



Research paper

Traditional medicinal plants used for treating emerging and re-emerging viral diseases in northern Nigeria



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ABSTRACT

Introduction: For decades, viral diseases have been treated using medicinal plants and herbal practices in the northern part of Nigeria. Though scarcely investigated, these medicinal plants could serve as potential sources for novel antiviral drugs against emerging and re-emerging viral diseases. Therefore, this study is aimed at investigating the medicinal practices and plants used to treat emerging and re-emerging viral diseases including hepatitis, poliomyelitis, monkeypox, smallpox, yellow fever, Lassa fever, meningitis, and COVID-19 in some northern states; Katsina, Kebbi, Kwara and Sokoto states.

Method: Administered questionnaires and oral interviews were used to collect information on medicinal plants, method of preparation of herbal formulations, diagnosis, and treatment of viral diseases. Medicinal plants were collected, botanically identified, and assigned voucher numbers. The plant names were verified using www.theplantlist.org, www.worldfloraonline.org and the international plant names index.

Result: A total of 280 participating herbal medicine practitioners (HMPs) mentioned 131 plants belonging to 65 families. Plant parts such as roots, bark, leaf, seed, and fruit were prepared as a decoction, concoction, infusion, or ointment for oral and topical treatment of viral diseases. *Moringa oleifera* (75.3%), *Elaeis guineensis* Jacq. (80%), and *Acacia nilotica* (70%) were the most frequently mentioned plants in Kebbi, Kwara and Sokoto states, respectively.

Conclusion: The study revealed scarcely investigated and uninvestigated medicinal plants used to treat hepatitis, poliomyelitis, monkeypox, smallpox, yellow fever, Lassa fever, meningitis, and COVID-19. Future studies should be conducted to determine the antiviral potency and isolate novel bioactive agents from these plants against viral diseases.

1. Introduction

Outbreaks of viral and infectious diseases have continuously affected the global population causing a high rate of morbidity and mortality. In some instances, the high rate of morbidity and mortality occurs in developing and underdeveloped countries. This can be attributed to a

lack of access to affordable healthcare, vaccination programs, and apathy towards vaccination. Indeed, emerging viral diseases such as COVID-19 pose serious health concerns to Nigeria and the global population. For instance, as of 27th June 2021, the Nigeria Center for Disease Control (NCDC) reported a total of 167, 467 COVID-19 cases and 2119 COVID-19 deaths in Nigeria [1]. Similarly, a total of 1031 Lassa

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fever cases with 214 deaths were recorded in 2020 [2]. Whereas, there were 65 deaths and 110 confirmed cases of meningitis [3].

For decades, medicinal plants and herbal practices have been used to treat infectious and other non-infectious diseases through the traditional practice of herbal medicine practitioners (HMPs) in Nigeria. In fact, several studies have reported the ethnomedicinal application of plants in treating diseases such as cancer, malaria, bacterial infections, etc. [4–7]. However, medicinal plants and practices used in treating viral diseases have been scarcely investigated especially in the northern part of Nigeria. Hence, an ethnopharmacological study could reveal uninvestigated plants from the northern part of Nigeria that could serve as sources of novel antiviral drugs. Besides, natural products and natural products mimic and constitute a lot of drugs used or being investigated in clinical trials [8].

Therefore, the present study was aimed at investigating and documenting the herbal practices and medicinal plants used for treating emerging and re-emerging viral diseases including hepatitis, poliomyelitis, monkeypox, smallpox, yellow fever, Lassa fever, meningitis, and COVID-19 in some northern Nigerian states; Katsina, Kebbi, Kwara and Sokoto. The selection of the three northwestern states of Kebbi, Katsina, and Sokoto was strategic considering the strong skepticism towards vaccination as evident during the polio vaccination and thus residents would seek alternative medicine that would include herbal medicine for treatment. Undoubtedly, the present study would be of interest to phytochemists, pharmacologists, and virologists and could contribute immensely towards the potential discovery of novel antiviral agents against viral diseases.

2. Methods

2.1. Ethnobotanical survey

A structured questionnaire along with an oral interview was administered to willing and consented traditional medicine practitioners to previously described protocols [9]. Ethical approval was granted by Kebbi State University of Science and Technology (KSUSTA/FLS/UREC/20–02) and thereafter, leading herbal practitioners in the study areas were contacted to provide links and contact of other known herbal practitioners. Oral consent was obtained from willing herbalists who provided information relating to traditional medicinal practices against viral diseases including hepatitis, smallpox, monkeypox, COVID-19, meningitis, yellow fever, and Lassa fever.

The study was conducted in the three northwestern states namely Katsina (12.3797° N, 7.6306° E), Kebbi (11.4942° N, 4.333° E), Sokoto (13.0533° N, 5.3223° E), and Kwara State located in the Northcentral part of Nigeria (8.9669° N, 4.3874° E). A total of 50 and 35 herbal practitioners were interviewed in the Sokoto metropolis in Sokoto state and the Ilorin metropolis of Kwara state, respectively. Similarly, 50 herbal practitioners were interviewed in the Katsina metropolis in Katsina State. Whereas, a total of 73 herbal practitioners were interviewed from the Yauri and Zuru emirates of Kebbi state. The survey was conducted from January to May 2021. Accordingly, the Nigerian center for disease control (NCDC), COVID-19 safety guidelines that included the use of face masks, hand sanitizers, and social distancing were strictly observed.

2.2. Plant collection and identification

All plants listed in the questionnaires were collected and botanically identified assigned voucher numbers and deposited at the herbarium of Umaru Musa Yaradua University Katsina and Kebbi State University of Science and Technology, Aliero, Nigeria. Furthermore, the plant names were authenticated using www.theplantlist.org, www.worldfloraonline.com, and international plant names index.

2.3. Frequency of citation

The frequency of citation (FC) for each plant was determined according to the previously described protocol [9]. $FC = NC/TI \times 100$. Where NC is the total number of citations for each plant and TI is the total number of informants.

2.4. Informant consensus factor

The informant consensus factor (ICF) was determined according to the previously described protocol [10]. $ICF = Nur-Nt/Nur-1$. Where Nur is the reported number of taxa usage for a disease category whereas, Nt is the total number of taxa used for the disease category. This determines the similarity in terms of medicinal plants used to treat any disease category by the herbal practitioners. An ICF value close to 1 or 0 is indicative of the agreement or random choice of medicinal plants used to treat a disease category by traditional medicine practitioners, respectively.

3. Results

3.1. Demographic profile and citation frequency of plants

A total of 208 herbal medicine practitioners across Katsina (50), Kebbi (73), Kwara (35), and Sokoto (50) states responded to the questionnaires and oral interviews. Demographic data showed that 50% of HMPs were women in Kwara state in contrast to 12%, 22%, and 12.4% in Sokoto, Katsina, and Kebbi State, respectively (Table 1). An analysis of the age distribution showed that 60%, 70%, 57.6%, and 20.4% of HMPs in Sokoto, Katsina, Kebbi, and Kwara States, respectively were within the age range of 41 years and above. Medicinal plants used for treating various viral diseases are listed in Tables 2, 3, 4, and 5 for Katsina, Kebbi, Kwara, and Sokoto states, respectively. The HMPs across all the states learned their trade mainly through inheritance or apprenticeship. A total of 131 medicinal plants belonging to 65 families were identified across these states that are used for treating hepatitis, meningitis, yellow fever, Lassa fever, COVID-19, smallpox, and monkeypox. A total of 10, 29, 44, and 18 plants were exclusively identified in Katsina (Table 2), Kebbi (Table 3), Kwara (Table 4), and Sokoto (Table 5) states. Whereas, a total of 41 medicinal plants were identified in two or more states. The plants *Azadirachta indica* A.Juss, *Eucalyptus globulus* Labill, and *Syzygium aromaticum* (L.) Merr. & L.M.Perry were the most frequently mentioned plants in Katsina state, each with a citation frequency of 30% (Table 2). In Kebbi state, *Moringa oleifera* Lam. (75.3%) *Mangifera indica* (71.2%), and *A. indica* (68.5%) were the most frequently cited medicinal plants (Table 3). Whereas, *Elaeis guineensis* Jacq. (80%), *Nymphaea lotus* L. (57.1%), *Piper guineense* Schumach. & Thonn. (57.1%) and *Euphorbia hirta* (51.4%) were the most frequently mentioned plants in Kwara state (Table 4). Similarly, *Acacia nilotica* (L.) Delile (70%), *Combretum micranthum* G. Don. (60%) and *Piliostigma reticulatum* (DC.) Hochst. (58%) were the frequently mentioned plants in

Table 1
Demographic profile of respondents.

s/no	Data	Sokoto	Katsina	Kebbi	Kwara
1	Age (years%)				
	18–30		10	12.4	55.8
	31–40	40	20	30.0	23.5
	41 and above	60	70	57.6	20.4
2	Educational status (%)				
	No formal education	24	84	68.5	17.6
	Formal education	76	16	31.5	82.4
3	Gender distribution (%)				
	Male	88	78	87.6	50
	Female	12	22	12.4	50

Table 2
Medicinal plants used for treating viral diseases in Katsina state.

	Scientific name	Family name	Local name	Common name	Voucher number	CF (%)	Diseases treated	Part used	Mode of Preparation	Route
1	<i>Acacia Senegal</i> (L.) Wild	Fabaceae	Dakwara	Gum Arabic tree	UMYUH 988	12	Smallpox	Leaves	Decoction	Oral
2	<i>Azadirachta indica</i> A.Juss.	Meliaceae	Darbejiya	Neem	UMYUH 712	30	COVID-19	Leaves	Concoction	Steaming
3	<i>Boscia salicifolia</i> Oliv.	Capparaceae	Zure	Willow leaved shepherd tree	UMYUH 707	16	COVID-19	Leaves	Decoction	Oral
4	<i>Carica papaya</i> L.	Caricaceae	Gwanda	Pawpaw	UMYUH 2263	16	Hepatitis	Leaves	Decoction	Oral
5	<i>Cassia occidentalis</i> L.	Fabaceae	Tafasar masar	Coffee senna	UMYUH 2242	16	Yellow fever	Whole plant	Decoction	Oral
6	<i>Cassia tora</i> L.	Fabaceae	Tafasa	Sickle senna	UMYUH 763	14	Yellow fever	Whole plant	Decoction	Oral
7	<i>Centaurea praecox</i> Oliv. & Hiern	Compositae	Dayi	Thistle	UMYUH 645	16	COVID-19	Whole plant	Maceration	Oral
8	<i>Combretum micranthum</i> G. Don	Combretaceae	Geza		UMYUH 2217	16	Yellow fever	Leaves	Decoction	Oral
9	<i>Diospyros mespiliformis</i> Hochst. ex A.DC.	Ebenaceae	Kanya	Jackalberry	UMYUH 124	14	Yellow fever	Leaves	Decoction	Oral
10	<i>Eucalyptus globulus</i> Labill	Myrtaceae	Turare	Blue gum	UMYUH 666	30	Yellow fever	Leaves	Concoction	Steaming
11	<i>Ficus polita</i> Vahl	Moraceae	Durumi	Heart leaved fig	UMYUH 1890	8	COVID-19	Leaves	Decoction	Steaming
12	<i>Ficus sycomorus</i> L.	Moraceae	Baure	Fig mullberry	UMYUH 1830	8	Yellow fever	Leaves/bark	Decoction	Oral
13	<i>Guiera senegalensis</i> J.F. Gmel	Combretaceae	Sabara		UMYUH 49	18	Yellow fever	Leaves	Decoction	Oral
14	<i>Lepidium sativum</i> L.	Brassicaceae	Zamantarore	Garden cress	UMYUH 2075	8	Meningitis	Leaves	Decoction	Oral
15	<i>Ludwigia octovalvis</i> (Jacq.) P.H. Raven	Onagraceae	Shashatau	Mexican primrose willow	UMYUH 2536	8	Meningitis	Leaves	Decoction	Topical
16	<i>Mangifera indica</i> L.	Anacardiaceae	Mangwaro	Mango	UMYUH 1921	14	Yellow fever	Leaves	Decoction	Oral
17	<i>Moringa oleifera</i> Lam.	Moringaceae	Zogale	Drumstick tree	UMYUH 1858	12	Yellow fever	Leaves	Decoction	Oral
18	<i>Musa sapientum</i> L.	Musaceae	Ayaba	Banana	UMYUH 2293	10	Hepatitis	Leaves	Decoction	Oral
19	<i>Parkia biglobosa</i> (Jacq.) G. Don	Fabaceae	Dorawa	African locus bean	UMYUH 1274	10	Yellow fever	Leaves	Decoction	Oral
20	<i>Phyllanthus amarus</i> Schumach. & Thonn.	Phyllanthaceae	Geron tsuntsaye	Stone breaker	UMYUH 2524	8	Hepatitis	Leaves	Decoction	Oral
21	<i>Piliostigma thonningii</i> (Schum.) Milne-Redh.	Fabaceae	Kalgo	Wild bauhinia	UMYUH 27	12	Hepatitis	Leaves	Decoction	Oral
22	<i>Piper guineense</i> Schumach. & Thonn.	Piperaceae	Masoro	Black pepper	UMYUH 2507	10	COVID-19	Seed	Concoction	Oral
23	<i>Prosopis africana</i> (Guill. & Perr.) Taub.	Fabaceae	Kirya	Iron tree	UMYUH 63	18	Yellow fever	Leaves	Decoction	Oral
24	<i>Sapium grahamii</i> (Stapf) Prain	Euphorbiaceae	Yazawa		UMYUH	12	Yellow fever	Bark	Decoction	Oral
25	<i>Sclerocarya birrea</i> (A. Rich.) Hochst.	Anacardiaceae	Danya	Marula	UMYUH 2256	10	Yellow fever	Leaves	Decoction	Oral
26	<i>Stereospermum kunthianum</i> Cham.	Bignoniaceae	Sansami	Tulip tree	UMYUH 675	8	Yellow fever	Leaves	Decoction	Oral
27	<i>Syzygium aromaticum</i> (L.) Merr. & L.M.Perry	Myrtaceae	Kananfari	Clove	UMYUH 681	30	COVID-19	Seeds	Decoction	Oral
28	<i>Tephrosia linearis</i>	Fabaceae	Tsintsiyar mahalba		UMYUH 1880	10	Smallpox	Leaves	Maceration	Topical
29	<i>Terminalia avicennioides</i> Guill. & Perr	Combretaceae	Baushe		UMYUH 669	16	Yellow fever	Bark	Decoction	Oral
30	<i>Trianthema pentandra</i> L.	Aizoaceae	Gadon Maciji		UMYUH 1916	10	Yellow fever	Leaves	Maceration	Oral

Sokoto state (Table 5).

