Effects of Microbial Contamination Associated with Traditional Herbal Formulations in Nigeria and its Health Implications to Human Health: A Review

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Article Info

E-ISSN: 3107-7137
Volume: 02
Issue: 01
Received: 06-11-2025
Accepted: 07-12-2025
Published: 05-01-2026
Page No: 10-19

Abstract
Microorganisms are known to be one of the cosmopolitan organisms mostly found in nature. Their presence in all forms of biotic and abiotic ecosystem showcase their immense potential in contaminating virtually most things found in nature. This review presents the insignificant roles played by microorganisms in the contamination of traditional herbal formulations sold in Nigeria, and also to showcase its detrimental health implications to human health. Before the introduction of modern medicine, Nigerians relied totally on herbs and other plant extracts for the treatment of different ailments. Presently, herbal medicine still remains popular due to its cultural acceptance, affordability, accessibility, and remedies to different types of health needs, ranging from pain relief, to immune support, gastrointestinal disorder, microbial diseases and digestive health effects. The contamination of herbal products in Nigeria by microbes occurs at different stages from the collection of plant extracts, processing, storage, up to distribution. Also, their formulations under non-sterile conditions, utilizing of contaminated water and improper handling by vendors also contributed to their contamination. The consumption of microbial contaminated herbs can cause health implications which can range from mild infections to life-threatening diseases. Also, the toxic metabolic byproducts produced by microbes in the herbs are highly pathogenic, which can lead to liver and kidney failure. To avoid these contaminations, proper hygiene and quality control measures should be implemented at all stages of herbal drug production. Also, Good Manufacturing Practices (GMP) including proper worker hygiene, and the usage of sterilized packaging tools should be employed during herbal formulations.

DOI: https://doi.org/10.54660/IJBBR.2026.2.1.10-19

Keywords: Nigeria, Microorganisms, Herbal Formulation, Contamination, Human Health

1. Introduction

Traditional herbal formulations have been an integral part of healthcare in Nigeria for centuries, with millions of people relying on them for the treatment of various ailments (Iyiola and Adegoke, 2024) [23]. These herbal remedies are often prepared using plant materials, roots, barks, seeds, and other natural substances. They are sold in markets, on the streets, and even in some licensed herbal shops (Kloos, 2024) [33]. However, due to poor handling, unhygienic processing, and inadequate quality control, these herbal products are frequently contaminated with harmful microorganisms. The presence of bacteria, fungi, and other pathogenic microbes in these herbal formulations raises significant public health concerns (Ovuru *et al*., 2024) [52]. Despite their widespread use and cultural significance, microbial contamination in herbal products can pose serious risks to human health, particularly for immunocompromised individuals and those with pre-existing medical conditions.

Microbial contamination of herbal products in Nigeria occurs at various stages of production, including collection, processing, storage, and distribution. Many herbal formulations are prepared under non-sterile conditions, often exposed to dust, contaminated water, and improper handling by vendors (Ovuru *et al*., 2024) [52]. Additionally, the lack of stringent regulatory oversight allows for the sale of herbal remedies that do not meet basic hygiene standards (Kosoe *et al*., 2024) [35]. Studies have shown that herbal products in Nigeria frequently contain pathogenic microorganisms such as Escherichia coli, Salmonella spp., Staphylococcus aureus and Aspergillus spp. which are known to cause gastrointestinal infections, food poisoning, and other illnesses (Odo *et al*., 2021) [45]. Furthermore, the packaging and storage of these products in open containers or unsealed plastic bags further increase the likelihood of microbial contamination (Safakas *et al*., 2025) [56].

One major source of microbial contamination in herbal formulations is the use of contaminated water during preparation (Ahiabor *et al*., 2024) [2]. Many herbalists and vendors rely on untreated water from wells, streams, or boreholes, which may harbor harmful bacteria and parasites (Ogwu *et al*., 2024) [50]. Additionally, the drying and grinding of herbal ingredients are often done in unhygienic environments where airborne contaminants, insects, and rodents can introduce pathogenic microbes (Ovuru *et al*., 2024) [52]. Some herbal formulations are also mixed with other substances, including honey and palm wine, which, if not properly handled, can serve as a medium for microbial growth. The absence of sterilization techniques, such as pasteurization or proper heat treatment, further exacerbates the risk of microbial contamination in these traditional medicines (Ovuru *et al*., 2024) [52].

