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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.thepiantlist.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 in some northern states; Katsina, Kebbi, Kwara and Sokoto states. 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
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 ethnomedical 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 ethnomedical study could reveal unidentified 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, Kwarar 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, 7.6300° E), Kebbi (11.49420 N, 4.333° E), Sokoto (10.0533° N, 4.3223° E), and Kwarar 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 Kwarar 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/NI * 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. Where Nur is the reported number of taxa used 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), Kwarar (35), and Sokoto (50) states responded to the questionnaires and oral interviews. Demographic data showed that 50% of HMPs were women in Kwarar 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 Kwarar 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 (Table 2), Kebbi (Table 3), Kwarar (Table 4), and Sokoto (Table 5) states. Whereas, a total of 41 medicinal plants were identified in two or more states. The plants Asadirachta 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 Kwarar state (Table 4). Similarly, Acacia nilotica (L.) Delile (70%), Combretum micranthum G. Don. (60%) and Pilostigma reticulatum (DC.) Hochst. (58%) were the frequently mentioned plants in

### Table 1

| s/no | Data     | Sokoto | Katsina | Kebbi | Kwarar |
|------|----------|--------|---------|-------|--------|
| 1    | Age (years%) |        |         |       |        |
| 1    | 18–30     | 10     | 12.4    | 55.8  |        |
| 2    | 31–40     | 20     | 30.0    | 23.5  |        |
| 3    | 41 and above | 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     |
and is often diagnosed by the yellowish coloration of the eye, palms, and swelling of the stomach. Meningitis is referred to as ‘ciwon kabin bau’ and is diagnosed by HMPs through detection of high body fever, persistent headache, and stiffness of muscles. Other infectious diseases such as monkeypox ‘karin bau’ and smallpox ‘karin bau’ are diagnosed using the same method by HMPs which include detection of high body fever, skin rash, and general body itch. 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 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 |
|----------------------------------|-------------|------------|----------------------------------|----------------|--------|-----------------------|--------------------|--------------------|-------|
| Acacia Senegal (L.) Wild         | Fabaceae    | Dakwara    | Gum Arabic tree                  | UMYUH 988      | 12     | Smallpox              | Leaves            | Decoction          | Oral  |
| Azadirachta indica A.Juss.       | Meliaceae   | Darbejiya  | Neem                             | UMYUH 712      | 30     | COVID-19              | Leaves            | Concoction         | Steaming |
| Boscia salicifolia Oliv.         | Capparaceae | Zure       | Willow leaved shepherd tree      | UMYUH 707      | 16     | COVID-19              | Leaves            | Decoction          | Oral  |
| Carica papaya L.                 | Caricaceae  | Gwanda     | Pawpaw                           | UMYUH 2263     | 16     | Hepatitis             | Leaves            | Decoction          | Oral  |
| Cassia occidentalis L.           | Fabaceae    | Tafasar masar | Coffee senna                  | UMYUH 2242     | 16     | Yellow fever          | Whole plant       | Decoction          | Oral  |
| Cassia tora L.                   | Fabaceae    | Tafasa     | Sickle senna                     | UMYUH 763      | 14     | Yellow fever          | Whole plant       | Decoction          | Oral  |
| Centaurea praecox Oliv. & Hiern  | Compositae  | Dayi       | Thistle                          | UMYUH 645      | 16     | COVID-19              | Whole plant       | Maceration         | Oral  |
| Combretum micranthum G. Don      | Combretaceae | Geza      |                                 | UMYUH 2217     | 16     | Yellow fever          | Leaves            | Decoction          | Oral  |
| Diospyros mespiliformis Hochst.  | Ebenaceae   | Kanya      | Jackalberry                      | UMYUH 124      | 14     | Yellow fever          | Leaves            | Decoction          | Oral  |
| Eucalyptus globulus Labill        | Myrtaceae   | Turare     | Blue gum                         | UMYUH 666      | 30     | Yellow fever          | Leaves            | Concoction         | Steaming |
| Ficus polius Vahl                | Moraceae    | Durumi     | Heart leaved fig                 | UMYUH 1890     | 8      | COVID-19              | Leaves            | Decoction          | Oral  |
| Ficus sycomorus L.               | Moraceae    | Baure      | Fig mulberry                      | UMYUH 1830     | 8      | Yellow fever          | Leaves/bark       | Decoction          | Oral  |
| Guiera senegalensis J.F. Gmel    | Combretaceae | Sabara           |                                 | UMYUH 49       | 18     | Yellow fever          | Leaves            | Decoction          | Oral  |
| Lapidium sativum L.              | Brassicaeae | Zamantarore | Garden cress                     | UMYUH 2075     | 8      | Meningitis            | Leaves            | Decoction          | Oral  |
| Ludwigia octovalvis (Jacq.)      | Onagraceae  | Shashatou   | Mexican primose willow           | UMYUH 2536     | 8      | Meningitis            | Leaves            | Decoction          | Oral  |
| Mangifera indica L.              | Anacardiaceae | Mangwaro     | Mango                            | UMYUH 1921     | 14     | Yellow fever          | Leaves            | Decoction          | Oral  |
| Moringa oleifer Lam.             | Moringaceae | Zogale     | Drumstick tree                   | UMYUH 1858     | 12     | Yellow fever          | Leaves            | Decoction          | Oral  |
| Musa sapientum L.                | Musaceae    | Ayabsa     | Banana                           | UMYUH 2293     | 10     | Hepatitis             | Leaves            | Decoction          | Oral  |
| Parkia biglobosa (Jacq.) G. Don   | Fabaceae    | Dorawa     | African locus bean               | UMYUH 1274     | 10     | Yellow fever          | Leaves            | Decoction          | Oral  |
| Phyllanthus amarus Schumach. & Thonn. | Phyllanthaceae | Geron     | Stone breaker                    | UMYUH 2524     | 8      | Hepatitis             | Leaves            | Decoction          | Oral  |
| Philosigma thomningii (Schum.)    | Fabaceae    | Tsuntsaie  |                                 | UMYUH 27       | 12     | Hepatitis             | Leaves            | Decoction          | Oral  |
| Piper guineense Schumach. & Thonn. | Piperaceae | Masoro     | Black pepper                     | UMYUH 2507     | 10     | COVID-19              | Seed              | Concoction         | Oral  |
| Prospis africana (Guill. & Perr.) Taub. | Fabaceae | Kiriya     | Iron tree                        | UMYUH 63       | 18     | Yellow fever          | Leaves            | Decoction          | Oral  |
| Sag屁um guaramii (Stapf) Prain    | Euphorbiaceae | Yazawa     |                                 | UMYUH 12       | 12     | Yellow fever          | Bark              | Decoction          | Oral  |
| Sclerocarya birrea (A. Rich.) Hochst. | Anacardiaceae | Danya  | Marula                          | UMYUH 2256     | 10     | Yellow fever          | Leaves            | Decoction          | Oral  |
| Stereospermum kunthianum Cham.    | Bignoniaceae | Sansami   | Tulip tree                       | UMYUH 675      | 8      | Yellow fever          | Leaves            | Decoction          | Oral  |
| Syzygium aromaticum (L.) Merr. & L.M.Perry | Myrtaceae | Kananfari | Clove                            | UMYUH 681      | 30     | COVID-19              | Seeds             | Decoction          | Oral  |
| Tephrosia linearis                | Fabaceae    | Tsintsiyar mahalba               |                                 | UMYUH 1880     | 10     | Smallpox             | Leaves            | Maceration         | Topical |
| Terminalia arvencisoides Guill. & Perr. | Combretaceae | Baunhe |                                 | UMYUH 669      | 16     | Yellow fever          | Bark              | Decoction          | Oral  |
| Trianechus pentandra 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 ‘karin bau’ and smallpox ‘karin bau’ are diagnosed using the same method by HMPs which include detection of high body fever, skin rash, and general body itch. 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
| s/no | Plant name | Family | Local name | Common Name | Voucher no | CF (%) | Disease treated | Parts used | Mode of preparation | Route |
|------|-------------|--------|------------|-------------|------------|--------|----------------|------------|--------------------|-------|
| 1.   | *Acacia nilotica* (L.) Delile | Mimosaceae | Bagaaruwa | Scented thorn | Kustua/psb/h/voucher no:294 | 15.1 | Hepatitis, monkey pox, meningitis, smallpox, poliomyelitis, COVID-19 | Leaf/stem | Decoction/ prepared with pap | Orally |
| 2.   | *Adansonia digitata* L. | Bombacaceae | Kuka | Baobab | Kustua/psb/h/voucher no:266 | 38.4 | Poliomyelitis, smallpox, yellow fever, meningitis, monkey pox, hepatitis | Stem bark | Decoction | Orally |
| 3.   | *Aframomum melegueta* K. Schum. | Zingiberaceae | Ciita | Alligator pepper/ grains of paradise | Kustua/psb/h/voucher no: s.n | 38.4 | Hepatitis, monkey pox, COVID-19, poliomyelitis, yellow fever | Whole plant | Decoction | Orally |
| 4.   | *Allium cepa* L. | Liliaceae | Albasa | Onion | Kustua/psb/h/voucher no: s.n | 12.3 | Poliomyelitis, meningitis, COVID-19, smallpox, meningitis | Bulb | Poultice/ the bulb is cut into pieces and added to a burning charcoal | Inhalation |
| 5.   | *Allium sativum* L. | Amaryllidaceae | Tafarnuwa | Garlic | Kustua/psb/h/voucher no: 356 | 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.   | *Aloe vera* (L.) Burm.f. | Liliaceae | Aloe vera | Aloe vera | Kustua/psb/h/voucher no: s.n | 1.36 | Meningitis | Whole plant | Decoction | Orally |
| 7.   | *Ananas comosus* (L.) Merr. | Bromeliaceae | Abarba | Pineapple | Kustua/psb/h/voucher no: s.n | 1.4 | Meningitis | Bark peel | Concoction/ boiled with banana | Oral |
| 8.   | *Annona senegalensis* Pers. | Annonaceae | Gwanda daji | Wild custard apple | Kustua/psb/h/voucher no: 504 | 1.4 | Poliomyelitis | Leaf and stem | Concoction | Orally |
| 9.   | *Angenum leiopterum* (DC.) Guill. & Perr. | Combretaceae | Marke | African Birch | Kustua/psb/h/voucher no: s.n | 2.7 | Monkey pox, poliomyelitis | Stem bark | Concoction/ boil with red potash and the | Orally |
| 10.  | *Azadirachta indica* A. Juss. | Meliaceae | Dogonyaro | Neem | Kustua/psb/h/voucher no: 61 | 68.5 | Smallpox, monkey pox, COVID-19, poliomyelitis, yellow fever, meningitis | Leaf | Decoction | Orally |
| 11.  | *Balanites aegyptica* (L.) Delile | Balanitaceae | Aduwa | Desert date | Kustua/psb/h/voucher no: 291 | 41.1 | Hepatitis, monkey pox, meningitis, smallpox, poliomyelitis | Stem bark | Decoction | Orally |
| 12.  | *Boscia senegalensis* (Pers.) Lam. ex Pior. | Combretaceae | Anza | Aizen | Kustua/psb/h/voucher no: s.n | 1.4 | Monkey pox | Root | Ointment/ root powder is mixed with salt and petroleum jelly (vasline) | Topically |
| 13.  | *Boswellia dalzielii* Hutch. | Burseraceae | Hanno | Frankincense tree | Kustua/psb/h/voucher no: s.n | 1.4 | Poliomyelitis, smallpox | Stem bark | Decoction | Orally |
| 14.  | *Bridelia ferruginea* Benth. | Phyllanthaceae | Kizni | | Kustua/psb/h/voucher no: s.n | 1.4 | Poliomyelitis | Leaf | Decoction | Orally |
| 15.  | *Calotropis procera* (Aiton) Dryand | Apocynaceae | Tumfaiya | Sodom apple | Kustua/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, Orally twice daily for ten days. |
| 16.  | *Carica papaya* L. | Caricaceae | Gwanda | Pawpaw | Kustua/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 | Decoction | Orally |
| 17.  | *Cassia occidentalis* L. | Fabaceae | Sanga sanga | Coffee senna | Kustua/psb/h/voucher no: s.n | 41.1 | Hepatitis, meningitis, COVID-19, yellow fever, poliomyelitis | Leaf | Concoction | Orally |
| 18.  | *Cassia singueana* Delile | Fabaceae | Runhu | Sticky pod | Kustua/psb/h/voucher no: s.n | 1.4 | Monkey pox | Leaf | Decoction | Orally |

