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*REVIEWARTICLE*

# MICROBIOLOGICAL QUALITY OF READY-TO-EAT FOODSIN BENIN: BIOLOGICAL CONTAMINANTAND HEALTH RISKS

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## Abstract

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In sub-Saharan Africa, the food trade represents a significant aspect of human activity. In Benin, public markets and other street stalls represent a significant presence. However, most vendors lack the basic infrastructure required to ensure product safety. Traditional foodstuffs, such as dried fish and other products that are not preserved, present a significant health risk owing to the presence of biological pathogens,which can cause significant damage to human health if ingested. Foods containing biological pathogens are thought to cause over 200 diseases.Africa, particularly Benin, is currently experiencing tremendous economic expansion and is of great interest for eliminating or minimizing the danger of food-borne diseases. Therefore, it is important to assess the type of pathogen responsible and the circumstances in which it causes health problems. This review considers the stock of biological contaminants in foods sold in Benin, the associated health risks, and highlights the food safety practices.



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## Introduction:-

Ready-to-eat foods are defined as food and drink products intended for instant consumption or for later consumption at a later date, without the need for additional processing or treatment that could significantly reduce the microbial load (Yah Clarence *et al*., 2009). Such products may be fruit and fruit-based, meat-, fish-, milk-, or similar (Bayili *et al*., 2019; Bedekelabou *et al*., 2021). These foods constitute an important source of nutritionally balanced meals that are readily available and adapted to the lifestyles of most consumers (Mengistu *et al*., 2022). In addition to delivering convenient and culturally suitable meals, ready-to-eat foods offer opportunities for social interaction and community-building (Salem *et al*., 2019). Suppliers of these foods also contribute to the sociocultural identity of the urban environments in which they operate (Tsang, 2002).

However, there are situations in which these food outlets do not adhere to the necessary hygiene and safety requirements, resulting in an elevated risk of foodborne illnesses. As estimated by the World Health Organization (WHO), ingestion of food contaminated with pathogens has the potential to cause or facilitate the transmission of numerous illnesses. These can manifest as either short- or long-term health complications, including diarrhea and cancer. Notably, these consequences are particularly prevalent among vulnerable populations, including the elderly, pregnant women, and infants (Ahéhéhinnou *et al*., 2024). In developing countries, food- and water-borne microbial pathogens are the primary causes of illness. Various microorganisms have been identified in ready-to-eat foods, including *Staphylococcus aureus*, Bacillus spp., Salmonella spp., *Escherichia coli, and* Aspergillusspp (Mutungi *et*

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*al*., 2019; Scallan *et al*., 2011). These pathogens pose a significant threat to public health and socioeconomic development, necessitating an urgent and comprehensive response. Furthermore, research has demonstrated that the incidence of antimicrobial resistance among food-borne pathogens has increased in recent decades (Eromo *et al*., 2016; Oladipo and Adejumobi, 2010). Therefore, it is essential to ascertain the microbial status of ready-to-eat foods to prevent foodborne illnesses and to promote health and well-being. The purpose of this study was to examine the microbiological quality of ready-to-eat foods and to show their involvement in multidrug-resistant bacteria expansion and the public health hazards associated with them in Benin.

## Material and Methods:-

This study took the form of a review of the available literature on the microbiological quality of ready-to-eat foods in Benin. A search in the African Journals Online (AJOL) database, as well as in Google Scholar and Scopus, was conducted using the terms, “microbiology, “bacteria OR fungi’’, “Cotonou OR Abomey-calavi OR Porto-novo’’, “northern OR southern Benin’’ and “west Africa’’ as keyword strings. This study was performed to collect additional publications between January 2009 and June 2024.

Publications mentioning Benin City (a Nigerian town), agricultural products, or food packaging were excluded from this review. Further articles were identified by manually searching the reference lists of the pertinent reports. The full text of the selected papers (open access) was retrieved from relevant sources, and data were organized into tables under various sections, such as food commodities, sampling points, isolated organisms, acceptability according to microbiological standards (**Table 1**), and resistance phenotypes.

## Results:-

### Ready-to-eat foods examined

The subjects of this review comprised of thirty-two different ready-to-eat foods, which were the focus of numerousstudies, with a total of 35 included in this study (**Figure 1**). The food items included in this category were fermented cereal porridges (Aklui, Akpan, Bita, Bobos, Fourra, Gbangba, Koko, Segagnega), dairy products (yoghurt, Dèguè millet, Dèguè couscous, Dègués maize, Dèguè sorghum), spontaneouslyfermentedmilk (wagashi), and meat. The remaining products included fish-based items, such as dried fermented fish, smoked dried fish, smoked fish, and fried fish, as well as beverages, such as pineapple juice, hibiscus juice, traditional fermented beer (Tchakpalo, Tchoukoutou), and herbal tea. Additionally, there were snacks such as Amon soja (soy cheese), Gbéli (chips derived from cassava), Roots of Borassus (boiled hypocotyls), and spices. The most extensively researched category is milk-based products, including yoghurt, Dèguè, and Wagashi. The products made from meat and fish, spices, and crisps are listed (**Table 2**).

