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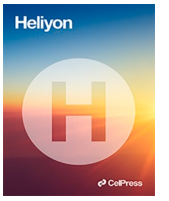

Review article

A review on microorganisms and mycotoxin contamination of selected '*swallow* meals' - Potential health risks to consumers

Ndukwe Maduka [a,*], Ositadinma Chinyere Ugbogu [b,c]

[a] *Department of Microbiology, Faculty of Science, Federal University Otuoke, Bayelsa State, Nigeria*
[b] *Department of Microbiology, Faculty of Biological and Physical Sciences, Abia State University, Uturu, Nigeria*
[c] *Faculty of Science and Computing, Amadeus University, Amizi, Abia State, Nigeria*

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ABSTRACT

Swallow is a local parlance used by Nigerians to describe ready-to-eat pasty foods rich in carbohydrates which include *fufu*, pounded yam, *amala*, *eba*, *lafun*, *tuwo*, among others; molded in small size balls using the palm and dipped inside a bowl of nutritious and delicious soup (okro, *edikaikong*, *egusi*, bitter leaf soups etc.) before swallowing it. *Swallow* meals are often prepared in households and eateries, without strict implementation of food hygiene, which predisposes the meal to contamination by microorganisms. The use of palm, often not properly washed, to eat *swallow* meal is a common practice that is capable of contaminating the food. Since *swallow* meals are regarded as street foods, microbial contamination, and subsequent release of mycotoxins above permissible limits into the food is a threat to public health. Therefore, we reviewed scientific papers published from 2000 to 2023 that reported various microorganisms and mycotoxins associated with *swallow* meals, starting from the preparation stages to the plate-ready meal. The dominant bacteria reported were *Bacillus* spp. and *Staphylococcus* spp., while the fungi are *Aspergillus* spp. Mycotoxins, which include aflatoxin, fumonisins, among others, were detected in some *swallow* meals, soup ingredients, and raw foodstuffs. Although only two incidences of foodborne outbreaks linked to contaminated *swallow meals* were reported, there is a need to regularly monitor the microbiological quality of the meals to avoid future outbreaks.

1. Background

Around 460 BC, Hippocrates asserted that food consumed by human beings is associated with certain illnesses [1]. At that time, it was difficult to explain what was contained in food, which could cause serious illnesses in humans after a meal. Consequently, millions of people have lost their lives as a result of eating food which ordinarily should not lead to death. Current scientific knowledge have shown that association between microorganisms, human beings, and food have been in existence for ages [2]. In every society, the quality of food available for the people to consume directly or indirectly impact their health and quality of life [3,4].

Historically, it has been established that certain foods, feeding habits, food art, and nutritional practices are associated with the culture of the people residing in a particular region. Naturally, people are desirous to consume varieties of foods commonly found within and outside their locality. A lot of people patronize foods associated with other cultures, which they often modify to suit their personal needs [5,6]. Culinary culture is influenced by the ways of life of the people in time past, geographical location, and strategies

* Corresponding author.
E-mail address: madukann@fuotuoke.edu.ng (N. Maduka).

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adopted by them for survival [7]. African culinary culture has been undergoing a lot of modifications since foreigners started visiting the continent, especially during the period of slave trade, leading to wide acceptability of 'modernized culinary culture' for Africans. The colonial masters introduced foods associated with their culture, while carrying out business transactions with Africans [8]. Since then till date, traditional African meals have been changing from time to time to suit the needs of the people [6].

According to Odeyemi [9], food is essentially one of the major disease transmission routes of pathogens. A wide range of micro-organisms are found in all types of food. Some of these organisms could be beneficial during food processing; responsible for food spoilage, or potentially harmful to human health [10]. Improper handling of food is a big threat to public health when such foods are consumed [11]. Every year, it is estimated that 600 million persons across the world experience illness, after consuming food and water contaminated with viable pathogenic bacteria or toxins released by spore formers or molds. Among the affected population worldwide, 420,000 estimated deaths occur annually, which involve 125,000 children less than 5 years old [12]. Annually, it is estimated that diarrhea associated with the consumption of contaminated food and non-potable water is the cause of 2.2 million deaths worldwide [13]. A total of 14,481 foodborne illnesses occurred in the USA in 2017, resulting from 841 foodborne outbreaks. Consequently, 827 patients were admitted in hospitals. Unfortunately, 20 deaths were recorded, while the patients were receiving medical treatment. Among the pathogens implicated in foodborne outbreaks in the USA, majority of them was caused by pathogenic bacterial species [14].

In 2006 and 2007, the Department of Public Health, Federal Ministry of Health, carried out a survey in Nigeria, aimed at evaluating the incidence of foodborne diseases in the country. The report shows that more than 2 million cases of foodborne illnesses occurred nationwide. Regrettably, more than 500 deaths occurred within that period as a result of foodborne illnesses [15]. Among the several causes of deaths in Nigeria in 2014, diarrhea account for 5 % mortality rate. More than 16 % of deaths that involve Nigerian children is caused by diarrhea [16]. Available statistics shows that more than 200,000 Nigerians die annually due to food poisoning [4,17]. Annually, it is estimated that the financial burden on Nigeria associated with foodborne diseases is US $ 3.6 billion [16,17]. There are two continents (Sub-Saharan Africa and Asia) in the world which account for the highest number of cases of foodborne diseases [3].

Despite the huge burden on Africa resulting from foodborne diseases, it is worrisome that many cases that occur in Nigeria are not reported to the authorities concerned for proper documentation, and necessary action. More than 90,000 cases of illnesses associated with consumption of contaminated foods occur annually in Nigeria. Epidemiological investigations are usually not carried out when foodborne outbreaks occur in the rural communities [16]. About 70 % of diarrheal diseases that occur in developing countries include *Escherichia coli* gastroenteritis, cholera, salmonellosis, brucellosis, shigellosis, campylobacteriosis, amoebiasis, poliomyelitis, typhoid, paratyphoid fevers, among others. These diseases are associated with consumption of food contaminated with pathogenic microorganisms [14,18].

1.1. Swallow meals

The phrase 'swallow meals', popularly called 'swallow' for short, is a typical 'Nigerian diet' that is not usually chewed, but swallowed [19,20]. ***Swallows*** are carbohydrate rich meals prepared from cereals (rice, maize, sorghum, millet, and wheat), tubers (cassava and yam), and starchy staples such as plantains. The majority of the raw foodstuffs required to prepare ***swallow*** meals grow abundantly in the tropical region. ***Swallow*** meal is a popular food consumed by most families in Nigeria. It is affordable, and the raw

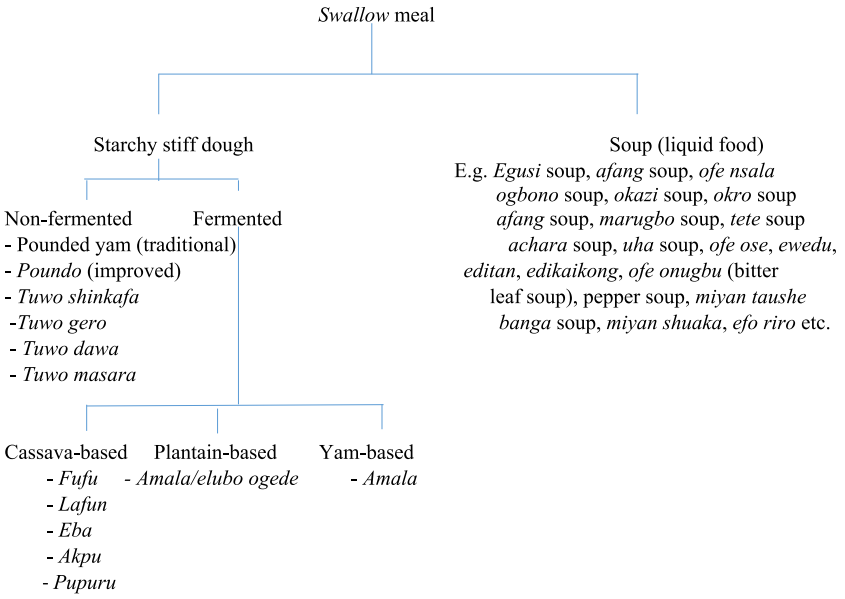

Fig. 1. Swallow meals popularly consumed by Nigerians.
Source: Primary

foodstuffs required to prepare the meal are readily available in the markets. In addition to carbohydrates, *swallow* meals are rich in minerals, and other nutrients [21]. Nigeria is rated the largest producer of cassava and yam in West Africa [22], and the world [23], respectively.

Soup is not the usual solid food rather, it is a liquid food prepared by boiling stewing ingredients, meat, fish, stockfish, vegetables, seasoning, etc., which becomes a broth that has a unique flavour. During the preparation of soup, locally produced thickeners are usually added to thicken the broth. It is the type of ingredients used in preparing soup that determine its nutritional composition and sensorial quality. Most people prefer to be served warm soup, while others would not mind if it was cold [24–29]. Fig. 1 shows a list of some locally prepared soups eaten by Nigerians.

Swallow meal is a combination of starchy food prepared from tubers, cereals or plantains, and consumed alongside *owerri* soup, *egusi* soup, *ukazi* soup, *ogbono* soup, *afang, ewedu, editan, banga* soup, *ofe-nsala*, okro soup, white soup, among others, which are regarded as Nigerian cuisines [8,27,30]. The majority of the *swallow* meals are prepared using cassava or yam tubers. They include *eba, amala, lafun, pupuru, fufu,* or *foo-foo,* also known as *akpu* by the people of south-eastern Nigeria [31–33]. *Swallow* meals, which include *fufu, eba, garri,* and *amala-lafun,* are prepared using cassava tubers [34,35]. Plantain is used to prepare *amala/elubo ogede,* while *iya* and *amala isu* are meals prepared using yam tubers. *Empkang nkuwo* is a locally prepared meal from cocoyam. Semolina is one of the products of wheat grains after milling [20]. *Garri* in cooked form is popularly called *eba* [36].

Adebayo et al. [37] compared the shelf life of ready-to-eat fermented foods (*fufu* and *eba*) and unfermented food (pounded yam), consumed as *swallow* meals. The food samples were stored at refrigeration (4 °C) and ambient temperatures (25 °C), under hygienic conditions. The microbial load of *eba* and pounded yam stored for 96 h was reported as 5.0 x 10^4 and 4.8 x 10^5 CFU/ml, respectively. At 96 h, the microbial load of *fufu* was quite lower than *eba,* and pounded yam. According to the results, the total bacterial count of the unfermented foods are significantly higher than the fermented foods. During the period of storage of the pounded yam, *Klebsiella aerogenes, Micrococcus varians, Proteus mirabilis, Streptococcus faecalis,* and *Staphylococcus epidermidis* were encountered in the product. *Lactobacillus plantarum* and *Staphylococcus epidermidis* were isolated from the stored *fufu* sample. The bacterial species isolated from *eba* include *Proteus mirabilis, Streptococcus faecalis,* and *Staphylococcus epidermidis*. At 96 h, the fungal count of *eba* was the highest, followed by pounded yam, and the least was *fufu*. The fungal species isolated from the pounded yam, during storage of the product include *Neurospora sitophila* and *Pencillium* sp. During storage of *eba*, the fungal species which include *Aspergillus niger*, *Mucor mucedo,* and *Penicillium* sp. were isolated from the product. *Aspergillus flavus* was isolated from the stored *fufu* sample. Fig. 1 shows the different types of starchy stiff dough and soups, which Nigerians refer to as *swallow* meals.

It is unusual for someone to swallow a starchy stiff dough as a meal, without combining it with a soup. However, a lot of people enjoy drinking soup without combining it with a starchy stiff dough. This is because, soup is tasty and nutritious. Most people enjoy eating *swallow* meals as long as different types of soups are made available. This is not the case with different types of starchy stiff dough, served with one type of soup.

Pupuru is a semi-solid starchy food popular among the people living in the riverine communities in the middle belt, east, and southern Nigeria [38]. It is prepared using fermented cassava flour. *Pupuru* is molded as a ball, and swallowed after dipping it in a bowl of delicious soup prepared with fish, meat, vegetable, and other ingredients [39,40]. It is widely believed that *pupuru* originated from Ilaje people residing in the riverine areas, and other localities in Ondo state [41]. *Pupuru* is commonly called 'ikwurikwu' by the people living in the east, middle belt, and riverine southern Nigeria [42–44].

In the third quarter of twentieth century, about 60 % of cassava produced in Nigeria was processed, and consumed as *fufu*. A similar product known as *garri* was produced using about 5 % cassava output in the fourth quarter of the century. *Fufu* is regarded as the largest product of cassava consumed as a *swallow* meal in Nigeria in the 21st century [45]. *Garri* processing is semi-mechanized unlike *fufu,* which is nearly 100 % manually processed. Traditionally, *fufu* processing is tedious, and time-consuming [46]. The shelf life of *garri* is longer than *fufu*. The aroma of *garri* is not offensive, unlike traditionally prepared *fufu* [34,36]. These factors are some of the limitations hindering the production of *fufu* in a large commercial quantity [45]. In order to reduce the stress involved in processing *fufu* using the traditional method, Sanni et al. [47] produced *fufu* flour using a flash and rotary dryer locally fabricated in Nigeria. The researchers did not ascertain the microbiological quality of the *fufu* flour, and compare it with wet *fufu,* prepared using the traditional method.

