Journal of Exploratory Research in Pharmacology **2026** vol. 11(3) | e00004
DOI: 10.14218/JERP.2026.00004

Review Article

Ethnopharmacology in Combating Emerging Diseases: Lessons from COVID-19 in Nigeria

Emmanuel Agbamu[1*], Triumph Balogun[2], Promise Kamsiyochukwu Okoro[3], Kabeerat Arike Balogun[2], Justinah Ekpoboredefe[2], Nduka Godsgift Iteh[2] and Christabel Ebulu[2]

[1]Department of Pharmaceutics and Industrial Pharmacy, Faculty of Pharmacy, Delta State University, Abraka, Delta State, Nigeria; [2]Faculty of Pharmacy, Delta State University, Abraka, Delta State, Nigeria; [3]Osun State University Health Centre, Okuku Campus, Osun State, Nigeria

Received: May 20, 2026 | **Revised:** June 22, 2026 | **Accepted:** July 07, 2026 | **Published online:** July 30, 2026

Abstract

Emerging diseases are those that appear in a population for the first time or previously existed, but rapidly increase in incidence or geographic range. During the coronavirus disease 2019 (COVID-19) pandemic, ethnopharmacological practices became prominent in Nigeria because herbal remedies were affordable, locally accessible, and supported by longstanding cultural trust. However, despite broad public use and some regulatory progress, evidence for the safety, efficacy, standardization, and clinical application of these remedies remains limited. This narrative review examines the integration of ethnopharmacology into Nigeria's COVID-19 response, evaluates its strengths, constraints, and lessons, and considers future pathways for incorporating ethnopharmacological practices into epidemic preparedness and response strategies. It reviews literature and regulatory information published from 2015 to 2025, focusing on herbal remedies used during the pandemic, regulatory listing processes, and key research gaps. Common remedies were derived from *Zingiber officinale*, *Allium sativum*, *Citrus limon*, *Curcuma longa*, and *Garcinia kola*. The National Agency for Food and Drug Administration and Control in Nigeria accelerated toxicological testing and listed 14 local herbal medicines, including Pax Herbal Cugzin, Niprimune, and IHP Detox Tea. This established a baseline safety for human consumption but did not validate therapeutic efficacy against severe acute respiratory syndrome coronavirus 2, which requires rigorous clinical trials. Although some formulations showed promising findings in preliminary clinical, *in silico*, and *in vitro* studies, the evidence was constrained by small pilot samples, absence of multiphase randomized controlled trials, insufficient *in vivo* pharmacokinetic data, and difficulties in isolating active compounds necessary for batch-to-batch consistency. Strengthening Nigeria's resilience to future epidemics will require sustained investment in scientific research infrastructure, toxicogenomic and metabolomic studies, robust intellectual property frameworks for indigenous knowledge, and transparent public communication to reduce misinformation and product misuse.

Introduction

Emerging diseases are diseases that either spread in a population for the first time or may have existed in the past but are spreading geographically or rapidly.[1] Beyond the immediate medical expenses, emerging diseases have significant economic effects. They may hinder travel and trade or raise unwarranted concerns, particularly if there are persistent rumors of deliberate use. Well-coordinated worldwide surveillance and response are the solutions to the global threat posed by emerging diseases. The first incident of coronavirus disease 2019 (COVID-19) was reported in Wuhan, China, in November 2019. How exactly it spread locally remains unknown. However, in less than 3 years, more than 500 million cases and over 6 million deaths were reported in approximately 194 countries.[2] The first case of COVID-19 in Africa was reported in Egypt on February 14, 2020, and within 3 years, nearly 9 million cases were reported, with about 175 thousand deaths.[3,4] The first reported case of COVID-19 in Nigeria was on February 27, 2020. The number of reported cases peaked at week 52, i.e., January 18 to 24, 2021.[5,6]

The pandemic exposed stark inequities in global healthcare infrastructure, particularly regarding the slow pace at which Western therapeutics and vaccines were transferred to developing

Keywords: COVID-19; Ethnopharmacology; Emerging diseases; Herbal medicines; Lessons; Nigeria.
***Correspondence to:** Emmanuel Agbamu, Department of Pharmaceutics and Industrial Pharmacy, Faculty of Pharmacy, Delta State University, Abraka, Delta State 330105, Nigeria. ORCID: https://orcid.org/0009-0000-6602-0387. Tel: +234-8023499842, E-mail: eagbamu@delsu.edu.ng
How to cite this article: Agbamu E, Balogun T, Okoro PK, Balogun KA, Ekpoboredefe J, Iteh NG, *et al*. Ethnopharmacology in Combating Emerging Diseases: Lessons from COVID-19 in Nigeria. *J Explor Res Pharmacol* 2026;11(3):e00004. DOI: https://doi.org/10.14218/JERP.2026.00004.

nations. Due to the fragile nature of the pharmaceutical supply chain, renewed global interest emerged in exploring alternative and complementary healthcare paradigms, specifically ethnopharmacology and natural product drug discovery, to build long-term pandemic resilience.[7]

A large number of existing therapeutic solutions trace their origins to indigenous botanical knowledge. In the face of a novel viral threat for which no specific, safe, and efficacious cure exists, targeted screening of medicinal plants offers a distinct strategic advantage. Rather than depending solely on time-intensive *de novo* synthetic drug discovery, ethnopharmacological approaches leverage centuries of empirical human observation. This approach focuses on identifying complex chemical entities with broad-spectrum antiviral, anti-inflammatory, and immunomodulatory properties that can mitigate severe symptom cascades.[8]

In sub-Saharan Africa, specifically Nigeria, African traditional medicine is a critical component of the integrated primary healthcare system. As a result of fragile formal healthcare infrastructure, economic constraints, and deep-seated cultural acceptance of traditional healing practices, an estimated 80% of the local population relies on herbal remedies.[9] At the peak of the COVID-19 pandemic, international borders were closed and global supply chains collapsed due to varying policies, such as lockdowns, leaving Nigeria with acute therapeutic shortages. In response, local populations and traditional healthcare practitioners turned to traditional remedies to manage symptoms such as fever, dry cough, and respiratory distress.[10] Ethnobotanical surveys across various geopolitical zones in Nigeria documented widespread use of prominent medicinal plants such as *Zingiber officinale* (ginger), *Allium sativum* (garlic), *Citrus limon* (lemon), and *Azadirachta indica* (neem), either as decoctions or infusions.[11] Recognizing this surge, institutional bodies in Nigeria, such as the National Institute for Pharmaceutical Research and Development (NIPRD) and the National Agency for Food and Drug Administration and Control of Nigeria (NAFDAC), accelerated efforts to evaluate and standardize a total of 14 herbal medicines against COVID-19.[12] This review aims to investigate how ethnopharmacology was used in Nigeria as part of the response to COVID-19, evaluate the strengths, constraints, and lessons learned from this strategy, and suggest a roadmap to include ethnopharmacological practices in emerging epidemic response plans and strategies.

Although several reviews have discussed the role of traditional medicine and ethnopharmacology in the management of COVID-19, most have focused on global perspectives, individual medicinal plants, or specific traditional medical systems, such as traditional Chinese medicine and Ayurveda, with limited emphasis on the Nigerian context.[7,11,13] This review aims to provide a distinct Nigerian perspective by integrating evidence on indigenous medicinal plants, regulatory responses by institutional bodies in Nigeria, such as the NAFDAC and the NIPRD, locally developed herbal formulations, and practical experiences of traditional medicine use during the pandemic. In addition, the review incorporates recent evidence published from 2015 to 2025, including updates on Nigerian herbal products undergoing clinical evaluation, emerging pharmacological studies of plant-derived antiviral agents, and evolving policy initiatives. Furthermore, this review adopted a translational perspective, linking traditional knowledge with clinical integration and future drug development pathways. By identifying research gaps and proposing strategies for scientific validation, standardization, and integration of ethnopharmacology into epidemic preparedness, this review provides a comprehensive framework for translating indigenous medicinal knowledge into evidence-based interventions for COVID-19 and future emerging infectious diseases.