(continued on next page)
| No. | Scientific Name                  | Family          | Common Name            | Description                                      | Use     | Administration                      | Dosage |
|-----|----------------------------------|-----------------|------------------------|--------------------------------------------------|---------|-------------------------------------|--------|
| 19. | *Cassia tora* L                  | Fabaceae        | Tafasa                 | Sickle senna                                      | Ksusta/pb/ | h/voucher no: s.n                  | 4.1    |
|     |                                  |                 |                        |                                                  | Leaf    | Decoction                          | Orally |
| 20. | *Cissus populnea* Guill. & Perr. | Vitaceae        | Loda                   |                                                  | Ksusta/pb/ | h/voucher no: 307                  | 8.2    |
|     |                                  |                 |                        |                                                  | Stem bark| Decoction                          | Orally |
| 21. | *Citrus aurantiifolia* (Christm.) Swingle | Rutaceae | Lemun tsami             | Lemon                                            | Ksusta/pb/ | h/voucher no: 285                  | 1.4    |
|     |                                  |                 |                        |                                                  | Leaf    | Decoction                          | Orally |
| 22. | *Citrullus lanatus* (Thunb.) Matsum. & Nakai | Cucurbitaceae | Kankana                | Water melon                                       | Ksusta/pb/ | h/voucher no: 285 a                 | 20.5   |
|     |                                  |                 |                        |                                                  | Seed    | Decoction                          | Orally |
| 23. | *Citrus sinensis*                | Rutaceae        | Lemun zaki             | Orange                                           | Ksusta/pb/ | h/voucher no: 284                  | 32.9   |
|     |                                  |                 |                        |                                                  | Leaves  | Decoction                          | Orally |
| 24. | *Combretum glutinosum* Perr.     | Combretaceae    | Tarauniya              |                                                  | Ksusta/pb/ | h/voucher no: s.n                  | 1.4    |
|     |                                  |                 |                        |                                                  | Stem bark| Decoction                          | Orally |
| 25. | *Combretum nigricans* Lepr. Ex Guill. & Perr. | Combretaceae | Tsiriri                |                                                  | Ksusta/pb/ | h/voucher no: s.n                  | 1.4    |
|     |                                  |                 |                        |                                                  | Root    | Powder                             | Orally |
| 26. | *Cucurbita maxima* Duchesne     | Cucurbitaceae   | Kabewa                 | Pumpkin                                          | Ksusta/pb/ | h/voucher no: s.n                  | 19.2   |
|     |                                  |                 |                        |                                                  | Leaf and seed| Decoction                          | Orally |
| 27. | *Detarium senegalense* J. F. Gmel. | Fabaceae | Taura                  | Tallow tree                                       | Ksusta/pb/ | h/voucher no: s.n                  | 10.9   |
|     |                                  |                 |                        |                                                  | Stem bark| Decoction                          | Orally |
| 28. | *Diospyros mespiliformis* Hochst. ex A.DC. | Ebenaceae | Kanya                  | Jackalberry                                       | Ksusta/pb/ | h/voucher no: 182                  | 46.6   |
|     |                                  |                 |                        |                                                  | Stem bark| Concocion or powdered stem bark is mixed with powder of tamarind and *Adansonia digitata* and shea butter to make as ointment | Orally or ointment is applied topically |
| 29. | *Evolvulus alsinoides* Linn.     | Convolvulaceae  | Kabiliikita            | Dwarf morning-glory                               | Ksusta/pb/ | h/voucher no: 523                  | 2.7    |
|     |                                  |                 |                        |                                                  | Leaf    | Decoction                          | Orally |
| 30. | *Ficus platyphylla* Delile       | Moraceae        | Gamji                  | Broad leaf Fig                                    | Ksusta/pb/ | h/voucher no: s.n                  | 20.5   |
|     |                                  |                 |                        |                                                  | Stem bark powder| Decoction                          | Orally and or bathing |
| 31. | *Ficus polita* Vahl              | Moraceae        | Durumi                 | Heart leaved fig                                  | Ksusta/pb/ | h/voucher no: s.n                  | 13.7   |
|     |                                  |                 |                        |                                                  | Leaf    | Decoction                          | Orally |
| 32. | *Ficus sycomorus*                | Moraceae        | Baure                  | Fig mulberry                                      | Ksusta/pb/ | h/voucher no: s.n                  | 8.2    |
|     |                                  |                 |                        |                                                  | Leaf and stem bark| Decoction                          | Orally |
| 33. | *Ficus thonningii* Blume         | Moraceae        | Chediya                | Common wild fig                                   | Ksusta/pb/ | h/voucher no: s.n                  | 2.7    |
|     |                                  |                 |                        |                                                  | Leaf/stem bark| Decoction                          | Orally |
| 34. | *Gardenia erubescens* Stapf. & Hutch | Rubiaceae | Gaude                  |                                                  | Ksusta/pb/ | h/voucher no: s.n                  | 2.7    |
|     |                                  |                 |                        |                                                  | Leaf    | Decoction                          | Orally |
| 35. | *Guiera senegalensis* J.F. Gmel. | Combretaceae    | Sabara                 | Moshi medicine                                    | Ksusta/pb/ | h/voucher no: s.n                  | 42.5   |
|     |                                  |                 |                        |                                                  | Leaf    | Decoction/ prepared with pap      | Orally |
| 36. | *Lannea microcarpa* Engl. & K. Krause | Anacardiaceae | Faru                   | African grape                                     | Ksusta/pb/ | h/voucher no: s.n                  | 15.1   |
|     |                                  |                 |                        |                                                  | Stem bark| Decoction                          | Orally for four days. |