3.2. Diagnosis of viral diseases by HMPs

The diagnosis of the viral diseases is similar for the northwestern states of Sokoto, Kebbi, and Katsina. Hepatitis is referred to as 'ciwon anta' and the majority of patients know through voluntary screening for blood donations before approaching HMPs for treatment or through observation of yellowish eyes. Yellow fever is referred to as 'shawara' and is often diagnosed by the yellowish coloration of the eye, palms, and swelling of the stomach. Meningitis is referred to as 'sankarau' and is

diagnosed by HMPs through detection of high body fever, persistent headache, and stiffness of muscles. Poliomyelitis referred to as 'ciwon shaninna' is diagnosed by HMPs through high body fever, persistent headache and stiffness of muscles. Other infectious diseases such as monkeypox 'kazuwa' and smallpox 'karin bau' are diagnosed using the same method by HMPs which include detection of high body fever, skin rashes, and general body itches. COVID-19 is referred to as 'Korona' and is diagnosed by HMPs through observation of high body fever, persistent cough, and running nose. However, it is important to note that there may be an incidence of misdiagnosis considering that COVID-19 infection is better confirmed through laboratory tests than simply relying on

Table 3
Medicinal plants used for treating viral diseases in Kebbi state.

s/no	Plant name	Family	Local name	Common Name	Voucher no	CF (%)	Disease treated	Parts used	Mode of preparation	Route
1.	<i>Acacia nilotica</i> (L.) Delile	Mimosaceae	Bagaruwa	Scented thorn	Ksusta/psb/h/voucher no:284	15.1	Hepatitis, monkey pox, meningitis, smallpox, poliomyelitis, COVID-19	Leaf/stem	Decoction/ prepared with pap	Orally
2.	<i>Adansonia digitata</i> L.	Bombacaceae	Kuka	Baobab	Ksusta/psb/h/voucher no: 266	38.4	Poliomyelitis, smallpox, yellow fever, meningitis, monkey pox, hepatitis	Stem bark	Decoction	Orally
3.	<i>Aframomum melegueta</i> K. Schum.	Zingiberaceae	Citta	Alligator pepper/ grains of paradise	Ksusta/psb/h/voucher no: s.n	38.4	Hepatitis, monkey pox, COVID-19, poliomyelitis, yellow fever	Whole plant	Decoction	Orally
4.	<i>Allium cepa</i>	Liliaceae	Albasa	Onion	Ksusta/psb/h/voucher no: s.n	12.3	Poliomyelitis meningitis, COVID-19	Bulb	Poultice/ the bulb is cut into pieces and added to a burning charcoal	Inhalation
5.	<i>Allium sativum</i> L.	Amaryllidaceae	Tafarnuwa	garlic	Ksusta/psb/h/voucher no: s.n	36.9	Poliomyelitis, COVID-19, monkey pox, meningitis, hepatitis	Whole plant	Concoction/ crushed and mixed with masoro the powder a half spoon of the powder is added in raw milk and	Orally before breakfast
6.	<i>Aloe vera</i> (L.) Burm.f.	Liliaceae	Aloe vera	Aloe vera	Ksusta/psb/h/voucher no: 356	1.36	Meningitis	Whole plant	Decoction	Orally
7.	<i>Ananas comosus</i> (L.) Merr.	Bromeliaceae	Abarba	Pineapple	Ksusta/psb/h/voucher no: s.n	1.4	Meningitis	Bark peel	Concoction/ boiled with banana	Oral
8.	<i>Annona senegalensis</i> Pers.	Annonaceae	Gwanda daji	Wild custard apple	Ksusta/psb/h/voucher no: 504	1.4	Poliomyelitis	Leaf and stem	Concoction	Orally
9.	<i>Anogeissus leiocarpus</i> (DC.) Guill. & Perr.	Combretaceae	Marke	African Birch	Ksusta/psb/h/voucher no: s.n	2.7	Monkey pox, poliomyelitis	Stem bark	Concoction/ boil with red potash and the	Orally
10.	<i>Azadirachta indica</i> A. Juss.	Meliaceae	Dogonyaro	Neem	Ksusta/psb/h/voucher no: 61	68.5	Smallpox, monkey pox, COVID-19, poliomyelitis, yellow fever, meningitis	Leaf	Decoction	Orally
11.	<i>Balanites aegyptiaca</i> (L.) Delile	Balanitaceae	Aduwa	Desert date	Ksusta/psb/h/voucher no: 291	41.1	Hepatitis, monkey pox, meningitis, smallpox, poliomyelitis	Stem bark	Decoction	Orally
12.	<i>Boscia senegalensis</i> (Pers.) Lam. ex Pior.	Capparaceae	Anza	Aizen	Ksusta/psb/h/voucher no: s.n	1.4	Monkey pox	Root	Ointment/ root powder is mixed with salt and petroleum jelly (vasline)	Topically
13.	<i>Boswellia dalzielii</i> Hutch.	Burseraceae	Hanno	Frankincense tree	Ksusta/psb/h/voucher no: s.n		Poliomyelitis, smallpox	Stem bark	Decoction	Orally
14.	<i>Bridelia ferruginea</i> Benth	Phyllanthaceae	Kizni		Ksusta/psb/h/voucher no: s.n	1.4	Poliomyelitis	Leaf	Decoction	Orally
15.	<i>Calotropis procera</i> (Aiton) Dryand	Apocynaceae	Tunfafiya	Sodom apple	Ksusta/psb/h/voucher no: s.n	17.8	Smallpox, COVID-19, monkey pox	leaf	Concoction/ also mixed with powdered stem bark of hanno	Orally for one week and a portion of it is used in bathing.
16.	<i>Carica papaya</i> L.	Caricaceae	Gwanda	Pawpaw	Ksusta/psb/h/voucher no: s.n	49.3	Hepatitis, meningitis, COVID-19, poliomyelitis, smallpox, yellow fever, monkey pox	Leaf	Concoction/ the leaf is mixed lemon leaves, small portion of red potash and boil, concocted	Orally twice daily for ten days.
17.	<i>Cassia occidentalis</i> L.	Fabaceae	Sanga sanga	Coffee senna	Ksusta/psb/h/voucher no: s.n	41.1	Hepatitis, meningitis, COVID-19, yellow fever, poliomyelitis	Decoction		Orally
18.	<i>Cassia singueana</i> Delile	Fabaceae	Runhu	Sticky pod	Ksusta/psb/h/voucher no: s.n	1.4	Monkey pox	Leaf	Decoction	Orally

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Table 3 (continued)

19.	<i>Cassia tora</i> L	Fabaceae	Tafasa	Sickle senna	Ksusta/psb/ h/voucher no: s.n	4.1	Hepatitis, meningitis	Leaf	Decoction	Orally
20.	<i>Cissus populnea</i> Guill. & Perr.	Vitaceae	Loda		Ksusta/psb/ h/voucher no: 307	8.2	Poliomyelitis, meningitis, monkey pox	Stem bark	Decoction	Orally
21.	<i>Citrus aurantifolia</i> (Christm.) Swingle	Rutaceae	Lemun tsami	Lemon	Ksusta/psb/ h/voucher no: 285	1.4	Yellow fever, poliomyelitis	Leaf	Decoction	Orally
22.	<i>Citrullus lanatus</i> (Thunb.) Matsum. & Nakai	Cucurbitaceae	Kankana	Water melon	Ksusta/psb/ h/voucher no: 285 a	20.5	Hepatitis, monkey pox, COVID-19, yellow fever, smallpox, poliomyelitis	Seed	Decoction	Orally
23.	<i>Citrus sinensis</i>	Rutaceae	Lemun zaki	Orange	Ksusta/psb/ h/voucher no: 284	32.9	Hepatitis, COVID-19, yellow fever, poliomyelitis	leaves	Decoction	Orally
24.	<i>Combretum glutinosum</i> Perr.	Combretaceae	Tarauniya		Ksusta/psb/ h/voucher no: s.n	1.4	Meningitis	Stem bark	Decoction	Orally
25.	<i>Combretum nigricans</i> Lepr. Ex Guill. & Perr.	Combretaceae	Tsiriri		Ksusta/psb/ h/voucher no: s.n	1.4	Hepatitis	root	Powder	Orally
26.	<i>Cucurbita maxima</i> Duchesne	Cucurbitaceae	Kabewa	pumpkin	Ksusta/psb/ h/voucher no: s.n	19.2	Monkey pox, smallpox	Leaf and seed	Decoction	Orally
27.	<i>Detarium senegalense</i> J. F. Gmel.	Fabaceae	Taura	Tallow tree	Ksusta/psb/ h/voucher no: s.n	10.9	Smallpox, yellow fever, COVID-19, meningitis	Stem bark	Decoction	Orally
28.	<i>Diospyros mespiliformis</i> Hochst. ex A.DC.	Ebenaceae	Kanya	Jackalberry	Ksusta/psb/ h/voucher no: 182	46.6	Hepatitis, monkey pox, meningitis, COVID-19, yellow fever, smallpox, poliomyelitis	Stem bark	Concoction or powdered stem bark is mixed with powder of tamarind and <i>Adansonia digitata</i> and shea butter to make as ointment	Orally or ointment is applied topically
29.	<i>Evolvulus alsinoides</i> Linn.	Convolvulaceae	Kahilikita	Dwarf morning-glory	Ksusta/psb/ h/voucher no: 523	2.7	Poliomyelitis	Leaf	Decoction	Orally
30.	<i>Ficus platyphylla</i> Delile	Moraceae	Gamji	Broad leaf Fig	Ksusta/psb/ h/voucher no: s.n	20.5	Poliomyelitis, smallpox, yellow fever, meningitis, monkey pox	Stem bark powder	Decoction/ powder can also be mixed with tamarida indica and ficus thoningi leaf and used as poultice.	Orally and or bathing
31.	<i>Ficus polita</i> Vahl	Moraceae	Durumi	Heart leaved fig	Ksusta/psb/ h/voucher no: s.n	13.7	Poliomyelitis, smallpox, yellow fever, meningitis, monkey pox	Leaf	Decoction	Orally
32.	<i>Ficus sycomorus</i>	Moraceae	Baure	Fig mullberry	Ksusta/psb/ h/voucher no: s.n	8.2	Poliomyelitis, meningitis	Leaf and stem bark	Decoction	Orally
33.	<i>Ficus thonningii</i> Blume	Moraceae	Chediya	Common wild fig	Ksusta/psb/ h/voucher no: s.n	2.7	Meningitis, smallpox	Leaf/stem bark	Decoction	Orally
34.	<i>Gardenia erubescens</i> Stapf. & Hutch	Rubiaceae	Gaude		Ksusta/psb/ h/voucher no: s.n	2.7	Poliomyelitis	Leaf and stem	Decoction	Orally
35.	<i>Guiera senegalensis</i> J.F. Gmel.	Combretaceae	Sabara	Moshi medicine	Ksusta/psb/ h/voucher no: s.n	42.5	Poliomyelitis, yellow fever, smallpox, COVID-19, meningitis, hepatitis, monkey pox	Leaf	Decoction/ prepared with pap	Orally
36.	<i>Lannea microcarpa</i> Engl. & K. Krause	Anacardiaceae	Faru	African grape	Ksusta/psb/ h/voucher no: s.n	15.1	COVID-19	Stem bark	Decoction	Orally for four days.

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Table 3 (continued)

37.	<i>Lawsonia inermis</i> L.	Lythraceae	Lalle	Henna	Ksusta/psb/ h/voucher no: 41	34.2	Monkey pox, meningitis, COVID-19, yellow fever,	Leaf	Decoction	Orally
38.	<i>Leptadenia hastate</i> Vatke	Apocynaceae	Yadiya		Ksusta/psb/ h/voucher no: s.n	12.3	Hepatitis, COVID-19, yellow fever, smallpox,	leaves	Decoction	Orally
39.	<i>Mangifera indica</i> L.	Anacardiaceae	Mangwaro	Mango	Ksusta/psb/ h/voucher no: 63	71.2	Hepatitis, monkey pox, meningitis, COVID-19, yellow fever, poliomyelitis, smallpox	Leaf	Decoction	Orally
40.	<i>Maytenus senegalensis</i> (Lam.) Exell	Celastraceae	Namijin tsada	Spike thorn	Ksusta/psb/ h/voucher no: s.n	1.4	Monkey pox	Stem bark	Ointment/ powder is mixed with shea butter	Topically
41.	<i>Momordica charantia</i> L.	Cucurbitaceae	Garahuni	Balsam pear	Ksusta/psb/ h/voucher no: s.n	34.2	Poliomyelitis, smallpox, yellow fever, meningitis, monkey pox, COVID-19, hepatitis	Leaf	Concoction/ the powder is boiled with tea	Orally
42.	<i>Moringa oleifera</i> Lam.	Moringaceae	Zogala	Moringa	Ksusta/psb/ h/voucher no: s.n	75.3	Hepatitis, meningitis, smallpox, monkey pox, COVID-19, yellow fever, poliomyelitis	Root	Concoction/ mixed with tafasa and boiled with red potash	Orally
43.	<i>Musa sapientum</i> L.	Musaceae	Ayaba	Banana	Ksusta/psb/ h/voucher no: s.n	31.5	Poliomyelitis, yellow fever, hepatitis	Leaf	Can be boiled with pineapple bark peel	Orally
44.	<i>Nicotiana tabacum</i> L.	Euphorbiaceae	Tinya		Ksusta/psb/ h/voucher no: s.n	1.4	Meningitis	Leaf	Decoction	Orally
45.	<i>Nigella sativa</i> L.	Ranunculaceae	Habbatu sauda	Black cumin	Ksusta/psb/ h/voucher no: s.n	6.8	Monkey pox, smallpox, COVID-19	Leaf/seed	Decoction/ used to prepare pap	Orally
46.	<i>Olea europea</i> L.	Oleaceae	Zaitun	Olive	Ksusta/psb/ h/voucher no: s.n	20.5	Smallpox, yellow fever, COVID-19, monkey pox	Leaves/ stem	Decoction/ prepared with pap	Orally
47.	<i>Parkia biglobosa</i> (Jacq.) G.Don	Mimosaceae	Dorawa	African locust	Ksusta/psb/ h/voucher no: 281	20.5	Poliomyelitis, smallpox, yellow fever, meningitis	Stem bark	Powder and used to prepare Pap	Orally (twice daily)
48.	<i>Parinari macrophylla</i> Sabine	Chrysobalanaceae	Gawasa		Ksusta/psb/ h/voucher no: 230 a	5.5	Poliomyelitis, monkey pox	Leaf	Decoction	Orally
49.	<i>Piliostigma thonningii</i> (Schum.) Milne-Redh.	Fabaceae	Kalgo	Wild baubinia	Ksusta/psb/ h/voucher no: 109	19.2	Poliomyelitis, smallpox, meningitis	Leaf and stem	Decoction	Orally
50.	<i>Piper guineense</i> Schumach. & Thonn.	Piperaceae	Masoro	Ashanti pepper	Ksusta/psb/ h/voucher no: s.n	20.5	Poliomyelitis, yellow fever, COVID-19, monkey pox, hepatitis	Seed	Powder/ can be mixed with milk and garlic	Orally
51.	<i>Prosopis Africana</i> (Guill. & Perr.) Taub.	Fabaceae	Kirya	Iron tree	Ksusta/psb/ h/voucher no: s.n	5.5	Hepatitis, meningitis, poliomyelitis	Leaf	Decoction	Orally
52.	<i>Psidium guajava</i> L.	Myrtaceae	Gwaiiba	Guava	Ksusta/psb/ h/voucher no: 67	53.4	Hepatitis, meningitis, COVID- 19, poliomyelitis, smallpox, yellow fever	Leaf	Decoction	Orally
53.	<i>Securidaca longipedunculata</i> Fresen	Polygalaceae	Uwa magunguna	Violet tree	Ksusta/psb/ h/voucher no: s.n	1.4	Meningitis	Stem bark	Concoction/ mixed with ginger, lemon and honey	Orally
54.	<i>Sterculia setigera</i> Delile	Malvaceae	Kukkuki	Karaya gum tree	Ksusta/psb/ h/voucher no: s.n	1.4	Monkey pox	Stem bark	Powder	Orally twice daily for one week

(continued on next page)

Table 3 (continued)

55.	<i>Syzygium aromaticum</i> (L.) Merr. & L.M. Perry	Myrtaceae	Kanumfari	Clove	Ksusta/psb/ h/voucher no: s.n	10.9	Hepatitis, COVID-19, yellow fever,	Seed	Decoction prepared with pap	Orally
56.	<i>Tamarindus indica</i>	Solanaceae	Tobacco	Tobacco	Ksusta/psb/ h/voucher no: s.n	12.3	Poliomyelitis, smallpox, yellow fever, meningitis	leaves	Decoction	Orally
57.	<i>Terminalia avicenioides</i> Guill. & Perr.	Combretaceae	Baushe		Ksusta/psb/ h/voucher no: s.n	23.3	Poliomyelitis, meningitis, monkey pox	Stem bark	Decoction	Orally
58.	<i>Vernonia amygdalina</i> Del.	Compositae	Shuwaka	Bitterleaf	315 b Ksusta/psb/ h/voucher no: s.n	16.4	Yellow fever, smallpox, COVID-19, meningitis, monkey pox	Leaf	Decoction	Orally
59.	<i>Vitellaria paradoxa</i> C.F. Gaertn	Sapotaceae	Kade	Shea	Ksusta/psb/ h/voucher no: s.n	27.4	Poliomyelitis, yellow fever, COVID-19, meningitis, monkey pox, hepatitis	Stem bark	Decoction	Orally for three days.
60.	<i>Vitex doniana</i> Sweet	Verbenaceae	Dunya	Black plum	320 Ksusta/psb/ h/voucher no: s.n	21.9	Monkey pox, COVID-19, smallpox, poliomyelitis	Leaf	Decoction	Orally
61.	<i>Ziziphium mauritiana</i> Lam.	Rhamnaceae	Magarya	Jujube	307 Ksusta/psb/ h/voucher no: s.n	34.2	Hepatitis, monkey pox, meningitis, COVID-19, yellow fever, poliomyelitis	Leaf	Decoction	Orally

symptoms.