Loi-loi is a starchy stiff dough eaten as a *swallow* meal. It is common among the people of Cross River, Rivers, and Akwa Ibom state. *Loi-loi* and *fufu* possess almost the same attributes [48]. *Lafun* and *amala* is a dry flour obtained from fermented cassava and yam, respectively. They are collectively known as 'elubo', which is a popular food product among the Yorubas in Nigeria [49,50]. Traditionally, the preparation of starchy stiff dough vary slightly from one individual to another. It is partly responsible for the inconsistent quality of the product sold in eateries [22,36,49,51–53]. Similarly, the steps involved in preparing any type of soup, and the ingredients to be used, are personal choices influenced by cultural background, purchasing power, among other factors.

Foodstuffs used in preparing *swallow meals* are popularly sold in the markets in the form of *garri*, cassava flour, whole wheat flour, yam flour, and plantain flour. Kenechukwu and Ndidi [54] reported that industrially processed flour had lower bacterial and fungal counts compared with locally processed flours commonly sold in open markets. *Bacillus* sp., *Staphylococcus* sp., *Escherichia* sp., *Salmonella* sp., *Klebsiella* sp., *Enterobacter* sp., *Micrococcus* sp., *Lactobacillus* sp., *Proteus* sp., *Pseudomonas* sp., *Clostridium* sp., and *Corynebacterium* sp. are bacterial isolates, while *Aspergillus flavus, Aspergillus niger, Rhizopus stolonifer, Saccharomyces* sp., *Geotrichum* sp., *Penicillium* sp., *Candida* sp., *Fusarium* sp., and *Mucor* sp. are fungi isolates encountered in both locally and industrially processed flour samples. Odu et al. [55] reported that the mean total heterotrophic count, total fungal count, Staphylococcal count, and Bacillus count of exposed cassava flour, plantain flour, and yam flour were higher than the packaged flour samples, with few exceptions. A similar result was reported by Mbata et al. [56]. The mean heterotrophic bacterial count of exposed yam and plantain flour is 6.2 x 10^5 and 7.2 x 10^5 CFU/g, while the values for the packaged yam and plantain flour is 3.4 x 10^4 and 3.6 x 10^4 CFU/g, respectively. Somorin et al. [57] reported that the microbial count of laboratory-milled yam flour (3.85 x 10^3-1.88 x 10^4 CFU/g) is lower than the

commercially-milled yam flour samples (2.5 x 10^5-4.33 x 10^5 CFU/g). According to the researchers, during milling of dried yam chips, the process introduced a wide range of bacterial and fungal species, capable of releasing toxins into the flour. The microorganisms encountered in the laboratory-milled yam flour were *Bacillus megaterium, Klebsiella oxytoca, Staphylococcus aureus, Pseudomonas aeruginosa, Corynebacterium* spp., *Proteus mirabilis, P. vulgaris, Enterobacter cloacae, Rhizopus nigricans, Aspergillus niger, A. flavus, A. fumigatus, Fusarium oxysporum, Penicillium citrinum,* and *P. oxalicum.* Meanwhile, the commercially-milled white yam flour were contaminated with *Bacillus megaterium, B. badius, Klebsiella oxytoca, K. pneumonia, Staphylococcus saprophyticus, S. epidermidis, S. aureus, Corynebacterium* spp., *Edwardsiella tarda, Escherichia coli, Enterobacter aerogenes,* and *Escherichia coli.*

Since the milling machines commercially used in processing yam flour could be a source of contamination to the product sold in the markets, Somorin et al. [57] carried out a swab analysis of the machines located in Abeokuta, Ibadan, and Mushin. The bacterial population that colonized the milling machines range from 1.32 x 10^3 to 2.1 x 10^3 CFU/g. *Enterobacter aerogenes, Bacillus megaterium, B. badius, B. megaterium, Staphylococcus epidermidis, S. saprophyticus, S. aureus, Klebsiella oxytoca, K. pneumoniae, Corynebacterium* spp., and *Proteus mirabilis* were isolated from the milling machines. The fungal species also isolated from the milling machines were *Aspergillus flavus, A. niger, A. fumigatus, Rhizopus oryzae, Penicillium oxalicum, Fusarium verticilliodes, Penicillium oxalicum, P. citrinum Aspergillus niger, A. flavus, Mucor* spp., and *Rhizopus oryzae.*

1.1.1. Amala

Fermented yam flour reconstituted using boiling water, stirred continuously until a pasty dough is obtained, is known as *amala*. After processing yam tuber (*Dioscorea* sp.), and it becomes yam flour, it is used to prepare *amala* [23]. Some individuals prefer to use *Dioscorea alata* (water yam) to prepare *amala* [50,57]. *Amala* is light brownish in colour [50,58]. In a Nigerian traditional setting, yam is consumed as chips, *fufu*, pounded yam, and *amala* [59,60]. *Dioscorea rotundata,* commonly known as white yam, is the variety preferred by most people who want to prepare pounded yam, and *elubo* (yam flour popular among the Yorubas). The brownish colour of ready-to-eat *amala* is not appealing to some people. The brown colour of *amala* is due to non-enzymatic browning reactions that take place between sugars and free amino acids present in the yam flour [61]. Plantain flour is a good alternative to yam flour for preparing *amala* [62]. Abulude and Ojediran [63] used yam flour fortified with cassava and plantain flour to prepare *amala.* The product had improved qualities compared with *amala* prepared using unfortified flours.

Akinnibosun and Ojo [64] evaluated the microbiological quality of *amala* sold in eateries, and roadside canteens in Benin City. The researchers reported the total viable bacterial counts (TVBC) of *amala* obtained from roadside canteens as 9.0 x 10^7±0.43 CFU/g, while the total fungal counts (TFC) was 7.0 x 10^4±0.15 CFU/g. The TVBC and TFC of *amala* obtained from the eateries was 3.1 x 10^3±0.40 and 1.5 x 10^3±0.04 CFU/g, respectively. The result shows that *amala* sold in the roadside canteens were exposed to a higher level of microbial contamination, than the product available in the eateries. Anibijuwon and Sunday [2] reported total bacterial counts of 1.00 x 10^4±1.0 CFU/g and 1.65 x 10^4±0.5 CFU/g, for *amala* sampled from two restaurants in Ilorin, while the total fungal counts was 3.5 x 10^3±0.5 CFU/g and 8.5 x 10^3±0.5 CFU/g.

Omohimi et al. [65] carried out microbiological analysis of different batches of processed yam in the form of chips, flakes, and flour. The samples were obtained from selected markets in southwest Nigeria. Yam chips or flakes are milled before it can be used to prepare *amala*. The total bacterial count of approximately 60 % of freshly processed yam in the form of chips and flakes, obtained from different processors exceeded the limit (1 x 10^6 CFU/g) approved by the International Commission on Microbiological Specification for Food (ICMSF). The bacterial population in 20 % of the samples is 1 x 10^7 CFU/g. *Staphylococcus aureus* detected in some of the samples, did not exceed 1 x 10^5 CFU/g. The total coliforms (approximately 2 x 10^2 CFU/g) were encountered in 40 % of the samples. The limit recommended by the ICMSF for total coliforms in flours is 1 x 10^4 CFU/g.

Omohimi et al. [65] reported that the total bacterial counts of processed yam (chips, flakes, and flours), purchased from different markets exceeded the ICMSF limit (1 x 10^6 CFU/g). Coliforms were detected in the samples, whereas *Salmonella* sp. was not. It was reported that fungi contaminated more than 90 % of the samples. In summary, the study revealed that the microbiological quality of processed yam (chips, flakes, and flour), obtained from different processors was better than the products in the markets. Unhygienic handling of yam chips, flakes, and flours could be responsible for the high level microbial contamination of *amala*. The exposure of yam chips, flakes, and flours in the market could also be a source of contamination of *amala*. Mycotoxins were not detected in all the fresh samples of processed yam (chips, flakes, and flour), obtained from different processors. However, some samples of the commodity purchased from the traders in selected markets were contaminated with aflatoxin B_1 (AFB_1), aflatoxin B_2 (AFB_2), aflatoxin G_1 (AFG_1), and aflatoxin G_2 (AFG_2). Most of the yam flour samples obtained from the markets were contaminated with AFB_1 (0.7–3.4 ppb), AFB_2 (0.1–0.7 ppb), AFG_1 (0.5–2.9 ppb), and AFG_2 (0.1–0.2 ppb). Only a few samples of yam chips and flakes were contaminated with AFB_1 (0.8–1.2 ppb) and AFG_1 (0.6–1 ppb). It is important to note that the packaged yam flour samples obtained from the supermarkets, were far less contaminated with aflatoxin compared with exposed yam flour samples obtained from open markets. The permissible limit of AFB_1 in any processed product directly consumed by humans or intended to be used as an ingredient in foodstuffs is 2 μg/kg [65].

A study that involved the detection of aflatoxins in yam flour after processing two (2) yam varieties, namely *Dioscorea rotundata and D. alata,* was carried out by Somorin et al. [66]. According to the results obtained from the study, aflatoxin B_1 (<0.02 limit of detection, LOD to 3.2 μg/kg) and aflatoxin G_1 (<0.05–3.5 μg/kg), were detected in 57 % and 21 % samples of the white yam flours, respectively. Fumonisin B_1 (FB_1) within the range of (<0.5 (LOD) to 91 μg/kg), were detected in 32 % of the samples of white yam flour. Aflatoxin B_1 (AFB_1) and fumonisin B_1, within the range of <LOD to 0.6 μg/kg and <LOD to 2 μg/kg was detected in the water yam flour, which involved 32 % and 5 % of the samples, respectively. Findings from the study showed that the yam flour meal (*amala*) subjected to cooking, which is part of the steps involved in preparing ready-to-eat *amala,* reduced the level of AFB_1 and AFG_1 in the product by 44 % and 51 %, respectively. In a related study, Chilaka et al. [67] detected *Fusarium* mycotoxins in 68 % samples of *amala,* obtained from selected markets in Nigeria. The dominant mycotoxin was fumonisin B_1, which was within the range of 29–155 μg/kg. The presence of

pathogenic microorganisms and mycotoxins in the white yam flour is a potential health risk to the general public who use the flour to prepare *amala*.

1.1.2. Tuwo

'Tuwo shinkafa' also called 'tuwo rice', is a local dish prepared using mashed cooked white rice (*Oryza sativa* L.). Ready-to-eat *tuwo shinkafa* is soft and sticky. Grains such as millet and maize can also be used to prepare *tuwo*. *Tuwo shinkafa* is a pudding popularly consumed in the northern states in Nigeria. The consumption of maize *tuwo* is common among the Hausas in the West African region. Due to inter-tribal interactions in the region, other tribes have added maize *tuwo* to their food menus [68]. The preparation of *tuwo* involves stirring any of the cereal flours in boiling water, until a complete gelatinization of the cereal flour is achieved. Sometimes, there will be a need to add more cereal flour, followed by cooking, and stirring until the paste becomes stiff. The thickness of *tuwo shinkafa* is influenced by personal choice [69]. To enjoy the meal, a small piece of *tuwo shinkafa* is swallowed after mixing it with a delicious native soup. *Tuwo masara* (maize), *tuwo gero* (millet), *tuwo dawa* (sorghum), *tuwo shinkafa* (rice), are indigenous swallow meals [21,70,71]. Soups commonly served with *tuwo shinkafa* include *Miyan kuka, Miyan taushe,* and *Miyan kubewa*. Noah and Omoyeni [71] reported the total viable count, *Staphylococcus* count, and fungal count of *tuwo shinkafa* prepared using rice flour as 1.01 x 10^2, 0.00 x 10^2, and 0.00 x 10^2 CFU/g, respectively. In five boarding schools in Zaria, Nigeria, Abdulkareem et al. [72] reported that the mean total aerobic plate count, *Bacillus cereus* count, *Staphylococcus aureus* count, and coliform count of *tuwo* (corn meal) range from 4.23 ± 2.0–5.04 ± 3.2, 3.97 ± 2.0–5.36 ± 3.6, viable bacteria not detected - 3.40 ± 0.8, viable bacteria not detected - 2.70 ± 0.0 $\log_{10}$ CFU/g, respectively. The concentration of mycotoxins in the plate-ready *swallow* meals in comparison with the uncooked flours was determined by Ezekiel et al. [73] in Kaduna and Nasarawa states. The study involved ready-to-eat *tuwo shinkafa*, *tuwo masara*, *eba*, *amala,* and a few other meals prepared from cereals (maize, rice, sorghum, and millet), popularly consumed in northern Nigeria. Mycotoxigenic fungi encountered in the food samples were *Alternaria, Aspergillus, Penicillium,* and *Fusarium* species. The study reported the presence of forty-six (46) metabolites in the ready-to-eat meals. It was also reported that 36 % of *tuwo masara* out of thirty-nine (39) food samples were contaminated with aflatoxins (0.5–12.5 μg/kg) and fumonisins (3.6–711 μg/kg). The non-detection of diacetoxyscirpenol, monoacetoxyscirpenol, tenuazonic acid, and citrinin in the *tuwo masara* samples, was attributed to processing of the maize flour into a thick pudding (*tuwo masara*), ready for consumption. The key findings in the study is that, the concentration of mycotoxins in the uncooked foods was higher than the cooked food.

