compound as a tenderizer (NAN, 2020). Similarly, the agency warned meat and fish sellers against using formaldehyde as a preservative to keep meat fresh (Odunsi, 2021).

In 2018, there were reports of a rather unusual incident in Bayelsa, a state located in the South-South region of Nigeria, where chicken meat was allegedly substituted with vulture meat and donkey carcasses. The suspected perpetrators sell this meat at very low prices to establishments such as restaurants, bars, and canteens that process them, making it more difficult for the end consumer to identify the species they are eating (Falade, 2018). Four other individuals were arrested in Edo State for illegally selling donkey meat (Peterson, 2021). Donkey meat is banned for human consumption in Nigeria after the Nigerian government recently banned the slaughter of donkeys, the consumption of donkey meat, and the illegal export of donkey hides to protect the animals from endangerment of extinction (Nwaiwu-Nnewi, 2020). Suya, a popular Nigerian beef kebab, has also been exposed as a product of fraudulent acts by butchers who sell dead animals to suya producers. Reportedly, 7 members of the same family died as a result of eating such a product in Abia state (Ukanwa, 2022). These instances of fraud in the meat sector show that meat processors are unaware of the impact of their cost-cutting measures on the health of consumers of their products. The apparent disregard for public health and consumer choice is exacerbated by the indifferent attitude of government officials who are supposed to ensure compliance with food safety regulations (Ukanwa, 2022). Table 3 shows a summary

Table 3. Reported cases of meat fraud in Nigeria

State/Region	Incident	Fraud category	Product involved	Reference
Kwara	Sale of contaminated meat	Adulteration	Raw meat	Rabiu (2021)
Lagos	Use of toxic materials for meat product processing	Adulteration	Ponmo (cow hide)	Lambo (2021)
Osun	Use of unauthorized substance as tenderizer	Adulteration	Cooked meat	NAN (2020)
Bauchi	Use of toxic chemical as preservative	Adulteration	Fresh meat	Odunsi (2021)
Bayelsa	Substitution of chicken with vulture	Misrepresentation	Processed and cooked chicken	Falade (2018)
Edo	Sales of illegal meat	Black or Grey Market	Donkey meat	Peterson (2021)
Lagos	Exhume and sale of unfit-for-consumption poultry products buried by law enforcement agents	Misrepresentation Adulteration	Fresh poultry meat	Ogbeche (2015)

of incidence of meat fraud gathered from online news sources. In many of the cases mentioned, suspects are typically fined and rarely brought to justice, while the public is urged to watch what they eat. This pedestrian approach to dealing with food fraud is why these problems still exist.

SUSCEPTIBILITY OF MEAT PRODUCTS TO FRAUD IN NIGERIA

Five major categories of food fraud as recognized by the EU are: adulteration/product tampering, counterfeiting, document forgery, grey market, and mislabeling (European Commission, 2021). Many of the instances highlighted in Figure 5 can be found in the Nigerian meat market. The vulnerability of meat products to fraud in Nigeria is fueled by several factors, including limited governance structures, limited traceability systems, and lack of public awareness. These conditions create an environment where fraudulent practices can thrive and compromise the quality, safety, and authenticity of meat products.

Consumers' ignorance or disregard of meat fraud is another of the causes of the increase in fraudulent activities by meat producers. Often, many meat buyers want quality or large quantities of meat for less than the going rate, and in an effort to satisfy their customers, these sellers resort to trickery and malicious means to achieve this. Secondly, due to the rising cost of living, resulting in high food prices, many Nigerians cannot afford the high prices of meat and meat products, so they look for cheaper alternatives. A good example of this is the high reliance of Nigerians on brown ponmo (cow skin) as a meat alternative. Despite numerous studies (Tijani and Ajayi, 2016; Tijani, 2017) showing that brown ponmo offers no nutritional benefits, and despite the federal government's warning against eating ponmo because of its mitigating effects on the leather industry, many continue to eat it anyway.

Meat producers also continue to face problems of limited or poor infrastructure, poor storage facilities, inadequate access to clean water, irregular power supply, lack of maintenance of meat processing machinery, and poor transportation systems. Products from these producers are usually contaminated and of low quality. Also, inadequate veterinary staff in slaughterhouses, abattoirs, and meat-producing plants to check the suitability of animals for processing has encouraged

Fig. 5. Categories of food fraud
Source: European Commission, 2021.

fraudulent practices such as processing sick or dead animals. Dead animals or animals unfit for consumption must be properly disposed of. However, some unscrupulous producers and processors buy these dead animals in large quantities and sell them as processed meat (Ukanwa, 2022). They are usually sold cooked and seasoned so that consumers do not know what they are eating.

