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# Medicinal plants used in Gabon for prophylaxis and treatment against COVID-19-related symptoms: an ethnobotanical survey

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**Background:** Gabon faced COVID-19 with more than 49,000 individuals tested positive and 307 recorded fatalities since the first reported case in 2020. A popular hypothesis is that the low rate of cases and deaths in the country was attributed to the use of medicinal plants in prevention and treatment. This study aimed to document the plants used for remedial and preventive therapies by the Gabonese population during the COVID-19 pandemic and to pinpoint specific potential plant species that merit further investigation.

**Methods:** An ethnobotanical survey involving 97 participants was conducted in Libreville. Traditional healers and medicinal plant vendors were interviewed orally using a semi-structured questionnaire sheet, while the general population responded to an online questionnaire format. Various quantitative indexes were calculated from the collected data and included the relative frequency of citation (RFC), use value (UV), informant consensus factor (ICF), relative importance (RI), and popular therapeutic use value (POPUP). One-way ANOVA and independent samples *t*-test were used for statistical analyses. *p*-values  $\leq 0.05$  were considered significant.

**Results:** The survey identified 63 plant species belonging to 35 families. Prevalent symptoms treated included fever (18%), cough (16%), fatigue (13%), and cold (12%). The demographic data highlighted that 52.58% of male subjects ( $p > 0.94$ ) aged 31–44 years were enrolled in the survey, of which 48.45% ( $p < 0.0001$ ) and 74.73% ( $p < 0.99$ ) of informants had university-level education. In addition, the results indicated that a total of 66% of the informants used medicinal plants for prophylaxis (34%), for both prevention and treatment (26%), exclusively for treatment (3%), and only for prevention (3%) while suffering from COVID-19, against 34% of the participants who did not use plants for prevention or treatment. *Annickia chlorantha*, *Citrus* sp., *Alstonia congensis*, *Zingiber officinale*, and *Carica papaya* emerged as the most commonly cited plants with the highest RFC (0.15–0.26), UV (0.47–0.75), and RI (35.72–45.46) values. Most of these plants were used either individually or in combination with others.

**Conclusion:** The survey reinforces the use of traditional medicine as a method to alleviate COVID-19 symptoms, thereby advocating for the utilization of medicinal plants in managing coronavirus infections.

#### KEYWORDS

COVID-19, Gabon, medicinal plants, prevention, treatment, survey

## 1 Introduction

After the World Health Organization lifted the public health emergency of international concern for COVID-19, statistics indicate that approximately 689 million people tested positive for COVID-19, with approximately 7 million fatalities attributed to the disease (<https://www.worldometers.info/coronavirus/>). Various therapeutic approaches were explored in the management of COVID-19, including antibiotics (azithromycin), antiparasitic agents (hydroxychloroquine), antiviral medications (remdesivir), monoclonal antibodies (casirivimab), steroids (dexamethasone), and immune modulators (tocilizumab), anticoagulants, as well as oxygen therapy and other supportive measures for patients experiencing respiratory distress (Mehraeen et al., 2022; Murakami et al., 2023; Panahi et al., 2023). Other approaches such as the search for new treatments using traditional remedies were also explored, as well as vaccines (Rahman et al., 2022; Soheili et al., 2023).

Gabon, with a population of approximately 2.3 million, has grappled with COVID-19, with statistics revealing approximately 49,000 individuals testing positive and resulting in 307 recorded fatalities since the first reported case in 2020 (<https://www.worldometers.info/coronavirus/country/gabon/>). The diagnostic of the disease was carried out by Laboratoire Professeur Daniel Gahouma. The latter was the specialized state-of-the-art technology specifically established to address the challenges posed by the pandemic. In addition, COVID-19 treatment protocols in Gabon have involved antibiotherapy in combination with vitamins, paracetamol, zinc, and vaccine.

However, despite the availability of medications and vaccines, and due to fears regarding potential adverse effects associated with vaccination, the Gabonese population has turned to medicinal plants for the prophylaxis and treatment of symptoms associated with this viral disease, similar to the populations of several other countries including Algeria, Brazil, Colombia, Cameroon, Morocco, and Peru (Belmouhoub et al., 2021; Villena-Tejada et al., 2021; Chebaibi et al., 2022; Cordoba-Tovar et al., 2022; Mvogo Ottou et al., 2022; da Silva et al., 2023). Most Gabonese people often rely on medicinal plants due to their long tradition of plant-based medicine. The Gabonese population strongly believes in the efficacy of medicinal plants, considering them crucial in managing COVID-19, particularly due to symptoms resembling those of malaria and flu. Indeed, several symptoms such as respiratory disorders, colds, coughs, fever, and joint pain commonly associated with flu and malaria are typically treated using plant-based remedies by the population. Ancestral knowledge passed down from generation to generation may contain treasures of effective natural remedies against this virus. Therefore, the present study aimed to document and valorize plants used by the Gabonese population to prevent or cure COVID-19 and to identify specific plant species deserving further investigation as potential treatments against coronavirus infections.

## 2 Materials and methods

### 2.1 Data collection

The survey was conducted in Libreville (Figure 1) between February and June 2022 involving participants from the general population, traditional healers, and medicinal plant vendors. A semi-structured questionnaire was developed for conducting direct interviews with randomly selected traditional healers and medicinal plant vendors. Meanwhile, an online questionnaire format was employed to engage the general population. This approach aimed to collect a comprehensive range of information within the population. The questionnaire was converted into a Google Docs form using Google services and was disseminated through various online-based social media platforms such as Facebook, Instagram, Messenger, and WhatsApp. These platforms were chosen as they were perceived to be the most accessible means of reaching the maximum population regarding the governmental measures of partial lockdown and restrictions on movement. A total of 97 participants responded to the survey, comprising both online respondents and those who participated in oral interviews. The questionnaire was designed with two main sections: the first focused on gathering information about the informants (including age, sex, level of education, and ethnic group affiliation), while the second aimed to obtain details regarding medicinal plants, their forms, prescriptions, COVID status, and methods of preparation.