### Micro-organisms or toxins sought in ready-to-eat foods

The most common groups of microorganisms systematically sought in ready-to-eat foods are aerobic mesophilic flora (a factor indicating hygienic conditions), coliforms (a factor indicating fecal contamination), and anaerobic sulphite-reducing bacteria. In addition, the genus and nature of the contaminating species were specified in these studies. The most common bacterial species are *Escherichia coli*, *Staphylococcus aureus*, and*Salmonella* spp..

*Escherichia coli* at levels exceeding microbiological standards have been detected in a number of food products, including dairy, meat, pineapple juice, salad, rice, and traditional beverages. *Salmonella* spp.have been identified in a variety of samples, including grilled meat, spices, and beverages (pineapple juice and herbal tea). *S. aureus* has been identified in dairy products, grilled meat, rice, fermented cereal porridges, and beverages (specifically, Tchakpalo and herbal tea). Other bacteria, including *Bacillus cereus*, *Clostridium perfringens*, *Listeriamonocytogenes*, and *Streptococcusinfantarius*, were also investigated (**Table 2**). The resistance profile of bacteria has also been evaluated in several studies, and the results are summarized in **Table 3**. The table lists the resistance phenotypes observed in the various studies that have been carried out, including Penicillin G, Ciprofloxacin, Amoxicillin/clavulanic acid and other antibiotics. In addition to bacteria, filamentous fungi, particularly *Aspergillus* section Flavi and aflatoxins, have also been investigated in the studies included in this review.

## Discussion and Recommendations:-

Recently, there has been a notable shift in the status of ready-to-eat foods in developing countries. They have evolved from a cultural identity in various regions of Benin to becoming a crucial element in the nutritional arsenal required to cope with the rising demands of the modern working environment. In addition to their nutritional qualities and social and convivial powers, ready-to-eat foods, owing to their intrinsic characteristics, present a potential short- or long-term health hazard for consumers.

Globally, bacteria responsible of gastroenteric diseases, *Staphylococcus* spp., and particularly *Staphylococcus aureus*, have persisted as biological contaminants of food throughout the years until the present day (Bintsis, 2017). The findings of this study reveal that the most sought-after microorganisms are *Escherichia coli*, *Salmonella* spp., *S. aureus*, anaerobic sulphite-reducing flora, and yeasts or fungi. *Bacillus cereus*, *Clostridium perfringens*, and *Listeriamonocytogenes* havebeen identified in only a few studies. The elevated levels of these pathogens in ready-to-eat foods suggest a deficiency in the critical control points during handling. Several studies have indicated that pathogens found in food may be endogenous or exogenous contaminants introduced during food handling, processing, or preparation (Rane, 2011). Therefore, poor hygiene, sanitary state of raw materials, quality of water used during cleaning or cooking, methods of food preparation, subsequent preservation, and human intervention may contribute to the prevalence of pathogens in ready-to-eat foods (Akinyemi *et al*., 2021). The studies included in this review indicated that all ready-to-eat foods were sampled from roadside vendors, local caterers, and makeshift workshops. It is also important to note that most vendors of ready-to-eat foods in Africa (and not only at the sampling sites) operate in unhygienic conditions, often on the roadside with rubbish or waste nearby (Adeyeye, 2017). It can be hypothesized that these conditions may be the underlying cause of the observed contamination rates. Such contamination may be further exacerbated by cross-handling of money in the street food trade (Muyanja *et al*., 2011). Bacteria such as *Staphylococcus aureus*, *Escherichia coli*, and Salmonella spp. were the most frequently detected in Benin as biological contaminants in ready-to-eat foods. Paudyal *et al*. (2017) also observed similar findings regarding ready-to-eat foods, specifically meat products, from various regions of Africa. The presence of *E. coli* and *Salmonella* spp in ready-to-eat foods predisposes consumers to diarrheal diseases. Bacterial diarrheal diseases are often trivialized, but they cause significant sequelae, including loss of absorptive surface, intestinal perforation, hemolytic uremic syndrome, and bacteremia. These diseases are particularly prevalent in children under five years of age, immunocompromised individuals, and the elderly (Ahéhéhinnou *et al*., 2024; Reiner *et al*., 2018; Troeger *et al*., 2018). *Staphylococcus aureus* is a gram-positive bacterium that causes a range of infections in humans. These include minor skin infections, such as boils and cellulitis, and more serious infections, such as pneumonia, meningitis, and abscesses in various parts of the body. It can produce enterotoxins in food that are difficult to detect and can cause gastrointestinal disorders (Le Loir *et al*., 2003). Similarly, *Clostridium perfringens*, an anaerobic sulfate-reducing bacterium, and *Bacillus cereus* also cause gastrointestinal disorders through the secretion of toxins (Bacon and Sofos, 2003). *C. perfringens* is primarily associated with unhygienic food handling and cross-contamination during processing. Owing to its capacity to form spores, this microorganism can survive unfavorable conditions, including aerobiosis and food processing procedures (Grenda *et al*., 2023). The ability of*B. cereus* to persist in food products is due to its capacity to form hydrophobic spores that can adhere to a wide range of surfaces and resisting elimination during cleaning or sanitation procedures (Dietrich *et al*., 2021). Owing to their distinctive characteristics, these microorganisms present a significant challenge to vendors and consumers of ready-to-eat food. *Listeria monocytogenes*, a recently introduced food-borne pathogen found in ready-to-eat foods marketed in Benin, also forms part of this cluster of microorganisms that evade preventive measures. *Listeria monocytogenes*can grow at refrigerated temperatures and often tolerates freezing temperatures, high salt content and low pH (Raheem, 2016). While pasteurization and cooking can eliminate *L. monocytogenes*, its presence in ready-to-eat foods is problematic, given that these foods are consumed without any further processing. Pregnant women with this infection are at risk of adverse fetal outcomes, including miscarriage, stillbirth and congenital malformations (Buchanan *et al*., 2017).