On the other hand, in Kwara state, hepatitis is known as 'Arun Jedojedo or Aisan Jedojedo' and is diagnosed by HMPs through observation of the yellowish nature of the eye which is mostly confirmed through laboratory tests. Similar yellowish eye, physical appearance, and laboratory tests are used for the diagnosis of yellow fever known as 'Iba pupa or Iba ponju'. The symptoms for monkeypox known as 'Pox Obo' and smallpox known as 'Sopona or Shapona or Igbona' are the same which include the physical appearance of rashes/blisters all over the body, high temperature, headache, and laboratory tests. Poliomyelitis is known as 'Arun Aromolapa romolese' is diagnosed via paralysis of one side of the body mostly starting with the left leg and arm and hospital diagnosis. Whereas, COVID-19 'Kofid 19' and Lassa fever 'Iba Orèrè' are diagnosed by HMPs in Kwara state via hospital diagnosis.

3.3. Informant consensus factor

The informant consensus factor was determined for each disease in each of the states studied as shown in Table 6. The ICF value for the diseases ranged from 0.86 - 0.91, 0.66 - 0.78, 0.22 - 0.71 and 0.79 - 0.89 for Katsina, Kebbi, Kwara, and Sokoto States, respectively. Whereas, there were no ICF values for poliomyelitis, monkey pox, and Lassa fever in Katsina state and Lassa fever in Kebbi state as no response was recorded on potential medicinal plants used to treat these diseases.

4. Discussion

Medicinal plants serve as a huge reservoir for potential novel bioactive agents against viral diseases and non-viral diseases. Therefore, the ethnomedicinal study provides an opportunity to reveal new and uninvestigated medicinal plants and herbal formulations as potential sources for antiviral agents against old and emerging viral diseases. Located in the northwestern part of Nigeria, the residents of Katsina, Kebbi, and Sokoto states are predominantly Hausa and Fulani although, there are other smaller tribes such as Dakarkari and Kambarawa amongst others and different dialects [11]. In contrast, Kwara state is located in the North-central part of Nigeria with Yoruba as the predominant tribe [9]. Evidently, the present study revealed plants that were common in all the states although in some instances these plants were used to treat different diseases with different modes of preparation. This could be attributed to the slight cultural differences among the northwestern states as well as the different geographical, climatic, and cultural differences with the north-central Kwara state. Interestingly, the informant Consensus factor for northwestern states indicated the HMPs agreed on the medicinal plants used to treat various categories of viral diseases studies in contrast to ICF values for Kwara state that suggested HMPs didn't fully agree or the choice of medicinal plants for certain diseases such as COVID-19, smallpox, and monkeypox were random. Nonetheless, the study revealed plants that could be used to combat these viral diseases affect the populace with fatal consequences.

The hepatitis B and C virus frequently cause inflammation of the liver which can result in liver cirrhosis and cancer. Besides vaccination, Nigerians in rural areas have for decades used herbal plants to treat hepatitis and other liver-related diseases. Herein, *Carica papaya*, *Psidium guajava*, *M. indica*, and *Ficus glumosa* were the more frequently mentioned plants used for treating hepatitis in Katsina, Kebbi, Kwara, and Sokoto states, respectively. Similarly, *C. papaya*, *Guiera senegalensis*, *M. indica*, *Musa sapientum*, *P. guineense* were reported by at least two or all of the states as plants used for treating hepatitis. Medicinal plants cited for treatment of hepatitis in the present study including *Phyllanthus amarus* *Senna occidentalis* and *Garcinia kola* have also been reportedly used to treat hepatitis and liver diseases in the southern part of Nigeria [12–14]. Likewise, *Acacia nilotica* *Guiera senegalensis* and *Leptadenia hastata* among others cited herein for treatment of hepatitis are also used to treat the same viral disease in Burkina Faso (Table 7) with pharmacological study validating the anti-hepatitis C activity of *A. nilotica* [15].

Table 4
Medicinal plants used for treating viral diseases in Kwara state.

s/no	Plant name	Family	Local name	Common Name	Voucher no	CF (%)	Disease treated	Parts used	Mode of preparation	Route
1.	<i>Aframomum melegueta</i> K. Schum	Zingiberaceae	Ewe atare	alligator pepper	Ksusta/psb/h/voucher no: sn	11.4	Monkey pox, smallpox	Leaves	Soaking in cold water	Topically, water extract is used to wash the affected body part. Two spoon daily
2.	<i>Ageratum conyzoides</i> (L.) L.	Compositae	Imi-esu	billygoat weed,	Ksusta/psb/h/voucher no: sn	14.3	Hepatitis, lassa fever, poliomyelitis	Stem bark	Powder	
3.	<i>Alafia barteri</i> Oliv.	Apocynaceae	Agbari-etu		Ksusta/psb/h/voucher no: sn	8.6	Meningitis, lassa fever	Leaf	Decoction	Orally
4.	<i>Aloe vera</i> (L.) Burm.f.	Xanthorrhoeaceae	Ewe erin	Aloe vera	Ksusta/psb/h/voucher no: 356	8.6	Meningitis, Lassa fever	Leaf	Concoction. Powder is mixed with shea butter and used ointment	Topical
5.	<i>Aloe barteri</i> (Baker)	Xanthorrhoeaceae	Eti irin		Ksusta/psb/h/voucher no: sn	14.3	Yellow fever, lassa fever	Leaf	Powdered leaf is mixed with little quantity of shear butter	Orally
6.	<i>Alstonia boonei</i> De Wild	Apocynaceae	Ahun	Stool wood	Ksusta/psb/h/voucher no: sn	37.1	Lassa fever, Yellow fever, monkey pox, smallpox	Stem bark	Concoction	Orally
7.	<i>Anacardium occidentale</i> L	Anacardiaceae	ewe kasu	Cashew	Ksusta/psb/h/voucher no: 63	17.1	Lassa fever, yellow fever	Leaf	Decoction	Orally
8.	<i>Ananas comosus</i> (L.) Merr.	Bromeliaceae	Ope oyinbo	Pineapple	Ksusta/psb/h/voucher no: sn	28.6	Lassa fever, yellow fever, COVID-19	Bark peel	Decoction	Orally
9.	<i>Anogeissus leiocarpus</i> (DC.) Guill. & Perr	Combretaceae	Ayin		Ksusta/psb/h/voucher no: sn	11.4	COVID-19	Roots	Decoction	Orally
10.	<i>Aristolochia ringens</i>	Aristolochiaceae	Akogun	Dutchman's pipe	Ksusta/psb/h/voucher no: 61	5.7	Yellow fever, lassa fever	Leaves	Decoction	Orally
11.	<i>Azadirachta indica</i> A. Juss.	Meliaceae	Ewe dogayaro	Neem tree	Ksusta/psb/h/voucher no: sn	5.7	Lassa fever, COVID-19	Leaf	Concoction with guava leaf	Orally
12.	<i>Bidens pilosa</i> L	Compositae	Abeere	Black Jack seed	Ksusta/psb/h/voucher no: sn	2.9	COVID-19	Seed	Decoction	Orally
13.	<i>Bridelia exaltata</i> F. Muell.	Phyllanthaceae	Ira	Scrub ironbark, brush ironbark	Ksusta/psb/h/voucher no: sn	8.6	Lassa fever	Stem bark	Decoction	Orally
14.	<i>Byrsocarpus coccineus</i> Schumach & Thonn.	Connaraceae	Amuje wewe	Huntsman's pepper	Ksusta/psb/h/voucher no: sn	34.3	Hepatitis, meningitis, lassa fever, yellow fever, smallpox, poliomyelitis	Leaves	Decoction	Orally
15.	<i>Calotropis procera</i> (Aiton) Dryand	Apocynaceae	Bomubomu	Sodom apple, rubber bush	Ksusta/psb/h/voucher no: 03	8.6	Poliomyelitis	Leaf	Decoction	Orally
16.	<i>Carica papaya</i> L	Caricaceae	Ewe ibepe	Pawpaw	Ksusta/psb/h/voucher no: sn	5.7	Hepatitis	Leaf	Decoction	Orally
17.	<i>Celastrus indica</i>	Celastraceae	Ponju-owiwi	Bittersweet	Ksusta/psb/h/voucher no: sn	17.1	Hepatitis, meningitis, yellow fever	Root	Decoction	Orally twice daily.
18.	<i>Chasmanthera dependens</i> Hochst.	Menispermaceae	Atoo		Ksusta/psb/h/voucher no: sn	14.3	Poliomyelitis, meningitis	Leaves	Decoction	Orally

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Table 4 (continued)

19.	<i>Chenopodium ambrosioides</i> L.	Amaranthaceae	Arunpale/ meturusi/ fininganmu Ewe gbegi	Mexican tea	Ksusta/psb/ h/voucher no: sn	17.1	Poliomyelitis, Meningitis	Root	Decoction	Orally
20.	<i>Chloris pilosa</i> Schumach. &Thonn.	Poaceae		Goose grass	Ksusta/psb/ h/voucher no: sn	20	Poliomyelitis, lassa fever	Roots	To be soaked in water for 24 h	Orally for three (3) days
21.	<i>Citrus aurantifolia</i> (Christm.) Swingle	Rutaceae	Osan weve	Citrus lemon	Ksusta/psb/ h/voucher no: 285	5.7	Yellow Fever	Leaf	Decoction	Orally
22.	<i>Cymbopogon citratus</i> (DC.) Stapf	Poaceae	Ewe tea	Lemon grass	Ksusta/psb/ h/voucher no: sn	17.1	Lassa fever, Yellow fever	Leaves	Concoction, mixed with leaf of ewuro and leaf of laali.	Orally, three (3) times daily.
23.	<i>Elaeis guineensis</i> Jacq.	Arecaceae	Igi Ope	African oil palm	Ksusta/psb/ h/voucher no: sn	80	Hepatitis, meningitis, lassa fever, yellow fever, poliomyelitis	Roots	Decoction	Orally
24.	<i>Enantia chlorantha</i> Oliv.	Annonaceae	awopa/ dokitagbo/yari	Africa yellow wood	Ksusta/psb/ h/voucher no: sn	48.6	Poliomyelitis, meningitis, lassa fever, yellow fever	Stem bark	Decoction	Orally
25.	<i>Entandrophragma utile</i> (Dawe & Sprague) Sprague	Meliaceae	Epo jebo	Sipo mahogany	Ksusta/psb/ h/voucher no: sn	5.7	Poliomyelitis, yellow fever	Leaf/ stem bark	Decoction	Orally and use for bathing
26.	<i>Euphorbia hirta</i> L.	Euphorbiaceae	Oro alago	Asthma weeds	Ksusta/psb/ h/voucher no: sn	51.4	Hepatitis, meningitis, lassa fever, yellow fever, poliomyelitis, monkey pox, smallpox, COVID-19	Stem bark	Decoction	Orally
27.	<i>Euphorbia lateriflora</i> Schumach.	Euphorbiaceae	Enuopiye			5.7	Smallpox	Stem bark	Decoction	Orally and use for bathing
28.	<i>Euphorbia unispina</i> NE Br.	Euphorbiaceae	Oro adete		Ksusta/psb/ h/voucher no: sn	22.9	Hepatitis, meningitis, yellow fever, poliomyelitis	Leaves	Decoction	One teaspoon to be taken orally every morning.
29.	<i>Garcinia kola</i> Heckel	Clusiaceae	Orogbo	Bitter kola	Ksusta/psb/ h/voucher no: sn	31.4	Hepatitis, meningitis, lassa fever, yellow fever, poliomyelitis	Roots	Decoction	Orally
30.	<i>Harungana madagascariensis</i> Lam. ex Poir	Hypericaceae	Aroje		Ksusta/psb/ h/voucher no: sn	11.4	Hepatitis, meningitis, poliomyelitis	Leaves	Decoction	Orally
31.	<i>Jatropha curcas</i> L.	Euphorbiaceae	Lapalapa	Fuel plant (jatropha)	Ksusta/psb/ h/voucher no: sn	8.6	Meningitis, lassa fever	Leaf	Decoction	Orally, one cup daily
32.	<i>Kigelia africana</i> (Lam.) Benth	Bignoniaceae	Ewe pandoro	Sussage tree	Ksusta/psb/ h/voucher no: sn	14.3	Hepatitis, yellow fever, poliomyelitis	Leaves	Decoction	Orally, two (2) tea spoon to be taken twice daily.
33.	<i>Lagenaria breviflora</i> (Benth.) Roberty	Cucurbitaceae	Tagiri	Wild colocynth	Ksusta/psb/ h/voucher no: sn	22.9	Monkey pox, smallpox	Leaf	Decoction	Orally
34.	<i>Lannea microcarpa</i> Engl. & K.Krause	Anacardiaceae	Ekudan		Ksusta/psb/ h/voucher no: sn	11.4	Hepatitis, meningitis, lassa fever	root	Decoction	Orally
35.	<i>Lawsonia inermis</i> L.	Lythraceae	Laali	Henna, Egyptian privet, cypress, shrub	Ksusta/psb/ h/voucher no: 41	5.7	Lassa fever	Leaf	Decoction	Orally
36.	<i>Mangifera indica</i> L.	Anacardiaceae	Ewe mangoro	Mango	Ksusta/psb/ h/voucher no: 63	31.4	Meningitis, Lassa fever, monkey pox, smallpox, COVID-19, hepatitis	Stem bark	Concoction. It is mixed with stem bark of awopa, ahun and egbesi. The juice is used to prepare pap	Orally
37.	<i>Momordica charantia</i> L.	Cucurbitaceae	Ewe ejirin	Balsam pear	Ksusta/psb/ h/voucher no: sn	48.6	Meningitis, lassa fever, yellow fever, poliomyelitis	Leaves	Decoction	Orally