Food production is generally not well-regulated in Nigeria. There is too much focus on ready-to-eat and packaged foods, medicines, and other fast-moving consumer goods (FMCG) by food safety agencies. Furthermore, there is a failure to pay close and adequate attention to unbranded and unpackaged foods, which make up the bulk of consumption among the middle class and less privileged Nigerians (Tijani, 2017). Street vendors (hawkers, stall holders), local canteens (bukateria), and roadside snack vendors are responsible for the majority of food consumed outside the home in Nigerian cities (National Bureau of Statistics, 2020). It is important that all food vendors maintain high standards to ensure that quality and authentic products are available to all consumers.

LEGAL FRAMEWORK FOR THE PREVENTION OF MEAT PRODUCT ADULTERATION IN NIGERIA

Across the world legal measures and laws exist to monitor and prevent meat product fraud. In the European Union, fraudulent activities involving food product are covered by Regulation (EC) No 178/2002 of the European Parliament and of the Council (Brooks et al., 2021). In Nigeria, the legal framework for combating meat product adulteration involves various laws and institutions which are not consolidated in a single enactment but are spread across different statutes (Uzoamaka, 2019). Many of these laws are long-standing from as far back as 1917 and they do not get reviewed often due to the lengthy and slow legislative process involved in the Nigerian national assembly (Okoruwa et al., 2022). Furthermore, the majority of these laws are proactive in nature; that is, they often focus on the final products and primarily target removing unsafe food from retail markets and punishing responsible parties after a lengthy investigatory process. This reactive approach may limit the effectiveness of prevention and early detection of meat product

adulteration (Okoruwa et al., 2022). Some major acts targeting meat products are listed below.

Criminal Code Act

Section 244 of the Criminal Code Act in Nigeria specifically addresses the offense of dealing with diseased meat. It states that anyone who knowingly brings the carcass of an animal that died of disease into a slaughterhouse or sells the carcass of a diseased animal is guilty of a misdemeanor and is liable to imprisonment for two years. This provision serves as a deterrent and provides a legal basis for prosecuting those involved in the adulteration of meat products.

Animal Diseases Control Act

Section 9(1) of the Animal Diseases (Control) Act CAP 17 LFN 2014 includes provisions related to the disposal of diseased animals. If an animal dies of a disease or is slaughtered in a manner contrary to the provisions of the Act and its carcass is deemed infected with a disease by a veterinary officer, the carcass must be disposed of through burning or as directed by the veterinary officer. These provisions help prevent the consumption of meat from diseased animals.

Meat Edict, 1968

The Meat Edict was amended in 1966 to empower the veterinary department to oversee the cleanliness, safety, and authenticity of meat and meat slaughterhouses across Nigerian states. Key provisions of the law include the maintenance of satisfactory sanitary environments, registration of slaughterhouses, the requirement for animals slaughtered for public consumption to be slaughtered in registered slaughterhouses, meat inspection by veterinary officers, condemnation of unwholesome meat by veterinary officers, stamping of fit-for-consumption animals by veterinary personnel, and prosecution of defaulters (Olukole, 2008). The Meat Edict acts as an important monitoring tool to ensure the quality and safety of meat products.

Hides and skin act: 6th Oct 1942 Ordinance

This law makes provision for the process, handling, preservation, and exporting of hides and skin. It provides guidelines for flaying, drying, preservation, and marketing of hides and skin, particularly those intended for export. However, it does not address the

processing and handling of these animal by-products as food products, as they were never intended for such use. Consequently, the diversion of hides and skins into the meat market as edible meat products violates established laws.

Federal Competition and Consumer Protection Act, 2018

The Federal Competition and Consumer Protection Act was created to develop and promote fair, efficient, and competitive markets in the Nigerian economy, thereby enabling citizens to access safe and quality products while protecting their rights. Part XV of the Act ensures consumers' right to information about a product in clear, understandable language, price, informative labelling, fair dealings, protection of consumers from false and misleading product representations, and preservation of consumers' right to quality and safe products. At the same time, part XVI of the law requires manufacturers to properly label their products and recall dangerous goods from the market.

The enforcement and implementation of these laws to prevent meat fraud are of the utmost importance. It ensures that instances of non-compliance are promptly addressed, and appropriate sanctions or punishments are administered by the relevant authorities (Uzoamaka, 2019).