### 2.2 Data analysis

#### 2.2.1 Quantitative analyses of the ethnobotanical data

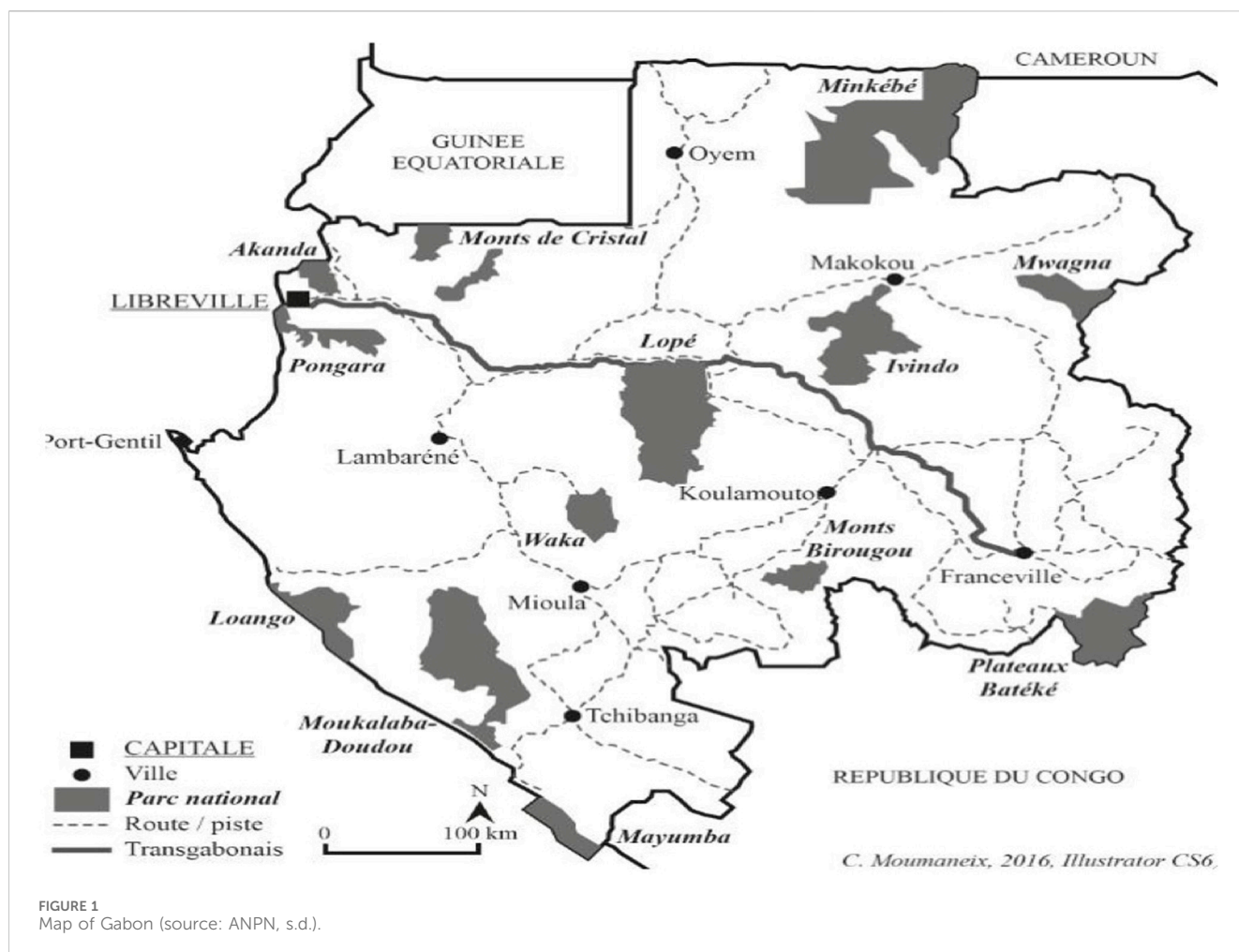
Various quantitative indexes were calculated from the collected data and included the relative frequency of citation (RFC), Use Value (UV), Informant Consensus Factor (ICF), Relative Importance (RI) and Popular Therapeutic Use Value (POPUP) (Anwar et al., 2023; Naceiri et al., 2021; Ndhlovu et al., 2023).

##### 2.2.1.1 Relative Frequency of Citation (RFC)

The Relative Frequency of Citation (RFC) demonstrates the local importance of each plant species. The RFC value ranges from 0 (none of the informants indicate a plant species as useful), to 1 (all informants indicate it as useful). RFC has been calculated as follows:

$$RFC = FC/N$$

Where FC denotes the number of informants mentioning the use of the species in any symptoms and N is the total number of informants participating in the survey.



### 2.2.1.2 The use value (UV)

The UV is an index highlighting the relative importance of plants known locally in traditional medicine. The use value of a plant species varies according to its cultural, geographical, and biological context. The UV determines the most frequently indicated plants in the treatment of an ailment. Use value was calculated using the following formula:

$$UV = \frac{\sum UI}{N}$$

Where *UI* is number of uses recorded for a given species by each informant, and *N* is the total number of informants participating in the survey.

### 2.2.1.3 Relative Importance (RI)

RI helps in the prioritization of plants based on their importance and prevalence in local knowledge systems. It is a useful tool for identifying significant plants with cultural, medical, or ritual significance to a society. It was determined as:

$$RI = \frac{(R \cdot Ph + R \cdot BS)}{2} \times 100$$

Where '*R-Ph*' stands for relative pharmacological properties. '*R-Ph*' is calculated by dividing number of uses (*U*) by total number

of use reports. '*R-BS*' is calculated by dividing number of diseases treated by a plant species by total number of diseases.

### 2.2.1.4 Informant Consensus Factor (ICF)

This index was calculated for informants' agreement on the reported treatment based on each category of disease. The following formula was used to calculate the informant consensus factor (ICF):

$$ICF = \frac{(Nur - Nt)}{(Nur - 1)}$$

where "Nur" is the total use reports for each category and "Nt" is the total number of species used for that category. The ICF scale is 0–1. A number close to 1 implies a high level of agreement or consensus among informants regarding the relevance of a given use category and the plants associated with it. A score closer to 0 shows a lack of consensus, implying that informants may have various or varying ideas regarding the relevance of a certain use category or the plants used for that purpose.

### 2.1.1.5 Popular therapeutic use value

The popular therapeutic use value (POPOT) shows the significance of a plant species for medicinal and therapeutic uses.

TABLE 1 Sociodemographic data about the participants of the study.