(continued on next page)
| No. | Plant Name                                      | Family   | Common Name | GenBank Accession | Leaves | Decoction          | Uses                                                                 |
|-----|-----------------------------------------------|----------|-------------|-------------------|--------|--------------------|----------------------------------------------------------------------|
| 37  | Lawsonia inermis L.                           | Lythraceae | Lalle       |                   |        | Decoction          | Monkey pox, meningitis, COVID-19, yellow fever, hepatitis             |
| 38  | Lepademia hastate Vatke                       | Apocynaceae | Yadiya      |                   |        | Decoction          | Monkey pox, meningitis, COVID-19, smallpox                            |
| 39  | Mangifera indica L.                           | Anacardiaceae | Mangwaro   | Mango             |        | Decoction          | Monkey pox, meningitis, COVID-19, yellow fever, poliomyelitis, smallpox |
| 40  | Maytenus senegalensis (Lam.) Exell            | Celastraceae | Namijin tsada | Spike thorn       |        | Powder             | Monkey pox                                                           |
| 41  | Momordica charantia L.                        | Cucurbitaceae | Garahuni   | Balsam pear       |        | Decoction          | Monkey pox, meningitis, COVID-19, yellow fever, hepatitis           |
| 42  | Moringa oleifera Lam.                         | Moringaceae | Zogala      | Moringa           |        | Powder             | Monkey pox, meningitis, COVID-19, yellow fever, poliomyelitis       |
| 43  | Musa sapientum L.                             | Musaceae  | Ayaba       | Banana            |        | Powder             | Can be boiled with pineapple bark peel                               |
| 44  | Nicotiana tabacum L.                          | Euphorbiaceae | Tinya      |                   |        | Decoction          | Meningitis                                                          |
| 45  | Nigella sativa L.                             | Ransunculaceae | Habbatu   | sauda             | Black cumin | Pigment use        | Monkey pox, smallpox, hepatitis                                     |
| 46  | Olea europea L.                               | Oleaceae  | Zaitun      | Olive             |        | Decoction          | Smallpox, yellow fever, COVID-19, monkey pox                         |
| 47  | Parkia biglobosa (Jacq.) G.Don                | Mimosaceae | Dorawa      | African locust    |       | Decoction          | Monkey pox, meningitis, COVID-19, yellow fever, poliomyelitis       |
| 48  | Parinari macrophylla Sabine                   | Chrysobalanaceae | Gwasa   |                   |        | Decoction          | Poliomyelitis, monkey pox                                           |
| 49  | Pilosigma thonningii (Schum.) Milne-Redh.     | Fabaceae  | Kalgo       | Wild bauhinia     |        | Pigment use        | Poliomyelitis, smallpox, meningitis                                |
| 50  | Piper guineense Schumach. & Thonn.            | Piperaceae | Masoro     | Ashanti pepper    |        | Powder             | Poliomyelitis, yellow fever, hepatitis                               |
| 51  | Prosopis africana (Guill. & Perr.) Taub.      | Fabaceae  | Kirya       | Iron tree         |        | Decoction          | Meningitis                                                          |
| 52  | Psidium guajava L.                            | Myrtaceae | Gwaiba      | Guava             |        | Powder             | Monkey pox                                                          |
| 53  | Securidaca longipedunculata Fresen             | Polygalaceae | Uwa      | magunguna         | Violet tree | Decoction          | Monkey pox                                                          |
| 54  | Sterculia setigeru Delile                     | Malvaceae | Kukkuki    | Karaya gum tree   |        | Powder             | Monkey pox                                                          |

(continued on next page)
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 Oterè’ are diagnosed by HMPs in Kwaras 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 Kamarawa 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 occidentals 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 hastate 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].

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| s/no | Plant name | Family | Local name | Common Name | Voucher no | CF (%) | Disease treated | Parts used | Mode of preparation | Route |
|------|------------|--------|------------|-------------|------------|--------|----------------|------------|---------------------|-------|
| 1.   | *Aframomum melegueta* 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. |
| 2.   | *Ageratum conyzoides* (L.) L. | Compositae | Imi-esu | billygoat weed, | Ksusta/psb/h/voucher no: sn | 14.3 | Hepatitis, lassa fever, poliomyelitis | Stem bark | Powder | Two spoon daily |
| 3.   | *Alafia barteri* Oliv. | Apocynaceae | Agbari-etu | | Ksusta/psb/h/voucher no: sn | 8.6 | Meningitis, lassa fever | Leaf | Decoction | Orally |
| 4.   | *Aloe vera* (L.) Burm.f. | Xanthorrhoeaceae | Ewe erin | Aloe vera | Ksusta/psb/h/voucher no: 356 | 8.6 | Meningitis, lassa fever | Leaf | Decoction. Powder is mixed with shea butter and used ointment | Topical |
| 5.   | *Aloe barteri* (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.   | *Alstonia boonei* De Wild | Apocynaceae | Ahun | Stool wood | Ksusta/psb/h/voucher no: sn | 37.1 | Lassa fever, Yellow fever, monkey pox, smallpox | Stem bark | Decoction | Orally |
| 7.   | *Anacardium occidentale* L | Anacardiaceae | ewe kasu | Cashew | Ksusta/psb/h/voucher no: 63 | 17.1 | Lassa fever, yellow fever | Leaf | Decoction | Orally |
| 8.   | *Ananas comosus* (L.) Merr. | Bromeliaceae | Ope oynbo | Pineapple | Ksusta/psb/h/voucher no: sn | 28.6 | Lassa fever, yellow fever, COVID-19 | Bark peel | Decoction | Orally |
| 9.   | *Anogeissus leiocarpus* (DC.) Guill. & Perr | Combretaceae | Ayin | | Ksusta/psb/h/voucher no: sn | 11.4 | COVID-19 | Roots | Decoction | Orally |
| 10.  | *Aristolochia ringens* | Aristolochiaceae | Akogun | Dutchman’s pipe | Ksusta/psb/h/voucher no: 61 | 5.7 | Yellow fever, lassa fever | Leaves | Decoction | Orally |
| 11.  | *Azadirachta indica* 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.  | *Bidens pilosa* L. | Compositae | Abeere | Black Jack seed | Ksusta/psb/h/voucher no: sn | 2.9 | COVID-19 | Seed | Decoction | Orally |
| 13.  | *Bridelia exulata* F. Muell. | Phyllanthaceae | Ira | Scrub ironbark, brush ironbark | Ksusta/psb/h/voucher no: sn | 8.6 | Lassa fever | Stem bark | Decoction | Orally |
| 14.  | *Byrsocarpus coccinus* Schumach & Thonn. | Conaraceae | Amuje weve | Huntsman’s pepper | Ksusta/psb/h/voucher no: sn | 34.3 | Hepatitis, meningitis, lassa fever, yellow fever, smallpox, poliomyelitis | Leaves | Decoction | Orally |
| 15.  | *Catalpa procera* (Aiton) Dryand | Apocynaceae | Bomobom | Sodom apple, rubber bush | Ksusta/psb/h/voucher no: 03 | 8.6 | Poliomyelitis | Leaf | Decoction | Orally |
| 16.  | *Carica papaya* L. | Caricaceae | Ewe ibepe | Pawpaw | Ksusta/psb/h/voucher no: sn | 5.7 | Hepatitis | Leaf | Decoction | Orally |
| 17.  | *Celastrus indica* | Celastraceae | Ponju-owiwi | Bittersweet | Ksusta/psb/h/voucher no: sn | 17.1 | Hepatitis, meningitis, yellow fever | Root | Decoction | Orally twice daily. |
| 18.  | *Chasmaphyllum dependens* Hochst. | Menispermaceae | Attoo | | Ksusta/psb/h/voucher no: sn | 14.3 | Poliomyelitis, meningitis | Leaves | Decoction | Orally |