In addition to their pathogenic nature, food-borne pathogenic bacteria pose a significant risk owing to their resistance to antibiotics. This review reports the phenomenon of antibacterial resistance in strains of *Escherichia coli* (from grilled meat, Dèguè, and salad) and *Staphylococcus aureus* (from grilled meat, Dèguè, and fermented drink) to some of the essential antibiotics of the World Health Organization, namely amoxicillin/clavulanic acid, Ceftriaxone and Ciprofloxacin (**Table 3**). A recent review on traditional African dishes showed the same conclusion regarding these antibiotics (Anyogu *et al*., 2021). Vancomycin, a vital antibiotic commonly used as a last resort treatment, has been shown to be resistant. This has been the case for S. aureus vancomycin-resistant isolates from from fermented beverages (N'Tcha *et al*., 2023). Similarly, Awopetu *et al*. (2016) describe a comparable scenario in *Staphylococcus aureus* isolates from fermented milk. The presence of these resistant bacteria in food may be attributed to the excessive use of antimicrobial drugs for prophylaxis and as growth promoters in veterinary medicine (Nhung *et al*., 2017; Van Boeckel *et al*., 2014). It is possible for food vendors to harbor bacteria that are resistant to antibiotics and contaminate foodstuffs through poor handling techniques. Another cause of contamination of food processing or preparation environments by antimicrobial-resistant bacteria is the presence of bacteria in the environment (Dougnon *et al*., 2021). A significant concern associated with the presence of resistant bacteria is their capacity to transfer resistance traits via mobile genetic elements to other bacteria or the consumer's intestinal microbiota (Zhao *et al*., 2009). Consequently, in the absence of intervention, human medicine will enter a post-antibiotic era, with simple infections becoming life-threatening (Meek *et al*., 2015). Collectively, these scenarios illustrate the substantial contribution of the food chain to global bacterial resistance burden.

In addition to bacteria, filamentous fungi can contaminate ready-to-eat food. In this review, studies that reported the presence of filamentous fungi and/or mycotoxins in foods included those that investigated spices, dried fish, yoghurt, Wagashi, pineapple juice, herbal teas, and kluiklui (peanut cake). Filamentous fungi may be associated with extrinsic natural contamination by dust particles containing spores (Aasa *et al*., 2023). Such ready-to-eat foods are frequently preserved and are subsequently resold. The lengthy storage period, conditions within the storage room, and intrinsic nature of each of these foods could all contribute to the observed fungal contamination (Kocić-Tanackov *et al*., 2007). Filamentous fungi pose the greatest risks to food quality and safety (Adetunji *et al*., 2021). This is because many filamentous fungi produce mycotoxins that reduce the marketability of food and pose a health risk to consumers due to their toxicity (Alshannaq & Yu, 2017). Aflatoxins are a group of mycotoxins secreted by filamentous fungi, particularly those of the genus Aspergillus, section Flavi (Fossou *et al*., 2024). Aflatoxin B1 is recognised for its genotoxicity and carcinogenic properties. Exposure to this toxin has been linked to an increased risk of liver cancer (Adjovi *et al*., 2023; Negash, 2018). The risk of cancer development as a result of exposure to various forms of aflatoxin is well documented (Williams *et al*., 2004). This risk is based on the cumulative dose over the lifetime. Conversely, individuals with pre-existing liver disease, such as hepatitis B, are at an elevated risk owing to the inherent compromise in the liver's detoxification capacity resulting from the hepatitis B virus. This leaves aflatoxins free of act (Allen *et al*., 1992).

Several scientific societies have issued recommendations in response to these scenarios. One such concern pertains to hygiene. The most straightforward method for preventing the transmission of pathogenic microorganisms is cleanliness (Saliba *et al*., 2023). Although hygiene is an effective method for preventing pathogen transmission, it is not a comprehensive solution. Other measures recommended by the World Health Organization include controlling storage conditions (separating raw food from cooked food), cooking food properly, and most importantly, using safe water and products. Furthermore, enhanced processing, packaging, storage, and handling methodologies must be devised and tailored for the African context. It is also essential to ensure that all those involved in the production chain are aware of potential options to improve product quality and reduce contamination by microorganisms and their toxins. In the context of multi-drug resistance, the control of antibiotic supply, for instance through the implementation of a prescription requirement prior to purchase, has the potential to mitigate the emergence of multi-drug-resistant strains (Alajel *et al*., 2024). This approach can also curtail adverse consequences associated with self-medication. It is also imperative to implement active surveillance of multi-resistant strains in healthcare centers. As part of the standard analysis of clinical samples, microbiological analysis laboratories must conduct antimicrobial susceptibility tests to monitor multi-drug-resistant strains. In the event of the emergence of new multiresistant strains, the strain repertoire should be updated (Aschbacher *et al*., 2020).multiresistant strains, it is recommended to update the strain repertoire (Aschbacher *et al*., 2020).