Variable	Demographic category	Number of informants (n = 97)	Frequency (%)	p-value
Female		46	47.42	>0.94
Male		51	52.58	
Age	18–30	20	20.62	<0.0001
	31–44	47	48.45	
	45–66	30	30.93	
Education	Primary school	3	3.09	>0.9999
	Secondary	21	21.65	
	University	73	75.26	
Ethnic group	Awandji	1	1.03	>0.9999
	Benga	1	1.03	
	Haussa	1	1.03	
	Kota	1	1.03	
	Kwélé	1	1.03	
	Vili	1	1.03	
	Vungu	1	1.03	
	Adouma	3	3.09	
	Massango	3	3.09	
	Myene	3	3.09	
	Mitsogo	8	8.25	
	Ghisir	11	11.34	
	Ndzebi	12	12.37	
	Punu	18	18.56	
Fang	32	32.99		

The following formula was used to calculate the popular therapeutic use value:

$$\text{POPUP} = \frac{\text{NURIT}}{\text{TUR}}$$

where “NURIT” is the number of use reports for each illness or therapeutic effect and “TUR” is the total number of use reports.

### 2.2.2 Statistical analysis

The recorded data were tabulated on Microsoft Excel spreadsheets. A descriptive and quantitative statistical method was applied (one-way ANOVA and independent samples *t*-test; *p*-values  $\leq 0.05$  were considered significant) to analyze and summarize the data.

## 3 Results

### 3.1 Sociodemographic features of informants

The social–demographic features of informants are presented in Table 1. The gender distribution revealed that women

constituted 47.42% of the respondents, while men were more predominant at 52.58%. The average age of participants was 39.41 years, ranging from 18 to 66 years, with the age group of 31–44 years being the most represented at 48.45% ( $p < 0.0001$ ). A significant majority of informants (74.73%) had attended university, while only 3.3% had completed primary school. The most represented ethnic affiliation was the Fang (30.77%), followed by the Punu (19.78%) and the Nzebi (13.19%). Ethnic groups such as the Awandji, Benga, and Haussa were among the least represented.

### 3.2 Frequency of COVID-19-related symptoms treated

COVID-19 symptoms are various. In this survey, prevalent symptoms included fever (18%), cough (16%), fatigue (13%), and cold (12%), as shown in Figure 2. Additionally, respiratory conditions (10%), general pain (8%), and breathlessness (7%) were managed by informants to a lesser extent. Sneezing, sore throat, and colic associated with COVID-19 were cited at 2% and 1%.

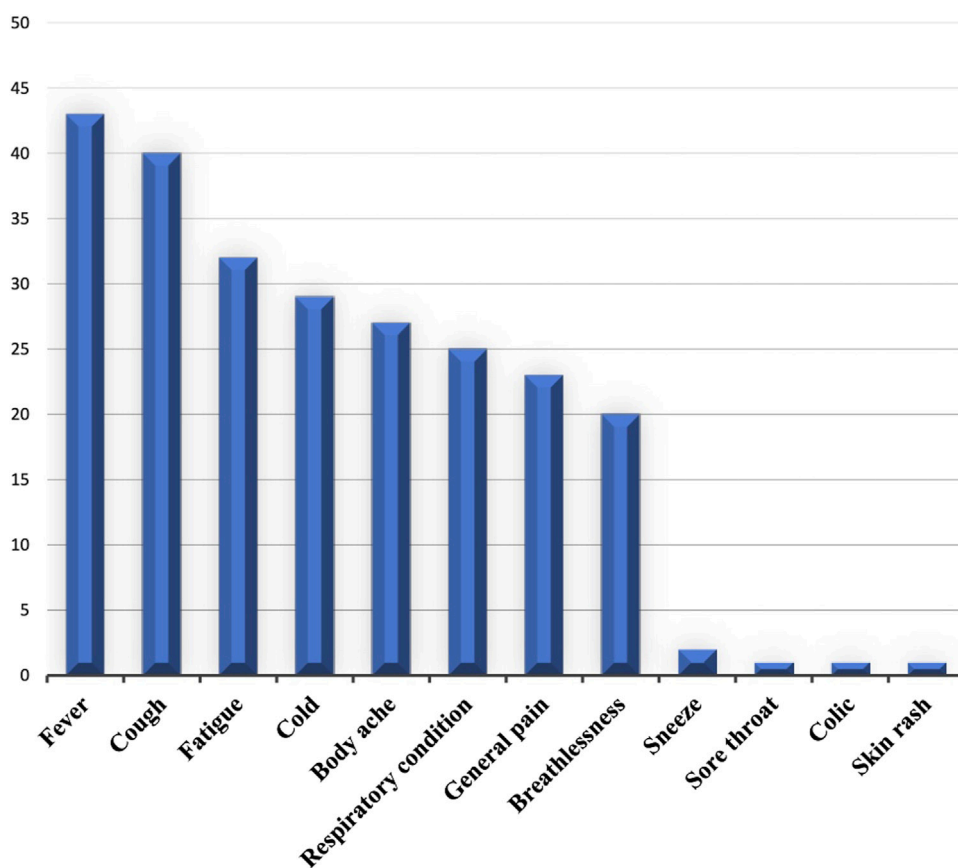


FIGURE 2 Treated symptoms.

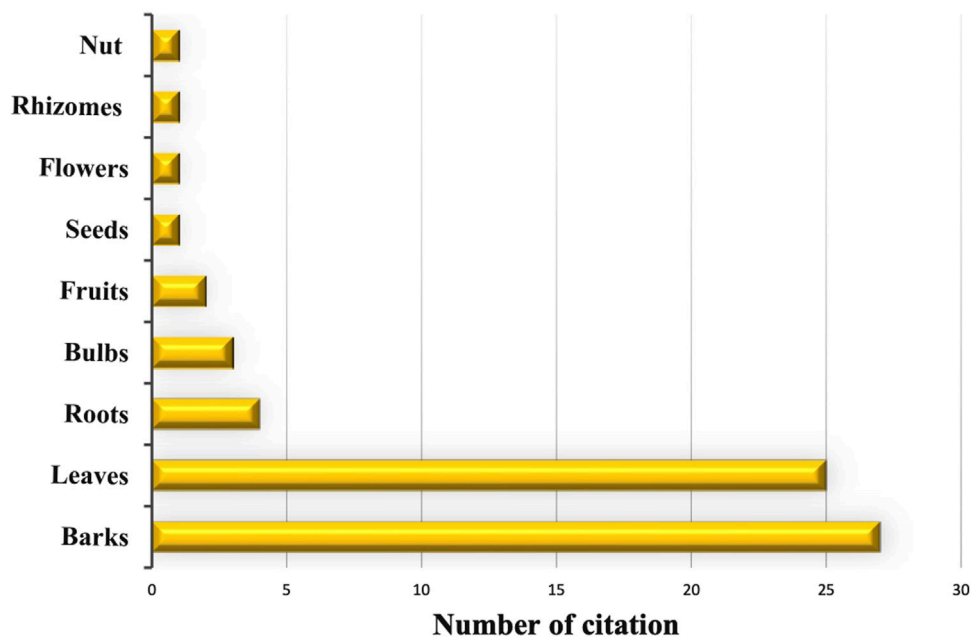


FIGURE 3 Plant parts used.