The study used a narrative review approach, and a literature search was conducted in scientific databases, including Google Scholar, PubMed, Scopus, and Web of Science, as well as institutional websites such as those of the World Health Organization (WHO), NAFDAC, and NIPRD. Search terms encompassed keywords derived from the topic and included "ethnopharmacology", "emerging diseases", "ethnopharmacology in emerging diseases", and "lessons from COVID-19 in Nigeria". The review was a narrative review, and studies published from 2015 to 2025 were grouped into themes (subheadings), which included traditional medicines used during COVID-19 in Nigeria and other parts of the world, gaps during the COVID-19 pandemic in Nigeria, ways through which ethnopharmacology has helped address emerging diseases in the country, and future research directions and prospects that policymakers and other stakeholders should consider. As this was a narrative review, no quantitative meta-analysis was undertaken, and no risk-of-bias assessment was performed.

Traditional medicine used during COVID-19

Reliance on medicinal plants has been attributed to their affordability, effectiveness, safety, cultural preferences, and ample accessibility whenever needed. Ethnobotanical surveys have documented extensive community knowledge and use of medicinal plants.[14] During the COVID-19 pandemic, traditional healers and communities continued to use diverse medicinal plants.[13,15]

Medicinal plants that were part of some traditional remedies include:

1. Ginger (*Zingiber officinale*): Used for respiratory relief and immune boosting[16]
2. Garlic (*Allium sativum*): Claimed to have antiviral properties[17]
3. Turmeric (*Curcuma longa*): Known for its anti-inflammatory and antioxidant effects[18]
4. *Artemisia annua*: Has antimalarial properties and has shown antiviral activity against severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2)[19]
5. Neem (*Azadirachta indica*): Used in West Africa for its antiviral properties[20]
6. Herbal teas: Herbal teas based on perilla and sage exhibit antiviral activity against SARS-CoV-2, including variants of concern such as Alpha, Beta, Delta, and Omicron.[21]

Several phytoconstituents in these plants have been implicated in their biological activities. Curcumin is a known phytoconstituent of *Curcuma longa* and is widely recognized for its profound anti-inflammatory and antioxidant mechanisms associated with SARS-CoV-2 infections.[18] Additionally, artemisinins (sesquiterpene lactone derivatives) in *Artemisia annua* have shown distinct *in vitro* antiviral activity directly against SARS-CoV-2 (Table 1).[17-20,22-24]

Table 1. Some medicinal plants and major phytoconstituents against COVID-19

Medicinal plant	Major phytoconstituents	Potential mechanism against COVID-19
Ginger (*Zingiber officinale*)	6-Gingerol, 6-Shogaol, 8-Gingerol, 10-Gingerol, Zingerone, Gingerenone A, Paradols, Zingiberene	Inhibits SARS-CoV-2 main protease (Mpro), suppresses viral replication, antioxidant and immunomodulatory effects[22]
Bitter kola (*Garcinia kola*)	Kolaviron, Garcinol, Garcinoic acid, Kolaflavanone, Garcinia biflavonoids, Xanthones	Anti-inflammatory, antioxidant, NF-κB inhibition, immune modulation, potential antiviral activity[23]
Lemon (*Citrus limon*)	Hesperidin, Eriocitrin, Diosmin, Naringin, Quercetin, Limonene, Limonin, Vitamin C	Inhibits viral entry and Mpro, antioxidant and immune-enhancing activities[24]
Neem (*Azadirachta indica*)	Azadirachtin, Nimbolide, Nimbin, Nimbidin, Gedunin, Quercetin, Salannin	Inhibits viral proteases and spike protein interactions, anti-inflammatory and immunomodulatory activities[20]
Sweet wormwood (*Artemisia annua*)	Artemisinin derivatives, Artemisinin, Artesunate, Artemisinic acid, Flavonoids, Quercetin, Luteolin, Chlorogenic acid	Inhibits SARS-CoV-2 replication and inflammatory pathways[19]
Garlic (*Allium sativum*)	Allicin, Ajoene, Alliin, Diallyl sulfide, Diallyl disulfide, S-allyl cysteine, Organosulfur compounds	Antiviral, immune stimulation, inhibition of viral replication and cytokine production[17]
Turmeric (*Curcuma longa*)	Curcumin, Demethoxycurcumin, Bisdemethoxycurcumin, Turmerone, Ar-turmerone, Curlone	Inhibits viral entry and replication, suppresses cytokine storm and oxidative stress[18]

China

China utilized traditional Chinese medicine extensively during the pandemic. Formulas such as Qingfei Paidu decoction (containing 21 herbs) were incorporated into national guidelines.[25,26] Another major product, Lianhua Qingwen capsules, improved symptoms and recovery time in patients with mild COVID-19.[27-30] A randomized, double-blind, international multicenter trial protocol has also been published for Lianhua Qingwen.[31]

India

AYUSH medicines were extensively used in India for COVID-19 prevention and management, including preparations containing Ashwagandha, Giloy, and Tulsi.[32,33] Clinical studies also evaluated traditional Indian medicines alone or alongside modern treatments.[34]

Africa

Traditional, complementary, and alternative medicine use is widespread across sub-Saharan Africa, although prevalence varies markedly across settings and populations.[35] In Madagascar, the government promoted COVID-Organics, a tonic made from *Artemisia annua*.[36,37] In South Africa, local herbs such as buchu, African potato, and Sutherlandia were used.[38,39]

Regulatory listing for herbal medicines used in Nigeria during COVID-19

A cross-sectional survey in southeastern Nigeria found that herbal products were the most commonly used form of self-medication for COVID-19 prevention or treatment and were usually self-prepared.[40] While many of these remedies are staples in Nigerian traditional medicine for treating respiratory symptoms, the WHO and NAFDAC emphasized that these remedies require rigorous scientific validation through clinical trials to confirm their safety and efficacy.[12]

A survey of Nigerian healthcare practitioners found that more than half considered herbal medicine use for COVID-19 unsubstantiated, while most supported further safety and efficacy research.[41] It is important to note that NAFDAC listing denotes that a product is safe for human consumption based on toxicological evaluations, without validating the product's efficacy in treating or curing COVID-19.[42] According to NAFDAC, the medicines are safe for consumption, but their efficacy remains to be established through rigorous clinical trials. Currently, the agency lists herbal medicines after conducting toxicological and microbiological evaluations to ensure that they are, at a minimum, safe. The listing status is valid for 2 years and is renewable. A claim of a cure must be subjected to clinical evaluation through well-controlled, randomized clinical trials following an approved clinical trial protocol.[42]

Frequently used natural remedies included lemon (*Citrus limon*), ginger (*Zingiber officinale*), garlic (*Allium sativum* L.), and turmeric (*Curcuma longa*).[43] These substances were typically prepared by either boiling them or extracting their active components through blending, followed by sieving to remove residues. To preserve them for repeated use, the mixtures were either reheated daily or stored in refrigerators. Other commonly used herbs included neem leaves (*Azadirachta indica*), pawpaw leaves (*Carica papaya*), guava leaves (*Psidium guajava*), lemongrass (*Cymbopogon citratus*), scent leaf (*Ocimum gratissimum*), bitter leaf (*Vernonia amygdalina*), detox tea, anise (*Pimpinella anisum*), and wormwood leaf (*Artemisia absinthium*).[43]

Collaborative scientific evaluation of Nigerian ethnomedicines predates COVID-19; one study involving NIPRD, Pax Herbal Clinic, and traditional healers screened indigenous remedies for antimycobacterial activity.[44]

Gaps during the COVID-19 pandemic in Nigeria

Lack of scientific validation for safety and efficacy

In Nigeria, ethnopharmacology surged during the COVID-19 pandemic. Many Nigerians, especially older adults and those with long-term medical conditions, resorted to native herbal remedies as preventive or curative measures due to limited access to biomedical solutions during the early stages of the outbreak.[45] Although the regulatory body (NAFDAC) accelerated the listing of some herbal remedies, they were not approved as potential cures. Hence, scientific evidence supporting their efficacy or interactions with other therapies was still lacking.