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Table 4 (continued)

38.	<i>Morinda lucida</i> Benth.	Rubiaceae	Ewe oruwo	Brimstone tree	Ksusta/psb/ h/voucher no: sn	25.7	Hepatitis, lassa fever, yellow fever	Roots	Concoction, mixed with dokita igbo(stb),epo cocoa(stb) and amuje(stb)	Juice to be taken twice daily.
39.	<i>Musa sapientum</i> L.	Musaceae	Ogede wewe	Banana	Ksusta/psb/ h/voucher no: sn	17.1	Hepatitis, meningitis, lassa fever, poliomyelitis	Roots	Decoction	Orally
40.	<i>Nauclea latifolia</i> Sm.	Rubiaceae	Koro Egbesi		Ksusta/psb/ h/voucher no: sn	14.3	Hepatitis, lassa fever, poliomyelitis	Roots	Soaked in water for 24h	Orally for three (3) days.
41.	<i>Nicotiana tabacum</i> L.	Solanaceae	Taba juku	Tobacco	Ksusta/psb/ h/voucher no: sn	17.1	Hepatitis	Leaf	Decoction	Orally
42.	<i>Nymphaea lotus</i> L.	Nymphaeaceae	Ewe osibata	White lotus	Ksusta/psb/ h/voucher no: sn	57.1	Hepatitis, meningitis, lassa fever, yellow fever, poliomyelitis	Stem bark	Decoction	Orally
43.	<i>Ocimum basilicum</i> L.	Lamiaceae	Ewe Efirin	Sweet Basil	Ksusta/psb/ h/voucher no: sn	22.9	Poliomyelitis, meningitis, hepatitis, meningitis, poliomyelitis	Stem bark	Decoction	Orally
44.	<i>Phyllanthus amarus</i> Schumach. & Thonn	Phyllanthaceae	Eyin olobe		Ksusta/psb/ h/voucher no: sn	5.7	COVID-19, hepatitis	Leaves	Decoction	Orally
45.	<i>Piper guineense</i> Schumach. & Thonn.	Piperaceae	Koko Iyere	Ashanti pepper	Ksusta/psb/ h/voucher no: sn	57.1	Hepatitis, meningitis, lassa fever, yellow fever, poliomyelitis, monkey pox, smallpox, COVID-19	Stem bark	Decoction	Orally
46.	<i>Plumbago zeylanica</i> L.	Plumbaginaceae	Ewe inabiri	Ceylon leadwort	Ksusta/psb/ h/voucher no: sn	45.7	Meningitis, yellow fever, lassa fever, poliomyelitis	Roots	Decoction	Orally
47.	<i>Psidium guajava</i> L.	Myrtaceae	Gurofa	Guava	Ksusta/psb/ h/voucher no: 67	14.3	COVID-19, lassa fever	Leaf/ stem bark	Decoction	Orally
48.	<i>Pycnanthus angolensis</i> (Welw.) Warb	Myristicaceae	Akomu	African nutmeg	Ksusta/psb/ h/voucher no: sn	17.1	Poliomyelitis, yellow fever	Stem bark	Decoction	Orally
49.	<i>Ricinus communis</i> L.	Euphorboraceae	Ewe lara	Castor oil plant	Ksusta/psb/ h/voucher no: sn	5.7	Yellow fever, poliomyelitis	Roots	Decoction	Orally
50.	<i>Saccharum officinarum</i> L.	Poaceae	Ireke	Sugar cane	Ksusta/psb/ h/voucher no: sn	5.7	Yellow fever, poliomyelitis	Whole plant	Raw	Orally
51.	<i>Secamone afzelii</i> (Roem. &Schult.) K.Schum.	Apocynaceae	Ewe Arilu		Ksusta/psb/ h/voucher no: sn	5.7	Poliomyelitis, yellow fever	Stem bark	Decoction	Orally
52.	<i>Securidaca longipedunculata</i> Fresen	Polygalaceae	Egbo ipeta	Violet tree	Ksusta/psb/ h/voucher no: 287	5.7	Poliomyelitis	Leaf/ stem	Decoction	Orally
53.	<i>Securinega virosa</i> (Roxb. ex Willd.) Baill.	Phyllanthaceae	Iranje		Ksusta/psb/ h/voucher no: sn	37.1	Hepatitis, lassa fever, yellow fever, poliomyelitis	Seeds	Decoction	Orally
54.	<i>Spondias mombin</i> L.	Anacardiaceae	Iyeye	Yellow mombin	Ksusta/psb/ h/voucher no: sn	2.9	Yellow fever			
55.	<i>Syzygium aromaticum</i> (L.) Merr. & L.M.Perry	Myrtaceae	Kanafuru	Clove	Ksusta/psb/ h/voucher no: sn	5.7	COVID-19	Seed	Decoction	Orally
56.	<i>Tamarindus indica</i> L.	Caesalpiniaceae	Ajagbon	Tamarind tree	Ksusta/psb/ h/voucher no: 66	5.7	Monkey pox, smallpox	Stem/ leaf	Decoction	Orally and use for bathing

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Table 4 (continued)

57.	<i>Terrapleura tetraptera</i> (Schum. & Thonn.) Taub	Fabaceae	Aidan	Kusta/psb/h/voucher no: sn	5.7	Smallpox	Seed	Concoction with a tin of milk	Orally twice daily
58.	<i>Trichilia monadelpha</i> (Thonn.) J.J. de Wilde	Meliaceae	Orudu	Kusta/psb/h/voucher no: sn	8.6	Poliomyelitis, lassa fever	Leaves	Decoction	Orally
59.	<i>Uvaria afzelii</i> G.F. Scott-Elliott	Annonaceae	Gbogbonise	Kusta/psb/h/voucher no: sn	5.7	Poliomyelitis, lassa fever	Seeds	Decoction	Orally
60.	<i>Vernonia amygdalina</i> Del.	Compositae	Ewe ewuro	Kusta/psb/h/voucher no: sn	11.4	Lassa fever	leaf	Decoction	Orally
61.	<i>Viscum album</i> L.	Santalaceae	Afomo	Kusta/psb/h/voucher no: sn	8.6	Poliomyelitis	Leaf	Decoction mixed with obi (leaf), agauon (stem bark)	Orally, juice taken three(3) times daily.
62.	<i>Vitellaria paradoxa</i> C.F. Gaertn.	Sapotaceae	Epo ori	Kusta/psb/h/voucher no: 320	5.7	Smallpox	Oil	Prepared as ointment	Topical
63.	<i>Xylopi aethiopica</i> (Dunnal) A. Rich.	Annonaceae	Eru	Kusta/psb/h/voucher no: sn	34.3	Meningitis, lassa fever, poliomyelitis	Seed	Decoction	Orally

An ethnomedicinal study identified *M. indica*, *Aloe vera*, *Vernonia amygdalina*, *Z. officinale* as medicinal used by patients diagnosed with viral and non-viral hepatitis in Uganda [16]. This is consistent with the present study although herein, *Z. officinale* was only used to treat yellow fever and COVID-19. Furthermore, *O. basilicum* and *Bidens pilosa* were reportedly used to treat hepatitis in Taiwan although *B. pilosa* [17] was used for the treatment of COVID-19 in the present study. Likewise, *C. papaya* and *Jatropha curcas* were reportedly used to treat hepatitis and hepatic disease in Peruvian Amazon [18].

Recent pharmacological studies have demonstrated the antiviral and anti-hepatitis effects of these plants. For instance, extracts of *G. senegalensis* induced anti-hepatitis B virus activity with an IC₅₀ value of 10.65 - 7.67 µg/ml [19], and further isolation studies produced myricetin-3- O-rhamnoside and quercetin that demonstrated anti-hepatitis B virus activity [20]. Similarly, potent anti-hepatitis C viral activity with over 70% inhibition at 100 µg/ml was reported for *A. nilotica*, *Syzygium aromaticum*, and *Zingiber officinale*. Conversely, weaker anti-hepatitis C virus activity was reported for *Tamarindus indica* (15%) *Adansonia digitata* (36.5%), *A. indica* (42%), *Balanites aegyptiaca* (8.4%), *Cymbopogon citratus* (54.3%), *Lepidium sativum* (45.1%), *Nauclea latifolia* (58.5%), *Nigella sativa* (42.7%), *Ocimum basilicum* (59.8%) [21]. In addition, anti-hepatitis virus activity of some of the plants cited herein including *Allium sativum* (hepatitis A), *Citrus limon* (hepatitis A), *Moringa olifera* (hepatitis B), *Phyllanthus amarus* (hepatitis C) and *Combretum glutinosum* (hepatitis B) have also been reported [13,22–24].

On the other hand, meningitis is an acute inflammation of protective membranes in the brain that can be caused by bacteria or viruses. For decades, medicinal plants have been used to treat meningitis, and herein, *A. digitata*, *A. vera*, and *A. nilotica* were the most cited plants used to treat meningitis in Kebbi, Kwara, and Sokoto States, respectively. Whereas, *L. sativum* and *Ludwigia octovalvis* were used to treat meningitis in Katsina state. An infusion of roots of *Combretum micranthum* and *Tamarindus indica* were used to treat meningitis in Kano State located in the Northwestern part of Nigeria [25]. Interestingly, *C. micranthum* (Sokoto and Kebbi state) and *T. indica* (Kebbi State) are also used to treat meningitis. Similarly, *A. indica* is used to treat meningitis in the North-central Nasarawa state [26] which is in agreement with the present study that cited *A. indica* for treatment of meningitis in Kebbi and Sokoto state. Similarly, *M. olifera* was reportedly used to treat meningitis in Ayurveda in agreement with its use for the treatment of meningitis in Kebbi State [27]. Contrarily, *A. senegalensis* was reportedly used to treat meningitis in Namibia [28] whereas, herein it is used to treat hepatitis, yellow fever, and poliomyelitis.

The poliovirus had a significant negative impact in Nigeria especially in the Northern part of Nigeria due to vaccine refusal. For instance, rumors and skepticism led to the suspension of polio vaccination in the northwestern state of Kano in 2003 resulting in a 2006 outbreak in 20 polio-free communities. Indeed, as an alternative to vaccination, the majority of the population in the North relies on herbal medicine and herbal medicinal practices for the treatment of polio. The present study identified *Terminalia avicenioides*, *M. indica*, and *C. micranthum* and the most frequently used plants to treat poliomyelitis. Whereas, *Anogeissus leiocarpus*, *Momordica charantia*, *Musa sapientum*, *Piliostigma thonningii*, and *T. indica* were cited by HMPs from at least two states as plants used for treating poliomyelitis. As shown in Table 7, medicinal plants cited in the present study for the treatment of poliomyelitis have already been validated for antiviral activity against the polio virus. For instance, *Adansonia digitata*, *Azadirachta indica*, *Boswellia dalzielii*, *Garcinia kola*, *Guiera senegalensis* have demonstrated potent activity against the polio virus [29–32]. In contrast, although *Annona senegalensis* and *Aframomum melegueta* are also cited for treatment against poliomyelitis, the plants did not induce antiviral activity against the polio virus [31,33]. Furthermore, pharmacological studies have demonstrated the anti-polio virus activity of medicinal plants including *Anacardium occidentale*, *Ananas comosus*, *Detarium senegalense*, *Lawsonia inermis*, and *Sterculia setigera* that were cited for treatment of other viral diseases in the present

Table 5
Medicinal plants used for treating viral diseases in Sokoto state.

s/no	Plant name	Family	Local name	Common Name	Voucher no	CF (%)	Disease treated	Parts used	Mode of preparation	Route
1.	<i>Acacia nilotica</i> (L.) Delile	Mimosaceae	Bagaruwa	Scented thorn	Ksusta/psb/h/ voucher no:284	70	Hepatitis, poliomyelitis, meningitis, monkey pox, smallpox, yellow fever	Leaf, bark	Boil in water then sieve	2–3 cup full to be taken orally 2–3 times daily
2.	<i>Allium sativum</i> L.	Amaryllidaceae	Tafarnuwa	Garlic	Ksusta/psb/h/ voucher no: s.n	10	Meningitis, COVID-19	Seed	Grind and pour into water then boil	2 cup full to be taken orally twice daily
3.	<i>Aloe vera</i> (L.) Burm.f.	Liliaceae	Aloe vera	Aloe vera	Ksusta/psb/h/ voucher no: 356	6	Hepatitis	Jell	Slice aloe leave and remove the jell. Grind until smooth	2–3 spoonful to be taken orally 2–3 times daily
4.	<i>Anacardium occidentale</i> L.	Anacardiaceae		Cashew	Ksusta/psb/h/ voucher no: 63	2	Smallpox	Root	Boil in water	2–3 cup full to be taken orally 2–3 times daily
5.	<i>Anogeissus leiocarpus</i> (DC.) Guill. & Perr	Combretaceae	Marke	African birch	Ksusta/psb/h/ voucher no: s.n	56	Meningitis, poliomyelitis, yellow fever, COVID-19	Bark, leaf, root	Boil in water and add red potassium, boil together then sieve	2–3 cupful to be taken orally thrice daily
6.	<i>Annona senegalensis</i> Pers.	Annonaceae	Gwanda daji	Wild custard apple	Ksusta/psb/h/ voucher no: 504	24	Hepatitis, yellow fever	Leaf, seed	Boil in water and add red potassium, boil together then sieve	2–3 cup full to be taken orally twice daily
7.	<i>Azadirachta indica</i> A. Juss.	Meliaceae	Darbejiya	Neem	Ksusta/psb/h/ voucher no: 61	24	Yellow fever, meningitis	Leaf, bark	Boil in water	2–3 cups to be taken orally 2–3 times daily
8.	<i>Boscia senegalensis</i> (Pers.) Lam. ex Pior.	Capparaceae	Anza	Aizen	Ksusta/psb/h/ voucher no: s.n	36	Smallpox, lassa fever	Root, leaf, bark	Boil in water together with lime juice then sieve	2–3 cups to be taken orally 2–3 times daily
9.	<i>Cassia occidentalis</i> L	Fabaceae	Tafasar massar	Coffee senna	Ksusta/psb/h/ voucher no: 71	2	Meningitis	Leaf	Infusion	To be applied to the affected part of the body
10.	<i>Cassia singueana</i> Delile	Fabaceae	Runhu	Sticky pod	Ksusta/psb/h/ voucher no: s.n	52	Hepatitis, meningitis	Flower, leaf, bark	Boil in water with some red potassium	To be taken orally / to be applied to the affected part of the body
11.	<i>Carica papaya</i> L.	Caricaceae	Gwanda	Pawpaw	Ksusta/psb/h/ voucher no: s.n	20	Hepatitis, yellow fever	Seed, leaf	Boil in hot water for 2–5 min then sieve	One cup full to be taken orally 2 times daily
12.	<i>Cinnamomum verum</i> J. Presl	Lauraceae		Cinnamon tree	Ksusta/psb/h/ voucher no: s.n	2	Yellow fever	Stem	Boil in water	To be taken orally
13.	<i>Citrus limon</i> (L.) Osbeck	Rutaceae		Lemon	Ksusta/psb/h/ voucher no: s.n	30	Meningitis, COVID-19	Fruit, Leaf	Pour into water and allow to infuse	2–3 cups to be taken orally 2–3 times daily
14.	<i>Cochlospermum tinctorium</i> Perrier ex A. Rich.	Bixaceae	Rawaya		Ksusta/psb/h/ voucher no: s.n	30	Yellow fever Hepatitis	Root, bark, leaf	Boil in water	To be taken orally
15.	<i>Combretum micranthum</i> G. Don.	Combretaceae	Geza		Ksusta/psb/h/ voucher no: 311	60	Hepatitis, poliomyelitis, meningitis, monkey pox	Leaf, bark	Boil in hot water for 2–5 min then sieve	To be applied to the affected part of the body/2 cup full to be taken orally twice daily
16.	<i>Cordia africana</i> Lam.	Boraginaceae			Ksusta/psb/h/ voucher no: s.n	52	Hepatitis, yellow fever	Root, leaf, seed, bark	Boil in water	To be taken orally
17.	<i>Cymbopogon citratus</i> (DC.) Stapf	Poaceae		Lemon grass	Ksusta/psb/h/ voucher no: s.n	4	Hepatitis	Leaf	Boil in water	2 cup full to be taken orally twice daily
18.	<i>Detarium senegalense</i> J.F. Gmel	Fabaceae	Taura	Detar/tallow tree	Ksusta/psb/h/ voucher no: s.n	4	Monkey pox, smallpox	Root, leaf, bark	Boil in water	2 cup full to be taken orally twice daily
19.	<i>Eleusine coracana</i> (L.) Gaertn.	Poaceae		Finger millet	Ksusta/psb/h/ voucher no: s.n	40	Monkey pox	Seed	Grind seed then pour into hot water and allow to infuse	2–3 cup full to be taken orally 2–3 times daily
20.	<i>Erythrina senegalensis</i> DC.	Fabaceae		Coral tree	Ksusta/psb/h/ voucher no: s.n	54	Poliomyelitis, lassa fever, yellow fever	Leaf, bark	Boil in water	2–3 cup full to be taken orally 2–3 times daily
21.	<i>Eucalyptus globulus</i> Labill	Myrtaceae		Blue gum	Ksusta/psb/h/ voucher no: s.n	2	COVID-19	Leaf	Boil in water	2–3 cup full to be taken orally 2–3 times daily
22.	<i>Ficus glumosa</i> Delile	Moraceae	Kawari	Rock fig	Ksusta/psb/h/ voucher no: s.n	50	Hepatitis, smallpox	Leaf, bark	Place in lukewarm water for 2–5 min then sieve	2 cup full to be taken orally twice or thrice daily
23.	<i>Ficus sycomorus</i> L	Moraceae	Baure	Sycamore fig	Ksusta/psb/h/ voucher no: s.n	16	Hepatitis, meningitis	Leaf	Boil in water	2–3 cup full to be taken orally 2–3 times daily

