IARJEDI
Int'l Academic Research Journals of Education and Digital inclusion
February-March, 2025: https://journals.classicmultilinks.com
Impact Factor: 4.5 **vol:** 1 **Issue:**1

MICROBIAL ASSESSMENT OF SOME BRANDED HERBAL MEDICINE SOLD IN OWERRI, IMO STATE

Nwachukwu, I.O
Department of Microbiology
Faculty of Biological Sciences
Imo State University, Owerri

ABSTRACT

This study aimed to assess the microbial quality of some branded herbal medicinesavailable in Owerri, Imo State, focusing on bacterial and fungal contaminationlevels. A total of three herbal remedies: Goko Cleanser, Agnes Nwamma, and 7Keys to Power—were analyzed for Total Heterotrophic Bacterial Count (THBC),Total Coliform Count (TCF), Total Salmonella/Shigella Count (TSS), and TotalFungal Count (TFC). The results revealed varying levels of microbialcontamination across the products. Goko Cleanser exhibited moderate bacterialcontamination (1.5×10^4 CFU/ml), low coliform contamination (6×10^3 CFU/ml),and moderate fungal contamination (6×10^3 CFU/ml). Agnes Nwamma showedlower bacterial (7×10^3 CFU/ml) and coliform counts (1×10^1 CFU/ml), with verylow fungal contamination (1×10^1 CFU/ml). 7 Keys to Power demonstrated thehighest bacterial contamination (1.4×10^4 CFU/ml), moderate coliform count (6×10^3 CFU/ml), and significant fungal contamination (9×10^3 CFU/ml). The bacterialisolates identified included *Escherichia coli,Salmonella* spp., and *Staphylococcusaureus,* while fungi such as *Aspergillus* spp. and *Mucor* spp. were isolated. Thepresence of these microorganisms, particularly pathogenic bacteria and fungi,raises concerns about the safety and hygienic quality of these products. The studyemphasizes the need for improved manufacturing practices, regular microbialtesting, better storage, conditions, and consumer awareness to ensure the safety of
herbal medicines.

Keywords: Herbal formulations; Imo State, Bacteria and fungi

INTRODUCTION

Herbal formulations have been a cornerstone of medical treatments in many developing countries for decades, with estimates suggesting that about 80% of ailments are treated using herbal medicine (Onyambu*et al*., 2022). These remedies are often the first choice due to their affordability, availability, perceived minimal side effects, and the belief that they can cure a wide range of diseases (Ali *et al*., 2005; Pallavi, 2022). In

Nigeria, as in many other developing nations, the use of herbal remedies has a long history and continues to be prevalent today. These remedies are widely available in shops and supermarkets and are commonly used for both prevention and treatment of various illnesses. However, the regulation of these products is often lax, leading to variations in their composition depending on the location (Ali *et al*., 2005; Eisenberg *et al*., 2021).

One of the main advantages of herbal remedies is their accessibility, along with their antioxidant properties, which have made them highly sought after (Eisenberg *et al*., 2021). It is widely believed that these remedies are effective, safe, and free of side effects, which has contributed to their widespread use. Some claims suggest that herbal remedies are effective against serious conditions such as cancer, diabetes, asthma, end-stage kidney disease, drug-resistant malaria, and AIDS (Pallavi, 2022; Itharat*et al*., 2021).

Despite the popularity of herbal remedies, there is growing concern about the purity and safety of these products, especially in Nigeria. The lack of stringent regulation and oversight means that these remedies are sometimes contaminated with microorganisms, which can alter their physical, chemical, or organoleptic properties, potentially reducing their therapeutic effectiveness (Roozbeh *et al*., 2022; Oluwatoyin and Adebayo, 2022). When herbal remedies are sold in the market without proper sterilization or supervision, they may pose significant health risks (WHO, 2021; Temu-Justin *et al*., 2021).

Previous studies have highlighted the contamination of herbal remedies with various microorganisms, including bacteria such as *E. coli*, *Klebsiella*, *Pseudomonas*, *Proteus*, *Salmonella typhi*, *Shigella spp.*, and *Staphylococcus aureus* (Okunlola*et al*., 2021; Abba *et al*., 2020). Moulds like *Aspergillus flavus*, *A. parasiticus*, *Trichosporium spp.*, *Mucor spp.*, *Candida spp.*, and *Penicillium sp.* have also been detected in herbal products (Halt, 2021; Bugno *et al*., 2006). Contamination levels exceeding permissible limits can pose serious health risks, particularly to elderly and immunocompromised individuals (Amaikeand Keller, 2021). This underscores the need for more stringent policies and regulations to ensure the safety and effectiveness of herbal remedies.