Herbal mixtures produced from Dogoyaro (neem), ginger, garlic, pawpaw leaves, soursop leaves, bitter plants, and lemongrass were either inhaled as steam or consumed as decoctions.[46] Clinical studies, toxicological evaluations, and phytochemical screening had not, however, been extensively performed on these mixtures. Their pharmacodynamics and pharmacokinetics in relation to COVID-19 were therefore unclear, raising significant safety concerns, especially for patients who were at high risk or who were taking traditional antiviral or antipyretic medications concurrently.

The problem was worsened by the lack of research infrastructure devoted to validating traditional treatments. Nigeria's intellectual property and patent regulations do not sufficiently support the official recognition or regulation of traditional knowledge, making it difficult to encourage traditional practitioners to participate in collaborative research.[47] Because of this gap, incorporating herbal knowledge into official healthcare systems became more difficult, reducing the potential for standardizing and potentially utilizing useful compounds through appropriate formulation and dose research. The use of unproven therapies had serious repercussions. Some users abandoned the idea of seeking hospital care because they believed that natural remedies would alleviate their symptoms. In other instances, high quantities of mixtures or improper combinations with medications may have increased the risk of renal problems or hepatotoxicity.[46,48] Furthermore, because these medicines lacked pharmacovigilance protocols, adverse effects were either misreported or underreported. Despite these challenges, reassurance and active engagement with traditional practitioners have proved successful through the established framework instituted by NIPRD and the strict, phased NAFDAC guidelines for herbal products.

Misuse and misinformation surrounding herbal remedies

The pervasive ignorance and misuse of herbal remedies during the pandemic represented a serious challenge. Early in the pandemic, the WHO issued a warning about the possibility of an "infodemic", in which an influx of false information spreads more rapidly than the virus itself. Nigeria was not exempt. Informal networks, places of worship, and especially social media platforms such as Facebook and WhatsApp were used to spread misinformation.[49] Unverified claims, such as killing the virus by steaming with lemon and ginger or preventing infection by consuming large amounts of garlic and onions, gained popularity despite a lack of evidence. A Nigerian survey reported widespread use of dietary and herbal supplements during the pandemic, with 88.5% of participants indicating that they had taken such products.[50] It is concerning that 30.8% of respondents reported that effective COVID-19 medications had already been developed but were being withheld for financial or political reasons. Some individuals also believed that spraying alcohol on the body or steaming were useful forms of treatment.[51] A false sense of security was exacerbated by this trend, making it more difficult to follow evidence-based recommendations such as masking, physical distancing, and ultimately immunization, as it became challenging to distinguish immune support from true antiviral treatment.

As a result, adaptive strategies and communication messages were required following vaccine hesitancy. Targeted awareness campaigns and messages providing transparent information about COVID-19 vaccine safety, efficacy, and development processes were also employed to promote accurate knowledge sharing and improve treatment acceptance and compliance.[49]

Addressing COVID-19 through ethnopharmacology in Nigeria

Nigeria is endowed with a rich heritage of medicinal plant species that may be utilized for a variety of purposes. Ethnopharmacology and medicinal plants have been used to manage several emerging diseases, such as COVID-19, human immunodeficiency virus (HIV)/AIDS, and antimicrobial resistance (AMR).

COVID-19

COVID-19 is a global disease caused by infection with SARS-CoV-2.[10] Vaccination has been one of the most practical and successful strategies to stop the spread of SARS-CoV-2 since the pandemic began. New vaccines for the pandemic are often verified and validated through rigorous and lengthy scientific procedures. Vaccines generally require preclinical testing and phased clinical trials to evaluate safety and efficacy, although accelerated pathways may be used during public health emergencies. Several African herbal remedies have reached various stages of clinical trials, although only a few have published phase III results.[12] Additionally, few Nigerian herbal remedies have progressed to various stages of preclinical trials or received regulatory clearance for testing in humans for COVID-19 management (Table 2).[52-54]

IHP Detox Tea is a polyherbal blend containing *Andrographis paniculata*, *Garcinia kola* (bitter kola), and *Psidium guajava* (guava). A total of 72 patients were enrolled in the trial program. The results revealed no deaths in the herbal treatment group compared with 3 deaths in the placebo group. Additionally, patients receiving IHP Detox Tea demonstrated faster viral clearance and were discharged earlier than controls (shorter time to negative polymerase chain reaction). The tea was generally well tolerated, and no severe adverse effects were observed.[52] However, the limited number of patients included in the study was too small to allow definitive clinical conclusions. Furthermore, NAFDAC has emphasized that extensive, multi-phase clinical trials are mandatory to scientifically prove efficacy and safety for full approval of herbal products.

Niprimune, on the other hand, is a capsule-based formulation of *Andrographis paniculata* and is listed by NAFDAC as a safe immune booster with planned clinical trials.[53] Although Niprimune, developed by NIPRD, has shown promise in

Table 2. Herbal remedies with clinical trial progress

Formulation	Description	Design	Results
IHP Detox Tea	This polyherbal blend contains *Andrographis paniculata*, *Garcinia kola* (bitter kola), and *Psidium guajava* (guava)	Pilot placebo-controlled RCT in Nigeria (NAFDAC approved trial at LUTH & NAUTH (n = 72 patients))	The pilot randomized clinical trial results indicated that patients using the tea cleared the virus faster and were discharged earlier than those in the placebo group[52]
Niprimune	The capsule is based on *Andrographis paniculata*	Preclinical & regulatory evaluation (NAFDAC-listed as safe immune booster; clinical trial planned)	Immuno-modulatory effect with promising preclinical results[53]
FORTE1	It is a polyherbal formulation combining *Moringa oleifera*, *Terminalia catappa*, *Bridelia ferruginea*, and *Scoparia dulcis*	The study utilized computational screening methods and *in silico* antiviral screening	Demonstrated mild to moderate inhibitory activity against the viral enzyme *in vitro* suggesting its potential for management of COVID-19 and related viral threats[54]

IHP, InterCEDD Health Products; LUTH, Lagos University Teaching Hospital; NAUTH, Nnamdi Azikiwe University Teaching Hospital; NAFDAC, National Agency for Food and Drug Administration and Control; RCT, randomized controlled trial.

Table 3. Herbal remedies studied for the management of HIV

Formulation	Description	Design	Results
α-Zam	Consists of two primary identified active plant components, *Nigella sativa* (Black Seed plant) and Honey	This was a longitudinal, observational cohort study comprising of 51 patients that were confirmed (Western blot) at LAUTECH teaching hospital and Ahmadu Bello University Teaching Hospital and completed α-Zam within 5 months between September 2008 and December 2009.	All symptoms and signs associated with HIV infection in all patients fully subsided within 4 weeks of commencement of α-Zam therapy and there was no evidence of negative drug interaction in those HIV patients using both the herbal and highly active anti-retroviral therapy (HAART)[55]
Jobelyn	It is a dietary supplement formulated from the leaf sheaths of *Sorghum bicolor*	This was a prospective, open-label, non-randomized observational Nigeria-based clinical study	Patients receiving antiviral therapy plus Jobelyn demonstrated significant improvement in CD4 count compared to baseline at 6 weeks and remained so at 12 weeks[56]

HIV, human immunodeficiency virus; LAUTECH, Ladoke Akintola University of Technology.

preliminary studies and cell cultures, it has not yet progressed through comprehensive clinical trials to unequivocally demonstrate efficacy in human populations.[53] Furthermore, as with many plant-derived phytomedicines, isolating the exact active compounds and ensuring batch-to-batch consistency present ongoing analytical challenges.