## Conclusion

In conclusion, ready-to-eat foodis an essential component of the diet of the Beninese population. As the demand for ready-to-eat foods continues to grow, it is becoming increasingly evident that current food safety standards do not meet the required level of acceptability. The principal agents detected in these foods are*Staphylococcus aureus*, filamentous fungi, and mycotoxins. Furthermore, multi-drug resistance observed in these pathogens represents a significant public health concern. To prevent the adverse effects of these pathogens and protect public health, it is essential to implement regular monitoring and effective surveillance, define and implement regulations, raise awareness, and foster collaboration among relevant parties.

**Competing Interest**

The authors declare that they have no known competing financial interests or personal relationships that could influence the work reported in this study.

### Authors' Contributions

UHA and JPMF designed the methodology and collected data. UHA and YCSA analyzed all data. UHA wrote the manuscript, which was critically reviewed for intellectual content by the YCSA. All the authors have read and approved the final version of the manuscript.

### Review Figure

**Figure 1**:Flow diagram of the literature search and selection of eligible studies.

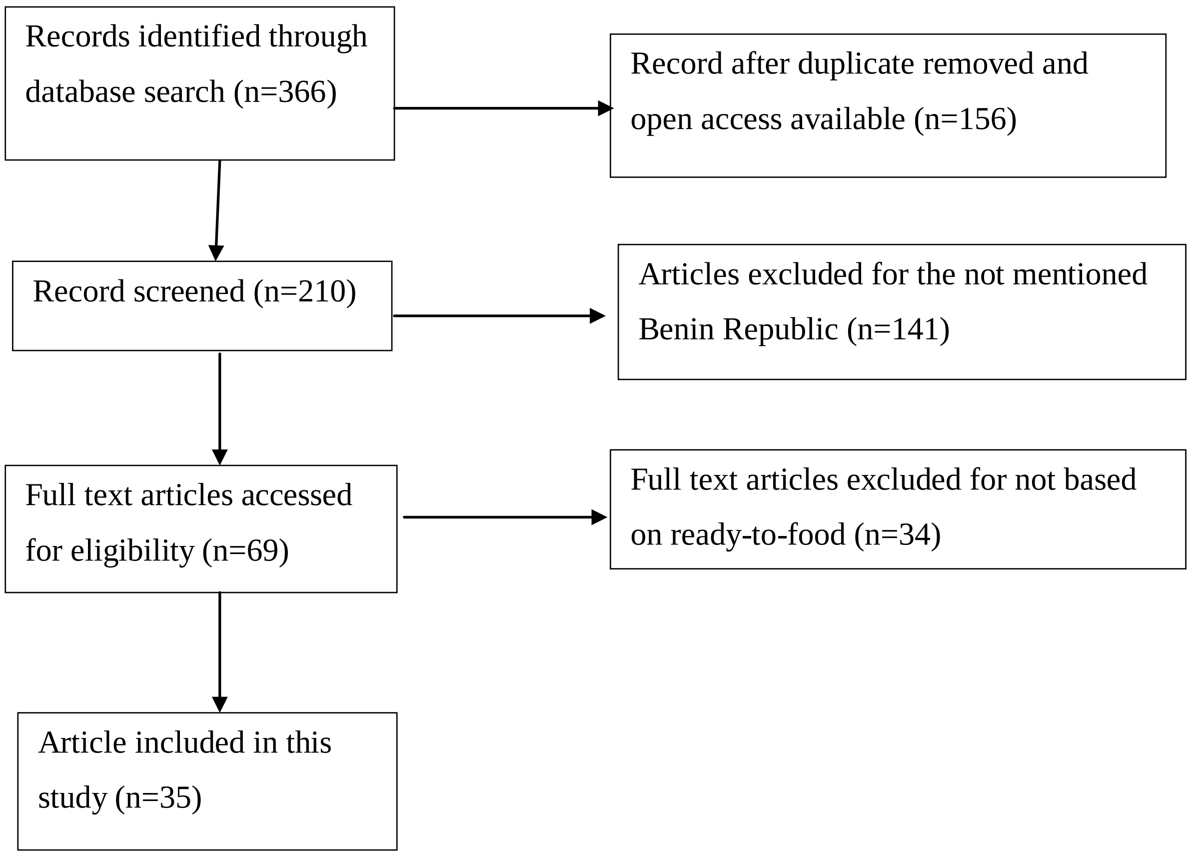


**Table 1**:Standards for microbiological quality of ready-to-eat foods.

| | Ready to eat food[a] | Drinking water[b] |
|---|---|---|
| Total mesophilic aerobic flora | $<10^6$ cfu/g | 50 cfu/mL |
| Total coliforms | $<10^4$ cfu/g | 0 cfu/100 mL |
| Fecal coliforms | $<10^2$ cfu/g | 0 cfu/100 mL |
| *Escherichia coli* | $<10^2$ cfu/g | 0 cfu/100 mL |
| Coagulase positive staphylococcus | $<10^3$ cfu/g | 0 cfu/mL |
| Anaerobic sulphite reducer | Absent in 25g | Absent in 25 mL |
| Salmonella | Absent in 25g | Absent in 25 mL |
| *Bacillus cereus* | $<10^3$ cfu/g | NA |
| *Clostridium perfringens* | $<10^3$ cfu/g | NA |
| Fungi | $<10^4$ cfu/g | 0 cfu/mL |
| Aflatoxine B1 | 5µg/Kg | NA |