Nigerian Agencies Tasked with Ensuring Authenticity in the Meat Industry

The National Agency for Food and Drug Administration and Control (NAFDAC), with its subunit Food's Safety and Applied Nutrition (FSAN) Directorate, oversees production in small- to medium-sized food establishments, provides inspection guidelines, and establishes the minimum good hygienic practices (GHP) required in the production, processing, and packaging of food of animal origin. The primary objective is to ensure both consumer protection and the safety of foodstuff. These agencies conduct inspections of production facilities and issue the required quality assurance certificates for products in cooperation with the Standards Organization Nigeria (SON).

The Standards Organization Nigeria (SON) is responsible for setting and implementing standards for all domestic and imported products. It establishes and ensures the application of standard measurement

procedures to products that require them. It also ensures that products meet all established standards and conducts inspections to ensure that all required safety information is included on product packaging. The Federal Competition and Consumer Protection Council (FCCPC) is the federal agency that handles complaints and protects consumers from unfair and deceptive trade practices. They monitor and investigate unhealthy competitive practices between businesses and among traders in the markets. They provide a platform for aggrieved or defrauded customers to fight back against companies or institutions that have violated consumer protection laws. To protect and promote exemplary behavior among Nigerian citizens, the National Orientation Agency (NOA) is charged with creating awareness, promoting positive attitudes, and fostering peace and harmony among citizens. The NOA works with food safety agencies, federal ministries, etc., to sensitize Nigerians on how the actions of these organizations benefit them. They also organize workshops and seminars to educate the public on the potential benefits and risks of certain activities. In addition, they provide information on food safety, health, and sanitation.

Other organizations involved in ensuring healthy practices in the Nigerian meat industry include the Federal Ministry of Health (FMOH), the Federal Ministry of Agriculture and Rural Development (FMARD), the Federal Ministry of Environment (FMEnv), the Federal Ministry of Industry, Trade and Investment (FMITI), the Federal Ministry of Education (FME), and the private sector.

IMPACT OF MEAT FRAUD ON NIGERIAN CONSUMERS

Food safety practices are a significant concern for Nigerian consumers, as evidenced by a self-reported study conducted in Ilorin among 869 meat consumers where 40 percent of the respondents showed "knowledge and practice levels of food safety" (Odetokun et al., 2022). Unhealthy and unsafe meat consumption can lead to various health risks, including exposure to allergens, toxic chemicals, and microbial contamination, resulting in direct, indirect, short-term, or serious health consequences (Onyeaka et al., 2022). A recent incident in Kogi State exemplifies these risks, where

the government banned meat consumption following the mysterious death of 20 cattle, some of which were discovered at the point of sale by health officials (Sahara Reporters, 2022). Unfit-for-consumption meat is often sold at lower prices to processors, who subsequently distribute it to unsuspecting consumers, thereby exposing them to the risk of zoonotic diseases. The outbreak of gastroenteritis in the Yagba West area of Kogi State in 2017, which resulted in 62 deaths, serves as an illustrative case where zoonotic diseases were transmitted through the consumption of contaminated meat (The Nation, 2017).

These incidents have significantly raised the awareness of Nigerian meat consumers, prompting them to be more cautious about their meat purchases. However, caution should be exercised regarding the reliability of shared health tips and advice on preventing meat adulteration, as many of these can be misleading, misinformative, or even pose greater health risks. For instance, some consumers have adopted the unhygienic practice of biting into the raw hide of fresh meat to assess its tenderness. Additionally, a social media platform user has suggested boycotting fresh meat in open markets that do not attract flies, alleging the use of insect repellents (Ezirigwe, 2018). Such practices of verifying meat authenticity are dangerous and expose consumers to additional foodborne hazards.

In Nigeria, where nearly 50% of the population is estimated to be Muslim, there is a lack of widespread understanding and proper implementation of halal meat concepts among butchers, processors, and consumers. Annabi and Lolade (2015) critical study on the perspectives of abattoir workers reveals that halal certification involves comprehensive adherence to specific practices throughout the entire production chain. However, several factors in Nigeria contribute to the meat being unworthy of halal certification, such as inadequate knowledge of the health and physiological condition of animals before slaughter, inhumane treatment, unclean slaughter environments, and a high risk of contamination. Consequently, many meat products in Nigeria may be falsely certified as halal based solely on the recitation of the shahada, without meeting the necessary halal criteria.