The health implications of consuming microbial contaminated herbal formulations are severe and can range from mild infections to life-threatening diseases (Ahiabor *et al*., 2024) [2]. Another critical issue associated with microbial contamination of herbal medicines is the potential for toxic metabolic byproducts produced by fungi and bacteria. Some fungal species produce mycotoxins, such as aflatoxins and ochratoxins, which are highly carcinogenic and can accumulate in the liver and kidneys, leading to organ failure (Patil *et al*., 2025) [53]. Bacterial endotoxins can also trigger inflammatory responses in the human body, leading to symptoms such as fever, shock, and multi-organ dysfunction. Bacterial contamination particularly from fecal coliforms like E. coli and Salmonella, can lead to severe diarrhea, typhoid fever, and foodborne illnesses (Yussuf *et al*., 2025) [65]. Fungal contamination, especially from Aspergillus species, presents another serious concern, as it can lead to aflatoxin poisoning, a condition linked to liver damage and cancer (Bisrat *et al*., 2024) [13].

In some cases, chronic exposure to microbial toxins from herbal medicines can lead to long-term health complications, including immunosuppression, respiratory issues, and neurological disorders (Kadiri *et al*., 2025) [30]. Moreover, some microbial strains found in herbal products are resistant to common antibiotics, posing an additional challenge in the treatment of infections caused by these contaminants.

Immunocompromised individuals, such as pregnant women, the elderly, and people living with chronic diseases like HIV/AIDS or diabetes, are at a higher risk of developing severe complications from these microbial infections (Khan *et al*., 2024) [32]. These dangers highlight the urgent need for improved regulatory control and safety measures in the herbal medicine industry.

Addressing the issue of microbial contamination in traditional herbal formulations in Nigeria requires a multifaceted approach (Ovuru *et al*., 2024) [52]. First, regulatory agencies such as the National Agency for Food and Drug Administration and Control (NAFDAC) should enforce stricter hygiene standards in the production and distribution of herbal medicines. Public awareness campaigns should also be conducted to educate both herbal practitioners and consumers about the risks associated with consuming contaminated herbal products (Rahman *et al*., 2025) [55]. Additionally, the adoption of modern processing techniques, such as proper drying, filtration, and sterilization, can help reduce microbial contamination. Standardized packaging and proper labeling of herbal medicines can also play a significant role in ensuring consumer safety. Collaboration between traditional herbal practitioners and scientific researchers can help bridge the gap between traditional medicine and modern safety practices (Sethi *et al*., 2025) [58].

While formulations remain a valuable part of Nigeria's healthcare system, microbial contamination poses a significant risk to public health traditional herbal (Atanda *et al*., 2025) [11]. Without proper regulation and quality control, consumers remain vulnerable to these dangers. There is an urgent need for improved hygiene practices, regulatory oversight, and scientific intervention to ensure that herbal medicines are safe for human consumption (Sethi *et al*., 2025) [58]. By addressing these challenges, Nigeria can enhance the safety and effectiveness of its traditional medicine sector while protecting the health of millions who depend on these remedies. This review was aimed to outline the microbial contamination of traditional herbal formulations sold in Nigeria and its health implications to human health.

Traditional Herbal Formulations in Nigeria

Traditional herbal formulations have been an essential part of Nigeria's healthcare system for centuries (Idowu, 2025) [22]. Long before the introduction of modern medicine, indigenous communities relied on herbs, roots, and plant extracts for the treatment of various ailments. These herbal remedies are often prepared using traditional knowledge passed down through generations, with each ethnic group in Nigeria having its unique healing practices (Kalu, 2022) [31]. Herbal medicine remains popular due to its affordability, accessibility, and cultural acceptance. Many people, especially in rural areas, turn to traditional herbal remedies as their first line of treatment for common illnesses, chronic conditions, and even spisritual healing. Despite advancements in modern medicine, traditional herbal formulations continue to play a crucial role in Nigeria's healthcare landscape (Akunna *et al*., 2023) [5].

The preparation of herbal medicines in Nigeria varies depending on the intended use and the healer's knowledge (Ogidi and Emaikwu, 2024) [48]. Herbalists, also known as traditional medicine practitioners, combine different plant parts such as leaves, roots, barks, seeds, and flowers to create potent remedies. Some herbal preparations are administered as decoctions (boiled extracts), infusions (soaked in water), powders, or topical pastes. Others are mixed with local drinks, palm wine, or honey to enhance their efficacy. However, one major challenge with herbal formulations in Nigeria is the lack of standardization in dosage and preparation methods. Since many herbal remedies are prepared using indigenous knowledge without scientific validation, there are concerns regarding consistency, efficacy, and possible side effects (Lulesa *et al*., 2025) [39].