*continued on next page*
| No. | Species Name | Family | Common Name | Preparation Method | Effects | Parts Used | Treatment Duration |
|-----|--------------|--------|-------------|--------------------|---------|------------|--------------------|
| 19. | *Chenopodium ambrosioides* L. | Amaranthaceae | Mexican tea | Kuasta/psh/ h/voucher no: sn | 17.1 | Poliomyelitis, Meningitis | Root Decoction Orally |
| 20. | *Chloris pilosa* Schumach. & Thonn. | Poaceae | Ewe gbegi | Kuasta/psh/ h/voucher no: sn | 20 | Poliomyelitis, lassa fever | Roots To be soaked in water for 24 h Orally for three (3) days |
| 21. | *Citrus aurantifolia* (Christm.) Swingle | Rutaceae | Citrus lemon | Kuasta/psh/ h/voucher no: 285 | 5.7 | Yellow Fever | Leaf Decoction Orally |
| 22. | *Cymbopogon citratus* (DC.) Stapf | Poaceae | Lemon grass | Kuasta/psh/ 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. | *Elaeis guineensis* Jacq. | Arecaceae | African oil palm | Kuasta/psh/ h/voucher no: sn | 80 | Hepatitis, meningitis, lassa fever, yellow fever, poliomyelitis | Roots Decoction Orally |
| 24. | *Enantia chlorantha* Oliv. | Annonaceae | Africa yellow wood | Kuasta/psh/ h/voucher no: sn | 48.6 | Poliomyelitis, meningitis, lassa fever, yellow fever | Stem bark Decoction Orally |
| 25. | *Entandrophragma utile* (Dawe & Sprague) Sprague | Meliaceae | Ewe tea Lemon grass | Kuasta/psh/ h/voucher no: sn | 5.7 | Poliomyelitis, yellow fever | Leaf/bark Decoction Orally and use for bathing |
| 26. | *Euphorbia hirta* L | Euphorbiaceae | Asthma weeds | Kuasta/psh/ h/voucher no: sn | 51.4 | Hepatitis, meningitis, lassa fever, yellow fever, poliomyelitis, monkey pox, smallpox, COVID-19 | Stem bark Decoction Orally |
| 27. | *Euphorbia lateriflora* Schumach. | Euphorbiaceae | Enusopiye | Kuasta/psh/ h/voucher no: sn | 5.7 | Smallpox | Stem bark Decoction Orally and use for bathing One teaspoon to be taken orally every morning. Orally |
| 28. | *Euphorbia unispina* NE Br. | Euphorbiaceae | Oro adete | Kuasta/psh/ h/voucher no: sn | 22.9 | Hepatitis, meningitis, yellow fever, poliomyelitis | Leaves Decoction Orally |
| 29. | *Garcinia kola* Heckel | Clusiaceae | Bitter kola | Kuasta/psh/ h/voucher no: sn | 31.4 | Hepatitis, meningitis, lassa fever, yellow fever, poliomyelitis | Roots Decoction Orally |
| 30. | *Harungana madagascariensis* Lam. ex Poiz Jatropha curcas L. | Hypericaceae | Aroje | Kuasta/psh/ h/voucher no: sn | 11.4 | Hepatitis, meningitis, poliomyelitis | Leaves Decoction Orally |
| 31. | *Jatropha curcas* L. | Euphorbiaceae | Lapalapa | Kuasta/psh/ h/voucher no: sn | 8.6 | Meningitis, lassa fever | Leaf Decoction Orally, one cup daily |
| 32. | *Kigelia africana* (Lam.) Benth | Bignoniaceae | Sussage tree | Kuasta/psh/ h/voucher no: sn | 14.3 | Hepatitis, yellow fever, poliomyelitis | Leaves Decoction Orally, two (2) tea spoon to be taken twice daily. Orally |
| 33. | *Lagenaria breviflora* (Benth.) Roberty | Cucurbitaceae | Wild colocynth | Kuasta/psh/ h/voucher no: sn | 22.9 | Monkey pox, smallpox | Leaf Decoction Orally |
| 34. | *Launaea microcarpa* Engl. & K.Krause | Anacardiaceae | Ekuadan | Kuasta/psh/ h/voucher no: sn | 11.4 | Hepatitis, meningitis, lassa fever | root Decoction Orally |
| 35. | *Lawsonia inermis* L. | Lythraceae | Henna, Egyptian privet, cypress, shrub | Kuasta/psh/ h/voucher no: 41 | 5.7 | Lassa fever | Leaf Decoction Orally |
| 36. | *Mangifera indica* L. | Anacardiaceae | Mango | Kuasta/psh/ h/voucher no: 63 | 31.4 | Meningitis, lassa fever, monkey pox, smallpox, COVID-19, hepatitis | Stem bark Decoction. It is mixed with stem bark of awopa, ahun and egbesi. The juice is used to prepare pap Orally |
| 37. | *Momordica charantia* L. | Cucurbitaceae | Balsam pear | Kuasta/psh/ h/voucher no: sn | 48.6 | Meningitis, lassa fever, yellow fever, poliomyelitis | Leaves Decoction Orally |
| No. | Species                  | Family     | Common Names                        | Part Used        | Plants/Herbal Component(s) Used | Therapies                                                                 |
|-----|--------------------------|------------|-------------------------------------|------------------|---------------------------------|----------------------------------------------------------------------------|
| 38  | Morinda lucida Benth.    | Rubiaceae  | Ewe oruwo Brimestone tree           | Roots            | Concoction, mixed with dokita   | Juice to be taken twice daily.                                             |
|     |                          |            |                                     |                  | epo cocoa(stb) and amuje(stb)   |                                                                            |
| 39  | Musa sapientum L.        | Musaceae   | Ogede wewe Banana                   | Roots            | Hepatitis, meningitis, lassa   | Orally                                                                     |
|     |                          |            |                                     |                  | fever, poliomyelitis           |                                                                            |
| 40  | Neeaulea latifolia Sm.   | Rubiaceae  | Koro Egbesi                         | Roots            | Hepatitis, lassa fever,        | Orally for three (3) days.                                                |
|     |                          |            |                                     |                  | poliomyelitis                   |                                                                            |
| 41  | Nicotiana tabacum L.     | Solanaceae | Taba juku Tobacco                   | Roots            | Crude                           | Orally                                                                     |
|     |                          |            |                                     |                  |                                |                                                                            |
| 42  | Nymphaea lotus L.        | Nymphaeaceae| Ewe osibata White lotus             | Roots            | Hepatitis, meningitis, lassa   | Orally                                                                     |
|     |                          |            |                                     |                  | fever, poliomyelitis           |                                                                            |
| 43  | Ocimum basilicum L.      | Lamiaceae  | Ewe Efiran Sweet Basil             | Roots            | Hepatitis, meningitis,         | Orally                                                                     |
|     |                          |            |                                     |                  | hepatitis, poliomyelitis       |                                                                            |
| 44  | Phyllanthus amarus Schumach. & Thonn. | Phyllanthaceae | Eyiin olome                         | Roots            | COVID-19, hepatitis             | Orally                                                                     |
|     |                          |            |                                     |                  | Stems                          |                                                                            |
| 45  | Piper guineense Schumach. & Thonn. | Piperaceae | Koko lyere Ashanti pepper           | Roots            | Hepatitis, meningitis, lassa   | Orally                                                                     |
|     |                          |            |                                     |                  | fever, poliomyelitis           |                                                                            |
| 46  | Plumbago zeylanica L.    | Plumbaginaceae | Ewe inahiri Ceylon leadwort         | Roots            | Meningitis, yellow fever,      | Orally                                                                     |
|     |                          |            |                                     |                  | lassa fever, poliomyelitis     |                                                                            |
| 47  | Psidium guajava L.       | Myrtaceae  | Gurofa Guava                        | Roots            | COVID-19, lassa fever           | Orally                                                                     |
|     |                          |            |                                     |                  | Stems                          |                                                                            |
| 48  | Pycnanthus angolensis (Welw.) Warb. | Myristicaceae | Akomu African nutmeg                | Roots            | Poliomyelitis, yellow fever    | Orally                                                                     |
|     |                          |            |                                     |                  | Stems                          |                                                                            |
| 49  | Ricinus communis L.      | Euphorboraceae | Ewe lara Castor oil meg            | Roots            | Yellow fever, poliomyelitis    | Orally                                                                     |
|     |                          |            |                                     |                  |                                |                                                                            |
| 50  | Saccharum officinarum L. | Poaceae    | Ireke Sugar cane                    | Whole plant      | Yellow fever, poliomyelitis    | Orally                                                                     |
|     |                          |            |                                     |                  |                                |                                                                            |
| 51  | Secamone afzelii (Roem. & Schult.) K.Schum. | Apocynaceae | Ewe Arilu                          | Roots            | Poliomyelitis, yellow fever    | Orally                                                                     |
|     |                          |            |                                     |                  | Stems                          |                                                                            |
| 52  | Securidaca longipedunculata Fresen | Polygalaceae | Egbo ipeta Violet tree              | Roots            | Poliomyelitis                   | Orally                                                                     |
|     |                          |            |                                     |                  | Leaf/stem                      |                                                                            |
| 53  | Securinega virosa (Roxb. ex Willd.) Baill. | Phyllanthaceae | Iranje                             | Roots            | Hepatitis, lassa fever,        | Orally                                                                     |
|     |                          |            |                                     |                  | poliomyelitis                   |                                                                            |
| 54  | Spondias mombin L.       | Anacardiaceae | Iyeye Yellow mombin                 | Seeds            | Yellow fever                    | Orally                                                                     |
|     |                          |            |                                     |                  |                                |                                                                            |
| 55  | Syzygium aromaticum (L.) Merr. & L.M.Perry | Myrtaceae | Kanafuru Clove                      | Seeds            | COVID-19                        | Orally                                                                     |
|     |                          |            |                                     |                  |                                |                                                                            |
| 56  | Tamarindus indica L.     | Caesalpinaceae | Ajagbon Tamarind tree               | Seeds            | Monkey pox, smallpox            | Orally and use for bathing                                                |

(continued on next page)
An ethnomedicinal study identified *M. indica*, *Aloë 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 IC$_{50}$ 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%), *Balantrea aegyptiaca* (8.4%), *Cymbopogon citratus* (54.3%), *Lepidium sativum* (45.1%), *Nutmeg 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 oleifera* (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 inflammatory 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. olfera* 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 northern 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 aveneoides*, *M. indica*, and *C. micranthum* and the most frequently used plants to treat poliomyelitis. Whereas, *Anogeissus leiocarpus*, *Momordica charantia*, *Musa sapientum*, *Pilostigma 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, *A. digitata*, *A. indica*, *Boswellia dalzielii*, *Garcinia kola*, and *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