FORTE1 is VIVE fortified with *Moringa oleifera*, *Terminalia catappa*, *Bridelia ferruginea*, and *Scoparia dulcis*.[54] The study utilized computational screening methods and *in silico* antiviral screening. The results showed that individual plant extracts comprising VIVE and FORTE1 exhibited mild to moderate inhibitory activity against the viral enzyme *in vitro*.[54] Despite its demonstrated *in vitro* activity, the study was limited to computational and *in vitro* testing. Viral inhibition has not yet been evaluated in robust and comprehensive clinical trials. As a result, *in vivo* parameters such as pharmacodynamics and pharmacokinetics have not been established. Furthermore, similar to other polyherbal remedies, FORTE1 contains a highly complex mixture of organic chemicals; therefore, it is difficult to determine which specific compounds or synergistic interactions are responsible for the antiviral effects. Further development of this formulation may be challenging due to its complex composition and polyherbal variability in quality and composition based on geographic sources, harvesting seasons, and preparation methods. This makes manufacturing a standardized dosage difficult.

HIV

Numerous scientific studies have clarified the therapeutic mechanisms by which these plants act, and several Nigeria-based studies have demonstrated that some medicinal plants may play key roles in the management of HIV (Table 3).[55,56]

The α-Zam study was a longitudinal, uncontrolled, open-label observational study. Without a control group (either a placebo group or a group receiving conventional highly active antiretroviral therapy (HAART) alone), it is methodologically difficult to definitively isolate the therapeutic effect of α-Zam from other interfering variables. Patients were taking the herbal remedy as an alternative or complementary therapy alongside HAART; hence, it becomes difficult to determine whether viral suppression and improved CD4 counts were driven by the herbal formulation, the HAART regimen, or a synergistic interaction between both. Furthermore, the study evaluated a cohort of only 51 patients who completed the therapy. Small sample sizes significantly reduce statistical power and limit the generalizability of results to wider populations. Similarly, as with other herbal formulations, inconsistencies in manufacturing protocols may limit batch-to-batch uniformity, which may greatly affect the findings. Similar to the α-Zam study, the Jobelyn study lacked a control group, had a short follow-up duration, a small sample size, limited pharmacokinetic data, and an absence of optimal therapeutic dosages, all of which should be addressed in future studies.

AMR

AMR has emerged as one of the most urgent worldwide public health issues.[57-59] This occurs when microorganisms, including bacteria, fungi, parasites, and viruses, undergo evolutionary processes that make them resistant to antimicrobial agents, which are frequently used to treat such infections.[57,60] Addressing the emergence of AMR is a difficult challenge that may not be easily solved. Antimicrobials are widely used in medicine, food production, and animal husbandry, making it difficult to control their use. A variety of strategies, including the creation of antibiotic substitutes, are needed to combat AMR.[61,62] Commonly used medicinal plants with antibacterial properties include *Bacopa monnieri*, *Andrographis paniculata*, *Nyctanthes arbor-tristis*, *Hibiscus sabdariffa*, *Gloriosa superba*, *Dioscorea pentaphylla*, *Dendrophthoe falcata*, *Dentella repens*, and *Solanum virginianum*.[63,64] Additionally, some strains have been isolated from plant parts with significant microbial activity.[65] For example, an endophytic *Bacillus amyloliquefaciens* strain isolated from *Bacopa monnieri* stem tissue exhibited antifungal activity against tested phytopathogens.[66] Studies indicate that more individuals may die in the near future from secondary bacterial infections resistant to antibiotics that were previously nonexistent. As a result, the scientific community has taken notice of the discovery of novel plant-based antimicrobials as a potential source of antibiotics.[63] Therefore, the main goals are to lower infection rates, rationalize antibiotic use, and guarantee long-term investment in the fight against antibiotic resistance.[57] It is therefore important to prioritize natural or herbal medicinal plants and advance existing traditional medicinal knowledge as remedial treatments that help reduce AMR (Table 4).[65,67-70]

Table 4. Selected medicinal plants and their uses

Medicinal plants	Medicinal uses
Bacopa monnieri	Demonstrated *in vitro* antibacterial activity against pathogenic *Staphylococcus aureus*[67]
Hibiscus sabdariffa	Used against pathogenic bacteria such as *Staphylococcus aureus* and *Salmonella* strains[68]
Solanum virginianum	Reported to have antioxidant properties as well as antibacterial activity against certain bacterial pathogens[69]
Gloriosa superba	Reported to exhibit antifungal and antibacterial activity[70]
Dioscorea pentaphylla	Demonstrated significant antibacterial activity against the skin-associated bacteria *Staphylococci*[65]

Limitations

This study has some limitations. As a narrative review, the study depended on published literature and institutional reports rather than a systematic review approach. This may have introduced selection bias and limited the comprehensiveness of the included evidence. Additionally, the review depended on secondary data from databases and official documents, many of which reported preliminary findings or observational evidence rather than robust randomized controlled trials. Although the review discussed several herbal medicines and ethnopharmacological interventions used during the COVID-19 pandemic in Nigeria, the availability of high-quality clinical evidence on safety, efficacy, pharmacokinetics, and long-term outcomes remains limited. Furthermore, some relevant indigenous knowledge and practices may not have been documented in published scientific reports, resulting in the possible exclusion of valuable local experiences.

Future research directions and prospects

During the COVID-19 pandemic, there were opportunities and challenges regarding the application of ethnopharmacology in the management of emerging diseases in Nigeria. Although traditional medicine offered immediate, culturally accepted, and available therapeutic options, future studies should aim to establish a strong scientific foundation regarding their safety, efficacy, and regulatory inclusion (Fig. 1).[9,71]

Scientific standardization and validation

Further studies focusing on phytochemical characterization, toxicogenomics, and robust, controlled clinical studies (which have been lacking) of Nigerian medicinal plants frequently used during COVID-19 are required.[72] Such studies will provide opportunities to standardize formulations, dosages, and pharmacokinetic parameters to promote consistency and safety.[10] Analytical methods, including metabolomics and bioinformatics, are now available to assist in determining bioactive compounds that drive antiviral, anti-inflammatory, and immunomodulatory effects.[73]

Integrative and collaborative research models

Cross-disciplinary research involving traditional healers, pharmacists, and biomedical scientists is becoming increasingly urgent to reconcile indigenous and Western therapeutic approaches.[72,74,75] The NIPRD has performed well in this aspect, which culminated in the development of Niprimune.[53] Despite the success achieved, more needs to be done, as some traditional practitioners with effective remedies have not been included.