In the context of Owerri, Imo State, this study aims to assess the microbial quality of branded herbal medicines available in the region. This assessment is crucial given the widespread use of these products and the potential risks associated with their contamination.

MATERIALS AND METHOD

COLLECTION OF SAMPLES

The research was carried out in Owerri Municipal, Imo State, Nigeria. Three herbal medicines, namely Goko Cleanser, Agnes Nwamma, and 7 Keys to Power, was randomly purchased from mobile promoters and shops and Douglas Road Owerri, Imo State.

MICROBIOLOGICAL ANALYSIS OF THE HERBAL REMEDIES

Three-fold serial dilution was carried out by introducing 1 ml of each sample of herbal medicines, serving as the stock solution into a sterile test tube containing 9 ml of sterile distilled water using sterile syringes. The tube was mixed and labeled 1:10 to obtain dilution 10^{-1}. One milliliter (1 ml) of dilution 10^{-1} was then be introduced into another test tube containing 9 ml of distilled water to achieve dilution 10^{-2}. Using separate 1 ml syringes, the samples was serially diluted up to the required dilution 10^{-3}(Chessbrough, 2011).

The bacterial count of the selected herbal medicines was determined by inoculating the herbal formulations onto sterile Nutrient Agar, Chocolate Agar, MacConkey Agar, Salmonella/Shigella Agar (SSA), and Sabouraud Dextrose Agar. The plates will be incubated at 37°C for 48 hours using the streak plate method. Fungi was isolated from the herbal remedies by inoculating them onto Sabouraud Dextrose Agar (SDA) plates in duplicates and incubating at 25°C for 5 days(Chessbrough, 2011).

PURIFICATION (SUBCULTURE) OF BACTERIAL ISOLATES

Colonies from the primary plates was aseptically picked with a sterile wire loop and streaked onto freshly prepared sterile Nutrient Agar plates using a streaking technique to ensure discrete colonies after incubation. Subculture plates will be incubated at 37°C for 24 to 48 hours. Discrete colonies from the subculture plates was then be streaked onto slants and further incubated for 24 hours at 37°C(Cheesbrough, 2011).

PURIFICATION OF FUNGAL ISOLATES

Colonies from the primary plates was aseptically picked with a sterile inoculation needle and streaked onto freshly prepared sterile Sabouraud Dextrose Agar (SDA) plates. These plates were incubated for 5 to 7 days at 28-30°C. Discrete colonies was transferred onto slants and further incubated for another 5 days at 28-30°C. Pure colonies was stored in the refrigerator at 10-15°C until needed for further characterization and identification (Cheesbrough, 2011).

MORPHOLOGICAL AND BIOCHEMICAL IDENTIFICATION OF ISOLATES

Characteristic colonies from appropriate plates were purified, Gram-staining and biochemically test such catalase test, oxidase

test, motility test, methyl red, citrate utilization, urease production, spore formation, and sugar fermentation will be performed to characterize bacterial isolates.(Cheesbrough, 2011).

MORPHOLOGICAL IDENTIFICATION OF FUNGAL ISOLATES

Macroscopic examination was involve observing colony features such as color, shape, and size. Microscopic examination was include studying fungal morphology using a compound microscope. A small portion of the mycelium was mounted on a glass slide, stained with lactophenol cotton blue, and observed. This process wasallowed for the identification of fungal structures, including hyphae and sporangia.

RESULTS

Table 1: The Total Heterotrophic Bacterial Count (THBC) for Goko Cleanser was found to be 1.5 x 10^4 CFU/ml, indicating moderate bacterial contamination. This suggests that while the product may have been exposed to environmental bacteria, the level is not excessively high. In contrast, Agnes Nwamma showed a much lower count of 7 x 10^3 CFU/ml, representing a minimal bacterial presence, which suggests relatively good hygiene or preservation practices. However, 7 Keys to Power exhibited 1.4 x 10^4 CFU/ml, which shows significant bacterial growth and could be an indicator of improper handling, storage, or contamination during production, suggesting the product may be more prone to bacterial spoilage.