**Note**: [a]: Standard for ready-to-eat foods by the New South Wales Food Authority (New South Wales Food Authority, 2009), [b]: Decree No. 2001-094 of February 20, 2001, setting standard for drinking water quality in Benin Republic (Adounkpe *et al*., 2017).

**Table 2**:- Microbiological contamination of ready-to-eat foods.

| Foods | Location | Microorganisms/Aflatoxins | Acceptability load | Reference |
|---|---|---|---|---|

| | | | | |
|---|---|---|---|---|
| Raw milk | Allada | *Escherichia coli*, Yeast/Fungi | - | (Djobo *et al.*, 2021) |
| | | *Staphylococcus* spp, *Salmonella* spp | + | |
| | Ouidah | *Staphylococcus* spp, *Escherichia coli*, Yeast/Fungi | - | |
| | | *Salmonella* spp | + | |
| | Zongo | *Staphylococcus* spp, Yeast/Fungi | - | |
| | | *Escherichia coli*, Salmonella spp | + | |
| | Dassa-Zoume, Gogounou | Faecal Coliforme | - | (Farougou *et alet al.*, 2012) |
| | | *Escherichia coli*, *Staphylococcus aureus*, Fungi | + | |
| Wagashi | Some Benin townships | *Escherichia coli*, *Streptococcusinfantarius* | NA<br>NA | (Sessou *et al.*, 2023) |
| | South Benin markets | *Escherichia coli*, Yeast/Fungi | - | (Aïssi *et al.*, 2009) |
| | | *Staphylococcus aureus*, *Salmonella* spp | + | |
| | North Benin Peulh sites | *Escherichia coli*, Yeast/Fungi | - | |
| | | *Staphylococcus aureus*, *Salmonella* spp, | + | |

**Note:** + the load complies with the standards (acceptable), - : the load is below the standards (not acceptable), NA : Not Attributed,

**Table 2 (continued):-** Microbiological contamination of ready-to-eat foods.

| Foods | Location | Microorganisms/Aflatoxins | Acceptability load | Reference |
|---|---|---|---|---|
| Yogurt (fermented milk) | Cotonou/Abomey-Calavi | Thermotolerant Gram Negative Bacteria,<br>*Staphylococcus* spp | -<br>- | (Tohoyessou, Mousse, Sina, Bade, *et al.*, 2020) |
| | | *Staphylococcus aureus* | NA | |
| Dèguè millet and couscous | Cotonou/Abomey-Calavi | Thermotolerant Gram Negative Bacteria,<br>*Staphylococcus*spp | -<br>- | |
| | | *Staphylococcus aureus* | NA | |
| Dèguè | Campus Abomey-calavi | *Escherichia coli* | - | (Komagbe *et al.*, 2019) |
| | | *Salmonella*spp, *Staphylococcus*spp, Fungi | + | |
| Dèguè maize/millet | Abomey-calavi | Fungi | - | (Tchekessi *et al.*, 2014) |
| | | *Staphylococcus aureus*, *Salmonella*spp | + | |
| Ccereal porridge | North Benin | *Staphylococcus aureus*, *Salmonella* spp | NA | (Karimou *et al.*, 2024) |
| | Campus Abomey-Calavi | Coagulase Positive Stapthyloccucus | - | (Komagbe *et al.*, 2019) |
| | | *Escherichia coliEscherichia coli*, *Salmonella* spp, Fungi | + | |

**Note:** + the load complies with the standards (acceptable), - : the load is below the standards (not acceptable), NA : Not Attributed,

**Table 2 (continued):-** Microbiological contamination of ready-to-eat foods.

| Foods | Location | Microorganisms/Aflatoxins | Acceptability load | Reference |
|---|---|---|---|---|
| Smoked dried fish | South Benin | *Escherichia coli*, *Bacillus cereus*, *Clostridium perfringens*, *Staphylococcus aureus*, *Salmonella* spp, Fungi | + | (Anihouvi *et al.*, 2019) |

| | | | | |
|---|---|---|---|---|
| Smoked fish | South Benin | *Escherichia coli*, | - | |
| | | *Bacillus cereus*, *Clostridium perfringens*, *Staphylococcus aureus*, *Salmonella* spp, Fungi | + | |
| Smoked, dried and fermented fish | Cotonou | Aspergillus Section Flavi, *Aspergillusniger*, Mucor spp | NA | (Adjovi *et al*., 2019) |
| Fried fish | Calavi kpota | Faecal Coliform | - | (Assogba *et al*., 2018) |
| | | *Staphylococcus aureus* | + | |
| Smoked fish | Calavi kpota | Faecal coliform | - | |
| | | *Staphylococcus aureus* | + | |
| | South Benin | Thermotolerant Coliform | - | (Kpodékon *et al*., 2014) |
| | | *Staphylococcus aureus*, *Salmonella* spp | + | |
| Fermented dried fish | Avlekete | *Staphylococcus aureus*, S*almonella* spp | + | (Dègnon *et al*., 2014) |
| | Meko | Total coliform | - | |
| | | *Staphylococcus aureus*, *Salmonella* spp | + | |
| | Cotonou | Faecal coliform | - | |
| | | *Staphylococcus aureus*, *Salmonella* spp*Salmonella* spp | + | |