Policy formulation and intellectual property protection

Regulatory and policy frameworks ought to be informed by research findings that support the incorporation of traditional medicine into medical care. Intellectual property protection of

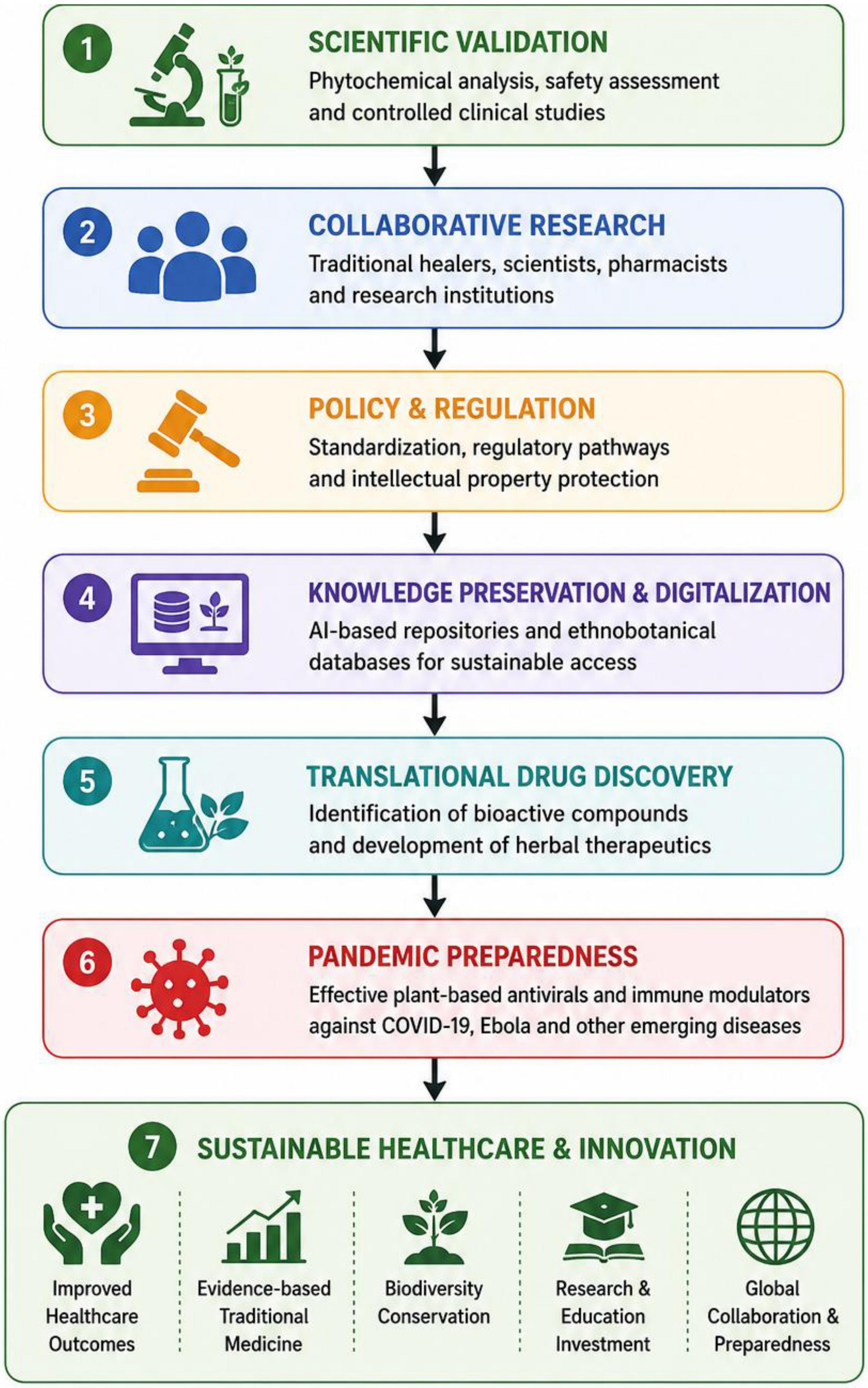

Fig. 1. Future research directions and prospects. AI, artificial intelligence.

indigenous knowledge will help preserve cultural heritage and promote innovation and commercialization of standardized herbal products.[47,51]

Knowledge preservation and digitalization

Digital technologies and artificial intelligence are increasingly shaping the organization and application of health information in personalized healthcare.[75] Ethnobotanical databases and digital repositories can preserve traditional herbal knowledge, improve long-term accessibility, and support biodiversity conservation and collaborative drug discovery.[76]

Predictive outlook

Preclinical evidence suggests that African medicinal plants may provide candidates for research against SARS-CoV-2, Ebola virus, and other viral infections.[77] Additionally, studies in Nigeria should focus on the sustainable exploitation and preservation of medicinal plants, as declining biodiversity continues to affect global preparedness.[8] Future development of ethnopharmacology in Nigeria will rely on long-term investment in scientific research, education, and international collaboration.

Conclusions

Ethnopharmacology played a visible and culturally important role in Nigeria's community-level response to COVID-19. It played an important role when the conventional healthcare system was overwhelmed. Many citizens used herbal remedies for symptom relief or perceived immune support, particularly when access to conventional healthcare was limited. The extensive utilization of herbs during the COVID-19 pandemic demonstrated confidence in traditional medicine. It is noteworthy that some herbal treatments showed promising *in vitro* results, and some progressed to clinical trials. COVID-19 exposed gaps in Nigeria's integration of traditional medicine into formal healthcare. The pandemic emphasized the need for research, regulation, and safety monitoring of ethnopharmacological agents. Additionally, collaboration among traditional healers, researchers, and policymakers is needed. This serves as a wake-up call to the Nigerian government, entrepreneurs, and pharmaceutical companies to invest in scientific research to evaluate and standardize traditional remedies from experimental studies to robust clinical trials, develop policies to regulate and integrate safe ethnopharmacological practices, promote public awareness of the benefits and risks of traditional medicine, and strengthen partnerships between traditional and orthodox healthcare systems in Nigeria. With the right framework, Nigeria can become a major contributor to integrating traditional wisdom with modern science to combat emerging diseases.

Acknowledgments

None to declare.

Funding

None.

Conflict of interest

The authors declare no conflict of interest.

Author contributions

Review conception (KAB), investigation, resources, writing-review (TB, JE, NGI, PKO, CE), editing, final review, and submission (EA). All authors have approved the final version and publication of the manuscript.

References

[1] Morse SS. Factors in the emergence of infectious diseases. Emerg Infect Dis 1995;1(1):7–15. DOI: 10.3201/eid0101.950102, PMID: 8903148.

[2] Hao YJ, Wang YL, Wang MY, Zhou L, Shi JY, Cao JM, *et al*. The origins of COVID-19 pandemic: A brief overview. Transbound Emerg Dis 2022;69(6):3181–3197. DOI: 10.1111/tbed.14732, PMID: 36218169.

[3] Salyer SJ, Maeda J, Sembuche S, Kebede Y, Tshangela A, Moussif M, *et al*. The first and second waves of the COVID-19 pandemic in Africa: a cross-sectional study. Lancet 2021;397(10281):1265–1275. DOI: 10.1016/S0140-6736(21)00632-2, PMID: 33773118.

[4] World Health Organization (WHO). WHO Coronavirus (COVID-19) Dashboard. Geneva (Switzerland): World Health Organization. Available from: https://www.arcgis.com/apps/dashboards/0c9b3a8b68d0437a8cf28581e9c063a9. Accessed June 20, 2026.

[5] Adegboye OA, Adekunle AI, Gayawan E. Early transmission dynamics of novel coronavirus (COVID-19) in Nigeria. Int J Environ Res Public Health 2020;17(9):3054. DOI: 10.3390/ijerph17093054, PMID: 32353991.

[6] Okoroiwu HU, Ogar CO, Nja GME, Abunimye DA, Ejemot-Nwadiaro RI. COVID-19 in Nigeria: account of epidemiological events, response, management, preventions and lessons learned. Germs 2021;11(3):391–402. DOI: 10.18683/germs.2021.1276, PMID: 34722361.

[7] Yimer G, Ekuadzi E, Fasinu P, de Melo AC, Pillai GC. Traditional medicines for COVID-19: Perspectives from clinical pharmacologists. Br J Clin Pharmacol 2021;87(9):3455–3458. DOI: 10.1111/bcp.14981, PMID: 34272755.