(continued on next page)

Table 5 (continued)

24.	<i>Guiera senegalensis</i> J.F. Gmel.	Combretaceae	Sabara	Moshi Medicine	Ksusta/psb/h/ voucher no: 48	44	Hepatitis, poliomyelitis	Leaf, bark, root	Boil in water then sieve	3 cup full to be taken orally twice daily
25.	<i>Heeria insignis</i> (Delile) Kuntze	Anacardiaceae	Kasheshe		Ksusta/psb/h/ voucher no: s.n	24	Hepatitis	Leaf	Boil in water then sieve out leaves	2-3 cup full to be taken orally twice daily
26.	<i>Hygrophila auriculata</i> (Schumach.) Heine	Acanthaceae			Ksusta/psb/h/ voucher no: s.n	16	Hepatitis, yellow fever	Leaf	Pour into water and boil for 5- 10 min, infusion	To be taken by mouth
27.	<i>Lannea microcarpa</i> Engl. & K.Krause	Anacardiaceae	Faru	African grape	Ksusta/psb/h/ voucher no: s.n	26	Hepatitis, poliomyelitis	Bark, stem, leaf	Boil in water then sieve	2 cup full to be taken orally twice daily
28.	<i>Mangifera indica</i> L.	Anacardiaceae	Mangwaro	Mango	Ksusta/psb/h/ voucher no: 63	16	Hepatitis, meningitis	Bark, leaf	Boil in water then sieve out leaves	3 cup full to be taken orally 3 times daily
29.	<i>Mentha piperita</i> L.	Lamiaceae		Peppermint	Ksusta/psb/h/ voucher no: s.n	2	COVID-19	Leaf	Boil in water then sieve out leaves	3 cup full to be taken orally 3 times daily
30.	<i>Mitragyna inermis</i> (Wild.) Kuntze	Rubiaceae			Ksusta/psb/h/ voucher no: s.n	24	Poliomyelitis, smallpox	Bark, leaf	Boil in water	2-3 cup full to be taken orally 2-3 times daily
31.	<i>Moringa oleifera</i> Lam.	Moringaceae	Zogale	Drumstick tree	Ksusta/psb/h/ voucher no: 121	10	Yellow fever	Leaf	Boil leaves in water and sieve out	3 cup full to be taken orally 3 times daily. Leaves can also be eaten
32.	<i>Nauclea diderrichii</i> (De Wild.) Merr.	Rubiaceae		Brimstone tree/ West African boxwood	Ksusta/psb/h/ voucher no: s.n	30	Hepatitis, yellow fever	Stem bark, leaf	Boil in water	2 cup full to be taken orally twice daily
33.	<i>Nigella sativa</i> L.	Ranunculaceae	Habbatu sauda	Black cumin	Ksusta/psb/h/ voucher no: s.n	6	Meningitis, COVID-19	Leaf, seed	Boil in water then sieve out	2 cup full to be taken orally twice daily. Oil can also be used
34.	<i>Piliostigma reticulatum</i> (DC.) Hochst.	Fabaceae		Camel's foot		58	Hepatitis, poliomyelitis, smallpox	Leaf	Boil in water	2 cup full to be taken orally twice daily
35.	<i>Pterocarpus erinaceus</i> Poir.	Fabaceae	Madobiya	African rosewood	Ksusta/psb/h/ voucher no: s.n	4	Poliomyelitis	Root	Boil in water then sieve	2 cup full to be taken orally twice daily
36.	<i>Psidium guajava</i> L.	Myrtaceae	Gwaiiba	Guava	Ksusta/psb/h/ voucher no: 67	10	Meningitis	Leaf	Boil in water then sieve	2-3 cup full to be taken orally 2-3 times daily
37.	<i>Securidaca longipedunculata</i> Fresen.	Polygalaceae	Uwa magunguna	Violet tree	Ksusta/psb/h/ voucher no: 287	12	Hepatitis, meningitis	Leaf	Boil in water then sieve out	To be applied to the affected part of the body/2 cup full to be taken orally 2 times daily
38.	<i>Swartzia madagascariensis</i> Desv.	Fabaceae		Snake bean	Ksusta/psb/h/ voucher no: s.n	20	Smallpox	Leaf, bark	Pour into water and boil for 5- 10 min	To be taken orally
39.	<i>Syzygium aromaticum</i> (L.) Merr. & L.M.Perry	Myrtaceae	Kanumfari	Clove	Ksusta/psb/h/ voucher no: s.n	22	Yellow fever, COVID-19	Fruit, Seed	Pour into water and boil for 5- 10 min	To be taken orally
40.	<i>Tamarindus indica</i> L.	Fabaceae	Tsamiya	Tamarind	Ksusta/psb/h/ voucher no: 66	6	Poliomyelitis, monkey pox	Root, whole plant	Pour into water and boil for 5- 10 min, infusion	To be taken orally
41.	<i>Terminalia avicennioides</i> Guill. & Perr.	Combretaceae	Baushe		Ksusta/psb/h/ voucher no: 315 b	2	Yellow fever	Leaf	Pour into water and boil for 5- 10 min	To be taken orally
42.	<i>Vernonia amygdalina</i> Del.	Compositae		Bitter leaf	Ksusta/psb/h/ voucher no: s.n	28	Hepatitis, yellow fever, meningitis	Leaf, seed, bark	Boil in water and sieve	2-3 cup full To be taken orally 2-3 times daily
43.	<i>Viscum album</i> L.	Santalaceae		Mistletoe	Ksusta/psb/h/ voucher no: s.n	6	Monkey pox, hepatitis	Seed, whole plant	Boil in water	2 cup full To be taken orally twice daily
44.	<i>Zingiber officinale</i> Roscoe	Zingiberaceae		Garden ginger	Ksusta/psb/h/ voucher no: s.n	20	Yellow fever, COVID-19	Seed, bark	Grind then pour into water and boil, sieve out and drink as tea	2-3 cup full to be taken orally 2-3 times daily
45.	<i>Ziziphus mauritiana</i> Lam.	Rhamnaceae	Magarya	Jujube	Ksusta/psb/h/ voucher no: 258 a	28	Poliomyelitis	Root, leaf	Boil in water and add some lime juice, sieve and drink as tea	2-3 cup full to be taken orally 2-3 times daily

Table 6
Informant consensus factor (ICF).

s/no	Diseases	ICF	Sokoto	Katsina	Kebbi	Kwara
1	Hepatitis	0.85	0.85	0.86	0.78	0.71
2	Meningitis	0.88	0.88	0.86	0.73	0.57
3	Lassa fever	0.89	NR	NR	NR	0.60
4	Yellow fever	0.85	0.85	0.87	0.78	0.59
5	Polio	0.88	NR	NR	0.66	0.50
6	Monkey pox	0.80	NR	NR	0.68	0.33
7	Smallpox	0.89	0.90	0.77	0.49	0.49
8	COVID-19	0.79	0.91	0.78	0.22	0.22

NR: No response was recorded for that disease category.

study [31,34,35]. Although, *L. inermis* is reportedly used to treat poliomyelitis in southwestern Nigeria [36]. Indeed, this nonetheless demonstrates the potential of Nigerian medicine against poliovirus.

Furthermore, the yellow fever virus causes acute viral hemorrhage that continues to cause morbidity and mortality in Africa. For over 21 years cases of yellow fever were not reported in Nigeria until its resurgent case was confirmed in Ifelodun Local Government Area, Kwara state in September 2017 [37]. Besides a successful vaccination campaign, Nigerians especially residents of rural areas also rely on herbal medicine for the treatment of yellow fever. Herein, *Eucalyptus globulus*, *M. indica*, and *Cochlospermum tinctorium*, and *M. sapientum* were cited as the most frequently used plants used for the treatment of yellow fever by HMPs in Katsina, Kebbi, Sokoto, and Kwara states. Previous studies have reported the use of medicinal plants in Nigeria for the treatment of yellow fever and other fevers. For instance, an infusion of fruit of *M. sapientum* was prepared with *Citrus paradise* to treat yellow fever. Similarly, the leaf and bark of *M. indica* were prepared with other plants as infusion or decoction to treat yellow fever by HMPs in Ogun State of Nigeria [38]. Furthermore, several plants used for the treatment of yellow fever as mentioned in the present study including *A. indica*, *C. papaya*, *Z. officinale*, *Citrus aurantifolia*, *Senna occidentalis*, *Alstonia boonei*, *Anacardium occidentale* among others were also reportedly used to treat yellow fever in Ogun State in agreement with the present study [38]. In addition, *A. indica*, *Erythrina senegalensis*, and *A. senegalensis* mentioned in the present study were also reportedly used to treat febrile illnesses including yellow fever HCPs in Gboko and Kastina-Ala communities in Benue state of Nigeria [39]. Pharmacological studies have also demonstrated the potent effect of different cultivars of *Musa* spp. (banana) against yellow fever virus with EC₅₀ of 6.27–46.2 µg/ml [40]. Interestingly, *M. Sapientum* was mentioned as the most frequently used plant to treat yellow fever in Kwara State. Furthermore, following 48 h treatment, *M. indica*, and *Enantia chlorantha* induced potent larvicidal effects against *Aedes aegypti*, a primary vector for yellow fever [41]. Similarly, *Psidium guajava* and *A. nilotica* induced a larvicidal effect against *A. aegypti* [42].

On the other hand, Lassa fever was discovered in Nigeria in 1969 and there have been regular episodes of outbreaks. A total of 963 confirmed laboratory cases of lass fever and 188 mortality were recorded as of April 2020 with the majority of the cases reported in Edo (32%), Ebonyi (8%), and Ondo (32%) states of Nigeria [43]. However, in contrast to yellow fever, studies on the treatment of Lassa fever by HMPs or the pharmacological effect of medicinal plants on Lassa fever have not been reported. The present study reported decoctions *Plumbago zeylanica* and *E. chlorantha* as the most frequently used plants to treat Lassa fever by HMPs in Kwara State. Interestingly, no response was recorded for Lassa fever treatment in Sokoto, Kebbi and Katsina states. This could be attributed to the fact that outbreaks are fewer in the northwestern states compared to the southern states of Nigeria. Although geographically, Kwara state is in the Northcentral part of Nigeria, it is however a western state with predominantly Yoruba tribe and other minority tribes such as Fulani, nupe, etc.

COVID-19 has negatively affected millions of people globally with

high mortality since it was declared a pandemic by the World Health Organization. Besides, the conventional medicine used to combat COVID-19, medicinal plants, and herbal medicine offer an alternative and have been used to treat COVID-19. Herein, *Aframomum melegueta*, *A. leiocarpus*, were the most frequently mentioned plants for the treatment of COVID-19 in Kebbi and Kwara States, respectively. Whereas, *S. aromaticum* was the frequently mentioned plant for Katsina and Sokoto States. Interestingly, HMPs from all the states mentioned *S. aromaticum* for the treatment of COVID-19.

Ethnomedicinal studies on the use of plants for COVID-19 treatment are limited in comparison to other viral diseases. To the best of our knowledge, this is the first study investigating the use of medicinal plants to treat COVID-19 in Nigeria. Nevertheless, a recent survey reported *S. aromaticum*, *Z. officinale*, *P. guajava*, and *A. indica*, as medicinal plants used by Nepalese during COVID-19 all of which have been mentioned in the present study as a remedy for COVID-19 [44]. Interestingly as shown in Table 7, most of the medicinal plants cited herein for COVID-19 treatment have been reportedly used to at least treat cold, flu, whooping cough, bronchitis, and other respiratory diseases and problems. For instance, *P. guajava* is used to treat cold and cough in African countries [45]. Whereas, *Anogeissus leiocarpus* is used to treat cold, fever, and acute respiratory infection in Africa [46]. Unlike other viral diseases, *in vitro* pharmacological studies and ethnomedicinal studies on the potency of medicinal plants against COVID-19 have been scarcely conducted. However, an *in silico* study suggested that *C. papaya* mentioned herein for COVID-19 treatment in Kebbi state could induce an *in vitro* antiviral effect against COVID-19 [47].