1.1.3. Pounded yam

Traditionally, pounded yam is a meal prepared using a mortar and pestle to pound boiled pieces of yam, until it becomes a thick and smooth pudding [74,75]. It is a well-recognized *swallow* meal eaten by the major tribes in Nigeria. The preparation of ready-to-eat (RTE) pounded yam is energy sapping and time consuming [74]. In order to reduce the stress and length of time involved in pounding cooked yam, a locally fabricated machine has been designed. Many families who prepare pounded yam at home have not started making use of the machine [76–79]. Instant pounded yam flour, popularly known as 'poundo yam', produced and packaged by medium scale industries, are available in the markets. The product save customers from the stress of using a mortar and pestle to prepare pounded yam [80,81]. The process of preparing ready-to-eat instant pounded yam involves measuring a particular quantity of yam flour. The predetermined quantity of yam flour is poured inside a boiling water. The mixture is continuously stirred until a desirable texture and taste is achieved [76,80]. In a recent study, Womboh et al. [82] reported that the mean total viable counts of pounded yam samples sold by food vendors in the major roads in Makurdi, is within the range of 2.61 x 10^5 to 3.25 x 10^5 CFU/g. Saleh et al. [83] reported that the mean bacterial counts of RTE pounded yam, obtained from three different sites in Katsina state is 1.70 x 10^5, 2.90 x 10^5, and 2.00 x 10^5 CFU/g. The samples of RTE pounded yam obtained from the three sites, had a mean *Escherichia coli* counts of 1.30 x 10^5, 1.30 x 10^5, and 1.20 x 10^5 CFU/g, while the *Staphylococcal aureus* counts were 4.50 x 10^5, 3.80 x 10^5, and 2.40 x 10^5 CFU/g. The mean coliform counts of the RTE pounded yam obtained from the three sites is 1.70 x 10^3, 2.80 x 10^3, and 1.30 x 10^3 CFU/g. According to Hemen et al. [84], the population of *Staphylococcus* sp., *Streptococcus* sp., *Salmonella* sp., *Shigella* sp., and *Escherichia coli* encountered in the ready-to-eat pounded yam, sold in a university cafeteria in Benue state is 1.11 x 10^{13}, 1.2 x 10^{13}, 6.3 x 10^{12}, 6.0 x 10^{11}, and 1.11 x 10^{13} CFU/ml, respectively. Muhammad et al. [85] carried out bacterial assessment of ready-to-eat pounded yam sold in the cafeterias, and canteens located in a tertiary institution in Dutse, Jigawa state. The viable bacterial population in the food samples were within the range of 5.6 x 10°-1.12 x 10^7 CFU/ml. Akinnibosun and Ojo [64] evaluated the level of microbial contamination of pounded yam sold in the eateries and roadside canteens in Benin City. The study showed that the total viable bacterial counts (TVBC) and total fungal counts (TFC) of pounded yam obtained from the roadside canteens is 7.4 x 10^4±0.63 CFU/g and 2.5 x 10^4±0.33 CFU/g, respectively. Surprisingly, no viable bacterial count was encountered in the pounded yam samples obtained from the eateries, but total fungal count (9.0 x 10^3±0.10 CFU/g) of the samples was reported. The presence of pathogens in the ready-to-eat pounded yam, pose a health risk to the consumers. The product is usually consumed without applying heat to reduce the microbial load to a safe level, before consumption.

According to Abdullahi et al. [75], the aerobic plate count of raw yam, shortly after the yam was pounded, and pounded yam left for 6 h in a restaurant/cafeteria/bukateria was 7.59 ± 0.45/6.05 ± 0.12/6.33 ± 0.64 $\log_{10}$ CFU/g, 5.77 ± 0.54/6.36 ± 0.46/5.63 ± 0.47 $\log_{10}$ CFU/g, and 6.74 ± 1.07/6.97 ± 0.27/7.76 ± 0.12 $\log_{10}$ CFU/g, respectively. The staphylococcal count of raw yam, shortly after the yam was pounded, and pounded yam left for 6 h in a restaurant/cafeteria/bukateria was 6.72 ± 0.88/5.86 ± 0.12/6.36 ± 1.38 $\log_{10}$ CFU/g, 5.55 ± 0.45/6.18 ± 0.54/5.72 ± 0.17 $\log_{10}$ CFU/g, and 6.80 ± 0.87/6.77 ± 0.20/6.67 ± 0.76 $\log_{10}$ CFU/g, respectively. In the same restaurant/cafeteria/bukateria, Abdullahi et al. [75], reported that the bacillus count of raw yam, shortly after the yam was pounded, and pounded yam left for 6 h in the food centres was 7.15 ± 0.98/0.46 ± 0.55/6.33 ± 1.20 $\log_{10}$ CFU/g, <1x10/5.60 ± 0.45/5.98 ± 2.60 $\log_{10}$ CFU/g, and 6.64 ± 1.08/6.87 ± 0.32/6.22 ± 0.18 $\log_{10}$ CFU/g, respectively. The coliform count of raw yam,

shortly after the yam was pounded, and pounded yam left for 6 h in a restaurant/cafeteria/bukateria was 5.89 ± 1.28/5.92 ± 6.27/5.37 ± 0.47 $\log_{10}$ CFU/g, 5.58 ± 0.47/6.38 ± 0.46/5.93 ± 4.60 $\log_{10}$ CFU/g, and 6.57 ± 1.08/6.66 ± 0.11/5.92 ± 5.72 $\log_{10}$ CFU/g, respectively. Shortly after the yam was cooked, as part of the process involved in preparing pounded yam in the food centres, Abdullahi et al. [75] also reported that the aerobic plate count, staphylococcal count, bacillus count, and coliform count of the samples was <1 x 10 $\log_{10}$ CFU/g.

1.1.4. *Fufu*

In parts of West Africa, yam (*Dioscorea* species), plantain (*Musca paradisiaca* AAB), cassava (*Manihot esculenta* crantz), and cocoyam (*Xanthosoma* species) are used in preparing *fufu*. Instant potato flakes, semolina, and rice could also be used to prepare *fufu*. The characteristic smell of *fufu* detestable to some persons could be attributed to uncontrollable activities of chance microorganisms responsible for fermentation of cassava during *fufu* processing [52,53]. Adegbehingbe et al. [86] reported that the mean total aerobic bacterial counts ($1.66x10^6$-$4.61x10^6$ CFU/g), lactic acid bacterial counts (2.4 $x10^6$-4.85 $x10^6$ CFU/g), and the fungal counts ($1.5x10^3$-$2.65x10^3$ CFU/g), were encountered in the *fufu* samples hawked by the producers. The production of *fufu* using the traditional method usually take place under unsanitary conditions [87]. Poor implementation of standard hygienic and safety practices increases the risk of microbial contamination of *fufu* [88]. The factors that predispose ready-to-eat *fufu* to microbial contamination include excessive handling, poor personal hygiene, the use of dirty hands, untreated water, and improperly washed mortar and pestle [89]. In order to reduce the level of microbial contamination of *fufu,* Obadina et al. [90] researched on the effectiveness of good hygienic practices (GHP), and good manufacturing practices (GMP) on the product. Before GMP and GHP was implemented during preparation of *fufu,* the aerobic count, anaerobic count, fungal count, coliform, feacal coliform, Bacillus count, *Staphylococcus,* and *Salmonella* spp. count of wet *fufu* is 4.0 x 10^4±1.5 x 10^4, <10, <10, 3.8 x 10^3±2.2 x 10^3, -ve, 2.2 x 10^2±1.7 x 10^2, 4.0 x 10^4±1.6 x 10^4, -ve CFU/g, while the result obtained after GMP and GHP was implemented is 4.5 $x10^2$±1.2 x 10^5, <10, <10, -ve, -ve, -ve, 2.3 x 10^2 ±1.0 x 10^2, and -ve CFU/g, respectively.

In a recent study, Addo et al. [78] reported that the bacterial count (4.90–5.88 x 10^3 CFU/g) of *fufu* processed with the aid of a motorized grinding machine is higher than *fufu* prepared using a mortar and pestle (2.01–2.76 x 10^3 CFU/g). According to the researchers, *fufu* prepared using grinding machines was contaminated with *Staphylococcus* sp., *Escherichia coli*, *Proteus* sp., and *Klebsiella* sp. The study also reported that *Escherichia coli, Proteus* sp., and *Klebsiella* sp. were present in the *fufu* prepared using a mortar and pestle. The crevices in grinding machines, and a dirty environment are possible reasons for the higher bacterial counts and bacterial species in the *fufu* prepared using a grinding machine compared with the *fufu* prepared using a mortar and pestle. In a recent study, Serwaa et al. [91] compared the bacterial load of mortar and pestle (used in various homes to pound *fufu*), with the grinding machines commercially used in preparing *fufu*. The researchers reported that the total viable count of grinding machines in the morning (before they were used in preparing *fufu*) and in the evening (after the machines have been used in preparing *fufu*) is 1.39 x 10^{12} and 1.63 x 10^{12} CFU/ml, respectively. The study also reported that the mortar and pestle, before and after it was used to pound *fufu,* had a total viable count of 8.67 x 10^{11} and 6.13 x 10^{11} CFU/ml, respectively. The bacterial genera reported in the study include *Staphylococcus, Diplococcus, Streptococcus,* and *Bacillus,* while the fungal genera include *Aspergillus, Fusarium, Trichophyton, Blastomyces, Penicillium,* and *Cladosporium*. The researchers did not differentiate the bacteria and fungi isolated from the grinding machines (before and after they were used to prepare *fufu*). The microorganisms reported from the swab test (before and after using the mortar and pestle to prepare *fufu*) were not differentiated too.

According to Omodamiro et al. [92], ready-to-eat *fufu* prepared using *fufu* flour is odourless. A flow diagram was used to describe the process of preparing *fufu* mash using the traditional method, and the modern method that produced an odourless *fufu* flour (sundried and oven dried). The researchers did not evaluate the microbiological quality of *fufu* prepared using the two methods. There is a limited information on the microbiological quality of ready-to-eat *fufu* prepared using *fufu* flour.

Adetunji et al. [32] reported that the bacterial counts of *fufu* sold in selected markets in Ilorin, is within the range of 3.0 ± 0.1 x 10^3 to 10.9 ± 0.1 x 10^4 CFU/g. Meanwhile, the fungal count of the samples is within the range of 9.0 ± 0.1 x 10^4 to 8.1 ± 0.1 x 10^5 CFU/g. The microbial population ranging from 3.5 x 10^6 -7.8 x 10^6 CFU/g was reported in the ready-to-eat wet *fufu* monitored for 7 weeks, within a university environment. On average, the microbial load of the *fufu* samples (5.5 x 10^6 CFU/g) evaluated in the study, is higher than the ready-to-eat foods, which include soup, semovita, and other available foods in the food center [15]. This result could be attributed to the unhygienic processes involved in preparing *fufu*, high moisture content of wet *fufu*, among other factors.

In terms of the level of microbial contamination, Akindele and Ibrahim [93] assessed the quality of *fufu,* and other ready-to-eat meals sold in bukateria, located in a university premises, Ado-Ekiti, Ekiti state. The researchers reported that the mean aerobic plate counts, and the fungal counts of *fufu* samples is within the range of 3.8 x 10^2 to 5.5 x 10^4 CFU/g, and 2.8 x 10^2 to 4.5 x 10^2 CFU/g, respectively. Omafuvbe et al. [94] also carried out microbiological analysis of the ready-to-eat *fufu* sold in Ile-Ife. The mean total mesophilic aerobic bacterial count, lactic acid bacterial count, Enterobacteriaceae, and *Staphylococcal* count is 3.44 ± 0.20, 3.06 ± 0.29, 3.41 ± 0.57, and 2.47 ± 0.27 $\log_{10}$ CFU/g, respectively. Yeast that is less than 1 $\log_{10}$ CFU/g, identified to be *Candida* species, was isolated from *fufu*. Bacterial species were the predominant microorganisms in the food samples.

Ewanfo et al. [95] evaluated the level of microbial contamination of the ready-to-eat *fufu,* sold in different markets in Benin City. The bacterial and fungal mean population of the samples range from 9.2 ± 8.4 x 10^7-10.1 ± 8.6 x 10^7 CFU/g, and 5.1 ± 4.4 x 10^7-5.6 ± 4.9 x 10^7 CFU/g, respectively. The bacterial species that had the highest and lowest percentage occurrence are *Escherichia coli* (30 %) and *Pseudomonas aeruginosa* (9 %), respectively. Among the fungal species isolated from the *fufu* samples, *Saccharomyces cerevisiae* (25 %) and *Rhizopus oryzae* (10 %), had the highest and lowest percentage occurrence, respectively.