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**Table 4 (continued)**

| No. | Family | Genus, Species | Common Name | Part | Month | Origin | Standard Preparation | Mode of Administration |
|-----|--------|----------------|-------------|------|-------|--------|----------------------|------------------------|
| 58. | Fabaceae | *Adansonia digitata* (L.) J. J. de Wilde | Dwarf baobab | Seed | any | Kebbi, Sokoto | Decoction | Oral |
| 59. | Fabaceae | *Azadirachta indica* A. Juss. | Neem | Leaf | dry | Kebbi | Decoction | Oral |
| 60. | Compositae | *Bidens pilosa* L. | Burundi | Leaf | all | Kebbi, Sokoto, Katsina | Decoction | Oral |
| 61. | Compositae | *Cynara cardunculus* L. | Artichoke | Leaf | any | Kebbi, Sokoto, Katsina | Decoction | Oral |

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**Note:** The table continues with additional entries, each corresponding to a specific medicinal plant, its common name, part used, month of use, origin, standard preparation, and mode of administration.
| s/no | Plant name                  | Family            | Local name | Common Name | Voucher no   | CF (%) | Disease treated                  | Parts used | Mode of preparation | Route               |
|------|----------------------------|-------------------|------------|-------------|--------------|--------|-----------------------------------|------------|---------------------|---------------------|
| 1.   | *Acacia nilotica* (L.) Delile | Mimosaceae        | Bagaruwa   | Scented thorn | Kusta/pbh/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.   | *Allium sativum* L.         | Amaryllidaceae    | Tafarnuwa  | Garlic      | Kusta/pbh/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 2-3 times daily |
| 3.   | *Aloe vera* (L.) Burm.f.    | Liliaceae         | Aloe vera  | Aloe vera   | Kusta/pbh/h/ voucher no: 356 | 6      | Hepatitis                         | Jell       | Slice aloe leave and remove the jell. Grind until smooth | 2-3 cup full to be taken orally twice daily |
| 4.   | *Anacardium occidentale* L. | Anacardiaceae     | Cashew     |            | Kusta/pbh/h/ voucher no: 63 | 2      | Smallpox                         | Root       | Boil in water          | 2-3 cup full to be taken orally 2-3 times daily |
| 5.   | *Anogeissus leiocarpus* (DC.) Guill. & Perr. | Combretaceae | Marke | African birch | Kusta/pbh/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 cup full to be taken orally twice daily |
| 6.   | *Annona senegalensis* Pers. | Annonaceae        | Gwanda daji | Wild custard apple | Kusta/pbh/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.   | *Asadirachta indica* A. Juss. | Meliaceae        | Darbejiya  | Neem        | Kusta/pbh/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.   | *Bosica senegalensis* (Pers.) Lam. ex Fior. | Capparaceae     | Anza       | Aizen       | Kusta/pbh/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.   | *Cassia occidentale* L.     | Fabaceae          | Tafasar    | Coffee senna | Kusta/pbh/h/ voucher no: 71 | 2      | Meningitis                      | Leaf       | Infusion                  | To be applied to the affected part of the body |
| 10.  | *Cassia singueana* Delile   | Fabaceae          | Runhu      | Sticky pod  | Kusta/pbh/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.  | *Carica papaya* L.          | Caricaceae        | Gwanda     | Pawpaw      | Kusta/pbh/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.  | *Cinnamomum verum* J. Presl | Lauraceae         | Cinnamon tree |             | Kusta/pbh/h/ voucher no: s.n | 2      | Yellow fever                    | Stem       | Boil in water          | To be taken orally |
| 13.  | *Cirtus limon* (L.) Osbeck  | Rutaceae          | Lemon      |             | Kusta/pbh/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.  | *Cochlospermum tinctorum* Perrier ex A. Rich. | Bixaceae        | Rawaya     |             | Kusta/pbh/h/ voucher no: s.n | 30     | Yellow fever Hepatitis           | Root, bark, leaf | Boil in water          | To be taken orally |
| 15.  | *Combretum micranthum* G. Don. | Combretaceae     | Geza       |             | Kusta/pbh/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.  | *Cordia africana* Lam.      | Boraginaceae      |             |             | Kusta/pbh/h/ voucher no: s.n | 52     | Hepatitis, yellow fever          | Root, leaf, seed, bark | Boil in water | To be taken orally |
| 17.  | *Cymbopogon cirratus* (DC.) Stapf | Poaceae        | Lemon grass |             | Kusta/pbh/h/ voucher no: s.n | 4      | Hepatitis                        | Leaf       | Boil in water          | 2 cup full to be taken orally twice daily |
| 18.  | *Detarium senegalense* J.F. Gmel | Fabaceae      | Taura      | Detar/tallow tree | Kusta/pbh/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.  | *Eleusine coracana* (L.) Gaertn. | Poaceae       | Finger millet |             | Kusta/pbh/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 twice daily |
| 20.  | *Erythrina senegalensis* DC. | Fabaceae         | Coral tree |             | Kusta/pbh/h/ voucher no: s.n | 54     | Poliomyelitis, lassa fever, yellow fever | Leaf, bark | Boil in water          | 2-3 cup full to be taken orally twice daily |
| 21.  | *Eucalyptus globulus* Labill | Myrtaceae        | Blue gum   |             | Kusta/pbh/h/ voucher no: s.n | 2      | COVID-19                         | Leaf       | Boil in water          | 2-3 cup full to be taken orally twice daily |
| 22.  | *Ficus glomosa* Delile      | Moraceae         | Kawari     | Rock fig    | Kusta/pbh/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.  | *Ficus sycomorus* L.        | Moraceae         | Baure      | Sycamore fig | Kusta/pbh/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)
| No. | Scientific Name | Family | Common Name | Method of Use | Part of Plant | Storage Method |
|-----|----------------|--------|-------------|---------------|---------------|---------------|
| 24. | *Guiera senegalensis* J.F. Gmel. | Combretaceae | Sabara | Moshi Medicine | Kuwta/psh/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. | *Heeria insignis* (Delile) Kuntze | Anacardiaceae | Kasheshe  | | Kuwta/psh/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. | *Hygropha asculata* (Schumach.) Heine | Acanthaceae | | | Kuwta/psh/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. | *Lannea microcarpa* Engl. & K. Krause | Anacardiaceae | Faru | African grape | Kuwta/psh/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. | *Mangifera indica* L. | Anacardiaceae | Mango | | Kuwta/psh/h/ voucher no: s.n | 16 | Hepatitis, meningitis | Bark, leaf | Boil in water then sieve out leaves 3 cup full to be taken orally 3 times daily |
| 29. | *Mentha piperita* L. | Lamiaceae | Peppermint | | Kuwta/psh/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. | *Moringa oleifera* Lam. | Moringaceae | Zogale | | Kuwta/psh/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 2-3 cup full to be taken orally twice daily |
| 31. | *Nauclea diderrichii* (De Wild.) Merr. | Rubiaceae | Habbatu sauda | | Kuwta/psh/h/ voucher no: s.n | 30 | Hepatitis, yellow fever | Stem bark, leaf | Boil in water 3 cup full to be taken orally twice daily |
| 32. | *Nigella sativa* L. | Ranunculaceae | Black cumin | | Kuwta/psh/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 2 cup full to be taken orally twice daily |
| 33. | *Pilocarpus reticulatum* (DC.) Hochst. | Fabaceae | Camel’s foot | | Kuwta/psh/h/ voucher no: s.n | 58 | Hepatitis, poliomyelitis, smallpox | Leaf | Boil in water 2 cup full to be taken orally twice daily |
| 34. | *Petrosigynus rainierae* Poit. | Fabaceae | Madobiya | African rosewood | Kuwta/psh/h/ voucher no: s.n | 4 | Poliomyelitis | Root | Boil in water then sieve 2 cup full to be taken orally twice daily |
| 35. | *Psidium guajava* L. | Myrtaceae | Guava | | Kuwta/psh/h/ voucher no: 67 | 10 | Meningitis | Leaf | Boil in water then sieve 2-3 cup full to be taken orally 2-3 times daily |
| 36. | *Securidaca longipedunculata* Fresen. | Polygalaceae | Violet tree | | Kuwta/psh/h/ voucher no: 207 | 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 To be taken orally |
| 37. | *Strychnos madagascariensis* Desv. | Fabaceae | Snake bean | | Kuwta/psh/h/ voucher no: s.n | 20 | Smallpox | Leaf, bark | Pour into water and boil for 5-10 min To be taken orally |
| 38. | *Syzygium aromaticum* (L.) Merr. & L.M.Perry | Myrtaceae | Glove | | Kuwta/psh/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 |
| 39. | *Terminalia avicennioides* Guill. & Perr. | Combretaceae | Baushe | | Kuwta/psh/h/ voucher no: 315 b | 2 | Yellow fever | Leaf | Pour into water and boil for 5-10 min To be taken orally |
| 40. | *Vernonia amygdalina* Del. | Compositae | Bitter leaf | | Kuwta/psh/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 |
| 41. | *Vaccinium album* L. | Santalaceae | Mistletoe | | Kuwta/psh/h/ voucher no: s.n | 6 | Monkey pox, hepatitis | Seed, whole plant | Boil in water 2 cup full To be taken orally twice daily |
| 42. | *Zingiber officinale* Roscoe | Zingiberaceae | Garden ginger | | Kuwta/psh/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 |
| 43. | *Ziziphus mauritiana* Lam. | Rhamnaceae | Magarya | | Kuwta/psh/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 |
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 Meludan Local Government Area, Kwarar 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 Cochlodpermum 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 Kwarar 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 paradisi 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. officinalis, Citrus aurantifolia, Senna occidentalis, Atelis boa nei, 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 Kwarar 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 Plamagago seylanica and E. chlorantha as the most frequently used plants to treat Lassa fever by HMPs in Kwarar State. Interestingly, no response was recorded for Lassa fever treatment in Sokoto, Kebbi and Kastina 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, Kwarar state is in the Northwestern 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. leiocephalus, and A. indica, were the most frequently mentioned plants for the treatment of COVID-19 in Kebbi and Kwarar 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 listed 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. officinalis, 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, Angiogisis leiocephalus 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 Vitus vulpina were reportedly used for the treatment of smallpox and other diseases [49]. In the present study, Acacia senegal, Gwillma senegalensis, Lagerania breviflora, P. reticulatum, L. inemis, and E. coracana, were cited as the most frequently mentioned plants used to treat smallpox in Katsina, Kebbi, Sokoto, and Kwarar states, 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, B. breviflora A. egypiticus, and E. coracana, were cited as the most frequently used plants to treat monkey pox in Kwarar, Kebbi, and Sokoto States, respectively. Interestingly, B. breviflora was mentioned as the most frequently used plant to treat both smallpox and monkeypox by HMPs in Kwarar 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 chickpox, smallpox in Ayurveda, and infectious diseases in Nigeria [52,53]. Furthermore, L. inemis 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 chicken pox), V. vergaund (fever and boils), and V. paradoxus (chicken pox and skin diseases) are used for treating skin diseases in Nigeria (Table 7) [15,56]. In contrast, Agaratum conyzoides and Ricinus communis are also reportedly used to treat crack-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