Over 40 years ago, the World health assembly accepted a report concluding the eradication of smallpox disease [48]. Besides the vaccination programs, rural areas also depended on herbal medicine for the treatment of smallpox, and thus it is important to document and possibly harness this knowledge. For instance, the ripe grapes of *Vitis vulpina* were reportedly used for the treatment of smallpox and other diseases [49]. In the present study, *Acacia senegal*, *Guiera senegalensis*, *Lagenaria breviflora*, *P. reticulatum*, were the most frequently mentioned plants used to treat smallpox in Katsina, Kebbi, Kwara and Sokoto state, respectively. On the other hand, there has been a reemergence of monkeypox in Nigeria in 2017 since the last human monkeypox was reported in 1978 with a total of 146 cases reported across 22 states [50]. In the present study, *L. breviflora*, *B. aegyptiaca*, and *Eleusine coracana*, were cited as the most frequently used plants to treat monkey pox in Kwara, Kebbi, and Sokoto States, respectively. Interestingly, *L. breviflora* was mentioned as the most frequently used plant to treat both smallpox and monkeypox by HMPs in Kwara State. Whereas, no response was recorded for medicinal plants used for treating the monkey virus in Katsina state. Ethnomedicinal studies have reported the use of medicinal plants cited herein for the treatment of smallpox, boils, itch, and other skin diseases. For instance, *A. nilotica* is reportedly used to treat smallpox in west African countries [51]. Similarly, *A. indica* is used to treat chickenpox, smallpox in Ayurveda, and infectious diseases in Nigeria [52,53]. Furthermore, *L. inermis* is mentioned as a treatment for smallpox in Islamic medicine and treatment of measles in Nigeria in contrast to its reported use for the treatment of monkeypox as shown in the present study [36,54]. Besides, medicinal plants cited herein for treatment of small and monkey pox have also been reportedly used to treat other skin diseases. This includes *C. procera* and *D. senegalense* that are used for treating boils and skin infections in Nigeria [31,55]. Likewise, *S. setigera* (measles and chickenpox), *V. amygdalina* (measles and boils), and *V. paradoxa* (chickenpox and skin diseases) are used for treating skin diseases in Nigeria (Table 7) [15,56]. In contrast, *Ageratum conyzoides* and *Ricinus communis* are also reportedly used to treat craw-craw in Africa although the plants were not cited for treatment of smallpox or monkey pox in the present study [57–59].

However, the antiviral activities of the aforementioned plants against smallpox and monkeypox virus have not been reported *in vitro*. Nonetheless, *in vitro* antiviral activity against the smallpox virus has

Table 7

Ethnomedicinal uses, antiviral activity and toxicity of medicinal plants used for treating viral diseases in northern Nigeria.

Plant name	Ethnomedicinal uses in literature	Antiviral activity	Toxicity/poisonous effect	Disease treated in present study
<i>Acacia nilotica</i> (L.) Delile	Woods are used to treat smallpox in west Africa [51]. Bark decoction is used to treat hepatitis in Burkina Faso [15].	Antiviral activity against HIV-1 protease [63], hepatitis C [64].	No significant in vivo and <i>in vitro</i> toxicity on rat and Vero cell lines [65].	Hepatitis, monkey pox, meningitis, smallpox, poliomyelitis, COVID-19, Yellow fever
<i>Acacia Senegal</i> (L.) Wild	Leaves used to treat typhoid fever in west Africa [66].		No toxicity was observed in vivo on F344 rats [67].	Smallpox
<i>Adansonia digitata</i> L.	Leaves are used to treat fever in Africa [68]. Bark is used to treat hepatitis in Burkina Faso [15].	Antiviral effect against polio virus, hepatitis C and Herpes simplex virus [21,29].	Nontoxic in acute toxicity study [69].	Poliomyelitis, smallpox, yellow fever, meningitis, monkey pox, hepatitis
<i>Aframomum melegueta</i> K. Schum.	Used to treat body pain, rheumatism, diarrhea, catarrh, congestion in Nigeria [70].	Inhibited measles and yellow fever virus. No activity against polio virus-1 [33,70].	Included in FDA of botanicals considered safe [71].	Hepatitis, monkey pox, smallpox, COVID-19, poliomyelitis, yellow fever
<i>Ageratum conyzoides</i> (L.) L.	Used to treat fever in Togo and HIV in Nigeria. Used to treat infectious diseases, headache, febrifuge, crawl, pneumonia, and burns in African countries [57,58].		No mortality or severe toxicity in acute and 28 days sub-chronic study [57].	Hepatitis, lassa fever, poliomyelitis
<i>Alafia barteri</i> Oliv.	Used to treat malaria, fever and rheumatic pain in southwest Nigeria [72].		Induced moderate toxicity on crustacean <i>A. salina</i> larvae [72].	Meningitis, lassa fever
<i>Allium cepa</i>	Used to treat cold and fever in Asia, hypertension in Nigeria and flu, cough and cold in Europe and south/north America [73].	Patent for the use of the extract for treatment of AIDS [74].	High dose of 500 mg/kg induced histological changes with 25% mortality rate [73].	Poliomyelitis meningitis, COVID-19
<i>Allium sativum</i> L.	Used to treat fevers and cold in India, Pakistan and middle east and as antibiotic in Africa [75].	Virucidal effect against HSV, vaccina, influenza, HIV and hepatitis A virus [22].	Generally poses little safety concerns [75].	Poliomyelitis, COVID-19, monkey pox, meningitis, hepatitis
<i>Aloe vera</i> (L.) Burm.f.	Used by Arabs to treat fever and burns in Africa, hepatitis in Uganda [16,76].	Induced antiviral activity against HSV1, HSV2, varicella- zoster virus, influenza virus, and pseudorabies virus, [77].	No report of adverse effect from clinical trials [76].	Meningitis, Hepatitis, lassa fever
<i>Alstonia boonei</i> De Wild	Used to treat malaria and fever in Nigeria and West Africa [78].		The LD ₅₀ of ethanol leaf extract is > 5000 mg/kg [79].	Lassa fever, Yellow fever, monkey pox, smallpox
<i>Anacardium occidentale</i> L.	Used to treat infectious and enteric conditions such as typhoid in Nigeria [80], and yellow fever in Benin and Malaysia [81].	Induced total inhibition of poliovirus, astrovirus, HSV1 [31].	Higher doses of hexane leaf extract at 6 g/kg caused anorexia, diarrhea, and syncope with LD ₅₀ at 16 g/kg [82]. Ingestion of seeds can cause burns/death [62].	Smallpox, Lassa fever, yellow fever
<i>Ananas comosus</i> (L.) Merr.	Used to treat intestinal worm, contraceptive, diuretic, jaundice, diarrhea, diabetes and bronchitis. Used to treat typhoid fever in southwest Nigeria [83].	Antiviral activity against polio virus-1 [34].	The leaf extract is not toxic [84]. Consumption of the peel can cause itching [62].	Meningitis, Lassa fever, yellow fever, COVID-19
<i>Annona senegalensis</i> Pers.	The leaf is used to treat cough, yellow fever, tuberculosis, chicken pox and smallpox in Nigeria [85,86]. Used to treat chicken pox, measles, fever, malaria and headache in Benin [87]. Leaf is used to treat hepatitis in Burkina Faso [15]. Used to treat meningitis in Namibia [28].	No antiviral activity detected against poliovirus, astrovirus, HSV1 [31].	Oral LD ₅₀ of 1296 g/kg [85].	Poliomyelitis, Hepatitis, yellow fever
<i>Anogeissus leiocarpus</i> (DC.) Guill. & Perr.	Used to treat hepatitis, fever, jaundice, cold, typhoid, yellow fever, tuberculosis, cough, acute respiratory infection in Africa [46]. Used to treat hepatitis in Burkina Faso [15].		LD ₅₀ was 1400 mg/kg in rats [46].	Monkey pox, poliomyelitis, Meningitis, yellow fever, COVID-19
<i>Aristolochia ringens</i>	Used to treat typhoid and fever in Nigeria and south America, respectively [88].		The LD ₅₀ of the aqueous root extract is greater than 10 g/kg [89].	Yellow fever, lassa fever
<i>Azadirachta indica</i> A. Juss.	Leaves are used in Ayurveda to treat viral infections, cold, influenza, herpes, chicken pox and fever [52]. Used as deterrent for small pox and infectious diseases in India. Malaria and meningitis treatment in Nigeria [26,53].	Isolated polysaccharides induced antiviral effect against poliovirus, anti-hepatitis C activity [21,30].	The LD ₅₀ of oil was 31.95 g/kg [90] whereas, 50–300 mg/kg of stem bark extract induced alteration in biochemical parameters [91].	Smallpox, monkey pox, COVID-19, poliomyelitis, yellow fever, Meningitis, Lassa fever
<i>Balanites aegyptiaca</i> (L.) Delile	Root is used to treat malaria whereas, seed oil is used to treat jaundice, yellow fever and syphilis in Nigeria [92].	Antiviral activity against hepatitis C [21] and antiviral activity against HIV [93].	The seed oil did not induce any toxicity in male Wister rats [94].	Hepatitis, monkey pox, meningitis, smallpox, poliomyelitis
<i>Bidens pilosa</i> L.	Used to treat fever, malaria in South Africa, all types of infection in Brazil, cold, flu and hepatitis in India [95], Yellow fever, influenza in Uganda,	Induced anti-influenza, anti-HIV, anti-herpes, anti-influenza, antisendai, antisindbis and anti-RSV activities [97].	An oral dose of 10 g/kg did not cause any mortality or changes in rats [96].	COVID-19

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Table 7 (continued)

<i>Boscia salicifolia</i> Oliv.	cough in China and hepatitis in Hong Kong [96] Used to treat typhoid in Kenya, tuberculosis in Tanzania, HIV/AIDS in Zambia, cough in Sudan and fever/malaria in Nigeria, Kenya and Sudan [98]		Toxicity studies on brine shrimp and Vero cells revealed LC ₅₀ of 22.8 µg/ml and CC ₅₀ of 304.9 µg/ml [98]	COVID-19
<i>Boswellia dalzielii</i> Hutch.	Used to treat diarrhea and fever [31]. Bark is used to treat malaria and yellow fever in Africa [99]	Induced total inhibition of poliovirus, astrovirus and 75% inhibition of HSV1 and equine HSV [31]	The LD ₅₀ of aqueous stem bark extract was > 3000 mg/kg [100]	Poliomyelitis, yellow fever
<i>Bridelia ferruginea</i> Benth	Used to treat diarrhea, fever, headache, stiffness and boils in Africa [101,102]		Acute and sub-chronic toxicity study at 5000 mg/kg did not induce any death or significant alteration of biochemical and histological parameters [101]	Poliomyelitis
<i>Byrsocarpus coccineus</i> Schumacher & Thonn.	Used to treat measles, jaundice, anemia, and skin disorders [103]		Ethanol root extract acute toxicity at 5000 mg/kg and subchronic toxicity at 800 mg/kg did not cause mortality or biochemical and hematological abnormalities [104]	Hepatitis, meningitis, lassa fever, yellow fever, smallpox, poliomyelitis
<i>Calotropis procera</i> (Aiton) Dryand	Used to treat boils, malaria, fever, pain, respiratory disease, cough, skin infection, cold and pneumonia, eczema in Ghana, Nigeria, Burkina Faso, India, Yemen and Saudi Arabia [55]	Induced antiviral effect against HIV, white spot syndrome virus and foot and mouth disease virus [55]	It is a toxic plant and induced dose dependent toxicity and nephrotoxicity <i>in vivo</i> [55]. Consumption of leaf can cause death [62]	Smallpox, COVID-19, monkey pox, poliomyelitis
<i>Carica papaya</i>	Used as part of herbal mixture to treat malaria, fungal and helminthic infection in Nigeria, and as antimalarial in Cameroun [105]. Fruits are used to treat hepatitis in Burkina Faso [15]	Induced inhibitory activity against dengue virus [105,106]	Subchronic toxicity including hypoglycemia, hypolipidemia hepatotoxicity, hyperuricemia have been reported for aqueous and ethanol leaf extract [107]	Hepatitis, meningitis, COVID-19, poliomyelitis, smallpox, yellow fever, monkey pox
<i>Cassia occidentals</i> L	Used to treat infection, jaundice, hepatitis, cirrhosis in Nigeria [85] and fever in Jamaica as well as whooping cough and skin diseases [108]. Leaves are used to treat hepatitis in Burkina Faso. Asthma, bronchitis, cough, mental disorders, fever, flu, febrifuge, skin disease, tuberculosis and hypertension China, Brazil, India. Malaria, fever and hepatitis in Nigeria [14,15]		LD ₅₀ is higher than 5 g/kg [85]. Seed extract induced subacute toxicity including hepatotoxicity in mice [109]. Raw pod and seed caused poisoning in children in India affecting the hepatic, skeletal, brain system and resulting in fatal coma [14]	Hepatitis, meningitis, COVID-19, yellow fever, poliomyelitis
<i>Cassia tora</i>	Leaves and seeds are used as a liver tonic, antimicrobial, skin diseases, fever, and cardiotonic in Ayurveda [110,111]	Dried seed extract inhibited replication SARS-CoV replication [112]	The ethanol seed extracts did not induce subchronic toxicity effect on biochemical parameters of rat [113]	Hepatitis, meningitis, yellow fever
<i>Chasmanthera dependens</i> Hochst.	Used to treat infectious diseases, pain, malaria, epilepsy, convulsions and fractures in Nigeria and West Africa [114]		Aqueous and methanol extract of leaf, root and stem did not exhibit any chronic toxicity on rats [115]	Poliomyelitis, meningitis
<i>Chenopodium ambrosioides</i> L.	Used to treat fever in Morocco and as treatment for lung and fungal infection in West Africa [116,117]	Induced antiviral activity against HSV-1 [118]	High doses of 12.31–31.89 g/kg caused lung congestion and necrosis of the kidney tubules [117]	Poliomyelitis, Meningitis
<i>Cordia africana</i> Lam.	Leaf powder is used to treat malaria, cough, skin rash, chest pain, jaundice, toothache and stomachache in Ethiopia [119,120]		Seed extract did not cause toxicity to mice at 2000 mg/kg [121]	Hepatitis, yellow fever
<i>Cinnamomum verum</i>	Used for treating indigestion, aching joints and respiratory and urinary troubles in India and Sri Lanka [122]	Essential oil induced antiviral activity against influenza, H1N1, HSV1 [123, 124]	No significant subchronic toxicity with LD ₅₀ greater than 1600 mg/kg in rabbits [125]	Yellow fever
<i>Cissus populnea</i> Guill. & Perr.	Root bark is used to manage pain in Mali and infected wound and boils in Cote d'ivoire [126] [127]		Long term effect of aqueous stem bark extract at 600 g/kg did not induced any significant changes in biochemical parameters [128]	Poliomyelitis, meningitis, monkey pox
<i>Citrus limon</i> (L.) Osbeck	Used to treat cold, scurvy, fever, chest pain in Romania, and used to treat fever, cough and high blood pressure in Trinidad [129]	Essential oil significantly reduced titer of hepatitis A virus on soft fruits surfaces [23], inhibition of HSV, anti-inflammatory, antimicrobial and effect on the nervous, cardiovascular and respiratory system [129]	Juice did not induce any acute and sub-acute toxicity in rats [130]	Meningitis, COVID-19
<i>Citrullus lanatus</i> (Thunb.) Matsum. & Nakai	Fruits are used to treat diarrhea and gonorrhea in Nigeria. Used to treat fever, yellowish urine, nephritis and diabetes in Islamic text and medicine [131,132]	Juice inhibited the entry and propagation of influenza virus <i>in vitro</i> and <i>in vivo</i> [133]	Ethanol seed extract did was not toxic at 1000 mg/kg [134]	Hepatitis, monkey pox, COVID-19, yellow fever, smallpox, poliomyelitis
<i>Citrus aurantifolia</i> (Christm.) Swingle	Used to treat fever, jaundice, headache, cough and malaria in Nigeria [135]. Fruit infusion is used to treat hepatitis in Burkina Faso [15]		Water extract did not show sign of toxicity however, 3.5 g/kg dose of fruit showed toxicity in rats [135]	Yellow fever, poliomyelitis

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Table 7 (continued)