A study carried out by Abass et al. [96], reported that the *fufu* flour samples obtained from different parts of Nigeria, was contaminated with aflatoxin B_1 (1.16 μg/kg), aflatoxin G_1 (not detected at a concentration < limit of detection), fumonisin B_1 (102.71

μg/kg), fumonisin B_2 (21.28 μg/kg), fumonisin B_3 (14.49 μg/kg), and zearalenone (1.89 μg/kg). The research findings by Abia et al. [97], revealed that the maize-*fufu* consumed in parts of Cameroon was contaminated with aflatoxin B_1 (0.3–1.8 μg/kg), cereulide (1–236 μg/kg), patulin (12–890 μg/kg), zearalenone (5–150 μg/kg), deoxynivalenol (14–55 μg/kg), nivalenol (116–372 μg/kg), and fumonisin B_1 (48–709 μg/kg).

1.1.5. Akpu

Leke et al. [98] reported that the total viable bacterial count, and fungal count of *akpu* obtained from different markets in Benue state, range from 3.2 x 10^5-6.5 x 10^5 CFU/g and 0–2.0 x 10^5 CFU/g, respectively. Coliforms were not encountered in the samples of *akpu*. In a related study, Hemen et al. [84] reported that a population of *Staphylococcus* sp., *Streptococcus* sp., *Salmonella* sp., *Shigella* sp., and *Escherichia coli* encountered in the fermented cassava (*akpu*) sold in a university cafeteria in Benue state is 1.28 x 10^{13}, 6.9 x 10^{12}, 5.6 x 10^{12}, 7.0 x 10^{11}, and 1.78 x 10^{13} CFU/ml, respectively. In another food service centre located in the University of Mkar, the population of *Staphylococcus* sp., *Streptococcus* sp., *Salmonella* sp., *Shigella* sp., and *E. coli* encountered in the fermented cassava (*akpu*) is 2.68 x 10^{13}, 2.18 x 10^{13}, 9.6 x 10^{12}, 3.0 x 10^{11}, and 2.13 x 10^{13} CFU/ml, while the values for the pounded yam is 3.62 x 10^{13}, 1.09 x 10^{13}, 5.4 x 10^{12}, 2.0 x 10^{11}, and 1.49 x 10^{12} CFU/ml, respectively. The presence of pathogenic microorganisms in the ready-to-eat *akpu* pose a health risk to the university community.

1.1.6. Lafun

Fermented cassava flour prepared in the form of ready-to-eat stiff porridge using boiling water is known as *lafun* [54]. According to Adetunji et al. [32], microbial contamination of *lafun* could occur at the stage of drying, milling, packaging, and storage. The researchers reported that the total bacterial count, and the total fungal count of the *lafun* sold in selected markets in Ilorin-West LGA, is within the range of 0.2 ± 0.1 x 10^4-5.4 ± 0.1 x 10^4 and 2.1 ± 0.1 x 10^5-8.2 ± 0.3 x 10^5 CFU/g, respectively. Adebayo-Oyetoro et al. [22] assessed the microbial load of cassava flour (*lafun*) in some parts of Ogun and Oyo states. The researchers reported that the total bacterial count of the cassava *lafun* flour obtained from different processing sites and markets, were within the range of 1.1 ± 0.11–4.8 ± 0.73 x 10^6 CFU/g and 3.2 ± 0.08–5.3 ± 1.23 x 10^6 CFU/g, respectively. The total fungal count within the range of 0–4.0 ± 0.39 x 10^3 CFU/g, and 0–4.0 ± 0.39 x 10^3 CFU/g, was encountered in the cassava *lafun* flours sampled from the processing sites and markets, respectively [22]. In a related study, Ashiru et al. [99] reported that the total plate counts of *lafun* flour obtained from the market is 2 x 10^5 CFU/g, while the yeast and mold count is 1 x 10° CFU/g. Lateef and Ojo [100] evaluated the level of microbial contamination at the various stages of processing cassava into *lafun,* in a study that involved sixteen processors of the product in two villages in Ogbomoso. The result showed that the microbial counts of *lafun* samples is within the range of 2.21 x10^4 to 9.91 x 10^4 CFU/g. The microorganisms encountered in the samples were *Salmonella* Typhimurium, *Staphylococcus aureus, Lactobacillus* sp., *Bacillus cereus, Escherichia coli, Klebsiella oxytoca, Aspergillus niger, A. fumigatus, A. flavus, Rhizopus oryzae,* and *Absidia corymbifera.* The microbiological quality of the *lafun* prepared by different processors in the Republic of Benin, was determined by Padonou et al. [101]. It was reported that the aerobic mesophilic count, *Bacillus* spp., Lactic acid bacteria, Enterobacteriaceae, total coliforms, and yeasts, were within the range of 4.3 x10^5-8.9 x10^8, 3.1 x 10^6-5.5 x 10^8, 4.7 x 10^4-5.3 x 10^7, 1.1 x 10^5-3.0 x 10^7, <10^2-2.3 x 10^5, and 2.5 x 10^2-5.3 x10^7 CFU/g, respectively. A study carried out by Abass et al. [96] reported the presence of aflatoxin B_1 (<limit of detection, LOD), aflatoxin G_1 (<LOD), fumonisin B_1 (88.09 μg/kg), fumonisin B_2 (10.70 μg/kg), fumonisin B_3, (<LOD), and zeralenone (7.6 μg/kg) in the samples of *lafun* obtained from processors in different locations in Nigeria. In a related study, Chilaka et al. [67] reported that the *lafun* obtained from selected markets, was contaminated with *Fusarium* mycotoxins. The result shows that fumonisin B_2, within the range of 30–392 μg/kg, was the dominant mean (μg/kg).

1.1.7. Pupuru

Pupuru is a meal rich in carbohydrates, prepared using fermented cassava flour. Aruwa and Ogundare [102] reported that the bacterial and fungal count of *pupuru* flour obtained from the traders, range from 0 to 6.6 x 10^4 CFU/ml and 0–4.0 x 10^4 CFU/ml, respectively. The bacterial species encountered in the samples include *Aeromonas* sp., *Acinetobacter* sp., *Enterobacter* sp., *Campylobacter* sp., *Klebsiella* sp., *Campylobacter* sp., *Corynebacterium* sp., and *Bacillus subtilis*. Also reported were fungal species, which include *Penicillium crustosum, P. chrysogenum, Aspergillus niger,* and *Rhizopus oryzae*. In a related study, Teniola et al. [44] reported that the viable bacteria count of *pupuru* balls, stored for 12 days at ambient temperature, range from 3.5 x 10^4-1.32 x 10^5 CFU/g. The microorganisms encountered in the *pupuru,* during the period of storage include *Bacillus subtilis*, *Lactobacillus* species, and *Staphylococcus aureus,* while the fungi isolates were *Fusarium* sp., *Rhizopus* sp., *Candida krusei*, *Aspergillus flavus*, *Aspergillus niger,* and *Penicillium* sp. According to Teniola et al. [44], the deterioration of the *pupuru* stored at room temperature, started on the fourth day. Adeyemo and Olaribigbe [40] detected aflatoxin (0.00096–0.0081 ppm) and fumonisin (0.08–0.68 ppb) in the *pupuru* flour sold in different markets in Okitipupa, Ondo state.

1.1.8. Eba

The level of microbial contamination of *garri*, invariably influence the quality of *eba,* i.e. cooked form of *garri* [96,103,104]. *Eba* prepared using yellow *garri*, white *garri,* and ijebu *garri* are popularly consumed in southern Nigeria. The addition of palm oil during the processing of *garri,* change the colour from white to yellow. The change in colour, makes yellow *garri* to become more attractive, than the white *garri*. It is not surprising that, the yellow *eba* is the choice of so many persons. Few studies have shown that, the yellow *garri* is richer in nutrients, than the white *garri* [105]. Adetunji et al. [32] reported that the total bacterial count (TBC) of yellow *garri* and white *garri*, range from 0.3 ± 0.1 x 10^4-2.0 ± 0.1 x 10^4 CFU/g and 0.6 ± 0.1 x 10^4-2.0 ± 0.1 x 10^4 CFU/g, respectively. The total fungal count (TFC), which ranges from 1.1 ± 0.1 x 10^5-5.9 ± 0.1 x 10^5 CFU/g, and 1.1 ± 0.1 x 10^5-6.1 ± 0.1 x 10^5 CFU/g, was reported

in the yellow *garri* and white *garri* samples, respectively. The TBC and TFC of ijebu *garri* is 0.3 ± 0.0 x 10^4 and 0.1 ± 0.0 x 10^5 CFU/g, respectively.

There are limited studies on microbiological assessment of ready-to-eat *eba* sold to the general public by food vendors, restaurants, and bukaterias [36]. A study carried out by Akinyemi et al. [106] reported that the bacterial count of street vended *eba* is 3.52 x 10^3 CFU/g. In a related study, Anibijuwon and Sunday [2] reported that the total bacterial count of the *eba* obtained from two restaurants in Ilorin is 1.15 x 10^4±3.5 CFU/g and 1.70 x 10^4±2.0 CFU/g, while the total fungal count is 3.5 x 10^3±0.5 CFU/g and 7.0 x 10^3±1.0 CFU/g.

In five boarding schools in Zaria, Nigeria, Abdulkareem et al. [72] reported that the mean total aerobic plate count, *Bacillus cereus* count, and *Staphylococcus aureus* count of *eba* consumed by the students, range from 0 to 4.00 ± 1.0 $\log_{10}$ CFU/g, 1.70 ± 0.7–4.41 ± 1.5 $\log_{10}$ CFU/g, and 0–4.11 ± 2.1 $\log_{10}$ CFU/g, respectively. Microbiological analysis of *garri* used in preparing *eba,* in the five boarding schools was reported. The result shows that the mean total aerobic plate count, *Bacillus cereus* count, and *Staphylococcus aureus* count range from 2.58 ± 1.2–4.72 ± 1.9 $\log_{10}$ CFU/g, 2.30 ± 1.6–3.87 ± 1.1 $\log_{10}$ CFU/g, 0–4.26 ± 1.0 $\log_{10}$ CFU/g, respectively. Viable bacterial colonies were not detected in some samples of *garri* and *eba.* Adebola and Abdullahi [107] reported that all the fungal species isolated from *garri* obtained from the markets, were present in the *eba* made from the *garri* stored for 3 days. The researchers did not carry out bacteriological analysis of *eba* and *garri*. Many researchers have reported different concentrations of mycotoxin in *garri* sold in different market locations. Ogiehor et al. [108] reported varying concentrations of aflatoxin B_1, aflatoxin B_2, aflatoxin G_1, and aflatoxin G_2 in *garri* purchased from selected markets across ten states in southern Nigeria. There are few studies so far carried out to determine the level of mycotoxin contamination of *eba*. Ezekiel et al. [73] reported that total fumonisin in the ready-to-eat *eba* is 3.7 μg/kg.

1.1.9. Semovita

Semovita is made by cleaning wheat grains, followed by conditioning, and milling of wheat grains into flour. Afterwards, the flour is supplemented with 10 % corn [70]. Semovita is one of the *swallow* meals consumed in Nigeria. It is not a locally prepared meal, which include *fufu, amala, lafun, eba, pupuru,* etc [5]. Since semovita manufactured and packaged by flour mills are not exposed to environmental contamination, it should be minimally contaminated with microorganisms. This is not the case with cassava flour, yam flour, and plantain flour, locally processed and sold in open markets. Adesetan et al. [15] reported that the microbial load of ready-to-eat (RTE) semovita, sampled from different vendors within a university campus in Ogun state at one (1) week interval, range from 1.2 x 10^6-5.0 x 10^6 CFU/g. On average, RTE semovita had the lowest microbial load (2.7 x 10^6 CFU/g), compared with other RTE foods evaluated in the study. In a related study, Hemen et al. [84] reported the presence of *Staphylococcus* sp. (8.9 x 10^{13} CFU/ml), *Streptococcus* sp. (1.5 x 10^{12} CFU/ml), and *Escherichia coli* (1.8 x 10^{12} CFU/ml), in the RTE semovita samples obtained from a university cafeteria. The ready-to-eat semovita samples also obtained from a public food service centre was contaminated with *Staphylococcus* sp. (7.0 x 10^{12} CFU/ml), *Streptococcus* sp. (9.13 x 10^{12} CFU/ml), and *Escherichia coli* (5.3 x 10^{12} CFU/ml). Atanda et al. [109] reported that the mean concentration of aflatoxin B_1 in the semovita samples obtained from Ogun state is 0.09 μg/kg.