| Plant name | Ethnomedicinal uses in literature | Antiviral activity | Toxicity/ poisonous effect | Disease treated in present study |
|------------|-----------------------------------|--------------------|----------------------------|--------------------------------|
| Acacia nilotica (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 in vitro toxicity on rat and Vero cell lines [65]. | Hepatitis, monkey pox, meningitis, smallpox, poliomyelitis, COVID-19, Yellow fever |
| Acacia Senegal (L.) Wild | Leaves are used to treat typhoid fever in west Africa [66]. | Antiviral effect against polio virus, hepatitis C and Herpes simplex virus [21,29]. | No toxicity was observed in vivo on F344 rats [67]. | Smallpox |
| Adansonia digitata L. | Leaves are used to treat fever in Africa [68]. Bark is used to treat hepatitis in Burkina Faso [15]. | | Nontoxic in acute toxicity study [69]. | Poliomyelitis, smallpox, yellow fever, meningitis, monkey pox, hepatitis |
| Aframomum melegueta K. Schum. | Used to treat body pain, rheumatism, diarrhoea, cataract, 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 |
| Ageratum conyzoides (L.) L. | Used to treat fever in Togo and HIV in Nigeria. Used to treat infectious diseases, headache, febrile, crustacean, and burns in African countries [57,58]. | | No mortality or severe toxicity in acute 28 days sub-chronic study [57]. | Hepatitis, lassa fever, poliomyelitis |
| Alafia barteri Oliv. | Used to treat malaria, fever and rheumatic pain in southwest Nigeria [72]. | Patent for the use of the extract for treatment of AIDS [74]. | Induced moderate toxicity on crustacean A. salina larvae [72]. | Meningitis, lassa fever |
| Allium cepa | Used to treat cold and fever in Asia, hypertension in Nigeria and flu, cough and cold in Europe and south/north America [73]. | Virucidal effect against HSV, vaccinia, influenza, HIV and hepatitis A virus [82]. | Generally poses little safety concerns [75]. | Poliomyelitis, COVID-19, meningitis, hepatitis |
| Allium sativum L. | Used to treat fevers and cold in India, Pakistan and middle east and as antibiotic in Africa [75]. | | No report of adverse effect from clinical trials [76]. | Meningitis, Hepatitis, lassa fever |
| Aloe vera (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]. | | |
| Alostia boomei De Wild | Used to treat malaria and fever in Nigeria and West Africa [78]. | | | |
| Anacardium occidentale 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 LD₅₀ at 16 g/kg [82]. Ingestion of seeds can cause burns/death [62]. | Smallpox, Lassa fever, yellow fever |
| Ananas comosus (L.) Merr. | Used to treat intestinal worm, contraceptive, diuretic, jaundice, diarrhoea, 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 |
| Annona senegalensis 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 LD₅₀ of 1296 g/kg [85]. | Poliomyelitis, Hepatitis, yellow fever |
| Anogeissus leiocarpus (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]. | LD₅₀ was 1400 mg/kg in rats [46]. | Monkey pox, poliomyelitis, Meningitis, yellow fever, COVID-19 | |
| Aristolochia ringens | Used to treat typhoid and fever in Nigeria and south America, respectively [88]. | Isolated polysaccharides induced antiviral effect against poliovirus, anti- hepatitis C activity [21,30]. | The LD₅₀ of the aqueous root extract is greater than 10 g/kg [89]. | Yellow fever, lassa fever |
| Asandra indica 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]. | The LD₅₀ 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 |
| Balanites aegyptiaca (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 COVID-19 |
| Bidens pilosa 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, | Antiviral activity against influenza, anti-HIV, antihypertensive, antiinflammatory, antidiabetic, antiviral and antifulvus activities [97]. | An oral dose of 10 g/kg did not cause any mortality or changes in rats [96]. | | (continued on next page)
| Plant Name                        | Uses                                                                                           | Toxicity Studies                                                                 | Notes                                      |
|----------------------------------|------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------|--------------------------------------------|
| *Boswellia dalzielii*            | Used to treat typhoid in Kenya, tuberculosis in Tanzania, HIV/AIDS in Zambia, cough in Sudan and fever in Nigeria, Kenya and Sudan [98] | Induced total inhibition of poliovirus, astrovirus and 75% inhibition of HIV-1 and equine HIV [31] | Toxicity studies on brine shrimp and Vero cells revealed LC₅₀ of 22.8 µg/ml and EC₅₀ of 304.9 µg/ml [98] | COVID-19                        |
| *Cassia occidentals*             | Used to treat diarrhea and fever [31]. Bark is used to treat malaria and yellow fever in Africa [99] | The LD₉₀ of aqueous stem bark extract was > 3000 mg/kg [100]                      | Poliomyelitis, yellow fever                |                               |
| *Carica papaya*                  | 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                              |                               |
| *Byrsocarpus coccineus*          | Used to treat measles, jaundice, anemia, and skin disorders [105]                                | 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 |                               |
| *Citrus aurantifolia*            | Used to treat cough, fever, jaundice, anemia, and skin disorders in India affected the hepatic, skeletal, brain system and resulting in fatal coma [14] | It is a toxic plant and induced dose dependent toxicity and nephropathy in vivo [55]. Consumption of leaf can cause death [62] | Smallpox, COVID-19, monkey pox, poliomyelitis |                               |
| *Citrullus lanatus*              | 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] | Subchronic toxicity including hepatopatia, hyperlipidemia and hepatotoxicity, hyperuricemia have been reported for aqueous and ethanol leaf extract [107] |                               |
| *Cordia africana*                | 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 [15]. | Induced inhibitory activity against Dengue virus [105,106] | Hepatitis, meningitis, COVID-19, poliomyelitis, smallpox, yellow fever, monkey pox |                               |
| *Cassia tora*                    | 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] | Hepatitis, meningitis, yellow fever |                               |
| *Chamaemelurus dependens Hochst.*| Used to treat infectious diseases, pain, malaria, epilepsy, convulsions and fractures in Nigeria and West Africa [114] | The ethanol seed extracts did not induce subchronic toxicity effect on biochemical parameters of rat [113] | Poliomyelitis, meningitis |                               |
| *Chenopodium ambrosioides L.*    | Used to treat fever in Morocco and as treatment for lung and fungal infection in West Africa [116,117]. Leaf powder is used to treat malaria, cough, skin rash, chest pain, jaundice, toothache and stomatchache in Ethiopia [119,120] | Induced antiviral activity against HIV-1 [118] | Poliomyelitis, meningitis |                               |
| *Cordia africana*                | Used to treat cough, fever, 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 [15]. | Induced inhibitory activity against Dengue virus [105,106] | Hepatitis, meningitis, COVID-19, poliomyelitis, smallpox, yellow fever, monkey pox |                               |
| *Cinnamomum verum*              | 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, HSV-1 [123,124] | No significant subchronic toxicity with LD₅₀ greater than 1600 mg/kg in rabbits [125] | Yellow fever                        |
| *Claus populea Guill. & Perr.*   | Root bark is used to manage pain in Mali and infected wound and boils in Cote d’livoire [126,127] | Long term effect of aqueous stem bark extract at 600 g/kg did not induce any significant changes in biochemical parameters [128] | Poliomyelitis, meningitis, monkey pox |                               |
| *Citrus limon (L.) Osbeck*       | Used to treat cold, scurry, 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 subacute toxicity in mice at 2000 mg/kg [121] | Meningitis, COVID-19            |
| *Citrullus lanatus*              | Fruits are used to treat diarrhea and goniomelaria in Nigeria. Used to treat fever, yellowish urine, nephritis and diabetes in Islamic text and medicine [131,132] | Essential oil induced antiviral activity against influenza, H1N1, HSV-1 [123,124] | Ethanol seed extract did was not toxic at 1000 mg/kg [134] | Hepatitis, monkey pox, COVID-19, yellow fever, smallpox, poliomyelitis |                               |
| *Citrus aurantifolia* (Christm.) Swingle | Fruits are used to treat fever, jaundice, headache, cough and malaria in Nigeria [135]. Fruit infusion is used to treat hepatitis in Burkina Faso [15] | Juice inhibited the entry and propagation of influenza virus in vitro and in vivo [133] | Water extract did not show sign of toxicity however, 3.5 g/kg dose of fruit showed toxicity in rats [135] | Yellow fever, poliomyelitis |                               |
| *Calotropis procera* (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] | Subchronic toxicity including hepatopatia, hyperlipidemia and hepatotoxicity, hyperuricemia have been reported for aqueous and ethanol leaf extract [107] |                               |
| *Carica papaya*                  | 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 [15]. | Induced inhibitory activity against Dengue virus [105,106] | Hepatitis, meningitis, COVID-19, poliomyelitis, smallpox, yellow fever, monkey pox |                               |
| *Cassia occidentalis 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 [15]. | Induced inhibitory activity against Dengue virus [105,106] | Hepatitis, meningitis, COVID-19, poliomyelitis, smallpox, yellow fever, monkey pox |                               |
| *Chamaemelurus dependens Hochst.*| Used to treat infectious diseases, pain, malaria, epilepsy, convulsions and fractures in Nigeria and West Africa [114] | Induced antiviral activity against HIV-1 [118] | High doses of 12.31–31.89 g/kg caused lung congestion and necrosis of the kidney tubules [117] |                               |
| *Cordia africana Lam.*           | Used to treat fever in Morocco and as treatment for lung and fungal infection in West Africa [116,117]. Leaf powder is used to treat malaria, cough, skin rash, chest pain, jaundice, toothache and stomatchache in Ethiopia [119,120] | Induced antiviral activity against HIV-1 [118] | Seed extract did not cause toxicity to mice at 2000 mg/kg [121] |                               |
| *Cinnamomum verum*              | 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, HSV-1 [123,124] | No significant subchronic toxicity with LD₅₀ greater than 1600 mg/kg in rabbits [125] | Yellow fever                        |
| *Claus populea Guill. & Perr.*   | Root bark is used to manage pain in Mali and infected wound and boils in Cote d’livoire [126,127] | Long term effect of aqueous stem bark extract at 600 g/kg did not induce any significant changes in biochemical parameters [128] | Poliomyelitis, meningitis, monkey pox |                               |
| *Citrus limon (L.) Osbeck*       | Used to treat cold, scurry, 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 subacute toxicity in mice at 130 | Meningitis, COVID-19            |
| *Citrullus lanatus*              | Fruits are used to treat diarrhea and goniomelaria in Nigeria. Used to treat fever, yellowish urine, nephritis and diabetes in Islamic text and medicine [131,132] | Essential oil induced antiviral activity against influenza, H1N1, HSV-1 [123,124] | Ethanol seed extract did was not toxic at 1000 mg/kg [134] | Hepatitis, monkey pox, COVID-19, yellow fever, smallpox, poliomyelitis |                               |
| *Citrus aurantifolia* (Christm.) Swingle | Fruits are used to treat fever, jaundice, headache, cough and malaria in Nigeria [135]. Fruit infusion is used to treat hepatitis in Burkina Faso [15] | Juice inhibited the entry and propagation of influenza virus in vitro and in vivo [133] | Water extract did not show sign of toxicity however, 3.5 g/kg dose of fruit showed toxicity in rats [135] | Yellow fever, poliomyelitis |                               |