<i>Citrus sinensis</i>	Used to treat cold, cough, and respiratory disorder in Chinese medicine, tuberculosis in Mexican medicine and angina, hypertension and diarrhea in France [136]		No adverse effect from consumption of orange juice [136]	Hepatitis, COVID-19, yellow fever, poliomyelitis
<i>Cochlospermum tinctorium</i> Perrier ex A.Rich.	Used to treat malaria in Mali. Used to treat liver disease, syphilis, measles, yellow fever, boils, fever and abdominal pain [137]. Decoction and powder of root are used to treat hepatitis in Burkina Faso [15]		Acute oral administration of root extract at 500 mg/kg did not induce toxic effect [137]	Yellow fever Hepatitis
<i>Combretum glutinosum</i> Perr.	Used to treat hepatic disease in Africa [24] and malaria in Senegal [138]. Whole plant powder is used to treat hepatitis in Burkina Faso [15]	Aqueous extract inhibited ACE and Hepatitis B surface antigen [24]	Oral dose of aqueous leaf extract at 2000 mg/kg did not induce acute toxicity [139]	Meningitis
<i>Combretum micranthum</i> G. Don.	Used for diuretic, digestion and gastrointestinal problem in Senegal and west Africa. The fresh leaves are also used to treat malaria in Burkina Faso and Cote d'Ivoire [140] [141] [142]. Powdered root is used to treat hepatitis in Burkina Faso [15]. Used to treat meningitis in Kano state, Northwestern Nigeria [25]	Extract induced antiviral activity against HSV-1 and HSV-2 [143]	LD ₅₀ for oral dose of hydroalcoholic leaf extract is above 5000 mg/kg and administration of 1000 mg/kg did not induce toxicity in rats [144]	Hepatitis, poliomyelitis, meningitis, monkey pox, yellow fever
<i>Cymbopogon citratus</i> (DC.) Stapf	Used to treat fever, analgesic and antiparasitic and anti-inflammatory in Africa, Asia and south America. Used to treat stomachache, toothache, bacterial and fungal infection in Algeria [145], headache and fever in India [146], malaria in Nigeria and Ghana [147]	Anti-HIV activity, anti-hepatitis C activity [21,148]	The plant has reportedly low toxicity [148]	Hepatitis, lassa fever, yellow fever
<i>Detarium senegalense</i> J.F. Gmel.	Used to treat boils, fever, skin disease and dysentery in Nigeria [31]	Induced 75% of poliovirus, astrovirus and HSV [31]	The seed oil did not induce toxicity on liver and kidney of rats [149]	Smallpox, yellow fever, COVID-19, meningitis, Monkey pox
<i>Diospyros mespiliformis</i> Hochst. ex A.DC.	Bark infusion and powder are used to treat hepatitis in Burkina Faso [15]. Used to treat syphilis, pneumonia, malaria and skin infections in Namibia [150]. Used to treat stomach problem, vomiting and diarrhea in South Africa [151]		LD ₅₀ of crude methanol leaf and bark extract was > 5 g/kg [152]	Hepatitis, monkey pox, meningitis, COVID-19, yellow fever, smallpox, poliomyelitis
<i>Elaeis guineensis</i> Jacq.	Used to treat headache, pain, malaria, cancer, boils, diarrhea, convulsion and gastrointestinal disorder in southern Nigeria. Used to treat gonorrhea, skin infection, bronchitis, and wound healing in Cameroun and Ghana [153]		Methanol leaf extract did not induce acute oral toxicity at 5 g/kg [154]. Consumption of leaf can cause discomfort [62]	Hepatitis, meningitis, lassa fever, yellow fever, poliomyelitis
<i>Eleusine coracana</i> (L.) Gaertn.	Used to treat diabetes, ulcer, osteoporosis and anemia [155]		Isolated probiotic strains did at 5000 mg/kg and 1000 mg/kg did not induce acute or subchronic toxicity in rats [156]	Monkey pox
<i>Enantia chlorantha</i> Oliv.	Used to treat malaria, boils, yellow fever, hepatitis, jaundice, typhoid fever, tuberculosis in Africa [157]	Induced antiviral and larvicidal effect against yellow fever virus and vector, anticonvulsion and antimicrobial activity [41,157,158]	Ethanol stem bark extract induced toxicity at high dose [159]	Poliomyelitis, meningitis, lassa fever, yellow fever
<i>Erythrina senegalensis</i> DC.	Used to treat malaria, fever, infections, pneumonia, neuralgia, malaria, jaundice, pain, diarrhea and typhoid fever in Mali [160]. Used to treat fever and malaria in middle belt and northern Nigeria [161]	Anti-HIV activity [160]	The LD ₅₀ of chloroform stem bark extract is 526 mg/kg with significant histopathological changes [162]	Poliomyelitis, lassa fever, yellow fever
<i>Eucalyptus globulus</i> Labill	Used to treat wound, fever and fungal infection by aboriginal Australians. Used to treat bronchitis, congestion of airways, sinus, asthma, toothache and headache [163,164]	Antiviral activity against HSV-1 and HSV-2 [165]	The essential oil is not toxic at lower dose [166]	COVID-19, Yellow fever
<i>Euphorbia hirta</i> L.	Used to treat gastrointestinal disorder, fever, skin diseases, bronchial and respiratory diseases in South Africa [167,168], cough, gonorrhea and tuberculosis [169]		Aqueous and ethanol extract are slightly toxic with 500 mg/kg as the maximum oral dose [170]. Ingestion of sap can cause vomiting [62]	Hepatitis, meningitis, lassa fever, yellow fever, poliomyelitis, monkey pox, smallpox, COVID-19
<i>Euphorbia lateriflora</i> Schumach.	Used to treat parasitic infection, blood disorder and urinary tract infection [171]		LD ₅₀ of whole plant ethanol extract > 5000 mg/kg [172]. Consumption of the sap and root may cause death [62]	Smallpox Poliomyelitis

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Table 7 (continued)

<i>Evolvulus alsinoides</i> Linn.	Used to treat dysentery, fever, strengthen the brain and memory, bronchitis, asthma and hemorrhages. Used to treat mental problems, epilepsy, insanity and nervous debility in India. Used to treat bronchitis, stomach ache and asthma in Nigeria, as love potion in Ghana and antimalaria, fever in India [173–175]		Higher doses were not lethal or toxic in rats [175]	
<i>Ficus platyphylla</i> Delile	Used to treat insomnia, psychosis, depression, epilepsy, pain and as an analgesic in Northern Nigeria [176]. Used to treat malaria and tuberculosis in Africa [177]	Induced antimalarial activity, behavioral and anticonvulsant effect, sedative effect, decreased cerebral ischemia, antimalarial and anti-inflammatory [177–180]	Intraperitoneal and oral LD ₅₀ were greater than 2000 mg/kg and 5000 mg/kg, respectively [176]	Poliomyelitis, smallpox, yellow fever, meningitis, monkey pox
<i>Ficus polita</i> Vahl	Used to treat infectious diseases, abdominal pain, dyspepsia and diarrhea [181]		LD ₅₀ of aqueous stem bark > 5000 mg/kg [182]	Poliomyelitis, smallpox, yellow fever, meningitis, monkey pox, COVID-19
<i>Ficus sycamorus</i> L.	Used to treat cough, skin infection, liver disease, diarrhea tuberculosis and stomach problem in Oman. Used to treat jaundice, ulcers, inflammation and respiratory and chest disease [183,184]		The LD ₅₀ of aqueous root extract was 3.20 ± 0.60 g/kg characterized by liver toxicity [184]	Poliomyelitis, meningitis, hepatitis, yellow fever
<i>Ficus thonningii</i> Blume	Used to treat diarrhea, gonorrhea and diabetes mellitus, bronchitis, urinary tract infection in Angola. Used to treat stomach pains, gastritis, gastric ulcers in Nigeria. Used also to treat influenza, sore throat, colds, liver disorders, skin disease, pneumonia, fever and toothache in African countries. Used in combination with other plants to treat polio in Mali [185]		The LD ₅₀ of oral aqueous leaf extract was > 3000 mg/kg [185]	Meningitis, smallpox
<i>Garcinia kola</i> Heckel	Used to treat headache, cure cough, dysentery, chest colds, liver disorders, diarrhea, laryngitis, bronchitis, and gonorrhea, fever, malaria in southern Nigeria [12]	Extract and fractions induced antiviral activity against measles virus, polio virus, yellow fever virus and HSV-1 [32]	The LD ₅₀ for seeds is > 5000 mg/kg [186]	Hepatitis, meningitis, lassa fever, yellow fever, poliomyelitis
<i>Gardenia erubescens</i> Stapf. & Hutch	Used to treat headache, sore nerve, navel pain, muscle ache in Burkina Faso. Used to treat malaria, anemia in Benin [187–189]		The LD ₅₀ of methanol extract is 550 mg/kg [190]	Poliomyelitis
<i>Guiera senegalensis</i> J. F. Gmel.	Used to treat enteric problems and worms in Nigeria [31]. Powdered infusion of root is used to treat hepatitis in Burkina Faso [15]	Induced 75% inhibition of poliovirus, astrovirus and HSV [31]	Plant is nontoxic at moderate doses but could be toxic at high dose over prolonged time [191]	Poliomyelitis, yellow fever, smallpox, COVID-19, meningitis, hepatitis, monkey pox
<i>Harungana madagascariensis</i> Lam. ex Poir	Used to treat typhoid, diarrhea, anemia in Cameroun, skin diseases in Ghana, analgesic and treatment of toothache in Guinea, Chronic diarrhea in Tanzania and Rwanda. Used to treat asthma, tuberculosis and fever [192,193]	Induced anti-HIV activity [194]	The LD ₅₀ of fruits was > 5000 mg/kg and long term use at high dose could induce toxicity [195]	Hepatitis, meningitis, poliomyelitis
<i>Hygrophila auriculata</i> (Schumach.)	Used to treat jaundice and other hepatic obstruction, malaria. Inflammation, gout, rheumatism, anemia, cough and pain. Used to treat diabetes in Sri Lanka, tuberculosis in Ghana [196–198]		The plant does not pose any toxic or side effects [196]	Hepatitis, yellow fever
<i>Jatropha curcas</i> L.	Used to treat diabetes in Nigeria, fever, malaria and convulsion in west Africa, headache and jaundice in India, and skin infection in Mali [199]	Antiviral activity against HIV [199]	Exhibited toxicity to different species including human, animals and microorganisms [199]	Meningitis, lassa fever
<i>Kigelia africana</i> (Lam.) Benth	Used to treat cancer, inflammation, skin infections, and diarrhea in Nigeria, boils, malaria, measles and STDs in Africa [200]		The aqueous stem bark is safe up to 5 g/kg [200]	Hepatitis, yellow fever, poliomyelitis
<i>Lagenaria breviflora</i> (Benth.) Roberty	Used as an abortifacient and to treat appendicitis, cancer and rheumatism in southern Nigeria [201–203]		LD ₅₀ of ethanol fruit extract is > 5000 mg/kg with hepatotoxicity at higher dose [204]	Monkey pox, smallpox
<i>Lannea microcarpa</i> Engl. & K. Krause	Bark decoction used to treat hepatitis in Burkina Faso, wound healing and schizophrenia spectrum disorder in Mali [15,205,206]		LD ₅₀ of aqueous trunk bark extract was 5000 mg/kg with no significant subchronic toxicity in rats [207]	COVID-19, hepatitis, poliomyelitis
<i>Lawsonia inermis</i> L.	Used to treat ring worm, infection and skin disease in South India. Mentioned as medicine for smallpox, chicken pox, ulcer, tumors in Islamic medical text. Used to treat fever, jaundice, cough, bronchitis and inflammation. Used to treat poliomyelitis and measles in southwest Nigeria [36,54]	Induced antiviral activity against Sindbis virus, HSV and polio virus [35]	LD ₅₀ greater than 1600 mg/kg [85]	Monkey pox, meningitis, COVID-19, yellow fever, lassa fever

Table 7 (continued)

<i>Leptadenia hastate</i> Vatke	Leaf ad root decoction are used to treat hepatitis in Burkina Faso. Used to treat catarrh, hypertension and skin disease in Nigeria [15,208]		Stem and aqueous leaf extract was considered safe at 2000 mg/kg [208]	Hepatitis, COVID-19, yellow fever, smallpox,
<i>Ludwigia octovalvis</i> (Jacq.) P.H. Raven	Used to treat nervous diseases, edema, dysentery, nephritis, diarrhea, headache and orchitis [209]		Extract at 800 mg/kg did not induce toxic effect on BALB/c mice for 28 days [209]	Meningitis
<i>Mangifera indica</i>	Leaf decoction is used to treat hepatitis in Burkina Faso and Uganda. Used to treat gastrointestinal, respiratory and genitourinary diseases, burn, itch, fever, cough, scurvy and throat/mouth infection [15,16,210,211]	Mangiferin induced antiviral activity and controlled HSV replication, Larvicidal effect against yellow fever vector [41,211]	Aqueous stem bark extract induced adverse effect and decreased the survival rate and emergence of younger flies of drosophila melanogaster [210]	Hepatitis, monkey pox, meningitis, COVID-19, yellow fever, poliomyelitis, small pox, lassa fever
<i>Maytenus senegalensis</i> (Lam.) Exell	Used to treat opportunistic infections in PLHIV, wound, chest pain, rheumatism. Used to treat tuberculosis, dysentery, pneumonia in Africa and malaria in Tanzania [212–214]	Stem bark extract inhibited HIV-1 replication and HIV-1 protease [63]	The plant was toxic to mice at 1200 mg/kg [212]	Monkey pox
<i>Mentha piperita</i> L.	Used to treat nausea, stomach disorders and indigestion, cough, cold in India [215]		Can deprive the human body iron and cause anemia when consumed excessively in combination with spearmint [216]	COVID-19
<i>Mitragyna inermis</i> (Wild.) Kuntze	Used to treat infectious diseases, jaundice, arthritis, contagious diseases, schistosomiasis in Mali and Cote d'ivoire. Used to treat malaria and recommended for recovering HIV patients [217]		The LD ₅₀ of hydroethanol leaf extract was > 3000 mg/kg [217].	Poliomyelitis, smallpox
<i>Momordica charantia</i> L.	Used to treat childhood viral disease, malaria, skin disease, fevers, gastrointestinal and gynecological problems in Togo, itch, hepatitis, flu, and fever in Brazil [218,219]	Induced antiviral activity against Herpes Virus-3, Influenza A and HIV-1 replication [220–222]	Induced hepatotoxic effect in animals and seed constituent (vicine) may induce favism [219]. Consumption of seed and root can cause gastrointestinal discomfort [62]	Poliomyelitis, smallpox, yellow fever, meningitis, monkey pox, COVID-19, hepatitis, lassa fever
<i>Morinda lucida</i> Benth.	Used to treat malaria, fever, typhoid fever, diabetes, hypertension and diarrhea in Northern and southern part of Nigeria [223]		LD ₅₀ of oral stem bark extract is > 5000 mg/kg [223]	Hepatitis, Lassa fever, yellow fever
<i>Moringa oleifera</i> Lam.	Used to treat Flu, malaria, headaches, skin diseases, bronchitis, asthma, herpes simplex arthritis, liver problem, fevers, typhoid fever and inflammation. Used to treat meningitis in Ayurveda [27,224, 225]	Inhibited Epstein Barr Virus, foot and mouth disease virus, Newcastle disease virus, hepatitis B virus, herpes simplex virus, influenza virus A and HIV [226, 227]	Aqueous leaf extract did not cause mortality at 6400 mg/kg [225]	Hepatitis, meningitis, smallpox, monkey pox, COVID-19, yellow fever, poliomyelitis
<i>Musa sapientum</i> L.	Used as a memory enhancer and to treat mental illness in west Africa, diarrhea, inflammation, eczema, burns, diabetes, cholera, dysentery and pain [228,229]	Induced anti-yellow fever virus activity [40]	The LD ₅₀ for aqueous extract of unripe fruit is > 5000 mg/kg [230]	Hepatitis, meningitis, lassa fever, poliomyelitis
<i>Nauclea diderrichii</i> (De Wild.) Merr.	Used to treat skin disease, cough, diuretic and diabetes in Cameroun. [231]		Ethanol leaf extract at 500 mg/kg induced toxic effect on gestational rat models [231]	Hepatitis, yellow fever
<i>Nauclea latifolia</i> Sm.	Used to treat fever, jaundice, malaria, diarrhea, stomach ache, chicken pox and tuberculosis in Nigeria [232]	Induced anti-hepatitis C activity [21]	LD ₅₀ of aqueous extract was > 18 g/kg [231]	Hepatitis, lassa fever, poliomyelitis
<i>Nicotiana tabacum</i> L.	Used as a mild stimulant, sedative and emetic agent in China. Used to treat skin diseases and tooth ache. Used as a stimulant, sedative and treatment of convulsions in Nigeria [233–235]	Induced anti-HIV1 and anti-TMV activity [233]	Tobacco leaf extract affected lipid profile and tissue of the liver [236]	Meningitis, hepatitis
<i>Nigella sativa</i> L.	Used to treat inflammation, jaundice, tertian fever, paralysis, headaches, cough and asthma in Unani medicine. Useful agaist Polio, leprosy, skin diseases such as boils, eczema, skin infection, and pain relief [237]	Anti-hepatitis C activity [237]	The acute toxicity of the major constituent thymoquinone is very low and well tolerated [237]	Monkey pox, smallpox, COVID-19
<i>Nymphaea lotus</i> L.	Used to treat guinea worm and rheumatic pain and tumor in northern and southern part of Nigeria. Used as sedative on nervous system, stomachache and heart disease [238, 239]		The LD ₅₀ of aqueous leaf extract is > 5000 mg/kg [239]	Hepatitis, meningitis, lassa fever, yellow fever, poliomyelitis
<i>Ocimum basilicum</i> L.	Used to treat diabetes and cardiovascular diseases in Turkey, pimples in India, ache and pain in Bulgaria and sedative in Spain. Used to treat headache, cough and diarrhea [240]	Anti-hepatitis C activity [21]	Hydroalcoholic extract did not cause any death or toxicity at 2 g/kg [241]	Poliomyelitis, meningitis, hepatitis, meningitis, poliomyelitis