1.1.10. Whole wheat flour

Whole wheat flour is prepared from intact wheat kernel. Bran, germ, and endosperm are contained in whole wheat flour, which has a course texture. The colour of whole wheat flour is light brown. The presence of bran in the whole wheat flour is responsible for the low gluten content of the product [110,111]. Ready-to-eat whole wheat is prepared by making a paste using the whole wheat flour and cold water. The paste is poured inside a pot containing boiling water placed on a gas stove, and stirred continuously for 1–3 min, until a dough of desirable texture is formed. A slight modification of the procedure involves pouring whole wheat flour directly inside boiling water until it becomes thick, followed by 1–2 min of cooking [70]. Whole wheat flour is consumed like other *swallow* meals. Although a large population of Nigerians consume whole wheat, available information on the microbiological quality of the product is limited. According to Shahzad et al. [111], the branded whole wheat flour has a better microbiological quality, than the unbranded whole

Plate 1. Ready-to-eat yellow *eba*. (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

wheat flour. Yeast was not detected in the branded whole wheat flour, whereas it was present in the unbranded whole wheat flour ($1.25 \times 10^1 \pm 0.35$–$6.4 \times 10^1 \pm 0.4$ CFU/g). Mold was also present in both the branded ($0.1 \times 10^2 \pm 0.4$–$0.8 \times 10^2 \pm 0.4$ CFU/g), and the unbranded whole wheat flour samples ($0.1 \times 10^2 \pm 0.1$–$1.95 \times 10^2 \pm 0.15$ CFU/g). The permissible limit for yeast and mold in the whole wheat flour, recommended by the Food Drug and Administration (FDA) is 10^2 CFU/g. According to Kenechukwu and Ndidi [54], a total heterotrophic bacteria count (THBC) of wheat flour, less than 3.5×10^5 CFU/g is regarded as low risk when it is consumed, because the product is likely not to cause foodborne illnesses.

1.1.11. Semolina and other starchy swallow meal

After wheat (*Triticum aestivum*) has been cleaned, conditioned, and milled, edible products such as semolina are obtained [112]. Durum wheat (*Triticum turgidum* L. subsp. *durum*), which has a coarse texture after grinding the endosperm, is known as semolina [110]. Semolina is one of the *swallow* meals consumed by a large population of Nigerians. Other foods regarded as *swallow* meals include oatmeal *swallow* and millet *swallow* [19]. Cereals such as rice and corn, milled as coarse middlings, are generally referred to as semolina. The preparation of ready-to-eat semolina is similar to whole wheat [54]. In the USA, the presence of myctotoxins in the durum wheat was reported by Manthey et al. [113]. A large quantity of wheat consumed in Nigeria is imported from the USA, and other European countries. Plates 1, 2, 3, 4, 5, 6, and 7 are samples of ready-to-eat *eba, fufu*, *amala*, *poundo*, semovita, whole wheat, and *pupuru*, respectively.

1.2. Swallow meals and food safety

Fermented foods which include starchy *swallow* meals, are regarded as microbiologically safe for human consumption [114]. This assertion might not be entirely correct because of poor hygienic practices, exposure of cassava, plantain, and yam flours in the open markets, excessive handling, dirty environment and utensils, among other factors, predispose *swallow* meals to microbial contamination. According to Sivamaruthi et al. [115], biogenic amines, bacterial toxins, mycotoxins, and cyanogenic glycosides are toxic compounds which could be released into food products during fermentation. Many fermented foods indigenous in Nigeria are contaminated with varying levels of mycotoxins [116]. When mycotoxins exceed the permissible limits in food, consumers could experience serious health effects which include liver tumors, brain damage, diarrhea, gastrointestinal problems, kidney damage, fertility problems, abortion, among others [117].

Due to high poverty rate in Nigeria in the past two decades, many families have little or no option than to introduce *swallow* meals to infants below one year. *Swallow* meals is not ideal for infants [118]. Although there has not been any reported case of foodborne illness or food intoxication directly linked to *fufu* [119], there is need for researchers and relevant regulatory bodies to regularly monitor the microbiological quality of the product sold in food centres, to prevent disease outbreaks. *Garri*, plantain flour, yam flour, etc. used in preparing *swallow* meals, ingredients used in preparing soup, and ready-to-eat *swallow* meals sold in food centres or served guests in ceremonies, should also be monitored. Guests in their large numbers attend ceremonies, prefer *swallow* meals to staple foods such as rice. Five families in Ilorin experienced symptoms of foodborne disease, after they consumed yam flour suspected to be contaminated with pathogenic microorganisms. A similar incident reported in Kano state, was linked to yam flour contaminated with lethal preservatives [120].

Ready-to-eat *fufu* is sold to customers in small wraps of different sizes. A transparent cellophane is commonly used to wrap ready-to-eat *fufu*. Akharaiyi and Gabriel [121] reported that, the *fufu* wrapped in small sizes had a lower microbial load, compared with bigger wraps of *fufu*. Several studies on the microbiological quality of ready-to-eat *fufu, amala, lafun,* and pounded yam have been reported. There are few studies on the microbiological quality of ready-to-eat *eba*. This is because, *eba* is generally regarded to be safe for human consumption [36]. There are limited studies on the microbiological quality of ready-to-eat *tuwo*, *pupuru*, whole wheat, semolina, and semovita.

Plate 2. Ready-to-eat *fufu*.

Plate 3. Ready-to-eat *amala*.

Plate 4. Ready-to-eat *poundo*.

Plate 5. Ready-to-eat semovita.

Omohimi et al. [65] reported that 22 % of yam flour samples obtained from selected markets in southwest Nigeria, were contaminated with aflatoxin B_1 which exceeded the permissible limit (2 μg/kg) for oil seeds, groundnuts, among other processed products. The researchers also detected aflatoxin B_2, aflatoxin G_1, and aflatoxin G_2 in the samples of yam flour. Cudjoe et al. [16]

Plate 6. Ready-to-eat whole wheat.

Plate 7. Ready-to-eat *pupuru*.

expressed concern that the enteric bacteria present in *swallow* meals such as *fufu,* could release shiga toxins above the permissible limits into the food. Table 1 shows the microorganisms isolated from foodstuffs used in preparing *swallow* meals. Table 2 shows the microorganisms isolated from *swallow* meals sold to the general public and laboratory-prepared meals.

1.3. Mycotoxin contamination of foodstuffs used in preparing swallow meals

Mycotoxins are secondary metabolites produced naturally by fungi. The fungi belong to the phyla *Ascomycota* and *Basidiomycota* [134]. Aflatoxin, ochratoxins, fumonisins, trichothecenes, patulin, citrinin, and zearalenone are mycotoxins of concern in commercialized edible foods [135,136]. *Aspergillus* sp., *Penicillium* sp., and *Fusarium* spp, are the three major producers of mycotoxins. *Aspergillus flavus*, *A. fumigatus*, *A. parasiticus,* and *A. niger,* naturally produce aflatoxins [96]. The presence of these fungal species in *swallow* meals increases the risk of mycotoxins being released into the product. Fungal contamination as a result of poor handling during processing, storage, and distribution of foodstuffs required to prepare *swallow* meals, are some of the predisposing factors for mycotoxins above permissible limits, to be released in the meal [116].

Limited studies have so far been carried out to monitor the level of mycotoxins in *swallow* meals sold in eateries, in different locations. Majority of the studies focus on *garri* flakes, cassava flour, yam flour, and plantain flour used in preparing *swallow* meals. Adeyemo and Olaribigbe [40] reported that the fermented cassava flour (*pupuru*) sold in different markets were contaminated with fumonisin and aflatoxins. The concentration of the mycotoxin reported in the study is below the limit approved by the National Agency for Food and Drugs Administration and Control (NAFDAC), which is 10 ppb and 6 ppb for aflatoxin and fumonisin, respectively. The concentration of aflatoxins in the fermented dried white yam used in preparing *gbodo,* and fermented dried plantain flour used in preparing *elubo ogede*, both products stored for 6 months, was evaluated by Jonathan et al. [62]. The total aflatoxins in the samples of *gbodo* and *elubo ogede,* stored for one month is 77.84 and 37.67 μg/kg, while the samples stored for six months is 96.34 and 65.17 μg/kg, respectively.

Table 1
Microorganisms isolated from the foodstuffs used in preparing *swallow* meals.

Fermented foods	Bacterial species	Fungal species	References
Yellow *garri*	*Bacillus* spp., *Pseudomonas* spp., *Bacillus cereus, Klebsiella* spp., *Staphylococcus aureus, Bacillus megaterium, Enterobacter* spp.	*Mucor* spp., *Fusarium* spp., *Penicillium* spp. *Aspergillus fumigatus, Aspergillus niger*, *Saccharomyces* spp.	[32,122]
White *garri*	*Pseudomonas aeruginosa*, *Lactobacillus* spp., *Klebsiella* spp., *Bacillus licheniformis, Staphylococcus aureus, Staphylococcus epidermidis*	*Pencillium* spp., *Aspergillus niger, Rhizopus* spp. *Aspergillus* spp., *Mucor* spp.	[32,122]
Garri ijebu	*Lactobacillus* sp.	*Aspergillus niger, A. fumigatus, Mucor* spp., *Saccharomyces* spp., *Saccharomyces* spp.	[32]
Garri	*Bacillus subtilis, Streptococcus faecalis, Staphylococcus aureus, Pseudomonas aeruginosa, Clostridium* spp., *Escherichia coli, Salmonella* spp., *Klebsiella* spp.	*Aspergillus niger, A. flavus, A. fumigatus, Penicillium citrinum, Rhizopus stolonifer, Botrytis cinerae, Fusarium moniuforme, Cladosporium* spp., *Penicillium* sp.	[107,108]
Cassava fermented *lafun*	*Staphylococcus aureus, Escherichia coli, Klebsiella oxytoca, Bacillus cereus, Clostridium sporogenes*	*Aspergillus niger, Aspergillus* spp., *Fusarium* spp., *Aspergillus flavus, Rhizopus* spp., *Penicillium* spp., *Mucor* spp.	[22,32]
Yam flour	*Staphylococcus aureus, Escherichia coli*	*Aspergillus flavus, A. niger, Aspergillus* spp., *Aspergillus fumigatus, Penicillium verricosum, Penicillium marneffei, Penicillium* spp., *Fusarium* spp., *Alternaria*	[65]
Plantain flour	*Staphylococcus aureus, S. epidermidis, Bacillus subtilis, Micrococcus* sp., *Enterobacter aerogenes, Klebsiella* sp., *Pseudomonas aeruginosa, Campylobacter* sp.	*Aspergillus flavus, A. niger, Penicillium* spp., *Geotrichum* sp., *Mucor* sp., *Trichoderma* sp., *Helminthosporium* sp.	[102,123]
Cassava flour	*Staphylococcus aureus, Escherichia coli, Proteus* spp.	*Saccharomyces cerevisiae*	[124]
Cassava flour (*pupuru*)	*Enterobacter* sp., *Klebsiella* sp., *Acinetobacter* sp., *Bacillus subtilis, Campylobacter* sp.	*Aspergillus flavus, Penicillium chrysogenum, Penicillium italicum, Fusarium moniliforme, Rhizopus stolonifer, Aspergillus niger, Penicillium crustosum*	[40,102]

Abass et al. [96] reported that some samples of *fufu* flour were contaminated with aflatoxin B_1 (1.16 μg/kg), fumonisin B_1 (102.71 μg/kg), fumonisin B_2 (21.28 μg/kg), fumonisin B_3 (14.49 μg/kg), and zearalenone (1.89 μg/kg). The researchers also detected fumonisin B_1 (88.09 μg/kg), fumonisin B_2 (10.70 μg/kg), and zearalenone (7.60 μg/kg) in *lafun*. Other mycotoxins which include aflatoxin G_1 detected in the *fufu* flour; aflatoxin B_1, aflatoxin G_1, and fumonisin B_3 detected in the *lafun* samples; were below the detection limit (μg/kg). In a related study, Leke et al. [98] evaluated the concentration of aflatoxins in the ready-to-eat *akpu* sold in some markets in Benue state. Findings from the study showed that aflatoxins, within the range of 1.30 ± 0.05–4.90 ± 0.08 ppm was detected in *akpu*. Aflatoxin (1.93 ± 0.05 ppm) was also detected in *akpu* prepared in the laboratory (control). Interestingly, the concentration of aflatoxin in the *akpu* samples, were below the maximum permissible limit (10 ppm).

Many researchers have reported varying concentrations of mycotoxins in *garri* sold in different locations. Sanyaolu et al. [137] reported 21.67 μg/kg, as the mean aflatoxin B_1 in the *garri* samples purchased from different vendors in Oron market. The result exceeded the permissible limit of 20 μg/kg or 20 ppb. Onyedum et al. [135] reported that the ochratoxin A, fumonisin, and total aflatoxin present in the samples of *garri* obtained from different parts of Niger state range from 1.30 to 170.1 μg/kg, 10–1390 μg/kg, and 2.60–55.40 μg/kg, while the yam flour samples are 1.20–8.20 μg/kg, 10–7200 μg/kg, and 5.0–39.45 μg/kg, respectively. The maximum concentration of aflatoxins approved by the European Commission is 4 μg/kg. The total aflatoxins and fumonisin in some samples of *garri,* were above the recommended limit. The European Union (EU) limit for fumonisin in food is 400 μg/kg. In a related study, Ogiehor et al. [108] reported that the concentration of aflatoxin in *garri* samples purchased from different markets in Anambra, Cross River, Delta, Edo, Enugu, Imo, Lagos, Ogun, Ondo, and Rivers states are within the range of 0.44–3.69, 0.32–4.57, 0.26–3.64, 0.13–4.46, 0.37–5.71, 0.14–3.16, 0.12–2.54, 0.25–1.66, 0.18–2.41, and 0.17–4.14 μg/kg, respectively.