(continued on next page)
Table 7 (continued)

| Plant Name | Description | Antiviral Activity | Toxicity |
|------------|-------------|--------------------|----------|
| *Citrus sinensis* | 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 |
| *Cochlospermum tinctorium* 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 [135] | Acute oral administration of root extract at 500 mg/kg did not induce toxic effect [135] | Yellow fever |
| *Combretum glutinosum* 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 [135] | Aqueous extract inhibited ACE and Hepatitis B surface antigen [24] | Meningitis |
| *Combretum micranthum* Glutinosum ex A.Rich. | Used for diuretic, digestion and gastrointestinal problem in Senegal and west Africa. The fresh leaves are also used to treat malaria and fistulas in skin and other wounds in Ghana [139] | Oral dose of aqueous leaf extract at 2000 mg/kg did not induce acute toxicity [139] | Meningitis |
| *Don. Cymbopogon citratus* (DC.) Stapf | Used to treat fever, analgesic and antiplasmocid and antiinflammatory 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] | Extract induced antiviral activity against HSV-1 and HSV-2 [134] | Hepatitis, poliomyelitis, meningitis, monkey pox, yellow fever |
| *Elaeis guineensis* J.F. Gmel. | Used to treat boils, fever, skin disease and dysentery in Nigeria [31] | Induced 75% of poliovirus, astrovirus and HSV [31] | Hepatitis, lassa fever, yellow fever |
| *Detarium senegalense* J.J. Don. | Used to treat fever, cancer, boils, diarrhea, convulsion and gastrointestinal disorder in southern Nigeria. Used to treat gonorhhea, skin infection, bronchitis, and wound healing in Cameroun and Ghana [133] | The seed oil did not induce toxicity on liver and kidney of rats [149] | Smallpox, yellow fever, COVID-19, meningitis, lassa fever, yellow fever, smallpox, poliomyelitis |
| *Diocurus mespiliformis* Hochst. ex A.DC. | Used to treat syphilis, pneumonia, malaria and skin infections in Namibia [136]. Used to treat stomach, vomiting and diarrhea in South Africa [131] | 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 |
| *Elaeis coracana* (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 [136] | Monkey pox |
| *Enantia chlorantha* Oliv. | Used to treat malaria, boils, yellow fever, hepatitis, jaundice, typhoid fever, tuberculosis in Africa [137] | Induced antiviral and larvicidal effect against yellow fever virus and vector, anticonvulsion and antimicrobial activity [24,157,158] | Poliomyelitis, meningitis, lassa fever, yellow fever |
| *Frythira senegalensis* DC. | Used to treat malaria, fever, infections, pneumonia, neutralic malaria, jaundice, pain, diarrhea and typhoid fever in Mali [140]. Used to treat fever and malaria in middle belt and northern Nigeria [161] | Anti-HIV activity [160] | Poliomyelitis, lassa fever, yellow fever |
| *Eucalyptus globulus* 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] | The LD_{50} of chloroform stem bark extract is 526 mg/kg with significant histopathological changes [162] | Poliomyelitis, lassa fever, yellow fever |
| *Euphorbia hirta* L. | Used to treat gastrointestinal disorder, fever, skin diseases, bronchial and respiratory diseases in South Africa [167,168], cough, gonorrhea and tuberculosis [169] | Ethanol stem bark extract induced toxicity at high dose [159] | Poliomyelitis, meningitis, lassa fever, yellow fever |
| *Euphorbia lateriflora* Schumach. | Used to treat parasitic infection, blood disorder and urinary tract infection [171] | The LD_{50} of whole plant ethanol extract > 5000 mg/kg [172]. Consumption of the sap and root may cause death [62] | Smallpox, COVID-19, yellow fever |