One of the significant advantages of traditional herbal formulations is their natural composition which makes them appealing to individuals who prefer organic and chemical-free treatments (El Bourakadi *et al*., 2024) [18]. Many plants used in traditional medicine, such as neem (Azadirachta indica), bitter leaf (Vernonia amygdalina) and scent leaf (Ocimum gratissimum) have been scientifically proven to possess antibacterial, antifungal, and anti-inflammatory properties. Additionally, some herbal remedies have gained international recognition for their potential in treating diseases such as malaria, diabetes, and hypertension. However, despite these benefits, there is a growing concern about the safety of herbal formulations due to microbial contamination, improper handling, and lack of regulatory oversight (Ahiabor *et al*., 2024) [2].

The herbal medicine industry in Nigeria is largely unregulated, leading to issues such as adulteration, contamination, and misleading health claims (Ahiabor *et al*., 2024) [2]. Many herbal medicines are sold in open markets, streets, and even online without proper quality control measures. Unlike modern pharmaceutical drugs, which undergo rigorous testing and approval by regulatory agencies such as the National Agency for Food and Drug Administration and Control (NAFDAC), most traditional herbal formulations do not go through strict clinical trials. This poses health risks to consumers who may unknowingly use contaminated or ineffective herbal products. Efforts are being made by regulatory bodies and research institutions to improve the quality and safety of herbal medicines, but there is still a long way to go in ensuring their standardization (Yadav *et al*., 2024) [63].

Traditional herbal formulations in Nigeria remain an integral part of the country's healthcare system, offering natural alternatives for treating various health conditions. While they provide numerous benefits, including affordability and accessibility, the lack of scientific validation, standardization, and proper regulation poses significant challenges (Ogbuagu *et al*., 2025) [47]. For herbal medicine to gain full acceptance in mainstream healthcare, there is a need for collaboration between traditional medicine practitioners, scientists, and regulatory agencies to improve safety, efficacy, and quality control. Public awareness and education on the proper use of herbal medicine are also essential in ensuring that people can reap the benefits of these ancient remedies without compromising their health (Mbelebele *et al*., 2024) [42].

Common Types of Herbal Remedies

Herbal remedies have been an integral part of traditional medicine for centuries, offering natural solutions for various health conditions (Li and Weng, 2017) [38]. These remedies are derived from different parts of plants, including leaves, roots, flowers, and seeds, and are often used in the form of teas, tinctures, capsules, or topical applications. While modern pharmaceuticals have gained prominence, herbal remedies continue to be widely used due to their perceived safety, effectiveness, and affordability (Javed *et al*., 2025) [27]. The diversity of herbal medicine means that different types of remedies cater to specific health needs, ranging from immune support to digestive health and pain relief (Jamal, 2023) [26].

One of the most popular categories of herbal remedies is immune-boosting herbs, which help strengthen the body's natural defenses against infections and diseases. Herbs such as echinacea, elderberry, and astragalus are widely used to support the immune system, especially during cold and flu season (Singha *et al*., 2025) [61]. Echinacea, for example, is believed to stimulate white blood cell production, while elderberry is rich in antioxidants and has antiviral properties. Similarly, garlic has been used for centuries for its antimicrobial effects and its ability to support cardiovascular health. These herbs are commonly consumed in teas, tinctures, or supplements to enhance immune function and reduce the severity of illnesses (Al-Worafi, 2025) [7].

Another significant category is herbal remedies for digestive health, which help improve digestion, alleviate bloating, and relieve gastrointestinal discomfort (Gupta *et al*., 2025) [19]. Peppermint, ginger, and fennel are well-known for their soothing effects on the digestive tract. Ginger, in particular, is highly effective for nausea and motion sickness, while peppermint can help with irritable bowel syndrome (IBS) by relaxing the muscles of the digestive system (Al-Worafi, 2025) [7]. Chamomile, another widely used herb, aids in digestion and has anti-inflammatory properties that can relieve stomach pain and indigestion. These herbs are often consumed as teas or extracts to promote a healthy digestive system (Julián-Flores *et al*., 2025) [29].