[8] Silveira D, Boylan F. Medicinal Plants: Advances in Phytochemistry and Ethnobotany. Plants (Basel) 2023;12(8):1682. DOI: 10.3390/plants12081682, PMID: 37111904.

[9] Kasilo OMJ, Wambebe C, Nikiema JB, Nabyonga-Orem J. Towards universal health coverage: advancing the development and use of traditional medicines in Africa. BMJ Glob Health 2019;4(Suppl 9): e001517. DOI: 10.1136/bmjgh-2019-001517, PMID: 31673437.

[10] Aborode AT, Rafiu R, Jennifer N. The effectiveness of the use of traditional medicine on COVID-19 in South-West Region of Nigeria. Chem Sci J 2020;11(5):214.

[11] Attah AF, Fagbemi AA, Olubiyi O, Dada-Adegbola H, Oluwadotun A, Elujoba A, *et al*. Therapeutic Potentials of Antiviral Plants Used in Traditional African Medicine With COVID-19 in Focus: A Nigerian Perspective. Front Pharmacol 2021;12:596855. DOI: 10.3389/fphar.2021.596855, PMID: 33981214.

[12] World Health Organization (WHO). WHO affirms support for COVID-19 traditional medicine research. Brazzaville: WHO Regional Office for Africa; 2021. Available from: https://www.afro.who.int/news/who-affirms-support-covid-19-traditional-medicine-research.

[13] Oladele JO, Ajayi EI, Oyeleke OM, Oladele OT, Olowookere BD, Adeniyi BM, *et al*. A systematic review on COVID-19 pandemic with special emphasis on curative potentials of Nigeria based medicinal plants. Heliyon 2020;6(9):e04897. DOI: 10.1016/j.heliyon.2020.e04897, PMID: 32929412.

[14] Ahmet Sargin S. Ethnobotanical survey of medicinal plants in Bozyazı district of Mersin, Turkey. J Ethnopharmacol 2015;173: 105–126. DOI: 10.1016/j.jep.2015.07.009, PMID: 26190351.

[15] Khadka D, Dhamala MK, Li F, Aryal PC, Magar PR, Bhatta S, *et al*. The use of medicinal plants to prevent COVID-19 in Nepal. J Ethnobiol

Ethnomed 2021;17(1):26. DOI: 10.1186/s13002-021-00449-w, PMID: 33832492.

[16] Mao QQ, Xu XY, Cao SY, Gan RY, Corke H, Beta T, *et al*. Bioactive Compounds and Bioactivities of Ginger (Zingiber officinale Roscoe). Foods 2019;8(6):185. DOI: 10.3390/foods8060185, PMID: 31151279.

[17] Rouf R, Uddin SJ, Sarker DK, Islam MT, Ali ES, Shilpi JA, *et al*. Antiviral potential of garlic (Allium sativum) and its organosulfur compounds: A systematic update of pre-clinical and clinical data. Trends Food Sci Technol 2020;104:219–234. DOI: 10.1016/j.tifs.2020.08.006, PMID: 32836826.

[18] Babaei F, Nassiri-Asl M, Hosseinzadeh H. Curcumin (a constituent of turmeric): New treatment option against COVID-19. Food Sci Nutr 2020;8(10):5215–5227. DOI: 10.1002/fsn3.1858, PMID: 33133525.

[19] Cao R, Hu H, Li Y, Wang X, Xu M, Liu J, *et al*. Anti-SARS-CoV-2 Potential of Artemisinins In Vitro. ACS Infect Dis 2020;6(9): 2524–2531. DOI: 10.1021/acsinfecdis.0c00522, PMID: 32786284.

[20] Eze MO, Ejike CECC, Ifeonu P, Udeinya IJ, Udenigwe CC, Uzoegwu PN. Anti-COVID-19 potential of Azadirachta indica (Neem) leaf extract. Sci Afr 2022;16:e01184. DOI: 10.1016/j.sciaf.2022.e01184, PMID: 35434432.

[21] Le-Trilling VTK, Mennerich D, Schuler C, Sakson R, Lill JK, Kasarla SS, *et al*. Identification of herbal teas and their compounds eliciting antiviral activity against SARS-CoV-2 in vitro. BMC Biol 2022;20(1): 264. DOI: 10.1186/s12915-022-01468-z, PMID: 36447206.

[22] Zubair MS, Maulana S, Widodo A, Pitopang R, Arba M, Hariono M. GC-MS, LC-MS/MS, Docking and Molecular Dynamics Approaches to Identify Potential SARS-CoV-2 3-Chymotrypsin-Like Protease Inhibitors from Zingiber officinale Roscoe. Molecules 2021;26(17): 5230. DOI: 10.3390/molecules26175230, PMID: 34500664.

[23] Tauchen J, Frankova A, Manourova A, Valterova I, Lojka B, Leuner O. Garcinia kola: a critical review on chemistry and pharmacology of an important West African medicinal plant. Phytochem Rev 2023;22: 1305–1351. DOI: 10.1007/s11101-023-09869-w, PMID: 37359709.

[24] Bellavite P, Donzelli A. Hesperidin and SARS-CoV-2: New Light on the Healthy Function of Citrus Fruits. Antioxidants (Basel) 2020;9(8):742. DOI: 10.3390/antiox9080742, PMID: 32823497.

[25] Su YC, Huang GJ, Lin JG. Chinese herbal prescriptions for COVID-19 management: Special reference to Taiwan Chingguan Yihau (NRICM101). Front Pharmacol 2022;13:928106. DOI: 10.3389/fphar.2022.928106, PMID: 36278162.

[26] Xu J, Liu H, Fan Y, Ji B. Traditional Chinese Medicine is effective for COVID-19: A systematic review and meta-analysis. Med Nov Technol Devices 2022;16:100139. DOI: 10.1016/j.medntd.2022.100139, PMID: 35527852.

[27] Xu Q, Song K, Clifford SP, Kong M, Huang J. Meta-analysis of Traditional Chinese Medicine Lianhua Qingwen in the Treatment of Coronavirus Disease 2019. J Anesth Transl Med 2023;2(2):20–26. DOI: 10.58888/2957-3912-2023-06-21, PMID: 38380434.

[28] Fan Z, Guo G, Che X, Yang Y, Liu Y, Li L, *et al*. Efficacy and safety of Lianhuaqingwen for mild or moderate coronavirus disease 2019: A meta-analysis of randomized controlled trials. Medicine (Baltimore) 2021;100(21):e26059. DOI: 10.1097/MD.0000000000026059, PMID: 34032734.

[29] Hu K, Guan WJ, Bi Y, Zhang W, Li L, Zhang B, *et al*. Efficacy and safety of Lianhuaqingwen capsules, a repurposed Chinese herb, in patients with coronavirus disease 2019: A multicenter, prospective, randomized controlled trial. Phytomedicine 2021;85:153242. DOI: 10.1016/j.phymed.2020.153242, PMID: 33867046.

[30] Zheng JP, Ling Y, Jiang LS, Mootsikapun P, Lu HZ, Chayakulkeeree M, *et al*. Effects of Lianhuaqingwen Capsules in adults with mild-to-moderate coronavirus disease 2019: an international, multicenter, double-blind, randomized controlled trial. Virol J 2023;20(1):277. DOI: 10.1186/s12985-023-02144-6, PMID: 38017515.

[31] Zhan YQ, Chen RF, Zheng QS, Li XW, Liu YN, Mootsikapun P, *et al*. Efficacy and safety of Lianhua Qingwen capsules combined with standard of care in the treatment of adult patients with mild to moderate COVID-19 (FLOSAN): protocol for a randomized, double-blind, international multicenter clinical trial. J Thorac Dis 2023;15(5): 2859–2872. DOI: 10.21037/jtd-23-281, PMID: 37324081.