TABLE 1. TOTAL HETEROTROPHIC BACTERIAL COUNT (THBC)

Herbal Remedy	THBC (CFU/ml)
Goko Cleanser	1.5 x 10^4
Agnes Nwamma	7 x 10^3
7 Keys to Power	1.4 x 10^4

Table 2: The **Total Coliform Count (TCF)** serves as an indicator of fecal contamination. **Goko Cleanser** had a coliform count of **6 x 10^3 CFU/ml,** reflecting a low level of coliform contamination. Although low, this still indicates the possibility of fecal matter or unsanitary handling during

preparation. **Agnes Nwamma** showed **1 x 10^1 CFU/ml,** which is very low and suggests that the product is relatively safe in terms of coliform contamination. However, **7 Keys to Power** demonstrated **6 x 10^3 CFU/ml,** signifying moderate coliform contamination, which raises concern for its cleanliness, as coliform bacteria are typically found in fecal matter and can be harmful if ingested.

TABLE 2. TOTAL COLIFORM COUNT (TCF)

Herbal Remedy	TCF (CFU/ml)
Goko Cleanser	6 x 10^3
Agnes Nwamma	1 x 10^1
7 Keys to Power	6 x 10^3

Table 3: The **Total Salmonella/Shigella Count (TSS)**is crucial for assessing the risk of gastrointestinal illness caused by pathogenic bacteria. **Goko Cleanser** tested **0 CFU/ml** for Salmonella/Shigella, indicating no detectable contamination from these pathogens, which is a favorable result. On the other hand, **Agnes Nwamma** showed a trace presence of **1 x 10^1 CFU/ml**, which could be due to limited contamination, but still warrants caution as Salmonella and Shigella are associated with severe foodborne illnesses. **7 Keys to Power** had **4 x 10^3 CFU/ml,** a moderate presence of Salmonella/Shigella, suggesting that this product may pose a higher health risk, especially if consumed without proper preparation or storage, as these pathogens are known to cause serious gastrointestinal diseases like dysentery and food poisoning.

Table 3. Total Salmonella/Shigella Count (TSS)

Herbal Remedy	TSS (CFU/ml)
Goko Cleanser	0
Agnes Nwamma	1 x 10^1

7 Keys to Power	4×10^3

The **Total Fungal Count (TFC)** provides insights into the level of fungal contamination in the herbal remedies. **Goko Cleanser** showed **6×10^3 CFU/ml,** indicating moderate fungal contamination. This could be attributed to inadequate storage conditions, such as exposure to moisture or improper sealing. **Agnes Nwamma** exhibited **1×10^1 CFU/ml,** which is considered low and suggests better preservation methods or less exposure to fungal spores. In contrast, **7 Keys to Power** showed a higher fungal count of **9×10^3 CFU/ml,** indicating significant fungal contamination. This is concerning, as excessive fungal growth can lead to the production of mycotoxins, which are harmful if ingested, especially in immunocompromised individuals.

Table 4. Total Fungal Count (TFC)

Herbal Remedy	**TFC (CFU/ml)**
Goko Cleanser	6×10^3
Agnes Nwamma	1×10^1
7 Keys to Power	9×10^3

TABLE 5. MORPHOLOGICAL AND BIOCHEMICAL IDENTIFICATION OF SUSPECTED BACTERIA

Presumed Bacterial Isolate	**Morphological Characteristics**	**Biochemical Test Results**
Escherichia coli	Gram-negative, rod-shaped, facultative anaerobe	Catalase positive, oxidase negative, lactose fermentation positive
Salmonella sp	Gram-negative, rod-shaped, motile	Catalase positive, oxidase negative, H2S production, non-lactose fermenter

Staphylococcus aureus	Gram-positive, cocci in clusters	Catalase positive, coagulase positive, mannitol fermentation positive

The bacterial isolates identified in the herbal remedies suggest common contaminants found in herbal products. ***Escherichia coli***, a Gram-negative, rod-shaped bacterium, was identified in the samples, which is often a marker for fecal contamination. The presence of *E. coli* in any product is a concern, as it indicates unsanitary conditions during processing or storage. Additionally, **Salmonella**was identified in some samples, particularly **7 Keys to Power,** where it was present in moderate amounts. *Salmonella* is a significant pathogen associated with foodborne illnesses, and its presence raises serious health concerns. ***Staphylococcus aureus,*** another pathogen found in the herbal remedies, is known for its ability to produce toxins and cause food poisoning, especially if the product is not handled properly.