Herbs for stress relief and mental well-being have also gained popularity due to the increasing prevalence of anxiety, stress, and sleep disorders (Yurdakul, 2025) [64]. Adaptogenic herbs like ashwagandha, rhodiola, and holy basil help the body adapt to stress and improve resilience. Ashwagandha, for instance, has been shown to lower cortisol levels, which can reduce stress and anxiety. Valerian root and passionflower are commonly used for their calming effects and their ability to promote restful sleep. Lavender, both as an essential oil and a tea, is also widely used to reduce anxiety and improve relaxation. These herbal remedies play a crucial role in supporting mental health without the side effects associated with pharmaceutical drugs (Henz *et al*., 2025) [20].

Lastly, pain-relieving and anti-inflammatory herbs are frequently used as natural alternatives to synthetic painkillers (Sarsaiya *et al*., 2025) [57]. Turmeric, which contains the active compound curcumin, is well known for its powerful anti-inflammatory properties and is often used to manage arthritis and joint pain. White willow bark, sometimes referred to as "nature's aspirin," has been used for centuries

to relieve headaches, muscle pain, and fever. Arnica is another widely used herbal remedy, particularly in topical forms, to reduce bruising, swelling, and pain from injuries. These herbs provide a natural way to manage pain and inflammation while minimizing the risks associated with long-term use of conventional painkillers (Kopustinskiene *et al*., 2022) [34].

Herbal remedies offer a vast array of health benefits and are deeply rooted in traditional medicine systems worldwide (Messaoudi *et al*., 2025) [43]. Whether used for immune support, digestive health, stress relief, or pain management, these natural remedies continue to provide effective solutions for various health concerns (Kumari, 2025) [37]. However, it is important to use them with proper knowledge, as some herbs can interact with medications or cause side effects when taken in excessive amounts. Consulting with a healthcare provider or a trained herbalist can help ensure the safe and effective use of herbal remedies. As interest in natural health continues to grow, these traditional treatments will likely remain an essential part of holistic wellness (Caballero-Gallardo *et al*., 2025) [15].

Importance of Herbal Medicine in Nigerian Healthcare

Herbal medicine has been an integral part of Nigerian healthcare for centuries, providing natural remedies for a wide range of illnesses. Before the introduction of Western medicine, indigenous communities relied on plant-based treatments to manage diseases, injuries, and infections (Oguntibeju, 2025) [49]. Even with the rise of modern medical practices, herbal medicine continues to play a significant role in Nigerian healthcare, particularly in rural and underserved areas where access to hospitals and pharmaceutical drugs is limited. Many Nigerians trust traditional medicine due to its deep-rooted cultural acceptance, affordability, and perceived effectiveness (Joel *et al*., 2025) [28]. With an estimated 80% of Nigerians using herbal remedies at some point in their lives, it is evident that traditional medicine remains a crucial aspect of healthcare in the country.

One of the most significant benefits of herbal medicine is its accessibility and affordability (Joel *et al*., 2025) [28]. Many Nigerians, especially those living in remote villages, cannot afford expensive hospital treatments or imported pharmaceutical drugs. Herbal remedies, on the other hand, are often locally sourced, making them a cost-effective alternative for the treatment of common ailments such as malaria, cough, digestive disorders, and skin infections (Odubo *et al*., 2024) [46]. Unlike conventional medicine, which often relies on synthetic chemicals, herbal medicine utilizes naturally occurring plants that are readily available in forests, farms, and local markets. This ease of access allows people to treat minor health conditions without the financial burden associated with hospital visits and prescription drugs.

In addition to being affordable, herbal medicine offers several therapeutic benefits with fewer side effects compared to synthetic drugs (Singh and Gohil, 2024) [60]. Many medicinal plants used in Nigeria, such as neem (Azadirachta indica), moringa (Moringa oleifera), bitter leaf (Vernonia amygdalina), and scent leaf (Ocimum gratissimum), have been scientifically proven to possess anti-inflammatory, antimicrobial, and antioxidant properties. These natural compounds help in boosting immunity, managing chronic diseases like diabetes and hypertension, and preventing infections. Unlike some pharmaceutical drugs that may cause severe side effects, herbal medicines are often considered gentler on the body. However, concerns remain regarding the correct dosage, preparation methods, and potential interactions with modern medicine, highlighting the need for further research and regulation (Ahmed and Tamim, 2025) [3].