While some fraudulent acts in meat production, such as misrepresenting the sex of the animal, its origin (wild-caught or farm-raised), manipulating scales, or adding bones to deceive buyers, may not directly impact consumer health, they significantly undermine consumer confidence and the right to know what they have purchased or are consuming (Kendall et al., 2019). To avoid being deceived, many consumers prefer trusted or verified brands, often resulting in increased expenditure.

IMPACT OF MEAT FRAUD ON THE MEAT INDUSTRY AND ECONOMY

Illegal beef production, particularly in unlicensed operations, accounts for 42.9 percent of reported food fraud in the global beef supply chain (Elliott et al., 2019). The coexistence of illegal and legal producers leads to unfair competition and advantages that often result in meat products being offered at lower prices. Licensed meat production facilities adhere to regulated standards to ensure product quality and authenticity. However, when fraudulent producers appear on the scene, genuine products may be imitated, safety practices may be ignored, or products unfit for human consumption, such as Bovine Spongiform Encephalopathy (BSE) meat, may be produced. These practices negatively impact the meat industry and cause losses for real companies that must compete in an unfair market. The closure of over 700 fast food outlets in Nigeria, including popular brands such as Mr. Bigg's, Tantalizers, Tastee Fried Chicken, and Sweet Sensation, has been attributed to low clientele and unfair competition from bukaterias and mama-put food outlets, resulting in a higher unemployment rate and loss of revenue for the economy (Abiola, 2019).

Illegal importation of meat poses a threat to the Nigerian meat industry. The poultry meat sector is particularly affected by this economic threat. However, Nigerian poultry production giants such as CHI Farms, Zartech, and Ajanla have played an important role in ensuring a level playing field by implementing stringent biosecurity measures, investing in modern technology and equipment, and collaborating with supervisory authorities to enforce strict adherence to safety and quality standards in their supply chains to produce quality products which consumers trust. Additionally, in light of government plans to crack down on illegal meat imports, CHI Farms planned to double production by expanding operations and improving

storage facilities while maintaining product quality in order to meet the increasing demand for quality poultry products and contribute to the overall growth of the Nigerian poultry industry (Umeh, 2019).

Other far-reaching effects of meat fraud in the Nigerian economy are evident in the lack of export of Nigerian meat products to international markets. This is due to the World Trade Organization's dissatisfaction with production standards (Onyeka, 2016). To address the problems of hygiene, poor quality, and fraud in the industry, the introduction of national meat laws has been proposed. In addition, religiously certified foods require the establishment of a halal certification body in Nigeria. This certification process would cover all stages of meat production, including rearing, feeding, slaughter methods, handling, processing, packaging, storage, and transportation. Such measures would ensure the inspection and certification of meat products and reassure consumers that the meat they consume meets global requirements and standards.

ANALYTICAL METHODS FOR MEAT FRAUD IDENTIFICATION AND PREVENTION IN NIGERIA

Detecting meat fraud is critical in Nigeria's burgeoning food industry. Recently, food manufacturers have realized the financial benefits of selling processed products. Nigerian indigenous chicken breeds are now sold in packaged form. Kilishi (beef jerky), a popular beef snack usually sold without a brand name, is now available in packaged form in stores. Meatballs can also be found in both physical and online markets. In addition, food sales have evolved greatly to include bulk cooked foods delivered directly to consumers. Given this boom in the industry, it is critical that consumer welfare and confidence is maintained through proper authenticity testing of meat products. Considering the high percentage of Muslim population in Nigeria, verification of meat for non-halal ingredients is of utmost importance.

With the critical lack of research and studies on meat product authenticity testing, there is an urgent need for Nigeria to take a cue from other African countries such as South Africa, Egypt, and Tunisia. These countries have devoted scientific resources to analytical studies for the prevention and detection of fraudulent meat products. Some of these studies include next-generation sequencing (NGS) analysis to detect contamination and mislabeling in processed and commercially available meat products in South Africa (Chaora et al., 2022), near-infrared hyperspectral imaging (NIR-HSI), a nondestructive imaging method used to distinguish between the four categories of patty (Edwards et al., 2023), and various mass spectrometry techniques to determine the regional origin of lamb (Erasmus et al., 2016, 2017, 2018). The analytical methods used by these researchers are summarized in Table 4. When these methods are grouped, the following categories can be identified.