**Note: +** the load complies with the standards (acceptable), - : the load is below the standards (not acceptable), NA : Not Attributed

**Table 2 (continued):-** Microbiological contamination of ready-to-eat foods.

| Foods | Location | Microorganisms/Aflatoxins | Acceptability load | Reference |
|---|---|---|---|---|
| Grilled chicken meat | Abomey-Calavi/Cotonou | Thermotolerant coliform, *Escherichia coli* | - | (Edikou *et al*., 2023) |
| | | *Staphylococcus aureus*, *Salmonella* spp | + | |
| Tchatchanga | Cotonou | *Escherichia coli*, *Staphylococcus* spp | - | (Assim *et al*., 2019) |
| | Cotonou | *Escherichia coli*, *Staphylococcus* spp | - | (Sina *et al*., 2019) |
| | Bohicon | *Escherichia coli*, *Staphylococcus aureus* | - | (Boko *et al*., 2017) |
| | | *Salmonella* spp | + | |
| | Hillacondji | *Escherichia coli*, *Staphylococcus aureus* | - | |
| | | *Salmonella* spp | + | |
| | Cotonou | *Staphylococcus* spp, *Salmonella* spp | - | (Anihouvi *et al*., 2013) |
| | | Faecal coliform, *Staphylococcus aureus* | + | |
| Grilled pork meat | South Benin | Enterobacteriaceae | - | (Anihouvi *et al*., 2020) |
| | | *Escherichia coli*, *Staphylococcus aureusBacillus cereus*, *Clostridium perfringens*, *Listeriamonocytogenes*, *Salmonella* spp | + | |
| Spice | Abomey-Calavi/Cotonou | Faecal coliform, Thermotolerant coliform | - | (Edikou *et al*., 2023) |
| | | *Escherichia coli*, *Staphylococcus aureus*, *Salmonella* spp*Salmonella* spp, | + | |

**Note: +** the load complies with the standards (acceptable), - : the load is below the standards (not acceptable), NA : Not Attributed

**Table 2 (continued):-** Microbiological contamination of ready-to-eat foods.

| Foods | Location | Microorganisms/Aflatoxins | Acceptability load | Reference |
|---|---|---|---|---|
| Spice | Some Benin townships | Fungi | - | (Akpo-Djènontin *et al*., 2018) |
| | | Aflatoxin B1 | - | |
| | Cotonou | *Staphylococcus* spp, *Salmonella* spp | - | (Anihouvi *et al*., 2013) |
| | South Benin | Aspegillus section Flavi, *Pencillium* spp | NA | (Gnonlonfin *et al*., 2013) |
| | | Aflatoxins | - | |
| Salad | Cotonou | *Escherichia coli*, Anaerobic Sulfito-Reducer bacteria | - | (Dègnon *et al*., 2018) |
| | | *Staphylococcus* spp, *Salmonella* spp | + | |
| | Abomey-Calavi/ Cotonou | *Escherichia coli* | - | (Moussé *et al*., 2016) |
| Rice and soup | Abomey-Calavi/ Cotonou | *Escherichia coli* | - | (Moussé *et al*., 2016) |
| Pineapple juice | Cotonou/Abomey-Calavi | Thermotolerant coliform, *Staphylococcus aureus* | - | (Noumavo *et al*., 2023) |
| | Campus of Abomey-Calavi | *Salmonella* spp, *Staphylococcus* spp | - | (Komagbe *et al*., 2019) |
| | | *Escherichia coli*, Anaerobic Sulfito-Reducer bacteria | + | |

**Note: +** the load complies with the standards (acceptable), - : the load is below the standards (not acceptable), NA : Not Attributed

**Table 2 (continued):-** Microbiological contamination of ready-to-eat foods.

| Foods | Location | Microorganisms/Aflatoxins | Acceptability load | Reference |
|---|---|---|---|---|
| Hibiscus juice | Campus Abomey-Calavi | Faecal coliform | - | (Komagbe *et al*., 2019) |
| | | *Escherichia coli*, Anaerobic Sulphite Reducer bacteria, *Staphylococcus* spp, *Salmonella* spp, Fungi. | + + | |
| Tchakpalo | South Benin | *Escherichia coli*, *Staphylococcus aureus*, | - | (Baba-Moussa *et al*., 2012) |
| | | *Salmonella* spp, Anaerobic Sulphite Reducer bacteria. | + | |
| Herbal tea | The 1ST, 2nd, 4th, 6th, 8th and 10th District of Cotonou | *Aspergillus flavus*, *Aspergillus niger* | - | (Adounkpe *et al*., 2017) |
| | | *Escherichia coli*, *Staphylococcus aureus*, *Salmonella* spp, *Salmonellatyphi*. | + | |
| | The 3rd, 11th, 12th and 13th Districts of Cotonou | *Escherichia coli*, *Staphylococcus aureus*, *Salmonella* spp, *Aspergillus flavus*, *Aspergillus niger*, | - | |
| | | *Salmonellatyphi*. | + | |
| | The 5th District of Cotonou | *Escherichia coli*, *Staphylococcus aureus*, *Salmonella* spp, *Aspergillus flavus*, *Aspergillus niger*. | - | |
| | The 7th District of Cotonou | *Escherichia coli*, *Salmonella* spp, *Aspergillus flavus*, *Aspergillusniger*, | - | |
| | | *Staphylococcus aureus*, *Salmonellatyphi* | + | |