Herbal medicine remains an essential component of Nigerian healthcare, offering a natural, accessible, and affordable alternative to conventional medicine (Idowu, 2025) [22]. Its widespread use, particularly in rural areas, highlights the importance of integrating traditional medicine into the country's healthcare system. While herbal remedies provide numerous health benefits, addressing the challenges of standardization, regulation, and scientific validation is crucial to ensuring their safety and effectiveness. With increased investment in research, education, and policy development, herbal medicine can complement modern healthcare and continue to serve as a valuable resource for disease prevention and treatment in Nigeria.

Preparation, Storage, and Distribution Methods of Herbal Drugs

Herbal drugs have been used for centuries in various traditional medicine systems, and their effectiveness largely depends on proper preparation, storage, and distribution (Herdiana, 2025) [21]. Unlike synthetic drugs, which are manufactured under strict laboratory conditions, herbal medicines require meticulous handling from harvesting to consumption to maintain their potency and safety. The process of preparing herbal drugs involves several key steps, including collection, drying, extraction, and formulation into different dosage forms. Proper storage is essential to prevent microbial contamination, degradation of active compounds, and loss of medicinal properties. Furthermore, effective distribution ensures that consumers receive high-quality herbal products that meet safety standards and regulatory requirements (Odo *et al*., 2021) [45].

Role of Technology in Herbal Product Distribution

With advancements in technology, the distribution of herbal formulations has become more efficient and widespread. E-commerce platforms and digital marketing have allowed herbal medicine manufacturers to reach a broader consumer base, making these products more accessible worldwide (Mukherjee, 2025). Online sales have also introduced the need for secure and temperature-controlled packaging to ensure that products arrive in good condition. Additionally, modern tracking systems, such as barcoding and RFID technology, help monitor the movement of herbal products through the supply chain, reducing the risk of counterfeit products entering the market (Raj *et al*., 2025).

Proper Packaging and Storage Practices

The final strategy for reducing microbial contamination involves proper packaging and storage of herbal formulations (Ovuru *et al*., 2024) [52]. Packaging materials should be sterilized and designed to prevent exposure to air, moisture, and light, all of which can promote microbial growth (Jahan *et al*., 2024). Airtight containers, vacuum-sealed pouches, and moisture-resistant blister packs are commonly used to maintain product stability. Herbal products should be stored in cool, dry environments to prevent fungal and bacterial proliferation. Temperature and humidity control in storage areas is essential, as excessive heat and moisture can create conditions for microbial contamination (Bhatt *et al*., 2024). Regular quality checks should be conducted to monitor microbial levels in stored products, ensuring that they remain safe for consumption throughout their shelf life. By implementing these packaging and storage measures, manufacturers can significantly extend the safety and efficacy of herbal medicines (Devi and Kumar 2024) [17].

Regulatory Framework and Quality Control Measures of Herbal Formulations

The regulation and quality control of herbal formulations are essential to ensuring their safety, efficacy, and consistency (W.H.O, 2024) [62]. Unlike synthetic drugs, which undergo rigorous testing and standardization, herbal medicines often face challenges in regulation due to their natural variability, diverse sources, and traditional usage. Many countries have established regulatory frameworks to monitor the production, distribution, and sale of herbal products to protect consumers from substandard or contaminated formulations (Devi and Kumar, 2024) [17]. These regulations ensure that herbal medicines meet acceptable safety standards, contain the correct active ingredients, and are free from harmful contaminants such as microbes, heavy metals, and pesticides. A well-defined regulatory framework helps maintain public confidence in herbal medicine while promoting scientific validation of traditional remedies (Paul and Kumar, 2024) [54].