DNA-based methods

The DNA-based method for species identification is one of the most widely accepted methods for identifying meat species. Since all living organisms have a unique genome, DNA can be extracted and a specific gene fragment can be detected with relatively high accuracy using sophisticated techniques (Adenuga and Montowska, 2023). DNA-based methods are known for their high sensitivity, multiple species identification, and quantification. In addition, DNA barcoding techniques facilitate the accurate identification of species in meat products without any prior knowledge of using a database known as the Barcode of Life Database (BOLD) (Ratnasingham and Hebert, 2007), which contains known reference sequences by comparing them to the DNA sequence of the unknown species. This technique as applied by (D'Amato et al., 2013) to verify the authenticity of the commercial labels of regular and game meat products in South African local markets, showed that 76.5% of the game meat samples were substituted. A similar approach can be replicated in Nigerian meat markets to verify game meat products' authenticity.

PCR-based methods

There are numerous DNA-based methods for authenticating meat species, but polymerase chain reaction (PCR) plays a central role in most assays (El Sheikha et al., 2017). PCR in conjunction with post-PCR analyses such as restriction fragment length polymorphism (PCR-RFLP) and sequencing (PCR sequencing) underpin the reliability of PCR experiments in species identification. In addition, species-specific PCR and multiplex PCR allow accurate and rapid species

Table 4. Analytical techniques employed for meat products authentication in some African countries

Country	Analytical method	Method category	Meat product	Aim	Activity	Outcome	References
1	2	3	4	5	6	7	8
South Africa	Near-Infrared Hyperspectral Imaging	Spectroscopy	Raw beef patties	To discover a cheap, novel, and non-destructive technique for meat authentication	Eight hundred beef patties were analysed to assess the potential of NIR-HSI to distinguish between the four patty categories	It was possible to distinguish between the four patty categories with accuracies ≥97%,	Edwards et al. (2023)
South Africa	Next-Generation Sequencing	DNA	Minced meat, biltong, burger patties, and sausages	To identify processed meat product mislabeling	Sequencing, Quality control, and filtering	Sausage samples showed the highest level of contamination with 46% of the samples having mixtures of beef, pork, or mutton in one sample.	Chaora et al. (2022)
South Africa	Real-time PCR	PCR	Ready-to-eat meat products	To detect animal species in commercial products	DNA extracted from 44 ready-to-eat meat products was screened for the presence of commonly reported undeclared animal species using Real-time PCR	27% of the meat products tested contained undeclared species.	Sreenivasan Tantuan and Viljoen (2021)
Tunisia	Visible reflectance spectroscopy technique	Spectroscopy	Meat from pasture-fed and stall-fed lambs	To discriminate meat produced in conventional systems pasture or stall-fed	The colour and the reflectance spectrum of different fat tissues were measured	The study confirmed the efficiency of the visible reflectance spectroscopy technique applied to perirenal fat in feeding systems authentication	Hajji et al. (2019)
South Africa	Isotope ratio mass spectrometry (IRMS)	Mass spectrometry	Homogenized and defatted meat of the *longissimus lumborum* muscle	Origin verification and authenticity	Powdered meat samples were broken down into gases which were then fed into an isotopic mass spectrometer to obtain isotope ratios	95% and 90% correct classification of the samples for the estimation model and validation models	Erasmus et al. (2018)
South Africa	Proton-transfer mass spectrometry (PTR-MS)	Mass spectrometry	Lamb meat and fat from the *longissimus lumborum* (LL) muscle	To use volatile fingerprints obtained through PTR-MS analysis as an authentication tool	Measuring the volatile fingerprints of lamb meat and fat samples, chemometric analysis (PLS-DA), classification of the samples based on their region of origin and overall origin	PLS-DA models successfully classified the samples based on their region of origin and overall origin with high accuracy	(Erasmus et al. 2017)

Table 4 – cont.