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Table 7 (continued)

<i>Olea europaea</i> L.	Used to treat malaria, febrifuge, bronchial asthma, inflammation, hypertension, diarrhea, respiratory, and urinary tract infection [242]	Induced antiviral activity against parainfluenza type 3 virus, haemorrhagic septicaemia rhabdovirus, hepatitis virus, rotavirus and herpes mononucleosis [243]	The LD ₅₀ for methanol leaf extract is 3475 mg/kg [244]	Smallpox, yellow fever, COVID-19, monkey pox
<i>Parkia biglobosa</i> (Jacq.) G.Don	Bark infusion is used to treat hepatitis in Burkina Faso, malaria, headache, cough, pain, skin infection, hepatitis, hypertension and skin diseases in Nigeria and other West African countries [15,245]		The LD ₅₀ for methanol and water and methanol extract is > 5000 mg/kg [246]	Poliomyelitis, smallpox, yellow fever, meningitis
<i>Parinari macrophylla</i> Sabine	Used to treat asthma, skin infections, dysentery, diarrhea in northern Nigeria [247]		The LD ₅₀ of aqueous stem bark is more than 5000 mg/kg [248]	Poliomyelitis, monkey pox
<i>Phyllanthus amarus</i> Schumach. & Thonn	Decoction and powder of whole plants are used to treat hepatitis in Burkina Faso. Used to treat malaria, chronic stomach pain, alcoholic and liver disease in Nigeria. Used to treat cough, bronchitis, hepatitis, tuberculosis, jaundice and fevers in India [13,15]	Antiviral activity against HIV-1, hepatitis C virus [13]	Has potential toxic effect and contains geraniin that has negative chronotropic, inotropic, hypotensive and ACE inhibitory effect [13]. Contact with the leaf and stem can cause itching [62]	Hepatitis, COVID-19
<i>Piliostigma thonningii</i> (Schum.) Milne-Redh.	Used to treat cough, inflammation and as an analgesic in Tanzania and Zimbabwe. Used to treat malaria, wound, ulcer, cough, bronchitis, leprosy, skin disease and fever in African countries [249]	Anti-tuberculosis and antilipidemic effect and anti HSV-1 activity [250–252]	The LD ₅₀ of ethanol leaf extract is > 5000 mg/kg [253]	Poliomyelitis, smallpox, meningitis, hepatitis
<i>Piper guineense</i> Schumach. & Thonn.	Used for treating neurodegenerative disease in West Africa. Used to treat malaria, convulsion, epilepsy, cough, boils, catarrh, bronchitis, and intestinal disease [254,255]		Oral dose of leaf extract ≤ 8000 mg/kg did not cause any death in rats [256]. Consumption of the root can cause stomachache and ulcer [62]	Poliomyelitis, yellow fever, COVID-19, monkey pox, hepatitis, meningitis, lassa fever, smallpox
<i>Plumbago zeylanica</i> L.	Used to treat diarrhea, skin disease, pain, intestinal parasite and inflammation, chronic cough/cold, itchy skin and chronic disease of the nervous system in India [257]		The root is reportedly a poison when administered orally to ostium uteri, although limited toxicity was observed in rabbits [257]	Meningitis, yellow fever, lassa fever, poliomyelitis
<i>Prosopis africana</i> (Guill. & Perr.) Taub.	Used to treat hepatitis, infectious diarrhea, dermatosis, ulcer and gonorrhea in Burkina Faso. Used for wound healing and relieve sore throat in southeast Nigeria [15,258]		The LD ₅₀ of l.p. methanol stem bark extract is 774 mg/kg [259]. Consumption of seed can cause death [62]	Hepatitis, meningitis, poliomyelitis, yellow fever
<i>Psidium guajava</i> L.	Used to treat febrifuge, cold, cough, itchy rashes sores, boils, cholera, diarrhea, respiratory problem, fever and skin problem in African, Latin America and southeast Asian countries [45]	Inhibited the H1N1 viruses, larvicidal effect against yellow fever vector [41, 260]	The LD ₅₀ of leaf extract is > 5 g/kg [45]	Hepatitis, meningitis, COVID-19, poliomyelitis, smallpox, yellow fever, lassa fever
<i>Pterocarpus erinaceus</i> Poir.	Used to treat fever, headache, skin infection, typhoid fever, malaria, measles, cough, leprosy and anemia in Benin republic. Used as abortifacient in Northern Nigeria and for fever in Ghana [261,262]		The LD ₅₀ of hydroethanolic stem bark extract is > 5 g/kg [263]	Poliomyelitis, Hepatitis, meningitis
<i>Ricinus communis</i> L.	Used as mosquito repellent, relieve stomachache, jaundice and toothache, convulsions, cold, catarrh, boils itching skin disease such as crawl-crawl [59]		Contains toxic compounds such as ricin and ricinine and has shown toxicity at 3 g/kg of oral administration [264]	Yellow fever, poliomyelitis
<i>Saccharum officinarum</i> L.	Used to treat liver related diseases, jaundice, hemorrhoid and dysentery in Nigeria [265]		Contains some polycyclic aromatic hydrocarbons (PAHs) [266]	Yellow fever, poliomyelitis
<i>Sclerocarya birrea</i> (A. Rich.) Hochst.	Bark decoction is used to treat hepatitis in Burkina Faso. Used to treat malaria, fever, headaches diarrhea, stomach ache, diabetes, cough and tuberculosis in Benin republic [15,267]		The LD ₅₀ of peel extract is > 3000 mg/kg [268]	Yellow fever
<i>Securidaca longipedunculata</i> Fresen	Used to treat epilepsy and convulsions in tropical Africa. Used to headache, skin infection, cough, fever, pneumonia, tuberculosis, malaria, typhoid, stomachache, nervous and circulatory system infection in Nigeria [269,270]		The LD ₅₀ of aqueous root bark extract is 3.16 g/kg [270]	Meningitis, poliomyelitis
<i>Securinega virosa</i> (Roxb. ex Willd.) Baill.	Used to treat rheumatoid, arthritis, eczema and crusted tetter in China, epilepsy and mental illness in West Africa. Used to treat malaria, liver disease, pain and inflammation [271]	Anti-HIV, anticonvulsant activity [271]	The LD ₅₀ of n-butanol root bark is 1257 mg/kg [272]	Hepatitis, lassa fever, yellow fever, poliomyelitis
				Monkey pox (continued on next page)

Table 7 (continued)

<i>Sterculia setigera</i> Delile	Used to treat fever and STDs, boils, whitlow, chickenpox, measles, jaundice, malaria and dysentery in Nigeria [31]. Leaves are used to treat hepatitis in Burkina Faso [15]	Induced total inhibition of poliovirus, astrovirus and HSV [31]	Relatively safe in vivo except at high dose such as 600 mg/kg over prolonged time of 28 days [273]	
<i>Syzygium aromaticum</i> (L.) Merr. & L.M. Perry	Used to treat burns, wound. Used to treat liver, bowel, and stomach disorders in India and China. Used to treat cholera, malaria and scabies [274]	Anti-HSV-1, anti-hepatitis C activity [21,275]	Recognized as safe at 1500 mg/kg [275]	Hepatitis, COVID-19, yellow fever,
<i>Tamarindus indica</i>	Roots are used to treat hepatitis in Burkina Faso. Used to treat respiratory problems, malaria, fever, parasitic infection, abdominal infection, diarrhea and wound healing in African countries. Used to treat meningitis in Kano state, Northwestern Nigeria [15,25,276]	Antiviral activity against hepatitis C [21, 276]	There was side effect on animals fed with seed extract in a two year study [276]	Poliomyelitis, Smallpox, yellow fever, meningitis, monkey pox
<i>Terminalia avicenoides</i> Guill. & Perr.	Bark decoction and infusion are used to treat hepatitis in Burkina Faso, gastrointestinal disorder, syphilis, bloody sputum, cough and skin diseases in Nigeria [15,277]		The LD ₅₀ of stem bark fraction is > 5000 mg/kg [278]	Poliomyelitis, meningitis, monkey pox, yellow fever
<i>Tetrapleura tetraptera</i> (Schum. & Thonn.) Taub	Used to treat leprosy, convulsion, inflammation, rheumatic pains, malaria, asthma [279]		The LC ₅₀ of aqueous stem bark extract on brine shrimp is 438 µg/ml [280]	Smallpox
<i>Trianthema pentandra</i> L.	Used to treat fevers, skin diseases, wound and toothache in Africa [281]			Yellow fever
<i>Vernonia amygdalina</i>	Used to treat malaria, yellow fever, hypertension, measles, boils, burns, stomach ache and vaginal itching in Nigeria, hepatitis in Uganda [16,56]		Aqueous leaf extract was non-lethal to mice at 5000 mg/kg [56]. Consumption of root can cause itching on the tongue [62]	Yellow fever, smallpox, COVID-19, meningitis, monkey pox, hepatitis, lassa fever
<i>Viscum album</i> L.	Used to treat hypertension, epilepsy, and asthma [282]	Antiviral activity against parainfluenza virus 2 [282]	The LD ₅₀ of leaf extract (i.p) is 420.70 mg/kg [283]	Monkey pox, hepatitis, poliomyelitis
<i>Vitellaria paradoxa</i> C. F. Gaertn	Leaves are used to treat hepatitis, malaria, fever, lung disorders, and mental disorders in Burkina Faso, skin disease, typhoid fever, rheumatism and microfilaria in Cameroun, chicken pox, tuberculosis, cough, skin diseases, rash, rheumatism and headache in Nigeria [15,284,285]		The LD ₅₀ of aqueous leaf extract is 12 g/kg [284]	Poliomyelitis, yellow fever, COVID-19, meningitis, monkey pox, hepatitis, smallpox
<i>Xylopiia aethiopica</i> (Dunna)A.Rich	Used to treat diarrhea, cancer in Nigeria, as an emetic in Gabon, Used to treat bronchitis, asthma, stomachache, headache, neuralgia, malaria, cough, epilepsy, anemia and dysentery [31, 286]	Did not inhibit poliovirus, astrovirus and HSV, antiviral activity against measles virus [31,287]	The LD ₅₀ of ethanol fruit extract is 3464 mg/kg [288]	Meningitis, lassa fever, poliomyelitis
<i>Zingiber officinale</i> Roscoe	Used to treat nervous diseases, asthma, catarrh, stroke and airways infection in Chinese medicine, hepatitis in Uganda [16,289]	Antiviral activity against hepatitis C, human respiratory syncytial virus and chikungunya virus [21,290,291]	It is generally considered a safe herbal medicine [289]	Yellow fever, COVID-19
<i>Ziziphus mauritiana</i> Lam.	Used to treat tumor in India, used to treat fever, respiratory diseases, diarrhea, liver disease and epilepsy. Used to treat diarrhea in northern Nigeria [292]	Anti-dengue virus activity [293,294]	Administration of 2000 mg/kg of ethanol fruit extract did not cause toxicity [295]	Hepatitis, monkey pox, meningitis, COVID-19, yellow fever, poliomyelitis

been reported for the medicinal plant *Sarracenia purpurea* and botanical preparations from the plant were proclaimed as a successful therapy against smallpox in the nineteenth century [60,61]. Undoubtedly, this demonstrated the significant role of medicinal plants in treating smallpox.

Plants and natural products are generally considered safe although some plants may be toxic or poisonous. The sap of *Euphorbia unispina* cited herein for treatment of hepatitis, meningitis, yellow fever, and poliomyelitis is poisonous and may cause death. Whereas, ingesting the seed of *A. occidentale* may cause burn and death [62]. However, the majority of the plants is nontoxic or may cause mild toxicity. For instance, the consumption of leaf of *E. guineensis* and *A. conyzoides* may cause gastrointestinal discomfort and stomach upset respectively [62].

4.1. Limitation of the research

The study did not test (*in vitro* and *in vivo*) to validate the claims on the potency of the plants mentioned against the respective viruses which underline the limitation of the present study

5. Conclusion

The present study revealed a total of 131 medicinal plants used to treat emerging and re-emerging viral diseases in northern Nigerian states of Katsina, Kebbi, Kwara, and Sokoto. Pharmacological studies suggested the antiviral activity of some of the plants mentioned herein for specific viral diseases studied. However, the majority of the plants

have not been studied for antiviral activities against the viral diseases they are reportedly used to treat. Therefore, these plants could serve as sources for novel antiviral agents and thus effort should be intensified towards unraveling the bioactivity as well as isolating the potent bioactive agents.

Author contributions

IBA, SK and IM were involved in the conceptual design. JBD, SAJ and UJ were involved in data collection and analysis of data from Kebbi state. IM and HY, were involved in data collection and analysis of data from Sokoto state. SSK collected and analyzed data from Katsina state. YZM, QON, MBF, and SOF collected and analyzed data from Kwara state. AM, IBA and ANUK analyzed the collective data and prepared the manuscript. DS did botanical identification and proof read the manuscript.

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Declaration of Competing Interest

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

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Data availability

Any additional information can be obtained from the author on request.

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