Microbial Contamination in Herbal Formulations: An Issue of Growing Concerns

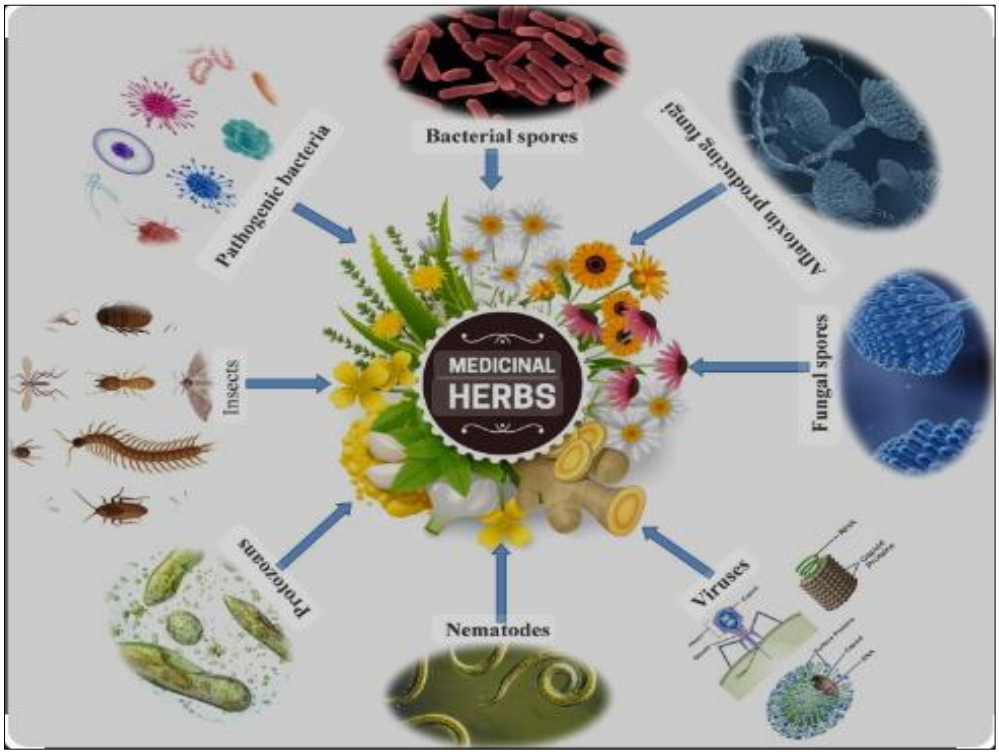
Despite its numerous benefits, herbal medicine in Nigeria faces challenges related to standardization and quality control (Mponda, 2025) [44]. Unlike modern pharmaceutical drugs, which undergo strict clinical trials and regulatory approval, many herbal medicines are produced without proper scientific validation. The lack of standardization in dosage and preparation increases the risk of ineffective or even harmful remedies being distributed. Additionally, some herbal formulations have been found to be contaminated with harmful microbes, heavy metals, or adulterants due to poor handling and storage practices (Ovuru *et al*., 2024; Oke, 2025) [52, 51].

Herbal formulations have been used for centuries in traditional medicine across the world. With the increasing preference for natural and plant-based remedies, the global herbal industry has experienced significant growth (Bhattacharjee *et al*., 2024) [12]. However, one major concern that threatens the safety and efficacy of these products is microbial contamination. The presence of bacteria, fungi, and other harmful microorganisms in herbal preparations can pose serious health risks to consumers (Ansari *et al*., 2024) [8]. Contamination can occur at various stages of production, including harvesting, processing, storage, and packaging. Since herbal products are often consumed directly or used in medicinal preparations, ensuring their microbiological safety is crucial for public health (Ahiabor *et al*., 2024) [2].

One of the primary sources of microbial contamination in herbal formulations is the raw plant material itself. Unlike synthetic pharmaceuticals, which undergo rigorous purification and sterilization, herbs are often collected from the wild or cultivated under conditions that expose them to soil microbes, animal waste, and environmental pollutants (Krochmal-Marczak *et al*., 2025) [36]. Inadequate drying, improper handling, and unsanitary storage can further contribute to microbial growth. Fungal contamination, particularly by species such as Aspergillus and Penicillium, is a significant concern due to their ability to produce mycotoxins, which are harmful to human health. Similarly, bacterial contaminants like Escherichia coli and Salmonella can lead to gastrointestinal infections and other serious illnesses (Adhikari, 2025) [1].

Another contributing factor to microbial contamination is the lack of standardized manufacturing practices in the herbal industry (Carbone *et al*., 2025) [16]. While pharmaceutical drugs are subjected to stringent quality control regulations, herbal formulations often lack uniform guidelines, particularly in developing countries. Many small-scale producers may not have the resources or expertise to implement proper hygiene, sterilization, and microbial testing protocols (Asante-poku *et al*., 2025) [10]. Additionally, the use of contaminated water, outdated processing equipment, and poor packaging materials can increase the risk of microbial proliferation. The absence of regulatory oversight further exacerbates the problem, allowing substandard and potentially hazardous herbal products to reach consumers (Sethi *et al*., 2025) [58].