1	2	3	4	5	6	7	8
South Africa	isotope ratio mass spectrometry (IRMS)	Mass spectrometry	Homogenized and defatted meat of the *longissimus lumborum* (LL) muscle	To differentiate between lambs from farms with different vegetation types	measuring the stable isotope ratios ($^{13}C/^{12}C$ and $^{15}N/^{14}N$)	The differences in $\delta^{13}C$ and $\delta^{15}N$ values showed promising potential for reliable authentication, particularly in determining the region of origin	Erasmus et al. (2016)
South Africa	ELISA, LCD array, Species-specific PCR, DNA sequencing	Immunoassay, DNA, PCR	139 processed meat products collected from retail outlets and butcheries	To assess the extent of mislabeling and fraudulent practices in meat products	A commercial DNA-based LCD array was used to initially screen, confirmed using species-specific polymerase chain reaction (PCR) and, in some cases, DNA sequencing	68% (95 out of 139) of the samples contained species that were not disclosed on the product labels, undeclared plant protein in meat	Cawthorn et al. (2013)
South Africa	DNA barcoding.	DNA	14 beef and 132 game label	To determine the authenticity of commercial labels of meat products, especially game meat	BLAST searches in GenBank for sequence comparison, maximum likelihood phylogenetic analysis	76.5% of the game meat samples were substituted	D'Amato et al. (2013)
Kenya	PCR-HRM analysis	PCR	107 meat samples from seven common livestock animals	To detect species substitution	PCR-HRM analysis was performed on these samples using primers targeting the three mitochondrial genes	10.3% species substitution was observed	Njaramba et al. (2021)
Egypt	Species-specific PCR-based method	PCR	Commercial meat products, uncooked beef burgers, sausages, kofta, and luncheon	To determine potential adulteration and/ or contamination with donkey, chicken, or human tissues	Species-specific PCR-based analysis was performed	87.5% of the analyzed beef samples were adulterated or mislabeled with one or more species	Omran et al. (2019)
Egypt	Species-specific PCR-based method	PCR	96 beef meat and meat product samples	To detect adulteration of crude and processed beef meat with horse and donkey tissue	PCR was used to detect the presence of horse and donkey tissue. Specific primers were used in PCR reactions.	6 out of 96 beef meat samples were positive for the presence of donkey tissue	Abd El-Razik et al. (2019)
Egypt	Polymerase Chain Reaction (PCR) and the Raw Meat Flow-ThroughTM Test.	PCR	30 beef meat product samples (hawawshi, sausage, and burger)	To detect species adulteration in meat products	DNA from the samples was extracted and subjected to PCR analysis, and adulterated samples detected by PCR were reanalyzed using the Raw Meat FlowThrough Test	80% of the examined samples contained undeclared meat species	Ahmed et al. (2020)

Table 4 – cont.

1	2	3	4	5	6	7	8
Egypt	SNP-based PCR-RFLP and forensically informative nucleotide sequence (FINS) methodologies	PCR	25 fresh red meat samples	To discriminate six red meat species (cattle, buffalo, goat, sheep, camel, and donkey) to ensure meat authenticity and prevent species substitution	PCR amplification of the mitochondrial 12S rRNA gene for all target species. FINS methodology was used for unambiguous identification. SNP-based PCR-RFLP to generate unique restriction fragment length polymorphism patterns for each species	One buffalo sample was substituted with cow meat, and one goat sample was substituted with sheep meat	Galal-Khallaf et al. (2021)
Tunisia	PCR-RFLP and species-specific Multiplex PCR	PCR	six commercial turkey sausage brands and fresh meat	To detect meat species in commercial meat products to ensure traceability and consumer confidence	gene using universal primers in PCR amplification of 359 bp cyt b. Enzymatic digestions of the amplified fragments	7 animal species were efficiently detected in pure and mixed meat samples. Triplex species identification	Gargouri et al. (2021)
Uganda	PCR-sequencing	PCR	229 bushmeat sample	To investigate bushmeat misidentification in northern Uganda.	PCR targeting specific genes and sequencing were performed to identify the species in the samples using NCBI BLAST	27.9% of the samples had disparate results between the species reported and the analysis using NCBI BLAST	Dell et al. (2021)
Tanzania	PCR-sequencing	PCR	151 bushmeat samples	To identify the species of origin of bushmeat in the Tanzanian market and confirm seller-reported species of origin	PCR and sequence analysis of the CytB gene were performed to determine the species of origin for each sample	30% of the bushmeat samples were misidentified by sellers	Schilling et al. (2020)
Egypt	Multiplex PCR coupled with 12S rDNA sequencing.	PCR	Frozen beef liver samples and cold cut samples.	To detect meat adulteration in frozen beef liver and cold-cut samples	Multiplex PCR to identify different types of meat residues. PCR-sequencing of 12S rRNA gene was performed to identify the species of frozen beef liver samples	62.5% of the processed beef samples were found to be contaminated with poultry residues	Galal-Khallaf (2021)
Egypt	PCR-RFLP (Polymerase Chain Reaction-Restriction Fragment Length Polymorphism)	PCR	Meat mixtures	To differentiate between mixtures of different animal species	PCR amplification using universal primers. Product digestion with two different restriction endonucleases	Unique banding pattern for each species or mixture, allowing for accurate identification	Farag et al. (2022)

identification. Abd El-Razik et al. (2019) achieved a sensitivity of 0.01% (w/w) for donkey or horse tissue in beef using their species-specific PCR assay to detect unwanted meat species in processed beef. Since many laboratories in Nigeria have PCR machines, PCR-based research for meat control should be encouraged.