(continued on next page)
| Plant Name                      | Use                                                                 | Antiviral Activity                                                                 | Toxicity                                                                 |
|--------------------------------|----------------------------------------------------------------------|-------------------------------------------------------------------------------------|--------------------------------------------------------------------------|
| *Evolvulus alpinus* 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 antimalarial, fever in India [173-175]. | Antiviral activity against HIV [199] Exhibited toxicity to different species including human, animals and microorganisms [199]. | Meningitis, lassa fever                                                                 |
| *Ficus pertyphylla* 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<sub>50</sub> were greater than 2000 mg/kg and 5000 mg/kg, respectively [176]. Poliomelitis, smallpox, yellow fever, meningitis, monkey pox |
| *Ficus polina* Vahl             | Used to treat infectious diseases, abdominal pain, dyspepsia and diarrhea [181]. | The LD<sub>50</sub> of aqueous stem bark was > 5000 mg/kg [182]. | Poliomelitis, smallpox, yellow fever, meningitis, monkey pox COVID-19 |
| *Ficus sycomorus* L.            | Used to treat cough, skin infection, liver disease, diabetes mellitus, bronchitis, urinary tract infection in India. Extract and fractions induced antiviral activity against measles virus, poliovirus, yellow fever virus and HSV-1 [32]. | The LD<sub>50</sub> of oral aqueous leaf extract was > 3000 mg/kg [185]. | Meningitis, smallpox                                                                 |
| *Ficus thornigii* Blume         | Used to treat diarrhea, gonorrhea and diabetes mellitus, bronchitis, urinary tract infection in Africa. Used to treat jaundice, ulcers, inflammation and respiratory and chest disease [183,184]. | The aqueous stem bark is safe up to 5000 mg/kg with no significant side effects [196]. | The LD<sub>50</sub> of methanol extract is 550 mg/kg [190]. Poliomylitis |
| *Garcinia kola* Heckel          | Used to treat headache, cure cough, dysentery, chest colds, liver disorders, diarrhea, laryngitis, bronchitis, and gonorrhea, fever, malaria in Benin [187-189]. | Extract and fractions induced antiviral activity against measles virus, poliovirus, yellow fever virus and HSV-1 [32]. | The LD<sub>50</sub> for seeds is > 5000 mg/kg [186]. Hepatitis, meningitis, lassa fever, yellow fever, poliomyelitis |
| *Gardenia erubescens* 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 aqueous stem bark is safe up to 5000 mg/kg with no significant side effects [196]. | The LD<sub>50</sub> of methanol extract is 550 mg/kg [190]. Poliomylitis |
| *Guiera senegalensis* 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]. Poliomylitis, yellow fever, smallpox COVID-19, meningitis, hepatitis, monkey pox |
| *Harungana madagascariensis* 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<sub>50</sub> of fruits was > 5000 mg/kg and long term use at high dose could induce toxicity [195]. Hepatitis, meningitis, poliomyelitis |
| *Hygrophila auriculata* (Schumach.) | Used to treat jaundice and other hepatic obstruction, malaria. Inflammation, gout, rheumatism, anemia, cough and pain. | The plant does not pose any toxic or side effects [196]. | The LD<sub>50</sub> of ethanolic fruit extract was > 5000 mg/kg with hepatotoxicity at higher dose [204]. Monkey pox, smallpox |
| *Jatropha curcas* 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 |
| *Kigelia africana* (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 [206]. | The aqueous stem bark is safe up to 5 g/kg [200]. Hepatitis, yellow fever, poliomylitis |
| *Lagenaria breviflora* (Benth.) Roberty | Used as an abortifacient and to treat appendicitis, cancer and rheumatism in southern Nigeria [201-203]. | LD<sub>50</sub> of aqueous trunk bark extract was 5000 mg/kg with no significant subchronic toxicity in rats [207]. | LD<sub>50</sub> greater than 1600 mg/kg [85]. Monkey pox, meningitis, COVID-19, yellow fever, lassa fever |
| *Lannea microcarpa* Engl. & K. Krause | Bark decoction used to treat hepatitis in Burkina Faso, wound healing and schizophrenia spectrum disorder in Mali [15,205,206]. | Induced antiviral activity against Sindbis virus, HSV and polio virus [35]. | LD<sub>50</sub> greater than 1600 mg/kg [85]. Monkey pox, meningitis, COVID-19, yellow fever, lassa fever |
| *Lawsonia inermis* L.           | Used to treat ring worm, infection and skin disease in South India. Mentioned as medicine for smallpox, chicken pox, ulcers, tumors in Islamic medical text. Used to treat fever, jaundice, cough, bronchitis and inflammation. Used to treat poliomyelitis and measles in southwest Nigeria [50,54]. | Induced antiviral activity against Sindbis virus, HSV and polio virus [35]. | LD<sub>50</sub> greater than 1600 mg/kg [85]. Monkey pox, meningitis, COVID-19, yellow fever, lassa fever |

(continued on next page)
### Table 7 (continued)

| Plant Name                      | Uses and Activities                                                                 |
|---------------------------------|--------------------------------------------------------------------------------------|
| **Leptadenia hastate** (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] |
| **Ludwigia octovalvis** (Jacq.) P.H. Raven | Used to treat nervous diseases, edema, dysentery, nephritis, diarrhea, headache and orchitis [209] |
| **Mangifera indica** (Lam.) Exell | 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] |
| **Mentha piperita** L.          | Stem bark extract inhibited HIV-1 replication and HIV-1 protease [63] |
| **Morinda lucida** Benth.       | The plant was toxic to mice at 1200 mg/kg [212] |
| **Moringa oleifera** Lam.       | Can deprive the human body iron and cause anemia when consumed excessively in combination with spearmint [216] |
| **Musanga cecropioides** (De Wild.) Kuntze | The LD<sub>50</sub> of hydroethanol leaf extract was > 3000 mg/kg [217]. |
| **Nauclea diderrichii** (De Wild.) Merr. | Inhibited Epstein Barr Virus, foot and mouth disease virus, Newcastle disease virus, hepatitis B virus, herpes simplex virus, influenza A and HIV [226, 227] |
| **Nauclea latifolia** Sm.        | Ethanol leaf extract at 500 mg/kg induced toxic effect on gestational rat models [221] |
| **Nicotiana tabacum** L.         | LD<sub>50</sub> of aqueous extract of unripe fruit is > 5000 mg/kg [223] |
| **Nigella sativa** L.            | The acute toxicity of the major constituent thymoquinone is very low and well tolerated [237] |
| **Nympheaea lotus** L.           | The LD<sub>50</sub> of aqueous leaf extract is > 5000 mg/kg [239] |
| **Ocimum basilicum** L.          | Anti-hepatitis C activity [237] |

(continued on next page)
**Table 7 (continued)**

| Plant Name                                      | Use                                                                 | LD$_{50}$ Effect                                                                 | Toxic Effect                                                                 |
|-------------------------------------------------|----------------------------------------------------------------------|---------------------------------------------------------------------------------|-------------------------------------------------------------------------------|
| Olea europea L.                                 | Used to treat malaria, febrifuge, bronchial asthma, inflammation, hypertension, diarrhea, respiratory, and urinary tract infection [242] | The LD$_{50}$ of methanol leaf extract is 3475 mg/kg [244]                       | Smallpox, yellow fever, COVID-19, monkey pox                                  |
| Parkia biglobosa (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                             |
| Parinari macrophylla 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] | The LD$_{50}$ of aqueous stem bark is more than 5000 mg/kg [248]              | Poliomyelitis, monkey pox                                                      |
| Pilostigma thonningii (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] | Antiviral activity against HIV-1, hepatitis C virus [13]                          | Hepatitis, COVID-19                                                            |
| Piper guineense 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 $\leq 8000$ 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 |
| Plumbago zeylanica 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 ovine uteri, although limited toxicity was observed in rabbits [257] | Meningitis, yellow fever, lassa fever, poliomyelitis                          |
| Prosopis africana (Guill. & Perr.) Tzub.         | Used to treat hepatitis, infectious diarrhea, dermatosis, ulcer and gonorrhoea 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                           |
| Psidium guajava L.                               | 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, smallpox, yellow fever, lassa fever           |
| Prerocarpus erinaceus 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, Heparitis, meningitis                                          |
| Ricinus communis L.                              | Used as mosquito repellent, relieve stomatibache, jaundice and toothbache, convulsions, cold, catarrh, boils itching skin disease such as crow-crow [59] | Contains toxic compounds such as ricin and ricinine and has shown toxicity at 3 g/kg of oral administration [264] | Yellow fever, poliomyelitis                                                    |
| Saccharum officinarum L.                         | Used to treat liver related diseases, jaundice, hemorrhoid and dysentery in Nigeria [265] | Contains some polycyclic aromatic hydrocarbons (PAHs) [266]                       | Yellow fever, poliomyelitis                                                    |
| Sclerocarya birrea (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                                                                  |
| Securidaca longipedunculata Frensen              | Used to treat epilepsy and convulsions in tropical Africa. Used to headache, skin infection, cough, fever, pneumonia, tuberculosis, malaria, typhoid, stomatibache, 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                                                    |
| Securinga virus (Roxb. ex Willd.) Baill.         | Anti-HIV, anticonvulsant activity [271] | The LD$_{50}$ of n-butanol root bark is 1257 mg/kg [272]                          | Hepatitis, lassa fever, 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].

### Table 7 (continued)

| Sterculia setigera | Used to treat fever and STDs, boils, whitlow, chickenpox, measles, jaundice, malaria and dysentery in Nigeria [31]. Leaves are used to treat hepatits 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] |
| Syzygium aromaticum (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 cholerla, malaria and scabies [274] | Anti-HSV-1, anti-hepatitis C activity [21,275] | Recognized as safe at 1500 mg/kg [275] |
| Tamarindus indica | 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] |
| Terminalia ivorensis 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 LD₅₀ of bark fraction is > 5000 mg/kg [278] |
| Tetrapleura tetraptera (Schum. & Thonn.) Taub | Used to treat leprosy, convulsion, inflammation, rheumatic pains, malaria, asthma [279] | | Poliomyelitis, meningitis, monkey pox, yellow fever |
| Trianta h pentandra L. | Used to treat fevers, skin diseases, wound and toothache is Africa [281] | | |
| Vernonio amygdalina | 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 |
| Viscum album L. | Used to treat hypertension, epilepsy, and asthma [282] | Antiviral activity against parainfluenza virus 2 [282] | The LD₅₀ of leaf extract (i.p) is 420.70 mg/kg [283] |
| Vitellaria paradoxa 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 LD₅₀ of aqueous leaf extract is 12 g/kg [284] |
| Xylopia aethiopica (Dunnal)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 dysentry [31, 286] | Did not inhibit poliovirus, astrovirus and HSV, antiviral activity against measles virus [31,287] | The LD₅₀ of ethanol fruit extract is 3464 mg/kg [288] |
| Zingiber officinale 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] |
| Ziziphus mauritiana 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] |

#### 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, Kwarar, 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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