The implications of microbial contamination in herbal formulations extend beyond individual health risks. Infections caused by contaminated products can lead to outbreaks, particularly among vulnerable populations such as the elderly, children, and individuals with weakened immune systems (Butabayev and Yoqubov, 2025) [14]. Moreover, microbial contamination can compromise the efficacy of herbal medicines, as bacteria and fungi may degrade active ingredients or produce harmful metabolites. This not only reduces the therapeutic potential of the product but also undermines consumer trust in herbal medicine as a whole. Addressing this issue is essential to ensuring that herbal formulations remain a safe and viable option for healthcare (Jaapar *et al*., 2025) [25].



Source: Ansari *et al.* (2024)

Fig 1: Contamination of Herbs by Different Pathogenic Microorganisms

Health Implications of Microbial Contamination in Herbal Medicines

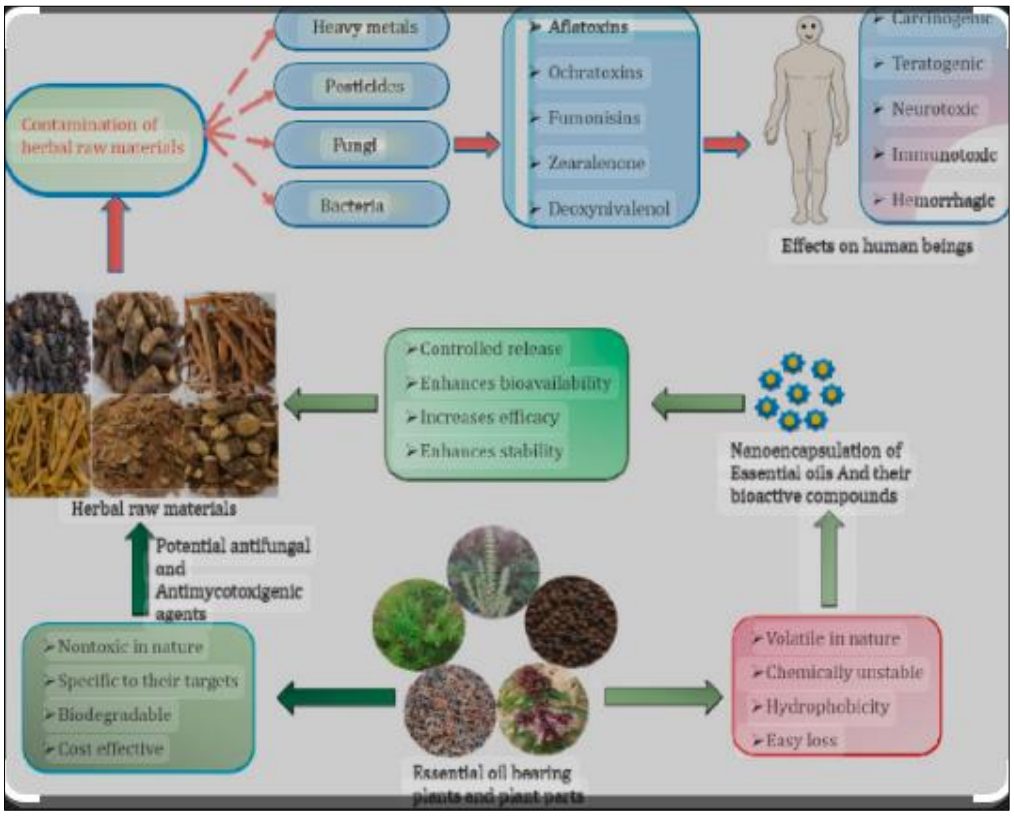
Microbial contamination in herbal medicines poses significant health risks to consumers, ranging from mild infections to life-threatening conditions (Ansari *et al*., 2024; Oke, 2025) [8, 51]. Herbal formulations, often perceived as natural and safe, can become hazardous when contaminated with bacteria, fungi, or other microorganisms (Esmaeili *et al*., 2025). Since these products are frequently consumed raw, applied topically, or brewed as teas, they can serve as direct entry points for harmful microbes into the human body. The impact of microbial contamination is particularly concerning for individuals with weakened immune systems, such as the elderly, pregnant women, and patients with chronic illnesses (Chedid *et al*., 2025). The potential health risks associated with contaminated herbal medicines is essential in promoting safer production and consumption practices (Ansari *et al*., 2024) [8].