Mass spectrometry-based methods

MS is an analytical method for detecting and measuring the masses of various molecules. This method is used to analyze nonvolatile compounds in a meat sample. Modern mass spectrometers can be programmed to detect specific peptides without the need for a bioinformatics database (Watson et al., 2017). High-performance liquid chromatography (HPLC) is a chromatographic technique used to separate, identify, and quantify the components of a sample. HPLC-MS identifies species in meat by identifying specific peptide markers. This allows for more specific identification and reduces overall laboratory time (Watson et al., 2017). Currently, HPLC is often combined with high-resolution mass spectrometry (MS). Other methods combined with MS include isotope ratio mass spectrometry (IRMS) (Erasmus et al., 2018) and proton transfer mass spectrometry (PTR-MS) (Erasmus et al., 2017).

Spectroscopy-based methods

Spectroscopy-based analyses are rapid, accurate, and nondestructive methods for determining the chemical composition of a variety of materials, including meat products. Spectroscopy techniques commonly used for meat authentication studies include near-infrared (NIR), Fourier transform infrared (FTIR), Raman, nuclear magnetic resonance (NMR) spectroscopy, and ultraviolet-visible (UV-Vis) and fluorescence spectroscopy. The operating principle of spectroscopic methods is based on the ability of biological, chemical, and physical components in meat products to emit measurable spectra when excited at specific wavelengths (Li et al., 2020; Saleem et al., 2022). These emitted spectra contain valuable information about the composition and properties of the samples. Subsequently, the spectra obtained are usually subjected to various chemometric analyses, such as multivariate statistical methods, to facilitate their interpretation and provide meaningful insights (Rohman, 2019). In Tunisia, the visible reflectance spectroscopy technique was used

to identify and discriminate lamb from conventional pasture and confinement. The result showed a range from 76.4% to 100% correctly identified meat origin (Hajji et al., 2019).

Immunoassays

Immunoassay techniques are a collective term for tests that use antibodies to detect the presence of specific proteins for species identification. Some important immunoassay techniques include enzyme-linked immunosorbent assay (ELISA), lateral flow immunoassay (LFI), and colorimetric immunoassay. The technique is based on the basic principle of immunochemistry, namely, the formation of an immune complex from an antigen and its specific antibody. It is highly adaptable and can also be used to detect genetic material. ELISA and lateral flow assays use specific monoclonal or polyclonal antibodies to identify targets labelled with appropriate antigens (Banerjee et al., 2023). Immunoassays are known to have a short test duration, contain inexpensive materials, are easy to understand, and do not require specially trained personnel (Asensio et al., 2008; Mandli et al., 2018). In their study, Cawthorn et al. (2013) used ELISA and LCD array methods and species-specific PCR and DNA sequencing to determine the degree of mislabeling in 139 processed meat products such as ground beef, burger patties, deli meats, sausages, and jerky from South African meat stores.

MULTI-STAKEHOLDERS' APPROACH IN ADDRESSING FRAUD IN THE NIGERIAN MEAT SECTOR

A comprehensive national food control system involving key stakeholders such as the government, food industry, consumers, and academic and scientific institutions is crucial for effectively managing and preventing food hazards, ensuring compliance with all food safety measures, and providing consumers with healthy and unadulterated products (Opia, 2020). The role of scientific institutes in combating meat fraud cannot be underestimated, as they conduct research and offer evidence-based solutions to address the issue. Researchers play a vital role in studying the prevalence and patterns of meat fraud, developing innovative detection methods, and establishing quality standards

for meat products. Their expertise can inform policy decisions and support industry practices aimed at ensuring the authenticity and safety of meat products. According to a report by Maestroni (2014), access to food control laboratories and related services is a fundamental requirement for generating surveillance data to manage food risks in a nation. However, the establishment and operation of laboratories come with significant costs, including expenses for equipment, tools, chemicals, and reagents. This can pose a challenge for individuals or institutions without sufficient financial resources to embark on such endeavors (Opia, 2020). Therefore, a more sustainable approach is to establish government-accredited laboratories that are readily available and accessible to producers, researchers, and consumers throughout the country (Maestroni, 2014). This would promote efficiency and collaboration and ensure the availability of reliable testing and analysis facilities for the detection of meat fraud.