TABLE 6. IDENTIFICATION OF FUNGI

Assumed Fungi Species	Microscopic Appearance	Hyphal Structure	Conidia	Colony Appearance (on agar)	Sporulation	Color of Colony (initial)
Aspergillus spp.	Conidiophores are branched with a swollen vesicle at the tip, producing conidia.	Septate hyphae (with internal divisions between cells).	Conidia are small, round, and arranged in chains.	Green, yellow, or blackish, velvety or powdery appearance.	Produces conidia from a vesicle in radial pattern.	White, yellowish, green, or brown.
Mucor spp.	Non-septate, branched hyphae with large	Non-septate hyphae (without	Large spherical sporangium containing	White to grayish, cottony or fluffy	Produces sporangia that release spores when	White to cream, turning darker

	sporangium containing sporangia.	internal divisions).	numerous round sporangia.	appearance.	ruptured.	(black or gray).

Fungal contamination in the herbal remedies was also noted, with ***Aspergillus* spp.** and ***Mucor* spp.** being the primary fungal isolates. ***Aspergillus* spp.** is a common environmental fungus that produces conidia in chains, and its colonies are typically green, yellow, or blackish with a velvety appearance. ***Mucor* spp.,** characterized by non-septate, branched hyphae and large sporangia, produces cottony, white to grayish colonies. These fungi are commonly found in decaying organic material and can pose a risk to human health, particularly in immunocompromised individuals, as they can lead to respiratory infections or other health issues when inhaled.

DISCUSSION

The Total Heterotrophic Bacterial Count (THBC) values indicated varying levels of bacterial contamination across the herbal remedies. **Goko Cleanser** showed a moderate bacterial contamination (1.5×10^4 CFU/ml), which aligns with other studies where herbal products were reported to harbor significant levels of bacteria due to improper storage and handling (Sornka*et al*., 2022). **Agnes Nwamma,** with a lower count of 7×10^3 CFU/ml, demonstrated relatively good hygienic conditions, which could be attributed to better preservation practices or packaging (Nwankwo and Olime, 2019). **7 Keys to Power,** on the other hand, exhibited a high bacterial count of 1.4×10^4 CFU/ml, indicating a significant level of bacterial growth. This suggests that either the herbal remedy underwent improper handling or was stored in suboptimal conditions, which is consistent with findings from similar studies indicating that herbal medicines can be prone to bacterial contamination, especially in tropical climates (Anie*et al*., 2023).

The Total Coliform Count (TCF) provides insight into fecal contamination, with **Goko Cleanser** (6×10^{-3} CFU/ml) showing a moderate level of contamination. This suggests the possibility of unsanitary conditions during preparation or handling, which can be associated with the handling of raw materials or water quality used during production (Nwokike, 2021). **Agnes Nwamma,** with a very low coliform count (1×10^1 CFU/ml), demonstrated better hygienic practices, while **7 Keys to Power** (6×10^3 CFU/ml) exhibited moderate fecal contamination, raising concerns about the product's safety, especially considering that coliforms are often indicators of poor sanitation and potential contamination with pathogenic bacteria such as *E. coli* (Saad *et al*., 2022).

The Total Salmonella/Shigella Count (TSS) indicates the presence of potentially harmful enteric pathogens. **Goko Cleanser** tested negative for *Salmonella/Shigella*, which is a favorable result, as these pathogens are responsible for serious gastrointestinal diseases (Akinmoladun*et al*., 2021). In contrast, **Agnes Nwamma** showed a trace amount (1 x 10^1 CFU/ml), while **7 Keys to Power** exhibited a significant presence (4 x 10^3 CFU/ml). The moderate contamination in **7 Keys to Power**raises health concerns as both *Salmonella* and *Shigella* are pathogens associated with foodborne illnesses such as dysentery and salmonellosis, which are particularly dangerous for vulnerable populations, including children and immunocompromised individuals (Ahiabor*et al*., 2024). Previous studies have also reported *Salmonella/Shigella* contamination in herbal products, often linked to unsanitary production and packaging conditions (Shiaka, *et al*., 2019).