Egbontan et al. [138] detected ergot alkaloids in 1 out of 4 samples of imported wheat grains used as a raw material in the flour mill industries in Nigeria, and all the samples (n = 10) of locally grown wheat grains. The researchers also reported that the concentrations of ergot alkaloids in the locally grown wheat grains were higher than the imported sample. Semolina, semovita, and whole wheat flour produced by flour mill industries are consumed as *swallow* meals [5,19,70]. Similarly, locally grown wheat grains are processed by individuals, mainly as whole wheat flour. Some northern states in Nigeria such as Kano and Jigawa, produce wheat grains in commercial quantity.

1.4. Microbiological assessment of native soups consumed as part of swallow meals

In Nigerian parlance, a soup that is stretchable and sticky such as *kuka, kubewa, okro, ewedu,* and *ogbono* are collectively known as *draw* soups. Another category of soup rich in vegetables such as *efo riro, edikang-ikong, oha, egusi,* and *efo* are collectively known as vegetable soups [139]. A study carried out by Akpoka et al. [11] reported that the mean total aerobic viable counts, mean total coliform counts, and mean total Staphylococcal counts of RTE soup samples sold in a restaurant in Okada is 4.80 ± 0.15 x 10^3, 1.00 ± 0.17 x 10^3, and 0.00 ± 0.00 CFU/g, while the samples obtained in another restaurant is 2.60 ± 0.12 x 10^3, 8.67 ± 1.20 x 10^3, and 3.70 ± 0.21 x 10^3 CFU/g, respectively. Samuel [132] reported that the total coliform count (TCC) encountered in street vended foods, which include *owoh* soup, *banga* soup, and *egusi* soup, sampled from different towns in Delta state is within the range of 0–2100, 73–510, 73–510, and 38–409 MPN/g, respectively. The total bacterial count (TBC) of *owoh* soup, *banga* soup, and *egusi* soup is within the range

Table 2
Microorganisms isolated from the *swallow* meals sold to the general public and laboratory-prepared meals.

Sample	Location	Bacterial species	Fungal species	References
Fufu	Benin City	*Staphylococcus aureus*, *Enterobacter aerogenes*, *Pseudomonas aeruginosa*, *Lactobacillus plantarum*, *Escherichia coli*, *Bacillus cereus*	*Saccharomyces cerevisiae*, *Aspergillus niger*, *Fusarium oxysporum*, *Penicillium candidum*, *Rhizopus oryzae*, *Candida albicans*	[95]
Fufu	Edo	*Bacillus* sp.	Not reported	[125]
Fufu	Ekpoma	*Streptococcus* sp., *Lactobacillus* sp., *Leuconostoc weisalle*, *Lactococcus* sp.	Not reported	[126]
Fufu	Ago-Iwoye	*Bacillus cereus*, *Salmonella* spp., *Staphylococcus aureus*, *Klebsiella* spp., *Micrococcus* spp., *Bacillus subtilis*	Not reported	[15]
Fufu	Ilorin	*Staphylococcus aureus*, *Streptococcus faecalis*, *Lactobacillus* sp.	*Saccharomyces* spp., *Candida* spp., *Aspergillus niger*	[32]
Fufu	Lokoja	*Klebsiella* sp., *Staphylococcus* sp., *Pseudomonas* sp., *Bacillus* sp., *Streptococcus* sp.	*Penicillium* sp., *Mucor* sp., *Fusarium* sp.	[127]
Fufu	Ile-Ife	*Bacillus subtilis*, *B. pumilus*, *B. cereus*, *Corynebacterium* sp., *Propionibacterium* sp., *Micrococcus varian*, *Staphylococcus aureus*, *Staphylococcus* sp., *Salmonella* sp., *Klebsiella* sp., *Citrobacter freundii*, *Enterobacter aerogenes*, *Lactobacillus plantarum*, *L. casei*, *L. bulgaricus*, *L. fermentum*	*Candida* sp.	[94]
Fufu	Ado-Ekiti	*Bacillus cereus*, *Escherichia coli*, *Salmonella* spp., *Shigella* spp. C*lostridium perfringens*, *Klebsiella* spp., *Proteus* spp., *Staphylococcus aureus*	*Mucor* spp., *Aspergillus* spp.	[93]
Fufu	Abakiliki	*Bacillus cereus*, *Staphylococcus aureus*	*Penicillium* spp., *Aspergillus flavus*, *A. niger*	[128]
Fufu	Akoko	*Staphylococcus aureus*, *Leuconostoc mesenteroides.*, *Bacillus cereus*, *Escherichia coli*, *Streptococcus* sp., *Lactobacillus plantarum*, *L. fermentum*	*Candida albicans*, *Mucor mucedo*, *Aspergillus niger*, *A. flavus*, *Fusarium oxysporum*, *Rhizopus stolonifer*, *Saccharomyces cerevisiae*, *Penicillium chrysogenum*	[86]
Akpu	Enugu	*Staphylococcus aureus*, *S. enteritidis*, *Escherichia coli*, *Streptococcus* spp., *Bacillus cereus*, *Klebsiella pneumonia*	*Aspergillus niger*, *Candida albican*	[129]
Eba	Lagos	*Serratia mascensens*	Not reported	[106]
Eba	Ilorin	*Staphylococccus aureus*, *Bacillus cereus*, *Escherichia coli*, *Salmonella* sp., *Shigella* sp.	*Aspergillus flavus*, *Mucor mucedo*, *Saccharomyces cerevisiae*	[2]
Lafun	Ogun and Oyo	*Escherichia coli*, *Bacillus cereus*, *Klebsiella oxytoca*, *Staphylococcus aureus*, *Clostridium sporogenes*	Not reported	[22]
Lafun	Ile-Ife	*Lactococcus plantarum*, *Lactobacillus bulgaricus*, *Lactobacillus casei*, *Lactococcus* sp., *Bacillus subtilis*, *Lactobacillus fermentum*, *Bacillus pumilus*, *B. cereus*, *B. macerans*, *B. circulans*, *Corynebacterium* sp., *Propionibacterium* sp., *Micrococcus varian*, *Staphylococcus aureus*, *Staphylococcus* sp., *Salmonella* sp., *Shigella* sp., *Klebsiella* sp., *Citrobacter freundii*, *Enterobacter aerogenes*	*Candida* spp., *Saccharomyces* sp. *Debaryomyces* spp.	[94]
Tuwo shinkafa	Zaria	*Bacillus cereus*, *Staphylococcus aureus*	Not reported	[72]
Pounded yam	Benin City	*Staphylococcus aureus*, *Bacillus subtilis*, *B. licheniformis*, *Klebsiella* sp.	*Aspergillus flavus*, *A. niger*, *Penicillium* sp., *Fusarium* sp.	[64]
Pounded yam	Yenagoa	*Shigella* spp., *Bacillus* spp., *Staphylococcus* spp., *Pseudomonas* spp., *Proteus* spp., *Klebsiella* spp., *Salmonella* spp., *Escherichia coli*	Not reported	[130]
Pounded yam	Makurdi	*Staphylococcus aureus*, *Escherichia coli*, *Proteus* spp., *Klebsiella* spp.	Not reported	[82]
Pounded yam	Katsina	*Escherichia coli*, *Staphylococcus aureus*	Not reported	[83]
Pounded yam	Dutse	*Streptococcus pneumoniae*, *Staphylococcus aureus*, *Escherichia coli*, *Salmonella* sp.	Not reported	[85]
Amala	Benin City	*Staphylococcus aureus*, *Bacillus subtilis*, *Micrococcus* sp.	*Mucor mucedo*, *Aspergillus flavus*, *Saccharomyces cerevisiae*	[64]
Amala	Lagos	*Alcaligens* spp., *Klebsiella* spp.	Not reported	[106]
Amala	Ilorin	*Staphylococcus aureus*, *Bacillus cereus*, *Escherichia coli*, *Salmonella* sp., *Shigella* sp.	*Aspergillus flavus*, *Mucor mucedo*, *Saccharomyces cerevisiae*	[2]
Semovita	Ago-Iwoye	*Staphylococcus aureus*, *Klebsiella* spp., *Micrococcus* sp., *Escherichia coli*	Not reported	[15]
Soup	Okada	*Staphylococcus* spp., *Enterobacter* spp.	Not reported	[11]
Melon seed soup	Kaduna	*Staphylococcus aureus*, *Bacillus cereus*, *Escherichia coli*	Not reported	[75]
Instant *egusi* soup	Kaduna	*Bacillus* sp., *Neisseria* sp., *Corynebacterium* sp.	*Aspergillus niger*, *Aspergillus* sp., *Penicillium* sp.	[27]
Egusi soup	Enugu	*Streptococcus faecalis*, *Bacillus* spp., *Escherichia coli*, *Klebsiella aerogenes*, *Staphylococcus aureus*	Not reported	[131]
Partially cooked *ukashi* soup	Ogba	*Vibrio* sp., *Enterobacter* sp., *Salmonella* sp., *Citrobacter* sp., *Klebsiella* sp., *Pseudomonas aeruginosa*	Yeast	[30]
Cooked *ukashi* soup	Ogba	*Salmonella* sp., *Enterobacter* sp.	Not detected	[30]
Ewedu	Lagos	*Proteus* sp., *Escherichia coli*, *Klebsiella* sp.	Not reported	[106]

(*continued on next page*)

Table 2 (*continued*)

Sample	Location	Bacterial species	Fungal species	References
Owho soup, *banga* soup, *egusi* soup	Delta state	*Bacillus* sp., *Salmonella* sp., *Staphylococcus epidermidis*, *Escherichia coli*	Not reported	[132]
Soup	Ogun state	*Bacillus cereus, S. aureus, Klebsiella* spp., *Micrococcus* sp., *Escherichia coli, Bacillus subtilis*	Not reported	[15]
Afang soup	Calabar	*Staphylococcus aureus, Escherichia coli*	Not reported	[133]
Egusi soup	Benin City	*Bacillus subtilis, E. aerogenes, P. aeruginosa, Klebsiella* sp.	*Mucor mucedo*, *Aspergillus flavus*, *A. niger, Fusarium* sp., *Penicillium* sp.	[64]
Vegetable soup	Benin City	*Staphylococcus aureus, E. aerogenes, P. aeruginosa, Klebsiella* sp.	*Mucor mucedo*, *Aspergillus flavus*, *A. niger, Fusarium* sp.	[64]

of 0–1.0 x 10^7, 3.1 x 10^3-1.0 x 10^5, and 2.7 x 10^4-1.5 x 10^6 CFU/g, respectively. The study further revealed that, the TBC and TCC of all the samples of *owho* soup were unacceptable. *Bacillus* sp. contaminated all the samples of *owho* soup. The total bacterial count (TBC) and TCC reported in 67 % samples of *banga* soup were unacceptable. It was also reported that 78 % and 67 % samples of *egusi* soup were unacceptable because of the TBC and TCC, respectively.

Bacteriological analysis of the ready-to-eat soup prepared, and sold in a university campus in Ogun state by street vendors, was reported by Adesetan et al. [15]. The bacterial load of the soup samples obtained from the vendors range from 1.9 x 10^6 to 7.7 x10^6 CFU/g. A freshly prepared soup left for few hours at room temperature, encourage the growth of microorganisms, because soup is a broth rich in nutrients. Akinnibosun and Ojo [64] reported that the total viable bacterial counts (TVBC) of vegetable soup sold in eateries, and roadside canteens in Benin City is 1.29 x 10^4±0.16 and 2.20 x 10^5±0.40 CFU/g, while the total fungal counts (TFC) is 3.5 x 10^4±0.18 and 9.5 x 10^4±0.20 CFU/g, respectively. The researchers also reported that the TVBC of *egusi* soup sold in the eateries, and roadside canteens in Benin City is 8.0 x 10^3±0.10 and 7.2 x 10^5±2.92 CFU/g, while the TFC is 8.0 x 10^3±0.01 and 5.3 x 10^4±0.22 CFU/g, respectively. Food spoilage microorganisms are capable of multiplying rapidly in any type of soup, unless it is properly preserved. A common method of preserving soup is by freezing [29].