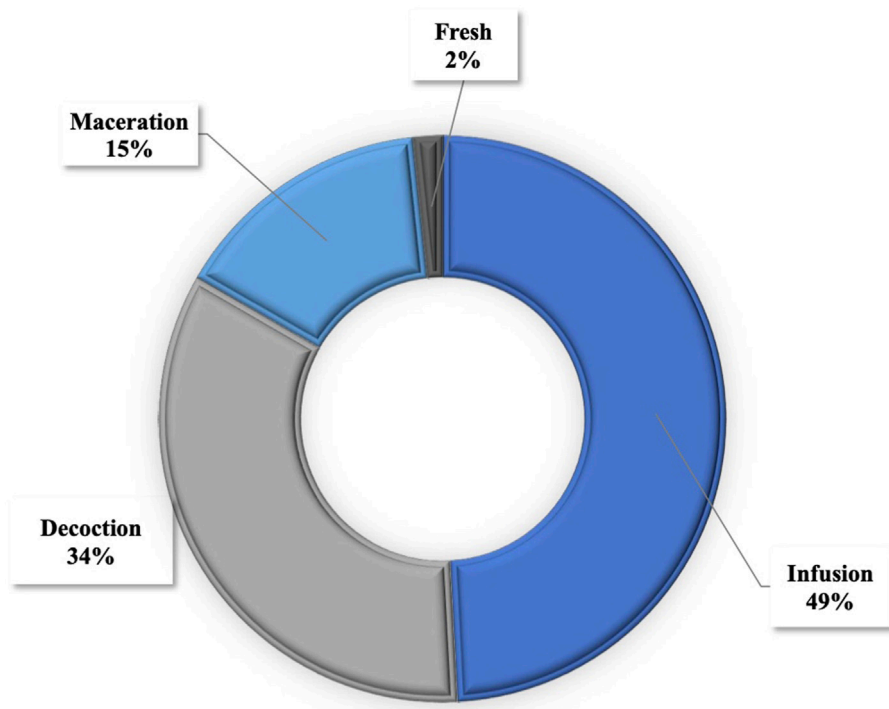


FIGURE 4  
Mode of preparation.

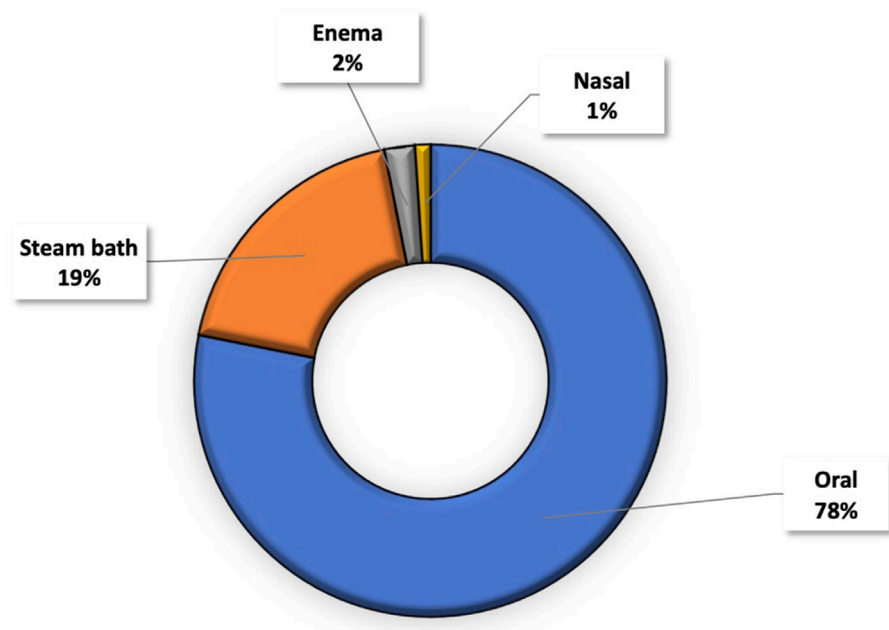


FIGURE 5  
Mode of administration.



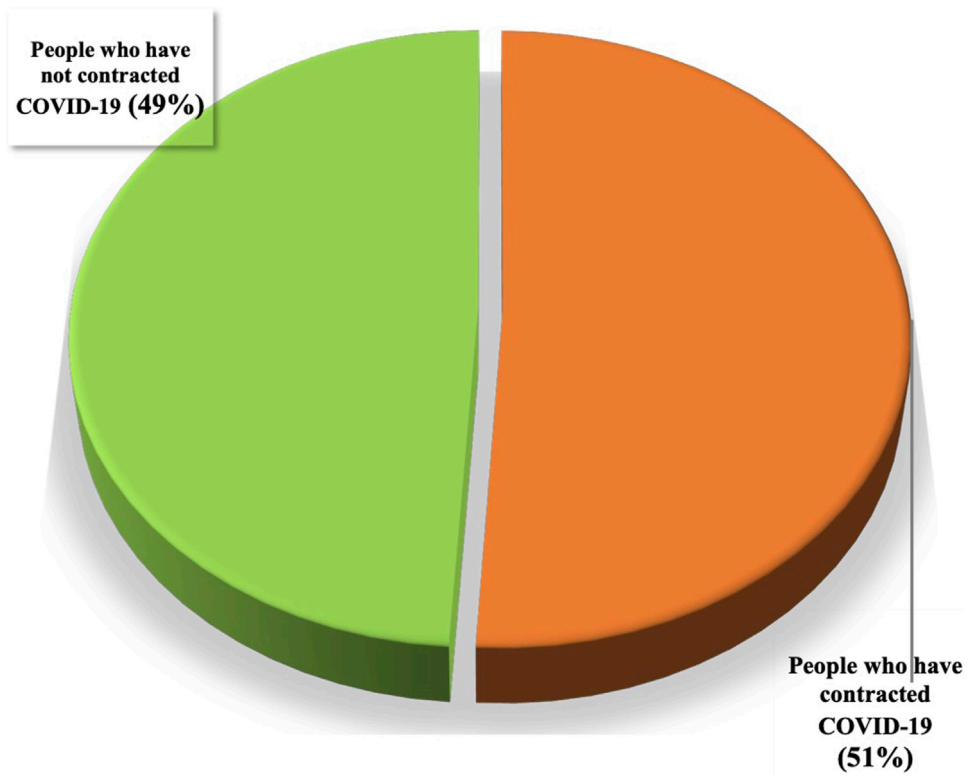


FIGURE 6 Proportion of people who have contracted COVID-19.