The Total Fungal Count (TFC) reveals that **Goko Cleanser** exhibited moderate fungal contamination (6 x 10^3 CFU/ml), which may be due to improper sealing or exposure to moisture. **Agnes Nwamma,** with a low fungal count (1 x 10^1 CFU/ml), indicated better storage practices or fewer opportunities for fungal growth. **7 Keys to Power** had a high fungal count (9 x 10^3 CFU/ml), which is concerning as fungi, particularly *Aspergillus spp.* and *Mucor spp.*, can produce mycotoxins that pose serious health risks when consumed. These fungi are often found in poorly stored or improperly sealed herbal products, and their presence in the samples is consistent with studies showing the risk of fungal contamination in herbal remedies, especially when exposed to humid environments (Ezenwa*et al*., 2024). *Aspergillus spp.* and *Mucor spp.*, well-known opportunistic pathogens, can cause respiratory and systemic infections, especially in immunocompromised individuals (Nwokike, 2021).

Bacterial and fungal isolates identified in this study highlight the diversity of microbial contaminants present in the herbal medicines. *Escherichia coli*, a common fecal contaminant, was identified in the samples, indicating possible unsanitary production conditions (Abba *et al.* 2009; Nwankwo and Olime 2019).The presence of *Salmonella* in some samples, particularly **7 Keys to Power,** is a significant concern as it is associated with gastrointestinal illnesses. *Staphylococcus aureus*, another pathogen found in the herbal remedies, is known for its ability to produce toxins and cause food poisoning, especially if the product is not handled properly (Ahiabor*et al.,* 2024). *Aspergillus spp.* and *Mucor spp.*, the fungal isolates identified in the samples, are commonly found in decaying organic matter and can pose a risk to human health, particularly in immunocompromised individuals, as they can lead to respiratory infections or other health issues when inhaled (Morin-Sardin*et al*., 2017).

The microbial contamination levels in the herbal medicines tested suggest the need for improved hygiene practices during production, handling, and storage. The presence of *E. coli*, *Salmonella*, *Staphylococcus aureus*, and fungi like *Aspergillus spp.* and *Mucor spp.* raises significant health concerns. Consumers should be cautious when purchasing and using herbal remedies, particularly in environments with poor regulatory oversight. Further studies and stricter quality control measures are essential to ensure the safety and efficacy of herbal products in the market.

CONCLUSION

The study revealed varying levels of microbial contamination in the herbal medicines tested, highlighting significant public health concerns. **Goko Cleanser, Agnes Nwamma**, and **7 Keys to Power**exhibited bacterial and fungal contamination, with notable pathogens such as *Escherichia coli*, *Salmonella spp.*, and *Staphylococcus aureus* identified in some of the products. The levels of contamination ranged from low to moderate, suggesting potential risks if consumed, particularly for vulnerable individuals such as children and immunocompromised persons. The presence of fecal contaminants, as indicated by coliform counts, along with fungal contamination from species like *Aspergillus spp.* and *Mucor spp.*, further reinforces the importance of maintaining stringent hygiene standards during the production, handling, and storage of herbal medicines.

These findings emphasize the need for quality control measures to mitigate microbial contamination in herbal remedies and ensure that products reaching consumers are safe for use. The presence of pathogenic microorganisms, especially those associated with gastrointestinal diseases, underscores the importance of consumer awareness and regulatory oversight in the herbal medicine industry.

REFERENCES

Abba, D., Inabo, H. I., Yakubu, S. E., andOlonitola, O. S. (2020). Contamination of herbal medicinal products marketed in Kaduna Metropolis with selected pathogenic bacteria. *African Journal of Traditional, Complementary and Alternative Medicines, 6*(1), 70-77.

Ahiabor, W.K., Darkwah, S and Donkor, E.S (2024) Microbial Contamination of Herbal Medicines in Africa, 2000-2024: *A Systematic Review. Environ Health Insights.* 30;18:11786302241293345. doi: 10.1177/11786302241293345.

Akinmoladun, O. O., and Abiola, M. O. (2021). Microbial analysis of some

herbal medicines in Nigeria: A case study of traditional herbs. *African Journal of Microbiology Research*, 15(10), 389-396.