**Note: +** the load complies with the standards (acceptable), - : the load is below the standards (not acceptable), NA : Not Attributed

**Table 2 (continued):-** Microbiological contamination of ready-to-eat foods.

| Foods | Location | Microorganisms/Aflatoxins | Acceptability load | Reference |
|---|---|---|---|---|
| Herbal tea | The 9th District of Cotonou | *Staphylococcus aureus*, *Salmonella* spp, Salmonella, typhi, *Aspergillus flavusAspergillus flavus*, *Aspergillusniger* | - | (Adounkpe *et al*., 2017) |
| | | *Escherichia coli* | + | |
| Amon soja | Dantokpa | Total coliform | - | (Tchekessi *et al*., 2021) |
| | | *Escherichia coli*, Anaerobic Sulfito-Reducer bacteria, *Staphylococcus aureusStaphylococcus aureus*, *Salmonella* spp | + | |
| Roots of Borassus (boiled Hypocotyl) | South Benin | Anaerobic Sulfito-Reducer bacteria, *Staphylococcus* spp | NA | (Ohin *et al*., 2018) |
| Kluiklui (peanut cake product) | Adjarra/Ouando | *Escherichia coli* | - | (Adjou *et al*., 2012) |
| | | Aflatoxine B1 | - | |
| | | Anaerobic Sulfito-Reducer bacteria, *Staphylococcus aureusStaphylococcus aureus*, Fungi | + | |
| | Dantokpa/Fidjrosse | *Escherichia coli*, Anaerobic Sulfito-Reducer bacteria | - | |
| | | Aflatoxine B1 | - | |
| | | *Staphylococcus aureusStaphylococcus aureus*, Fungi | + | |

**Note: +** the load complies with the standards (acceptable), - : the load is below the standards (not acceptable), NA : Not Attributed

**Table 2 (continued):-** Microbiological contamination of ready-to-eat foods.

| Foods | Location | Microorganisms/Aflatoxins | Acceptability load | References |
|---|---|---|---|---|
| Kluiklui (peanut cake product) | Pahou/Ouidah/Come | *Escherichia coli*, Anaerobic Sulfito-Reducer bacteria | - | (Adjou *et al*., 2012) |
| | | Aflatoxine B1 | - | |
| | | *Staphylococcus aureusStaphylococcus aureus*, Fungi | + | |
| | Bohicon | *Escherichia coli* | - | |
| | | Aflatoxine B1 | - | |
| | | Anaerobic Sulfito-Reducer bacteria, *Staphylococcus aureusStaphylococcus aureus*, Fungi | + | |
| | Abomey/Cove | *Escherichia coli* | - | |
| | | Aflatoxin B1 | - | |
| | | Anaerobic Sulphite-Reducer bacteria, *Staphylococcus aureus*, Fungi | + | |
| Gbeli | Abomey-Calavi | Faecal coliform, *Staphylococcus* | - | (Noumavo *et al*., |

| | | | |
|---|---|---|---|
| (Chip derived from cassava) | spp*Staphylococcus* spp | | 2022) |

**Note: +** the load complies with the standards (acceptable), - : the load is below the standards (not acceptable), NA : Not Attributed

**Table 3**:- Resistance profile of some bacteria isolated from ready-to-eat foods.

| Pathogens | Total | Isolate from | Antibiotic resistance | Location | References |
|---|---|---|---|---|---|
| *Staphylococcus aureus* | 11 | Tchatchanga | Cefoxitim (81,81%), Imipenem (72,72%) Amoxicillin/clavulanic acid (63,63%) gentamicin (63,63%) | Cotonou | (Assim *et al.*, 2019) |
| *Escherichia coli* | 9 | Tchatchanga | Cefoxitim (100%), nalidixic acid (100%) Ciprofloxacin (88,88), Gentamicin | Cotonou | (Adjou *et al.*, 2012) |
| *Staphylococcus* spp | NA | Grilled goat and chicken meat | Oxacillin (50%), Penicillin G (36%), Oxytetracyclin (33%), Trimethoprim/sulfométhoxazole (29%) Gentamicin (5%), Vancomycin (2%), Ciprofloxacin (2%). | Cotonou | (Sina *et al.*, 2019) |
| *Escherichia coli* | 6 | Dèguè | Sulfonamide (75%), Tetracyclin (75%), Cefotaxim (30%), Ampicillin (16%) Cephalotin (16%), Amoxicillin/Clavulanic acid (16%), **Aztreonam, Cefoxitim, Chloramphenicol, Ciprofloxacin, Gentamicin** | Campus of Abomey-Calavi | (Komagbe *et al.*, 2019) |
| *Staphylococcus aureus* | 3 | Pineapple juice/Dèguè | Ampicillin (100%), Aztreonam (100%), Cefoxitim (100%), Tetracycline (100%), **Amoxicillin/clavulanic acid, Cephalotin, Cefotaxim, Chloramphenicol, Ciprofloxacin, Sulfonamide, gentamicin** | Campus of Abomey-calavi | (Komagbe *et al.*, 2019) |
| Gram negative Bacilli | 57 | Tchoukoutou, Tchakpalo | Ampicillin (100%), Chloramphenicol (100%), Cefoxitim (100%), Ceftriaxon (100%) nalidixic acid (43,5%), Trimethoprim/sulfométhoxazole (32,85%), Doxycyclin (32,4%) Gentamicin (1,85%) | North Benin | (N'Tcha *et al.*, 2023) |