Numerous reports have highlighted that food processors and retailers prioritize quantity, profit margin, and volume over the quality, freshness, and authenticity of raw materials or products they produce (Ezirigwe, 2018; Omemu and Aderoju, 2008). Therefore, the responsibility of regulating the meat sector lies with all industry stakeholders, including meat producers, processors, and distributors. It is crucial for them to reassess their objectives and establish consultative forums where members adhere to regulated standards, ensuring that every stage and level of production is properly vetted and scrutinized to meet accepted standards. Industry stakeholders need to work closely with scientific institutes and embrace the outcomes of research to incorporate them into their production strategies. For instance, in a study conducted on street-vended meat pies sold in Lafia, Nasarawa State, Nigeria, it was found that although the level of microbial contamination in the meat pies was within the acceptable threshold for human consumption, improper storage beyond two days could render them harmful to health (Okoro et al., 2021). Therefore, it is crucial to properly label such products, clearly indicating the type of meat used, production date, and sell-by or best-before date to prevent intentional and unintentional fraudulent activities, such as the sale of expired meat products.

There is a significant amount of work to be done by the Nigerian government to effectively secure the meat industry against the risks associated with meat fraud. A crucial first step is the complete overhaul of the entire production chain within the meat industry. It is imperative that animals raised for consumption undergo comprehensive monitoring and vetting by national veterinary agencies, starting from day zero up to the point of slaughter. Abattoirs and slaughterhouses should be renovated to meet standardized operating practices, and strict enforcement and appropriate punishment should be applied to any violations.

The government must ensure that all meat production businesses, their products, and trademarks are duly registered with the appropriate agencies such as NAFDAC, SON, and CAC (Corporate Affairs Commission). This registration will facilitate the implementation of a functional traceability system for meat products. Additionally, the issue of unbranded, unlabeled, or unregistered meat products must be addressed as it is a major source of product adulteration in the country. Regular and standardized routine checks should be conducted on production grounds, products, and market surveys to ensure compliance with established standards. Establishing a regulatory framework that promotes integrity and accountability is vital for the meat sector. Government agencies should facilitate information sharing and coordination among stakeholders, support research and development efforts, and provide financial incentives to encourage compliance with industry standards.

CONCLUSIONS

In Nigeria, the meat industry grapples with substantial challenges related to safety, hygiene, and product authenticity. This is well-reflected in the body of literature by Nigerian scholars, who have extensively examined various aspects of the meat sector, including production enhancement, spoilage prevention, industry challenges, and market constraints. Notably, a considerable focus has been placed on ensuring the safety of meat products. Consumers have been duly cautioned regarding ready-to-eat meat items, as demonstrated in the work of Erhirhie et al. (2020). Furthermore, recommendations for public awareness and improved coordination within the food supply value chain have been put forth as means to cultivate a comprehensive national food safety system (Omojokun,

2013). Some scholars argue that enhancing the oversight of the meat slaughter process by local authorities (Nwanta et al., 2008) and empowering butcher associations to enforce standards within meat markets (Grace et al., 2012) can significantly elevate product quality within the sector.

While these approaches outlined by the scholarly community are pivotal for promoting product and consumer safety, a concurrent understanding of product fraud, its limitations, and prevention has been relatively underrepresented. This article underscores the vulnerability of Nigerian meat products to fraudulent practices, stemming in part from consumer preferences for cost-effective items and the limited coordination within the meat sector due to the absence of robust standards enforcement in areas such as product metrology, sales, and packaging.

Through this review, it has become evident that a considerable research gap exists within the domain of meat product authenticity. Existing research, albeit limited, is often subsumed under the broader subject of food safety. It is imperative to communicate to the Nigerian populace that food fraud extends beyond product imitations, specifically within the realm of meat. In publishing this article, we aim to lay the foundation for food safety researchers and regulatory agencies in Nigeria to initiate investigations into meat product verification. By showcasing methods, objectives, and findings from analogous research conducted in other African nations, we seek to encourage future studies. We recommend that future research endeavors to incorporate consumer opinions on meat fraud as a starting point. Understanding what consumers perceive regarding possible adulteration in their consumption is a foundational step toward progress.

Furthermore, we anticipate that forthcoming research will delve into verifying product species claims, geographical origins, and halal certifications, among other aspects. As research continues to evolve, we aspire to reach a stage where consumers can employ home-test kits to confirm product claims independently. Ultimately, we encourage Nigerian food safety authorities to play an active role in the realm of meat safety, ensuring that all food items, whether packaged, unpackaged, or locally produced, meet established standards.

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