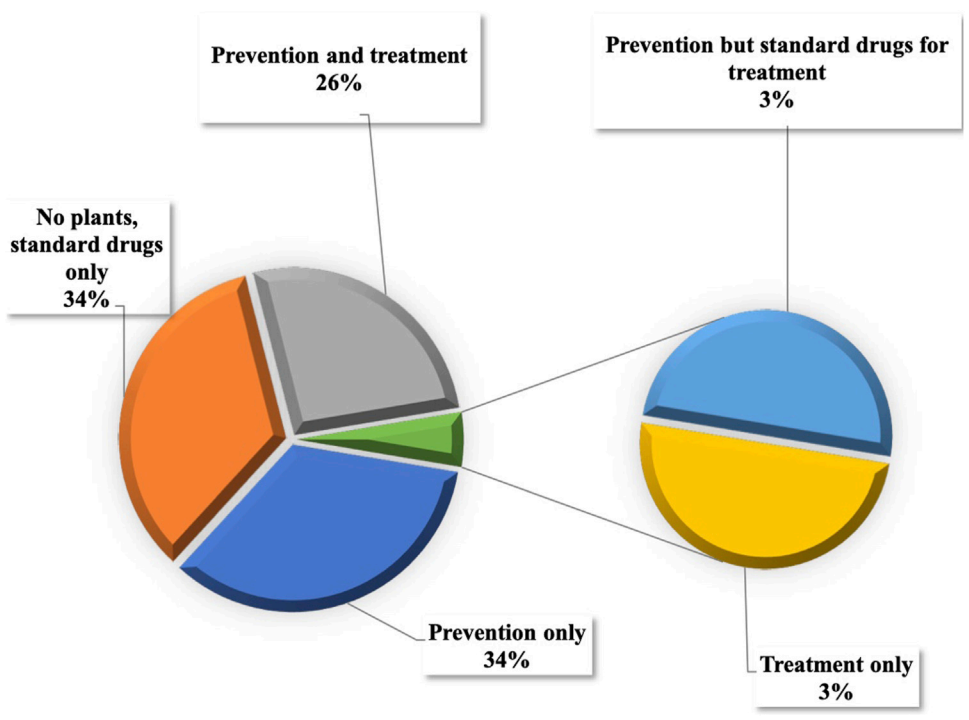


FIGURE 7 Use of medicinal plants in the treatment and/or prevention of COVID-19.

TABLE 2 Ethnobotanical data on plants used to treat and prevent COVID-19.

N°	Family	Scientific name	Vernacular name	Plant parts	Growth form	RFC	UV	RI (%)
1	Acanthaceae	<i>Acanthus montanus</i> (Nees) T.Anderson	Mabangue pele	Roots	Perennial	0.02	0.03	12.66
2	Anacardiaceae	<i>Mangifera indica</i> L.	Mwiba	Leaves and barks	Tree	0.11	0.32	34.94
3		<i>Pseudospondias longifolia</i> Engl.	Musungubali	Barks	Tree	0.01	0.04	16.88
4	Annonaceae	<i>Annona muricata</i> Lin.	Corossol	Leaves	Tree	0.02	0.05	21.09
5		<i>Annickia chlorantha</i> (Oliv.) Setten and Maas	Nfo'o	Barks	Tree	0.26	0.75	45.46
6		<i>Xylopia aethiopica</i> (Dunal) A. Rich	Mugana	Leaves	Tree	0.01	0.02	8.44
7		<i>Greenwayodendron suaveolens</i> Engl. and Diels	Muamba noir	Leaves and barks	Tree	0.12	0.3	18.17
8		<i>Cleistopholis staudtii</i> Engl. and Diels	Ovoc	Barks	Tree	0.01	0.04	16.88
9	Apocynaceae	<i>Alstonia congensis</i> Engl.	Ekouk	Leaves and barks	Tree	0.22	0.71	45.25
10		<i>Tabernanthe iboga</i> Baill.	Dibuga	Root barks	Shrub	0.02	0.02	8.44
11		<i>Picalima nitida</i> T. Durand and H. Durand	Dugundu	Barks and fresh leaves	Tree	0.06	0.13	21.5
12	Asteraceae	<i>Ageratum conyzoides</i> L.	Burongu	Barks	Weed	0.01	0.04	16.88
13		<i>Artemisia annua</i> L.		Leaves	Shrub	0.1	0.25	34.58
14		<i>Gymnanthemum amygdalinum</i> (Delile) Sch.Bip. syn <i>Vernonia amygdalina</i>	Ndole	Leaves	Shrub	0.06	0.23	38.64
15	Bignoniaceae	<i>Newbouldia laevis</i> (P.Beauv.) Seem. ex Bureau	Isope	Leaves and barks	Tree	0.08	0.24	34.53
16	Bombacaceae	<i>Ceiba pentandra</i> (L.) Gaertn.	Dum	Leaves	Tree	0.01	0.04	16.88
17	Burseraceae	<i>Aucoumea klaineana</i> Pierre	Okume	Barks	Tree	0.08	0.3	18.17
18		<i>Canarium schweinfurthii</i> Engl.	Aiele	Barks	Tree	0.01	0.02	8.44
19		<i>Dacryodes edulis</i> (G.Don.) H. J. Lam.	Safu	Barks and leaves	Tree	0.01	0.05	16.93
20	Caricaceae	<i>Carica papaya</i> L.	Mulolu	Leaves	Tree	0.15	0.62	44.78
21	Combretaceae	<i>Combretum micranthum</i> G.Don	Kinkeliba	Roots	Shrub	0.08	0.35	35.1
22	Costaceae	<i>Costus lucanusianus</i> JA.Braun. and K.Schum.	Mikwissa	Leaves	Perennial herb	0.05	0.21	34.37
23	Euphorbiaceae.	<i>Alchornea cordifolia</i> (Schumach) Müll. Arg.	Mumbundjeni	Leaves	Shrub or small tree	0.01	0.03	12.66
24	Fabaceae	<i>Cylicodiscus gabunensis</i> Harms	Madume	Leaves	Tree	0.02	0.08	17.08
25		<i>Copaifera religiosa</i> J.Léonard	Mutombi	Barks	Tree	0.01	0.01	4.22
26		<i>Distemonanthus benthamianus</i> Baill.	Muvengui	Barks	Tree	0.02	0.05	12.76
27		<i>Osodendron altissimum</i> (Hook.f.) E.J.M.Koenen	Difyoru balossi	Barks	Tree	0.01	0.01	4.22
28		<i>Pterocarpus soyauxii</i> Taub.	Padouk	Barks	Tree	0.03	0.1	17.19
29		<i>Pentaclethra macrophylla</i> Benth.	Muvandji	Barks	Tree	0.02	0.04	16.88
30		<i>Senna occidentalis</i> (L.) Link	Muwiwisi	Leaves	Shrub	0.02	0.04	16.87
31		<i>Tetrapleura tetraptera</i> (Schum. and Thonn.) Taub.	Gyaga	Fruit	Tree	0.03	0.06	25.31
32		<i>Guibourtia tessmannii</i> (Harms) J.Léonard.	Kevazingo	Barks	Tree	0.03	0.1	17.19
33		Hypericaceae	<i>Harungana madagascariensis</i> Lam. ex Poiret	Musasa	Barks	Tree	0.01	0.02
34	Irvingiaceae	<i>Irvingia gabonensis</i> (Aubry-Lecomte ex O'Rorke) Baill.	Mundjuka	Barks	Tree	0.01	0.04	16.88
35	Lamiaceae	<i>Mentha suaveolens</i> Ehrh.		Leaves	Perennial herb	0.03	0.07	17.03
36		<i>Ocimum gratissimum</i> L.	Messep	Leaves	Perennial herb	0.07	0.2	42.65