[32] Thakar A, Panara K, Goyal M, Kumari R, Sungchol K. Ayush [Indian System of Medicines] prophylaxis against COVID-19: A living systematic review and meta-analysis (second update). J Integr Complement Med 2024;30(7):602–619. DOI: 10.1089/jicm.2023.0357, PMID: 38422192.

[33] Singh RS, Singh A, Kaur H, Batra G, Sarma P, Kaur H, *et al*. Promising traditional Indian medicinal plants for the management of novel Coronavirus disease: A systematic review. Phytother Res 2021;35(8): 4456–4484. DOI: 10.1002/ptr.7150, PMID: 34132429.

[34] Ahmad S, Zahiruddin S, Parveen B, Basist P, Parveen A, Gaurav, *et al*. Indian Medicinal Plants and Formulations and Their Potential Against COVID-19-Preclinical and Clinical Research. Front Pharmacol 2020; 11:578970. DOI: 10.3389/fphar.2020.578970, PMID: 33737875.

[35] James PB, Wardle J, Steel A, Adams J. Traditional, complementary and alternative medicine use in Sub-Saharan Africa: a systematic review. BMJ Glob Health 2018;3(5):e000895. DOI: 10.1136/bmjgh-2018-000895, PMID: 30483405.

[36] Nie C, Trimpert J, Moon S, Haag R, Gilmore K, Kaufer BB, *et al*. In vitro efficacy of Artemisia extracts against SARS-CoV-2. Virol J 2021; 18(1):182. DOI: 10.1186/s12985-021-01651-8, PMID: 34496903.

[37] Kapepula PM, Kabengele JK, Kingombe M, Van Bambeke F, Tulkens PM, Sadiki Kishabongo A, *et al*. Artemisia Spp. Derivatives for COVID-19 Treatment: Anecdotal Use, Political Hype, Treatment Potential, Challenges, and Road Map to Randomized Clinical Trials. Am J Trop Med Hyg 2020;103(3):960–964. DOI: 10.4269/ajtmh.20-0820, PMID: 32705976.

[38] Docrat TF, Marnewick JL, Abdul NS. The phytotherapeutic potential of commercial South African medicinal plants: current knowledge and future prospects. In: Ramasami P, editor. Basic Sciences for Sustainable Development: Energy, Artificial intelligence, Chemistry, and Materials Science. 1st ed. Berlin, Boston: De Gruyter; 2023: 197–216. DOI: 10.1515/9783110913361-009.

[39] Monicca TB, Tsetselelane DM. African traditional medicine as a COVID-19 treatment and the South African Government response. Phar J Theo 2024;105(4):1–16. DOI: 10.46222/pharosjot.105.42.

[40] Amuzie CI, Kalu KU, Izuka M, Nwamoh UN, Emma-Ukaegbu U, Odini F, *et al*. Prevalence, pattern and predictors of self-medication for COVID-19 among residents in Umuahia, Abia State, Southeast Nigeria: policy and public health implications. J Pharm Policy Pract 2022;15(1):34. DOI: 10.1186/s40545-022-00429-9, PMID: 35501929.

[41] Ibrahim JA, Esievo KB, Fatokun OT, Adigwe OP. Knowledge, attitude and practice of health care practitioners in Nigeria towards the use of plants/herbal medicines in the management of COVID-19. J Complement Med Res 2023;14(2):157–163. DOI: 10.5455/jcmr.2023.14.02.24.

[42] National Agency for Food and Drug Administration and Control. NAFDAC's Position On local claims for Covid-19 remedies. 2020. Available from: https://nafdac.gov.ng/nafdacs-position-on-local-claims-for-covid-19-remedies/. Accessed May 20, 2026.

[43] Ejike CE. COVID 19 and African traditional medicine. In: Ikechukwu AK, Kanu CC, Ndubisi EJO, editors. COVID 19, and Afrocentric perspective: Health and Economic Implications. 1st ed. Maryland: Association for the Promotion of African Studies; 2021:1–35.

[44] Ibekwe NN, Nvau JB, Oladosu PO, Usman AM, Ibrahim K, Boshoff HI, *et al*. Some Nigerian anti-tuberculosis ethnomedicines: a preliminary efficacy assessment. J Ethnopharmacol 2014;155(1): 524–532. DOI: 10.1016/j.jep.2014.05.059, PMID: 24911338.

[45] Alabi GO, Dada SO, Adebodun SA, Obi OC. Knowledge of COVID-19 and perception of Nigerians towards the use of herbal medicine in its treatment. Nig J Pharma Res 2022;17(2):157–166. DOI: 10.4314/njpr.v17i2.2.

[46] Xu X, Zhu R, Ying J, Zhao M, Wu X, Cao G, *et al*. Nephrotoxicity of Herbal Medicine and Its Prevention. Front Pharmacol 2020;11: 569551. DOI: 10.3389/fphar.2020.569551, PMID: 33178019.

[47] Amechi EP, Ezirigwe J. Traditional knowledge on the medicinal uses of plants (TKMUP) in Nigeria. In: Lawal-Arowolo A, Ola K, editors. Routledge Handbook of COVID-19 in Africa. Abingdon: Routledge; 2022:109–128. DOI: 10.4324/9781003250883-7.

[48] Parvez MK, Rishi V. Herb-Drug Interactions and Hepatotoxicity. Curr Drug Metab 2019;20(4):275–282. DOI: 10.2174/13892002206 66190325141422, PMID: 30914020.

[49] Wonodi C, Obi-Jeff C, Adewumi F, Keluo-Udeke SC, Gur-Arie R, Krubiner C, *et al*. Conspiracy theories and misinformation about COVID-19 in Nigeria: Implications for vaccine demand generation communications. Vaccine 2022;40(13):2114–2121. DOI: 10.1016/j.vaccine.2022.02.005, PMID: 35153088.

[50] Holdbrooke SJA, Afolabi BM, David NA, Kareem KO, Salako A, Aina OO. Perception, knowledge, and consumption pattern of dietary supplement used during COVID-19 pandemic among black Africans: Perspective of Nigerians. Dialogues Health 2023;2:100106. DOI: 10.1016/j.dialog.2023.100106, PMID: 36744009.

[51] Adeyemi K. Misinformation about COVID-19 among internet users in Nigeria: Tools to effective public awareness, prevention and control. Int J Mod Anthropol 2021;2(15):469–482. DOI: 10.4314/ijma.v15i2.4.

[52] National Agency for Food and Drug Administration and Control (NAFDAC). The Efficacy and Safety of IHP [InterCEDD Health Products] Detox Tea [a Special Blend of Andrographis paniculata; Burm F., Garcinia kola Heckel and Psidium guajava L.] for the Treatment of Coronavirus Disease 2019 [COVID-19]: A Pilot Randomized Clinical Trial. 2022. Available from: https://nafdac.gov.ng/clinical-trial-database/. Accessed May 20, 2026.

[53] National Institute for Pharmaceutical Research and Development (NIPRD). COVID-19 Drug 'Niprimune' Receiving International Recognition. 2020. Available from: https://niprd.gov.ng/niprd-covid-19-drug-niprimune-receiving-international-recognition/. Accessed May 20, 2026.

[54] Olubiyi OO, Attah FA, Strodel B, Eberle RJ, Coronado MA, Akinseinde O, *et al*. Novel dietary herbal preparations with inhibitory activities against multiple SARS-CoV-2 targets: A multidisciplinary investigation into antiviral activities. Food Chem Adv 2025;7: 100969. DOI: 10.1016/j.focha.2025.100969.