Henry et al. [133] carried out bacteriological analysis of *afang* soup obtained from stationary food vendors under a shade, food vendors who were not staying under a shade, and mobile food vendors at five different locations in Calabar. The aerobic plate count (APC) of *afang* soup obtained from the mobile vendors, stationary vendors (with a shade), and stationary vendors (without a shade) range from 2.5 x 10^6 to 3.9 x 10^6, 1.2 x 10^6 to 2.2 x 10^6, and 1.90 x 10^6 to 3.5 x 10^6 CFU/g, while the *Staphylococcus aureus* count is 2.6 x 10^6 to 4.2 x 10^6, 1.8 x 10^6 to 3.2 x 10^6, and 2.4 x 10^6 to 4.0 x 10^6 CFU/g, respectively. The *Escherichia coli* count of *afang* soup obtained from the mobile vendors range from 1.4 x 10^6 to 3.2 x 10^6 CFU/g. *Escherichia coli* was not detected in some samples of *afang* soup obtained from stationary vendors (with or without shade) in some locations. The highest *E. coli* counts of *afang* soup sampled from stationary food vendors without a shade, and food vendors under a shade is 2.8 x 10^6 and 2 x 10^6 CFU/g, respectively. Most of the soup samples obtained from the mobile food vendors had the highest microbial load, when compared with the soup sampled from the stationary food vendors. The aerobic plate count, *Staphylococcus aureus* count, and *Escherichia coli* count of all the samples of *afang* soup, exceeded the set limit by the International Commission for Microbiological Specification for Foods (ICMSF). In a recent study, Osalumhense and Ekundayo [140] reported that *egusi* soup, vegetable soup, and okro soup sold by street vendors at Ikoba-Okha LGA,

Plate 8. Ready-to-eat *edikaikong* soup.

Edo state, were contaminated with microorganisms.

The level of microbial contamination of the ready-to-eat vegetable soup and pepper soup served in ships moving in Nigeria water ways, was reported by Adiama et al. [141]. According to the report, the bacterial count of vegetable soup and pepper soup is 47 x 10^4 and 55 x 10^5 CFU/g, respectively. *Salmonella* spp. was isolated from the vegetable soup, while *Leuconostoc* spp was found in the pepper soup. The research findings by Datsugwai et al. [27] indicate that the *egusi* soup prepared with vegetable is less vulnerable to contamination by microorganisms, compared with the *egusi* soup prepared without vegetable. A possible reason for this result is the effect of natural antimicrobial substances present in some vegetables used in preparing soup.

In a recent study, Eboh et al. [29] surprisingly did not detect bacteria in a freshly prepared *egusi* soup. After refrigerating the soup for 3, 7, 14, and 21 days, the total bacterial count of the soup was 5.0 x 10^3, 6.2 x 10^3, 4.8 x 10^3, and 5.0 x 10^3 CFU/ml, respectively. The bacterial species encountered in the soups were *Staphylococcus aureus, Streptococcus* sp., and *Bacillus* sp. Plates 8, 9, 10, 11, and 12 are samples of ready-to-eat *edikaikong* soup, okro soup, bitter leaf soup, *egusi,* and vegetable soup.

According to Abdullahi et al. [75], the aerobic plate count of melon seed soup and the soup left for 6 h in a restaurant/cafeteria/bukateria was 7.38 ± 0.39/5.56 ± 0.45/7.28 ± 0.92 and 6.03 ± 4.88/6.23 ± 0.40/6.89 ± 1.52 $\log_{10}$ CFU/g, respectively. The staphylococcal count of melon seed soup and the soup left for 6 h in a restaurant/cafeteria/bukateria was 6.61 ± 0.92/6.39 ± 0.51/6.27 ± 1.33 and 6.66 ± 1.08/6.48 ± 1.50/7.03 ± 0.98 $\log_{10}$ CFU/g, respectively. In the same restaurant/cafeteria/bukateria, Abdullahi et al. [75], reported that the bacillus count of melon seed soup and the soup left for 6 h in the food centres was 6.30 ± 0.75/6.33 ± 0.51/6.62 ± 1.17 and 5.58 ± 0.48/6.09 ± 0.55/6.07 ± 1.00 $\log_{10}$ CFU/g, respectively. The coliform count of melon seed soup and the soup left for 6 h in a restaurant/cafeteria/bukateria was 6.10 ± 0.25/6.11 ± 0.61/6.29 ± 1.35 and 5.76 ± 2.11/5.88 ± 6.27/6.28 ± 1.17 $\log_{10}$ CFU/g, respectively. Shortly after the melon seed soup was cooked in the food centres, Abdullahi et al. [75] also reported that the aerobic plate count, staphylococcal count, bacillus count, and coliform count of the samples was <1 x 10 $\log_{10}$ CFU/g.

1.5. Mycotoxigenic fungi and mycotoxins detected in soup ingredients

Different types of ingredients, thickeners, condiments, spices, fish, and meat are used in preparing soup. Few studies have been carried out to determine the concentration of mycotoxins in the various soup ingredients. The presence of fungal species capable of producing mycotoxin have been reported in some of the ingredients. A study carried out by Junaid et al. [142] reported that *Aspergillus flavus, Penicillium* sp., and *Rhizopus* spp. capable of producing mycotoxin, contaminated the stockfish sold in different markets in Plateau state. Aflatoxin B_1 (0–1.50 μg/ml) and ochratoxin (0–0.8 μg/ml) was detected in the samples of stored smoked catfish [143]. *Aspergillus flavus* and *Aspergillus parasiticus* capable of producing aflatoxin in the ready-to-use soup thickeners were isolated from 'akpalata' (*Afzelia africana*), 'offor' (*Detarium microcarpum*), 'achi' (*Brachystegia eurycoma*) and 'ukpo' (*Mucuna flagellipe*) displayed in open markets in the south-eastern part of Nigeria [144]. Okwu et al. [145] detected aflatoxin B_1, which range from 8.5 to 95, 8.0–90, 4.5–56, and 4.0–50 μg/g in *akpalata, offor, achi,* and *ukpo* displayed in selected markets in south-eastern Nigeria. In a related study, Fashogbon et al. [7] detected aflatoxins, which range from 1.05 ± 0.64–5.10 ± 0.07 ppb in *Irvingia gabonensis* var. *gabonesis* kernels displayed by retailers in different markets in Oyo state. *Irvingia gabonensis* is known as 'apon' and 'ogbono' in Yoruba and Igbo language, respectively. The distribution of toxigenic metabolites of fungi in the melon seeds obtained from vendors in Benue state was reported by Esan et al. [146]. The researchers reported that the mean concentration of mycotoxins in *egusi* (melon), which include

Plate 9. Ready-to-eat okro soup.

Plate 10. Ready-to-eat bitter leaf soup.

Plate 11. Ready-to-eat *egusi* soup.

aflatoxicol, aflatoxin B_1, aflatoxin B_2, aflatoxin G_1, aflatoxin M_1, alternariol (AOH), AOHmethylether, beauvericin, citrinin, dihydrocitrinone, ochratoxin A, ochratoxin B, and sterigmatocystin is 2.04, 9.13, 1.66, 0.52, 0.61, 0.53, 3.72, 0.34, 2.83, 2.21, 112, 94.2, and 1.71 μg/kg, respectively. The quantity of AFB_1 detected in melon (*Colocynthis citullus* L.) and bush mango (*Irvingia gabonensis*) seeds, obtained from selected markets in Lagos state, exceeded the recommended limit (2 μg/kg) [147]. The mean total aflatoxins detected in all the samples of melon seeds exceeded the EU approved limit (4 μg/kg), which also include 88 % and 50 % of discoloured and non-discoloured bush mango, respectively. The study further revealed that the mean AFB_1 (50.4 μg/kg) and mean total aflatoxins (62.9 μg/kg) of hand peeled melon seeds are higher than the mean AFB_1 (16.9 μg/kg) and the mean total aflatoxins (25.8 μg/kg) detected in the melon seeds shelled with a machine. Based on the concentration of aflatoxins reported in the study, *egusi* peeled with a machine is safer for human consumption than the *egusi* peeled manually. The researchers also reported that the discoloured bush mango had a mean total AFB_1 of 95.4 μg/kg and the mean total aflatoxins of 112 μg/kg, while the non-discoloured bush mango is 5.8 μg/kg and 4.4 μg/kg, respectively.

According to Negedu et al. [148], mold can attack different species of pepper, which include *Capsicum chineze, C. frustescens, C. annum, C. pabescens,* and *C. baccatum*, among others, leading to the contamination of the product by mycotoxins. A study carried out by Anthony et al. [149] detected aflatoxin B_1 (2.00–12.4 μg/kg), aflatoxin B_2 (0.55–4.95 μg/kg), aflatoxin G_1 (0.55–10.0 μg/kg), and aflatoxin G_2 (0.55–2.70 μg/kg) in the red hot chili pepper, while the dried samples were within the range of 0.05–2.50, 0.05–0.90, 0.50–4.25, and 0.55–3.20 μg/kg, respectively. The researchers did not detect aflatoxin in both fresh and dry samples of okra

Plate 12. Ready-to-eat vegetable soup.

(*Abelmoschus esculentus*), commonly used to prepare soup.

1.6. Risk of microbial contamination of swallow meals from the palm

Poor handling of soup ingredients and raw foodstuffs used in preparing *swallow* meals could lead to microbial contamination of the food. The consumption of such foods is a threat to public health [150]. The hand used by food handlers have been reported as the main source of microorganisms that contaminate foods. A wide range of microorganisms predominantly bacteria, belonging to the families Staphylococcaceae, Corynebacteriaceae, Streptococcaceae, and Propionibacteriaceae are among the group of microbes that constitute microbiome of the hands. Fungal species which include *Malassezia* spp. and *Aspergillus* spp. are the least predominant microorganisms found in the hands [151].

The two categories of microorganisms that usually colonize the hands are referred as transient and resident microorganisms [151]. *Staphylococcus aureus, S. epidermidis, Corynebacteria* spp., *Micrococcus* sp., and some members of Enterobacteriaceae family constitute the resident group of microbes, while the transient microbes which are usually pathogenic include *Escherichia coli, Shigella* spp., *Salmonella* spp., *Clostridium perfringens, Giardia lamblia*, Norwalk virus, and Hepatitis A virus [152].

Traditionally, *swallow* meals are eaten with the palm instead of cutlery. It is an age-long tradition for Africans to use their palm to eat different types of food. This eating habit is likely to contaminate *swallow* meals with microorganisms if the palms are not properly washed [153]. In a traditional setting, a lot of people do not derive satisfaction using cutlery to eat *swallow* meal. They prefer using their palms because small balls of stiff starchy dough is easy to mold, and swallowed after dipping it inside a bowl of soup.

When the palm or hands come in contact with dirty surfaces, they become contaminated with dirts and a wide range of microorganisms. The hand is a vehicle for spreading about 60 % of gastrointestinal infections [14,154]. Abdullahi et al. [75] did swab analysis of workers' hands in food centres, where melon seed soup, pounded yam, and other foods are sold in Zaria, Kaduna State. The researchers reported that the aerobic plate count, Staphylococcal count, Bacillus count, and coliform count of hand swab of restaurant workers is 6.07 ± 0.19, 7.56 ± 0.40, $<1 \times 10$, and $<1 \times 10$ $\log_{10}$ CFU/g, while the workers in the cafeteria is 6.95 ± 0.21, 6.91 ± 2.9, 5.78 ± 0.12, and 6.85 ± 0.20 $\log_{10}$ CFU/g, respectively. The swab analysis result of worker's hands in the bukateria shows that the aerobic plate count, Staphylococcal count, Bacillus count, and coliform count is 5.41 ± 0.43, 7.34 ± 1.17, $<1 \times 10$, and $<1 \times 10$ $\log_{10}$ CFU/g, respectively. Proper washing of hands with soap and clean water will reduce the risk of diarrohoeal diseases [155]. A study carried out by Burton et al. [156] showed that handwashing using non-bactericidal soap and water is more effective in eliminating bacteria colonizing the palms, than using water only. In a traditional setting where *swallow* meal is served, a small basin of water is usually placed by the corner for washing of hands. Some researchers have expressed concern about the level of microbial contamination of water used by individuals to wash their hands before eating *swallow* meals. The pathogens present in the untreated water used for handwashing could contaminate the food before it is consumed. High population of *Escherichia coli* in the water used for handwashing is partly responsible for the survival of the bacterium in the hands after handwashing. The temperature of water, availability of soap, and the procedure adopted in washing both hands in relation to time, influences the effectiveness of handwashing. The United States Food and Drug Administration (FDA) recommend the use of water at 40 ± 2 °C to wash hands [14,157].

According to Mihalache et al. [157], standard washing of hands involve the use of water and soap. The steps recommended which include washing, scrubbing, rinsing, and drying should last for 20 s. Swab analysis of the hands used by food handlers working in food service outlets is an indicator of the level of compliance of handwashing, food handling, and personal hygienic practices [151,158]. In a bid to increase public awareness about hand hygienic practices, promote the culture of people washing their hands regularly with

soap and clean water, 15th October 2008, was declared by the Global Public-Private Partnership for Hand washing, as the Global Hand Washing Day, for the first time. The declaration was a strategic move by the United Nations General Assembly to promote sanitation globally. Because of the declaration made in 2008, it was designated as the International Year of Sanitation [159].