(Continued on following page)



TABLE 2 (Continued) Ethnobotanical data on plants used to treat and prevent COVID-19.

N°	Family	Scientific name	Vernacular name	Plant parts	Growth form	RFC	UV	RI (%)
37	Lauraceae	<i>Persea americana</i> Mill.	Muvoka	Leaves	Tree	0.01	0.02	8.44
38	Lecythidaceae	<i>Petersianthus macrocarpus</i> (P.Beauv.) Liben	Mbindju	Ecorces	Tree	0.01	0.01	4.22
39	Liliaceae	<i>Allium cepa</i> L.	Oignon	Bulbs	Perennial herb	0.02	0.03	12.66
40		<i>Allium sativum</i> L.	Ail	Bulbs	Perennial herb	0.04	0.1	25.52
41		<i>Aloe vera</i> (L.) Burm.f.	Aloe	Leaves	Perennial herb	0.01	0.07	29.53
42	Malvaceae	<i>Cola nitida</i> (Vent.) Schott and Endl.	Cola	Nut and barks	Tree	0.05	0.14	25.73
43	Moraceae	<i>Milicia excelsa</i> (Welw.) C.C.Berg.	Iroko	Barks	Tree	0.02	0.02	8.44
44	Moringaceae	<i>Moringa oleifera</i> Lam.	Moringa	Leaves	Tree	0.04	0.09	21.3
45	Musaceae	<i>Musa x paradisiaca</i> L.	Mupala	Leaves	Perennial	0.11	0.26	34.63
46	Myristicaceae	<i>Pycnanthus angolensis</i> (Welw.) Warb.	Ilomba	Barks	Tree	0.01	0.01	4.22
47		<i>Scyphocephalum mannii</i> (Benth.) Warb.	Sorro	Barks	Tree	0.01	0.07	17.04
48		<i>Staudtia kamerunensis</i> Warb.	Niove	Barks	Tree	0.09	0.45	18.95
49	Myrtaceae	<i>Psidium guajava</i> L.	Ngwaba	Leaves	Shrub or small tree	0.07	0.2	34.32
50		<i>Syzygium aromaticum</i> (L.) Merr. and L.M.Perry.	Clove	Dried flowers	Tree	0.04	0.08	29.58
51	Poaceae	<i>Cymbopogon citratus</i> (DC.) Stapf	Esosi	Leaves	Perennial grass	0.1	0.26	34.63
52	Rhamnaceae	<i>Maesopsis eminii</i> Engl.	Mosangea	Barks	Tree	0.01	0.01	4.22
53	Rubiaceae	<i>Mitragyna ciliata</i> Aubrév. and Pellegr.	Bahia	Barks	Tree	0.09	0.13	17.34
54		<i>Coffea mannii</i> (Hook.f.) A.P.Davis	Azeme	Barks	Shrub	0.01	0.02	8.44
55		<i>Sarcocephalus pobequinii</i> Hua ex Pobég. and Pellegr.	Kombe ningo	Barks	Tree	0.01	0.07	17.04
56	Rutaceae	<i>Citrus</i> sp.	Diali	Fruits, barks, leaves	Shrubs or small tree	0.23	0.66	36.66
57		<i>Zanthoxylum heitzii</i> (Aubrév. and Pellegr.) P. G. Waterman	Ndungu	Leaves and barks	Tree	0.01	0.01	4.22
58	Simabouraceae	<i>Simaba africana</i> Baill.	Issindu ighale	Roots	Tree	0.03	0.03	12.66
59	Solanaceae	<i>Capsicum chinense</i> Jacq.	Nungu	Seeds	Shrub	0.02	0.04	16.88
60	Tiliaceae	<i>Ancistrocarpus densispinosus</i> Oliv.	Eege	Leaves	Shrub or small tree	0.01	0.04	16.88
61	Urticaceae	<i>Musanga cecropioides</i> R.Br. ex Tedlie	Parasolier	Barks	Tree	0.03	0.13	17.34
62	Vitaceae	<i>Cissus quadrangularis</i> L.	Dyaba	Aerial parts	Perennial herb	0.02	0.08	17.08
63	Zingiberaceae	<i>Zingiber officinale</i> Roscoe	Maketa	Rhizomes	Perennial herb	0.17	0.47	35.72

### 3.3 Frequency of plant parts used

The survey unveiled that nearly all plant parts were used in the treatment of COVID-19. Informants mostly used bark (42%) and leaves (38%) for their remedies, while roots, bulbs, and fruits were used to a lesser extent, accounting for 7%, 6%, and 3%, respectively. Less commonly utilized were parts such as seeds, flowers, rhizomes, and nuts, each representing 1% (Figure 3).