**Note**: The normal font: phenotypic resistance observed and % (resistant isolates/total isolates) reported by the authors. Bold font: Resistance tested but not found.

**Table 3 (continued)**: Resistance profile of bacteria isolated from ready-to-eat foods.

| Pathogens | Total | Isolate from | Antibiotic resistance | Location | References |
|---|---|---|---|---|---|
| Positive Coagulase staphylococcus | 16 | | Penicillin (100%), Vancomycin (100%), Cephalotin (100%), Chloramphenicol (100%), Cefoxitim (100%), Cefoxitim (100%), Ceftriaxon (100), Erythromycin (100%), Trimethroprim/Sulfomethoxazole (100%), Streptomycin (57%), nalidixic acid (40%), Gentamicin (40%) | North Benin | (N'Tcha *et al.*, 2023) |
| Negative Coagulase staphylococcus | 26 | Tchoukoutou/Tchakpalo | Penicillin (100%), Vancomycin (100%), Cephalotin (100%), Chloramphenicol 100%), Cefoxitim (100%), Chloramphenicol (100%), Cefoxitim (100%), Ceftriaxon (100), Erythromycin (100%), Trimethroprim/Sulfomethoxazole | North Benin | (N'Tcha *et al.*, 2023) |

| | | | | | |
|---|---|---|---|---|---|
| | | | (100%), Streptomycin (55%), nalidisic acid (37%), Gentamicin (20%) | | |
| *Escherichia coli* | 62 | Street foods (Salad, rice, Vegetable Soup) | Amoxicillin (100%), Amoxicillin/clavulanic acid (100%), Penicillin G (100%), Chloramphenicol (98%) Gentamicin (94%) nalidixic (88%) Cefotaxim (65%), Ciprofloxacin (63%) Tobramycin (52%) Ceftriaxon (48%), oflaxocin (45%) Imipenem (4%) | Cotonou/ Abomey-Calavi | (Moussé *et al.*, 2016) |
| Negative Gram Bacilli | 63 | Kitchen environment and food products | Amoxicillin (93,65%), Cefotaxim (85,7%), Ertapenem (61,90%), Amoxicillin/clavulanic acid (57,14%), Ceftriaxon (52,38%), Aztreonam (44,44%) Imipenem (25,39%), Gentamicin (14,28%) Ciprofloxacin (7,93%) | South Benin | (Dougnon *et al.*, 2021) |

**Note**: Normal font: phenotypic resistance observed and % (resistant isolates/total isolates) reported by the authors. Bold font: Resistance tested but not found.

**Table 3 (continued)**:- Resistance profile of some bacteria isolated from ready-to-eat foods.

| Pathogens | Total | Isolate from | Antibiotic resistance | Location | References |
|---|---|---|---|---|---|
| Negative Coagulase Staphylococcus | 49 | Fermented milk (Yoghurt, Degue couscous et millet) | Penicillin (100%), Cefotaxim (95%), Lincomycin (95%), Amoxicillin (75%), Fusidic acid (70%), Amikacin (70%), Cefoxitm (70%) Amoxicillin/clavulanic acid (70%), Fosfomycin (60%), Gentamicin (65%), Ofoxacin (50%), Trimethroprim/Sulfomethoxazole (40%), Tetracyclyne (37%), Erythromycin (25%) Ciprofloxacin (20%) | Cotonou/ Abomey-Calavi | (Tohoyessou, *et al*., 2020) |
| Positive Coagulase Staphylococcus | 28 | Fermented milk product | Penicillin G (100%), Lincomycin (90%), Fusidic acid (82%), Amoxicillin (85%), Cefotaxim (85%), Amoxicillin/Clavulanic acid (79%) Cefoxitim (70%), Ciprofloxacin (70%), Amikacin (70%) Tetracycline (70%), Trimethroprim/Sulfomethoxazole (65%), Fosfomycin (60%), Ofloxacin (50%), Gentamicin (50%) Erythromycin (45%) | Cotonou/Abomey-Calavi | (Tohoyessou, *et al*., 2020) |

**Note**: Normal font: Phenotypic resistance observed and % (resistant isolates/total isolates) reported by the authors. Bold font: Resistance tested but not found.

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