[55] Onifadee AA, Jewel AP, Okesina AB. Virologic and immunologic outcome of treatment of HIV infection with a herbal concoction, α-Zam, among clients seeking herbal remedy in Nigeria. Afr J Tradit Complement Altern Med 2011;8(1):37–44. DOI: 10.1625/jcam.8.37, PMID: 22238482.

[56] Ayuba GI, Jensen GS, Benson KF, Okubena AM, Okubena O. Clinical efficacy of a West African sorghum bicolor-based traditional herbal preparation Jobelyn shows increased hemoglobin and CD4+ T-lymphocyte counts in HIV-positive patients. J Altern Complement Med 2014;20(1):53–56. DOI: 10.1089/acm.2013.0125, PMID: 24283768.

[57] Prestinaci F, Pezzotti P, Pantosti A. Antimicrobial resistance: a global multifaceted phenomenon. Pathog Glob Health 2015;109(7): 309–318. DOI: 10.1179/2047773215Y.0000000030, PMID: 26343252.

[58] Antimicrobial Resistance Collaborators. The burden of bacterial antimicrobial resistance in the WHO African region in 2019: a cross-country systematic analysis. Lancet Glob Health 2024;12(2): e201–e216. DOI: 10.1016/S2214-109X(23)00539-9, PMID: 38134946.

[59] Ruckert A, Lake S, Van Katwyk SR. Developing a protocol on antimicrobial resistance through WHO's pandemic treaty will protect lives in future pandemics. Global Health 2024;20(1):10. DOI: 10.1186/s12992-024-01015-1, PMID: 38297334.

[60] Kumar SG, Adithan C, Harish BN, Sujatha S, Roy G, Malini A. Antimicrobial resistance in India: A review. J Nat Sci Biol Med 2013; 4(2):286–291. DOI: 10.4103/0976-9668.116970, PMID: 24082718.

[61] Lim JS, Chai YY, Ser WX, Haeren AV, Lim YH, Raja T, *et al*. Novel drug candidates against antibiotic-resistant microorganisms: A review. Iran J Basic Med Sci 2024;27(2):134–150. DOI: 10.22038/IJBMS.2023.71672.15593, PMID: 38234674.

[62] Salam MA, Al-Amin MY, Salam MT, Pawar JS, Akhter N, Rabaan AA, *et al*. Antimicrobial Resistance: A Growing Serious Threat for Global Public Health. Healthcare (Basel) 2023;11(13):1946. DOI: 10.3390/healthcare11131946, PMID: 37444780.

[63] Anand U, Jacobo-Herrera N, Altemimi A, Lakhssassi N. A Comprehensive Review on Medicinal Plants as Antimicrobial Therapeutics: Potential Avenues of Biocompatible Drug Discovery. Metabolites 2019;9(11):E258. DOI: 10.3390/metabo9110258, PMID: 31683833.

[64] Usharani K, Jincy K, Neeraja PT. Screening and evaluation of potential bioactive compounds for antibacterial activity in Indian medicinal plants of Bacopa monnieri, Eclipta alba, Aegle marmelos and Centella asiatica. Int J Front Chem Pharm Res 2022;1(1):14–23. DOI: 10.53294/ijfcpr.2021.1.1.0053.

[65] Kumar S, Mahanti P, Singh NR, Rath SK, Jena PK, Patra JK. Antioxidant activity, antibacterial potential and characterization of active fraction of Dioscorea pentaphylla L. tuber extract collected from Similipal Biosphere Reserve, Odisha, India. Braz J Pharm Sci 2018;53(4):e17006. DOI: 10.1590/s2175-97902017000417006.

[66] Jasim B, Benny R, Sabu R, Mathew J, Radhakrishnan EK. Metabolite and Mechanistic Basis of Antifungal Property Exhibited by Endophytic Bacillus amyloliquefaciens BmB 1. Appl Biochem Biotechnol 2016;179(5):830–845. DOI: 10.1007/s12010-016-2034-7, PMID: 26945577.

[67] Emran TB, Rahman MA, Uddin MM, Dash R, Hossen MF, Mohiuddin M, *et al*. Molecular docking and inhibition studies on the interactions of Bacopa monnieri's potent phytochemicals against pathogenic Staphylococcus aureus. Daru 2015;23(1):26. DOI: 10.1186/s40199-015-0106-9, PMID: 25884228.

[68] Portillo-Torres LA, Bernardino-Nicanor A, Gómez-Aldapa CA, González-Montiel S, Rangel-Vargas E, Villagómez-Ibarra JR, *et al*. Hibiscus Acid and Chromatographic Fractions from Hibiscus Sabdariffa Calyces: Antimicrobial Activity against Multidrug-Resistant Pathogenic Bacteria. Antibiotics (Basel) 2019;8(4):218. DOI: 10.3390/antibiotics8040218, PMID: 31718033.

[69] Saraswathi K, Bharkavi R, Khusro A, Sivaraj C, Arumugam P, Alghamdi S, *et al*. Assessment on in vitro medicinal properties and

chemical composition analysis of Solanum virginianum dried fruits. Arab J Chem 2021;14(12):103442. DOI: 10.1016/j.arabjc.2021.103442.

[70] Khan H, Khan MA, Mahmood T, Choudhary MI. Antimicrobial activities of Gloriosa superba Linn (Colchicaceae) extracts. J Enzyme Inhib Med Chem 2008;23(6):855–859. DOI: 10.1080/14756360701747409, PMID: 18615278.

[71] Wong YMA, Ahn S, Bana A, Dua PK, Eggers R, Kuruvilla S, *et al*. Policy implications of WHO's Global traditional medicine strategy 2025-2034. Bull World Health Organ 2025;103(11):715–721. DOI: 10.2471/BLT.25.293414, PMID: 41180270.

[72] Yadav V, Kaushik P. Phytochemicals against COVID-19 and a gap in clinical investigations: an outlook. Indian J Biochem Biophys 2021;58(5):403–407. DOI: 10.56042/ijbb.v58i5.44153.

[73] Wang Z, Guo S, Cai Y, Yang Q, Wang Y, Yu X, *et al*. Decoding active compounds and molecular targets of herbal medicine by high-throughput metabolomics technology: A systematic review. Bioorg Chem 2024;144:107090. DOI: 10.1016/j.bioorg.2023.107090, PMID: 38218070.

[74] Elechi KW, John KA, Ezigbo UG, Olumeko I, Okonkwo M, Adeoye A. Health outcomes teams and the advancement of herbal medicine research in Nigeria: A COVID-19 case study. J Pharmacog Phytochem 2025;14(2):351–357. DOI: 10.22271/phyto.2025.v14.i2e.15307.

[75] Johnson KB, Wei WQ, Weeraratne D, Frisse ME, Misulis K, Rhee K, *et al*. Precision Medicine, AI, and the Future of Personalized Health Care. Clin Transl Sci 2021;14(1):86–93. DOI: 10.1111/cts.12884, PMID: 32961010.

[76] Zouraris D, Graikou K, Vasileiou P, Dimitrov V, Stevanovic ZD, Bilia AR, *et al*. EthnoHERBS: Harnessing traditional herbal knowledge for biodiversity conservation and innovative health solutions. Comput Struct Biotechnol J 2025;29:85–94. DOI: 10.1016/j.csbj.2025.03.035, PMID: 40231173.

[77] Beressa TB, Deyno S, Mtewa AG, Aidah N, Tuyiringire N, Lukubye B, *et al*. Potential Benefits of Antiviral African Medicinal Plants in the Management of Viral Infections: Systematic Review. Front Pharmacol 2021;12:682794. DOI: 10.3389/fphar.2021.682794, PMID: 35002686.