### 3.4 Frequency of the methods of preparation and administration of ethnomedicinal remedies

In the formulation of plant-based remedies for the prevention and treatment of COVID-19, methods such as infusion, decoction, and maceration were predominantly utilized, comprising 49%, 34%, and 15%, respectively (Figure 4). The administration of these remedies was

TABLE 3 Ten popular recipes used in the prevention and/or treatment of COVID-19-related symptoms.

	Recipe	Plant parts	Preparation	Posology	Administration
1	<i>Annickia chlorantha</i> + <i>Alstonia congenis</i> + <i>Syzygium aromaticum</i>	Nfo'o + Ekouk + Clous de Girofle	Barks and flower	Maceration, infusion, and decoction	2–3 times/day Drink
2	<i>Musa x paradisiaca</i> + <i>Carica papaya</i> + <i>Mangifera indica</i> + <i>Cymbopogon citratus</i> + <i>Citrus sp.</i> + <i>Aloe vera</i> + <i>Psidium guajava</i>	Mupala + Mulolu + Mwiba + Esosi + Diali + Aloe+ Ngwaba	Dead leaves, fresh leaves, and fruit	Decoction	2–3 times/day Drink
3	<i>Mangifera indica</i> + <i>Psidium guajava</i> + <i>Cymbopogon citratus</i>	Mwiba + Ngwaba + Esosi	Leaves	Decoction	Twice/day Drink Steam bath
4	<i>Annickia chlorantha</i> + <i>Carica papaya</i> + <i>Zingiber officinale</i> + <i>Citrus sp.</i>	Nfo'o + Mulolu + Maketa + Diali	Barks, fruits, rhizome, and leaves	Decoction	2–3 times/day Drink
5	<i>Allium sativum</i> + <i>Citrus sp.</i> + <i>Zingiber officinale</i>	Ail + Diali + Maketa + Honney	Fruit, bulb and rhizome	Maceration	More than three times/day Drink
6	<i>Gymnanthemum amygdalinum</i> + <i>Carica papaya</i> + <i>Mangifera indica</i>	Ndolè+ Mulolu + Mwiba	Leaves	Infusion	2–3 times/day Drink
7	<i>Moringa oleifera</i> + <i>Senna occidentalis</i>	Moringa + Muwiwisi	Barks and leaves	Infusion	Once/day Steam bath
8	<i>Artemisia annua</i> + <i>Cymbopogon citratus</i> + <i>Annona muricata</i> + <i>Tetrapleura tetraptera</i>	Artemesia + Esosi + corosole + Gyaga	Leaves and fruit	Infusion	Once/day Enema
9	<i>Annickia chlorantha</i> + <i>Alstonia congenis</i> + <i>Ocimum gratissimum</i>	Ñfo'o + Ekouk + Messep	Barks	Infusion	Once/day Drink
10	<i>Senna occidentalis</i> + <i>Newbouldia laevis</i> + <i>Zingiber officinale</i> + <i>Citrus sp.</i> + <i>Cymbopogon citratus</i> + <i>Allium cepa</i> + <i>Allium sativum</i> + <i>Syzygium aromaticum</i> + <i>Cola nitida</i>	Kinkéliba + Isope + Maketa + Diali + Esosi + Oignon + Ail + Clous de Girofle + Cola	Leaves, fruit, rhizome, and bulb	Maceration, infusion, and decoction	2–3 times/day Drink

primarily oral (78%), while 19% were applied through steam baths. Enema and nasal administration accounted for 2% and 1%, respectively (Figure 5).

### 3.5 Frequency of the disease amongst the informants and use of plants in prevention or treatment

Among the participants, 51% tested positive for COVID-19, as confirmed by PCR analysis, while 49% either did not exhibit any symptoms or did not contract the disease (Figure 6). The survey also uncovered that 34% of the informants did not use plants for either prevention or treatment. Among the remaining participants, 34% utilized plants for prophylaxis, 26% for both prevention and treatment, 3% exclusively for treatment, and 3% used medicinal plants solely for prevention in conjunction with standard drugs while they were sick with COVID-19 (Figure 7).

### 3.6 Ethnomedicinal plants used

The survey on medicinal plants used for the prevention and treatment of COVID-19 within the general population, traditional healers, and medicinal plant vendors identified 63 plant species belonging to 35 families (Table 2). These plants were utilized either individually or in combination with other species to formulate remedies. The listed species are presented in alphabetical order

by family. For each plant, we provide information on the family, scientific name, vernacular name, part used, and growth form.

The family most abundantly represented, with the highest number of species, was Fabaceae (nine species), followed by Annonaceae (five species), Apocynaceae, Asteraceae, Burseraceae, Liliaceae, Myristicaceae, and Rubiaceae (three species each). Other families were represented by only one or two species, such as Lamiaceae, Musaceae, and Zingiberaceae. These plants were primarily characterized as trees, perennials, shrubs, or weeds. Table 3 presents 10 popular recipes cited by the informants for either prevention, treatment, or both. The table indicates the recipe, the plant parts used, the modes of preparation and administration, and the posology, which was mostly 2–3 times per day, especially for the remedies taken orally. The recipes were a mixture of at least two different plants and could be made of more than nine plants.

### 3.7 Importance of the plants through RFC, UV, and RI

Several indexes allowed the identification of the most valuable plants that were used to treat COVID-19 symptoms in Gabon (Table 2). On a global scale, species exhibiting the highest values across the various indexes calculated are deemed useful and significant for COVID-19 management and should be further assessed through pharmacological analysis for drug development purposes.

The relative frequency of citation (RFC) index varied from 0.01 to 0.26 and indicated that species like *Annickia chlorantha* (0.26), *Citrus sp.* (0.23), *Alstonia congenis* (0.22), *Zingiber officinale* (0.17), and