1. Gastrointestinal Infections and Food Poisoning

One of the most immediate health risks of microbial contamination in herbal medicines is gastrointestinal infections (Alharbi *et al*., 2024). Pathogenic bacteria such as Escherichia coli, Salmonella, and Shigella can be introduced into herbal products through contaminated water, poor hygiene practices, or unsanitary processing conditions. When ingested, these bacteria can cause severe food poisoning symptoms, including nausea, vomiting, diarrhea, abdominal cramps, and fever. In extreme cases, bacterial infections from contaminated herbal products can lead to dehydration and hospitalization, particularly in vulnerable individuals. The lack of proper sterilization and quality control in the production of herbal medicines increases the risk of exposure to these harmful pathogens (Ovuru *et al*., 2024) [52].

2. Fungal Infections and Mycotoxin Poisoning

Fungal contamination is another major concern in herbal medicines, particularly when they are stored under humid or poorly controlled condition (Devi and Kumar, 2024) [17]. Molds such as Aspergillus, Penicillium, and Fusarium can grow on herbal materials, producing toxic secondary metabolites known as mycotoxins. These toxins, including aflatoxins, can cause severe health issues such as liver damage, immunosuppression, and even cancer. Long-term consumption of mycotoxin-contaminated herbal medicines may contribute to chronic illnesses, including liver cirrhosis and hepatocellular carcinoma (Zhang *et al*., 2025). Mycotoxin poisoning is particularly dangerous because these toxins are heat-stable, meaning they cannot be easily destroyed through normal cooking or brewing processes. This makes proper drying, packaging, and storage essential in preventing fungal contamination in herbal products (Zhang *et al*., 2025).



Source: Singh *et al.* 2022

Fig 2: Detrimental Health Implications Caused by the Consumption of Herbs Contaminated by Microorganisms

Preventive Measures to Reduce Contamination

To minimize contamination during processing and handling, strict hygiene and quality control measures must be implemented at every stage of herbal drug production (Wang *et al*., 2023). Good Manufacturing Practices (GMP) are followed, including regular cleaning of equipment, use of sterilized packaging materials, and proper worker hygiene (Yetgin, 2024). Herbal materials should be thoroughly dried before processing to prevent moisture-related contamination, and grinding equipment must be cleaned between batches to avoid cross-contamination (Riffat *et al*., 2024). Workers involved in handling herbal formulations should wear protective gear and maintain proper hand hygiene to reduce the risk of microbial introduction. Additionally, microbiological testing should be conducted on both raw materials and finished products to detect and eliminate contaminants before distribution. By implementing these preventive measures, manufacturers can ensure that herbal formulations remain safe, effective, and free from harmful microorganisms (Ovuru *et al*., 2024) [52]. Herbal formulations, often perceived as natural and safe, can become hazardous when contaminated with bacteria, fungi, or other microorganisms.

Conclusion

Herbal medicine remains a popular source of medication in Nigeria. These herbs have been known to cure various ailments in human's health including gastrointestinal disorder, microbial diseases and digestive health effects, among others. Herbal formulations can often become hazardous when contaminated with pathogenic bacteria, yeasts, moulds, or other microorganisms. The microbial contamination of herbal products in Nigeria occurs at different stages, such as the collection, processing, storage, and distribution stage. Non-aseptic conditions employed by vendors also contributes to the microbial contamination experienced in daily lives. The implications of microbial contamination in herbal formulations extend just beyond individual health risks, but can also lead to disease outbreaks particularly among vulnerable populations. The consumption of these types of herbal formulation can cause various health effects including kidney dysfunction, hepatitis, immunosuppression, and liver damage which can be severe or life-threatening to human health.

Recommendations

It is recommended that;

1. Mitigating the risks associated with microbial contamination should be ensured in order to implement quality control measures throughout the herbal production process
2. Good agricultural and collection practices should be enforced when dealing with the raw materials used for the production of herbs
3. Good Hazard Analysis and Critical Control Points (HACCP) should always be adopted to minimize microbial contamination at every stage from production up to the consumption by final consumers
4. Regular microbiological testing should always be conducted so as to significantly reduce the presence of harmful microorganisms present in the herbal medicines produced
5. Enforcement of standards for herbal products by regulatory bodies (e.g., NAFDAC, WHO) should be done, so as to ensure that they meet safety criteria before reaching consumers
6. Prioritizing microbiological safety should be emphasized on in order to protect public health and

maintain the integrity of traditional and modern herbal medicine practice in Nigeria.

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How to Cite This Article

Ahmed SK, Garba FI, Fardami AY. Effects of microbial contamination associated with traditional herbal formulations in Nigeria and its health implications to human health: a review. Int J Biol Biomed Res. 2026;2(1):10–19. doi:10.54660/IJBBR.2026.2.1.10-19.

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