1.7. Health risks associated with consumption of swallow meals contaminated with microorganisms

The consumption of *swallow* meals contaminated with *Salmonella, Shigella, Vibrio, Staphylococcus, Escherichia coli, Clostridium perfringens*, *Bacillus cereus, Citrobacter diversus, Proteus mirabilis, Proteus vulgaris* or *Citrobacter* spp. could result in gastroenteritis [160]. *Pseudomonas, Klebsiella, Enterobacter,* and *Proteus* are responsible for enterotoxigenic gastroenteritis [1]. According to Graves [161], gastroenteritis is a medical condition manifested by inflammation of the stomach, small intestine or large intestine. The symptoms of gastroenteritis are vomiting, nausea, diarrhea, weakness, loss of appetite, fever or chills, bloating, and abdominal cramps [160]. Globally, *Escherichia coli* has been recognized as a pathogen associated with gastro-enteric disease [162]. In different parts of the world, cases of foodborne outbreak linked to *Citrobacter freundii,* have been reported. The pathogen is implicated with severe gastroenteritis [160]. It is possible for healthy individuals to experience gastroenteritis after ingesting food contaminated with *Serrtaia marcescens*. Infections caused by the bacterium manifest several symptoms which include diarrhea, chills, fever, and abdominal cramps [163].

The growth and multiplication of *Clostridium* sp. in *swallow* meals could release toxins into the product. After eating *swallow* meals contaminated with enterotoxins and neurotoxins produced by *Clostridium perfringens* and *Clostridium botulinum,* the individual could experience gastroenteritis and paralysis, respectively. Cramping and acute diarrhea could be experienced by individuals after ingesting food contaminated with enterotoxins released by type A *Clostridium perfringens. C. perfringens* Type C strain is responsible for clostridial necrotizing enteritis. It is a rare and fatal disease condition [164]. The symptoms of ingesting toxins produced by *Clostridium perfringes* include abdominal cramping, occasional vomiting, and frequent watery stools. The people who experience these symptoms rarely manifest fever and nausea [1,161].

The symptoms of food intoxication manifest rapidly after consuming foods contaminated with *Clostridium* spp., *Escherichia coli, Staphylococci* spp. and *Salmonella* sp. The symptoms include diarrhea, vomiting, headache, nausea, and abdominal cramp [165]. The consumption of *swallow* meals contaminated with *Salmonella, Shigella*, and *Escherichia coli* could manifest symptoms which include abdominal cramps, diarrhea, fever, vomiting, and headache. Headache, abdominal pain, cough, rose spots, fever, cough, nausea, constipation, vomiting, chills, bloody stools, and malaise are the symptoms that could manifest after consuming food contaminated with *Salmonella typhi* [1].

Pseudomonas aeruginosa commonly associated with food spoilage is implicated in food poisoning. It is responsible for secondary infections especially in the immunocompromised individuals, which include gastrointestinal infections, among others. The organism is capable of increasing the permeability of cells, leading to leakage of its content, and death of the cell [162,166].

Proteus mirabilis regarded as a foodborne pathogen could cause disease in humans after consuming food contaminated with the bacterium. *Proteus mirabilis* is capable of producing urease which facilitate the manifestation of urinary tract infections [162]. According to Addo et al. [78], *Proteus* sp. could be responsible for disease conditions in humans, which include urinary tract infections (UTI), bacteraemia, gastroenteritis, and pneumonia.

Micrococcus sp. could contaminate food, which include *swallow* meals. The bacterium is associated with several infections, which include bacteremia, septic arthritis, septic shock, meningitis, and endocarditis [167].

The consumption of *swallow* meals contaminated with *Streptococcus* sp. could cause food poisoning, and manifest symptoms which include nausea, vomiting, sore throat, stuffy nose, rash, and fever [141]. According to Katzenell et al. [168], the infection caused by *Streptococcus pharyngitis,* spread by contaminated food, is more severe than airborne *S. pharyngitis*. The symptoms of foodborne *Streptococcus pharyngitis* include enlarged tonsils, submandibular lymphadenopathy, pharyngeal erythema, enlarged tonsils, and sore throat.

Staphylococcus aureus is associated with foodborne intoxication and poisoning. If the bacterium is allowed to grow in food, *S. aureus* has the ability to release enterotoxins responsible for food intoxication when such foods are consumed. The symptoms which could manifest after ingesting food heavily contaminated with *S. aureus* include vomiting, nausea, abdominal cramps, castration, and retching [1,169]. According to Ire et al. [170], *S. aureus* is part of the organisms responsible for folliculitis, furuncles, erysipelas, carbuncles, cellulitis, meningitis, and scalded skin syndrome (toxemia).

Although *Enterobacter* sp. is associated with nosocomial infections, the consumption of foods contaminated with the bacterium could cause illnesses, particularly in children and immunocompromised individuals. Therefore, parents should be aware of the risk involved in feeding their children with street foods such as *swallow* meals, which could be contaminated with microorganisms. *Enterobacter cloacae* is implicated with disease conditions which include neonatal meningitis, bacteraemia, septicemia, pneumonitis, post-neurosurgical meningitis, and urinary tract infection [171,172]. According to Paul et al. [162], *Corynebacterium xerosis* could cause certain disease conditions in immunocompromised individuals, which include arthritis, septicemia, and pleuropneumonia.

Starchy foods are favourable for the growth of *Bacillus cereus* [161]. The consumption of *swallow* meals contaminated with *B. cereus* could cause food poisoning under certain conditions that necessitate haemolysis, production of phospholipases C, and enterotoxins. *Bacillus cereus* responsible for food poisoning syndrome are of two types - diarrheal and emetic type. The symptoms of the diarrheal type include pain, watery diarrhea, and abdominal pain. Nausea and vomiting are symptoms of the emetic type. The fact that *B. cereus* is a spore former, and capable of surviving food processing conditions, enhances the ability of the organism to cause food poisoning [173].

The consumption of food contaminated with *Shigella* sp. could cause a disease condition known as shigellosis. *Shigella* sp. manifest symptoms in the body, which include diarrhea, fever, vomiting, pus, blood or mucus in the stools, abdominal pain, and cramps.

Sometimes, bloody diarrhea does not happen in infants infected with *Shigella* sp. Dysentery could manifest after eating foods contaminated with *Shigella* sp. Among the serogroups of *Shigella*, *S. dysenteriae* type 1 is mainly responsible for epidermic dysentery [1,161]. *Shigella* sp. responsible for traveler's diarrhea manifest certain symptoms, which include watery diarrhea, anorexia, malaise, abdominal pain, cramping, low-grade fever, nausea and vomiting. There is a possibility that these symptoms will advance to colitis, bloody diarrhea, and tenesmus [161].

Exposure of food to high level mycotoxins produced by fungi could cause harmful effects in humans, which include neurotoxicity, immune toxicity, carcinogenicity, tetratogenicity, hepatotoxicity, reproductive toxicity, indigestion, developmental toxicity, among others [145,174]. Patients suffering from hepatitis B virus and hepatitis C virus infections, as well as children, are likely to experience the adverse health effects caused by aflatoxins [175]. Ingestion of food contaminated with *Mucor* species and *Rhizopus* species could elicit certain infections known as zygomycosis, which could manifest as septic arthritis, renal infections, respiratory infections, pulmonary infections, gastritis, mucocutaneous, and rhinocerebral infections [140].

Fusarium species, and *Aspergillus* species are capable of producing toxins that could contaminate food. The consumption of such foods could cause a disease condition generally referred to as fusariosis. Food commodities could be contaminated with *Aspergillus flavus, Aspergillus niger,* and *Aspergillus versicolor*. The infections caused by these fungal species usually affect immunocompromised individuals. *Aspergillus* species are known to produce mycotoxins, which have negative effects on human health [176].

Despite the benefits of *Candida* sp. in the production of fermented foods and alcoholic beverages, the presence of this fungus in the *swallow* meals, could have health implications. *Candida* sp. could cause infections in the human body, particularly in the gastrointestinal tract. It is responsible for systemic infections [177].

Although *Penicillium* sp. is widely distributed in nature, it does not often cause human infections. Penicilliosis is a general name used to describe infections associated with *Penicillium* sp. Some species of *Penicillium* could produce mycotoxins, which could enter the food chain [176].

For several decades, *Saccharomyces cerevisiae* has been generally regarded as a non-pathogenic fungus. The safety of the fungus in food has not been in doubt until recently, when scientists regarded *S. cerevisiae* as one of the emerging opportunistic pathogens. The infection caused by S. *cerevisiae* mostly affect immunocompromised individuals and patients that are critically sick. *Saccharomyces cerevisiae* is associated with vaginitis in healthy females, cutaneous infection, systemic infections in the blood stream, as well as essential organs in patients whose immune systems have been seriously compromised [178].

1.8. Health risk associated with consumption of swallow meals contaminated with mycotoxin

The consumption of *swallow* meals contaminated with mycotoxin in high doses is harmful to health. Outbreaks of diseases, especially in many countries in Africa and Asia, as a result of consuming foods contaminated with mycotoxins have been reported. Human diseases associated with aflatoxins include Reye's syndrome, Indian childhood cirrhosis, liver cancer, kwashiorkor, and chronic gastritis. Stunted growth in children is associated with aflatoxin. It is also responsible for immunosuppression and reduces body resistance to disease causing agents implicated with human immunodeficiency virus (HIV) and tuberculosis, among other diseases. According to Balwan et al. [117], aflatoxins could cause bile duct hyperplasia and hemorrhage in the intestinal tract. There seems to be a connection between ochratoxins and the development of tumors in the urinary tract. With regards to toxicity, aflatoxin B_1 is regarded as the most potent aflatoxin. It is a carcinogen of the liver. In 2010, it was estimated that Nigeria recorded 10,130 cases of liver cancer, of which 7761 were attributed to aflatoxins [105]. Aflatoxins could cause loss of balance, loss of coordination, headaches, recent memory decline, insomnia, fibrosis, necrosis, diarrhea, intestinal hemorrhage, and vomiting [175]. In humans, hematological disorder is caused by tenuazonic acid. Abortion caused by peniccillic acid also slows down growth rate and immunity. Patulin is neurotoxic. It causes hemorrhages in the brain and lungs. Patulin is also responsible for gastrointestinal problems, diarrhea, neural syndrome, vomiting, and reduced weight gain [117]. Fumonisin B_1, B_2, and B_3 are associated with oesophageal cancer in humans. Ochratoxins are associated with Balkan endemic nephropathy [105,179]. Ochratoxin A causes damage to the liver and kidney. It is also responsible for loss of appetite, nausea, and suppression of the immune system [117]. The consumption of food contaminated with fumonisins in high concentration will increase the risk of people experiencing neural tube defects [97]. Fumonisins are responsible for equine leukoencephalomalacia. The disease affects the brain and often fatal. Fumonisins are also responsible for swelling of the lungs and thorax, which is a disease condition known as porcine pulmonary oedema syndrome [179]. Diarrhea and abdominal pains have been reported in individuals after consuming food contaminated with fumonisin B_1. Although ergot alkaloids are pharmaceutically beneficial, it have been associated with neural disorders, vasoconstriction, agalactia, and skin necrosis [66,180]. According to Adeyeye [179], ergotism caused by ergot is grouped into two - gangrenous (seriously affect blood supply) and convulsive (affect the central nervous system). In humans, zearalenone cause vulvovaginitis, vaginal prolapse, rectal prolapse, abortion, anestrus, fertility problems, as well as malformation of ovaries and testicles [117].

2. Conclusion

Several bacterial and fungal species have been reported in *swallow* meals sold to the general public in food centres. Among them are pathogenic bacteria and mycotoxigenic fungi. Few microorganisms reported in this review article could play useful roles at the various stages of processing raw foodstuffs required to prepare *swallow* meals. Other microorganisms are regarded as contaminants capable of causing foodborne infections, intoxication, and spoilage. Mycotoxins were detected in some soup ingredients, raw foodstuffs, and *swallow* meals. The widely accepted practice of using the palms to eat *swallow* meals without proper washing, the use of dirty utensils, poorly sanitized grinding machines, mortar and pestle, undue exposure of soup ingredients and foodstuffs used in preparing *swallow*

meals to the environment, an unsanitary processing environment, poor personal hygiene of food handlers, among other factors, predispose *swallow* meals to contamination by microorganisms and mycotoxins beyond the permissible limits set by the regulatory bodies. The consumption of such meals could have a serious effect on human health.

CRediT authorship contribution statement

Ndukwe Maduka: Writing – original draft, Conceptualization. **Ositadinma Chinyere Ugbogu:** Writing – review & editing.

Recommendation

To ensure that microorganisms and mycotoxins present in the *swallow* meals are within safe limits, strict implementation of food hygiene, environmental hygiene, personal hygiene, good manufacturing practices, good kitchen practices, good agricultural practices, maintenance of good storage conditions, and proper handwashing before eating *swallow meals* are recommended. Individuals who prefer using their palms to eat *swallow* meals are advised to wash it properly using soap and running water. Adequate heating of *swallow* meals shortly before it is consumed is highly recommended.

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