Ali, N., Hashim, N. H., Saad, B., Safan, K., Nakajima, M., & Yoshizawa, T. (2005). Evaluation of a method to determine the natural occurrence of aflatoxins in commercial traditional herbal medicines from Malaysia and Indonesia. *Food and Chemical Toxicology, 43*(12), 1763-1772.

Amaike, S., and Keller, N. P. (2021). Aspergillus flavus. *Annual Review of Phytopathology, 49*, 107-133.

Anie, O.C., Egbon, O.T., Enemchukwu, C.M and Adushoke, E.L, (2022) The Microbial Quality of Herbal Products, *Journal ofDrug Delivery and Therapeutics.* 12(5):64-69 DOI: http://dx.doi.org/10.22270/jddt.v12i5.5590.

Bugno, A., Almodovar, A. A. B., Pereira, T. C., Pinto, T. J. A., and Sabino, M. (2006). Occurrence of toxigenic fungi in herbal drugs. *Brazilian Journal of Microbiology, 37*(1), 47-51.

Eisenberg, D. M., Davis, R. B., Ettner, S. L., Appel, S., Wilkey, S., Van Rompay, M., and Kessler, R. C. (2021). Trends in alternative medicine use in the United States, 1990-1997: Results of a follow-up national survey. *Journal of the American Medical Association, 280*(18), 1569-1575.

Halt, M. (2021). Moulds and mycotoxins in herb tea and medicinal plants. *European Journal of Epidemiology, 14*(3), 269-274.

Itharat, A., Houghton, P. J., & Kessler, R. C. (2021). Trends in alternative medicine use in the United States, 1990-1997: Results of a follow-up national survey. *Journal of the American Medical Association, 280*(18), 1569-1575.

Morin-Sardin, Stéphanie., Patrice Nodet., Emmanuel Coton., Jean-Luc Jany., (2017) Mucor: A Janus-faced fungal genus with human health impact and industrial applications/*Fungal Biology Reviews.* (31)1:12-32,https://doi.org/10.1016/j.fbr.2016.11.002

Okunlola, A., Babatunde, A. A., & Oluwatoyin, A. O. (2021). Evaluation of Pharmaceuticals and Microbial Quality of some Herbal Medicinal Product in South Western Nigeria. *Tropical Journal of Pharmaceutical Research, 61*(1), 661-670.

Oluwatoyin, A. I., & Adebayo, L. (2022). Assessment of the microbial quality of some oral liquid herbal medicines marketed in Ile-Ife, South-Western Nigeria. *African Journal of Microbiology Research,* 10(38), 1618-1624.

Onyambu, M. O., Chepkwony, H. K., Thoithi, G. N., Ouya, G. O., andOsanjo, G. O. (2022). Microbial quality of unregulated herbal medicinal products in Kenya. *African Journal of Pharmacology and Therapeutics, 2*(2), 70-77.

Pallavi, K. (2022). Natural and Herbal Remedies for Cancer Treatment. *Inventi Impact: Planta Activa*, 140-147.

Roozbeh, J., Hashempur, M. H., & Heydari, M. (2022). Use of herbal remedies among patients undergoing hemodialysis. *Iranian Journal of Kidney Diseases, 7*(6), 492-495.

Shiaka, G.P.,Orji, I.V., Idris, A., Yakubu, B.M. (2019) Bacteriological Quality of Some Herbal Medicines Commonly Sold In Dutse Metropolis, Jigawa State.Dutse Journal of Pure and Applied Sciences (DUJOPAS) 4(1):394-403.

Sornka, D. L., Lawson, S., Wachukwu, C. K., & Abbey, S. D. (2022). Assessment of the Microbial Quality of Mekocin, Goko Cleanser and Omega Roots Commercially Sold as Liquid Herbs in Nigerian Markets. *International Journal of Pathogen Research*, *9*(2), 31–37. https://doi.org/10.9734/ijpr/2022/v9i230222

Temu-Justin, M., Lyamuya, E. F., &Makwaya, C. K. (2021). Source of microbial contamination of natural therapeutically used locally prepared herbal medicines sold on the open market in Dar es Salaam, Tanzania. *African Journal of Health Sciences, 18*(1-2), 1-7.

World Health Organization (WHO). (2021). *Quality control methods for medicinal plant materials*. World Health Organization. https://www.who.int

World Health Organization (WHO). (2021). WHO guidelines on good manufacturing practices (GMP) for herbal medicines. Geneva: World Health Organization.