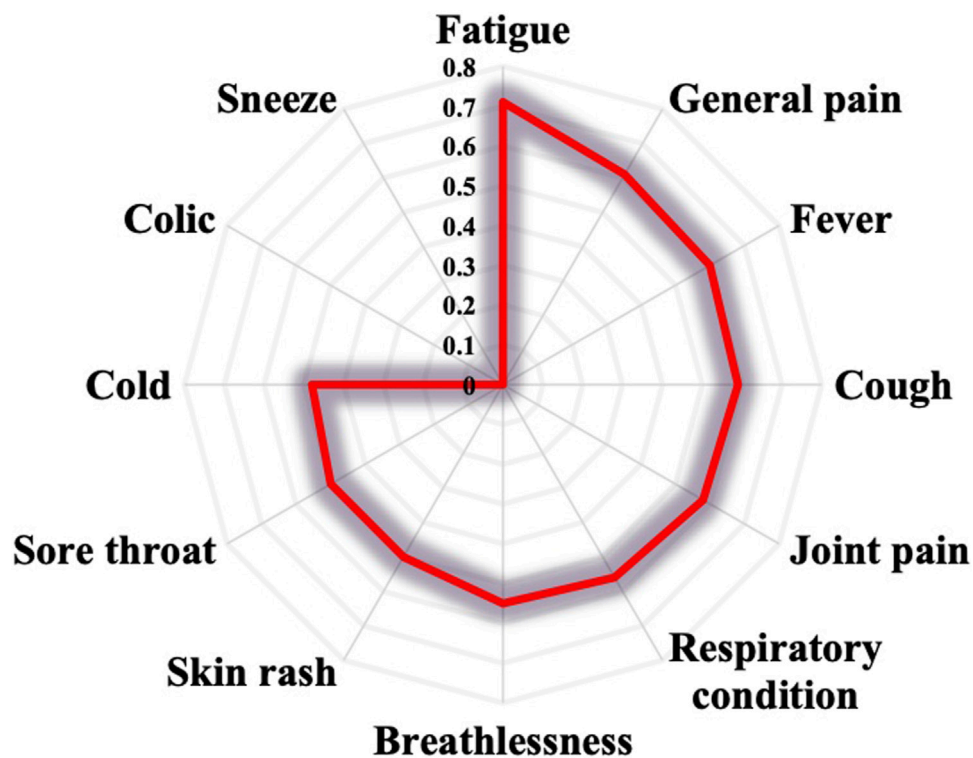


FIGURE 8 Informant consensus factor (ICF).

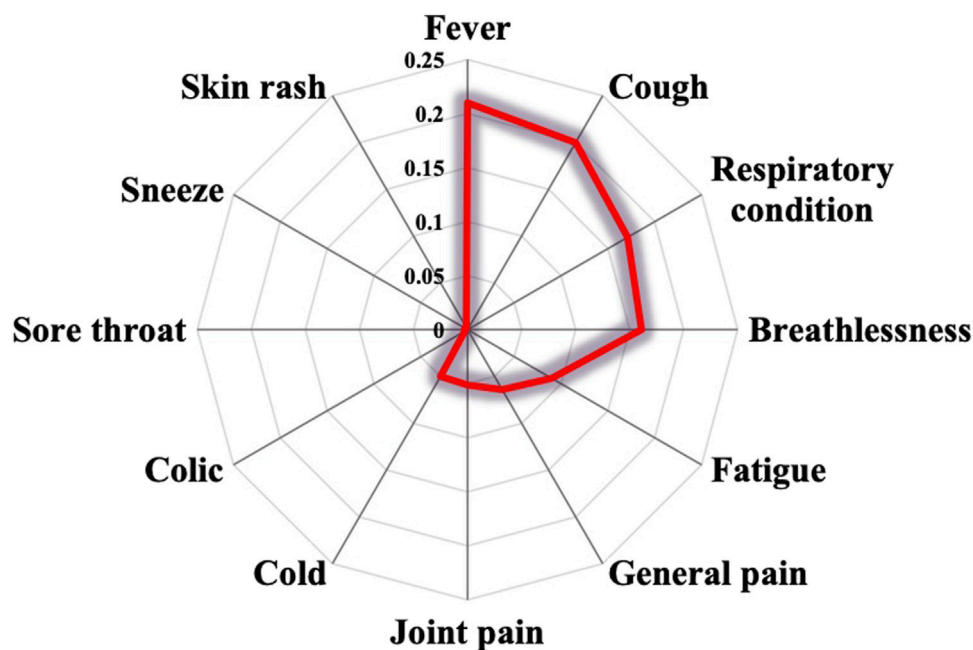


FIGURE 9 Popular therapeutic use value (POPUP).

*Carica papaya* (0.15) were the most frequently cited by informants. The lowest index calculated (0.01) was for plant species like *Ageratum conyzoides*, *Dacryodes edulis*, or *Sarcocephalus pobeguini*.

In the present study, the species have use values (UVs) ranging from 0.01 to 0.75. Species such as *Annickia chlorantha* (0.75), *Alstonia congensis* (0.71), *Citrus* sp. (0.66), *Carica papaya* (0.62), *Zingiber*

*officinale* (0.47), *Staudtia kamerunensis* (0.45), and *Mangifera indica* (0.32) presented the highest values. The lowest value of 0.01 was found for *Zanthoxylum Heitzii* and *Copaifera religiosa*.

The relative importance (RI) index had percentages ranging from 4.22% to 45.46%. The highest values were displayed by *Annickia chlorantha* (45.46%), *Alstonia congensis* (45.25%), *Carica papaya* (44.78%), *Ocimum gratissimum* (42.65%), *Gymnanthemum amygdalinum* (38.64%), *Citrus* sp. (36.66%), *Zingiber officinale* (35.72%), *Combretum micranthum* (35.1%), *Mangifera indica* (34.94%), *Cymbopogon citratus* (34.64%), *Musa x paradisiaca* (34.64%), and *Artemisia annua* (34.58%). The lowest value calculated (4.22%) corresponded to *Zanthoxylum heitzii* and *Copaifera religiosa*.

### 3.8 ICF and POPUT

The survey results revealed that the cited plants were employed to address various symptoms associated with COVID-19, including cold, cough, breathlessness, fatigue, fever, and general pain. The calculated indexes indicated that ICF values ranged from 0 to 0.71. The highest ICF (0.71) was observed for fatigue, followed by general pain (0.61), fever (0.6), cough (0.59), joint pain (0.58), respiratory condition (0.56), and breathlessness (0.55). The lowest ICF values were obtained for colic and sneezing (Figure 8).

Regarding the POPUT index, the values varied from 0.002 to 0.21. Symptoms such as cough, fever, respiratory condition, and breathlessness obtained the highest values (higher than 0.1), while the lowest values were calculated for skin rashes, colic, and sore throat (Figure 9).

## 4 Discussion

The present study aimed to highlight the plants used in Gabon to prevent and/or treat symptoms associated with COVID-19. Survey participants included individuals from the general population, traditional healers, and medicinal plant vendors. The findings revealed that most of the participants were male subjects, with the predominant age group being 31–44 years. These results suggest that men displayed a greater interest in the survey compared to women, likely due to the prevalence of male traditional healers and medicinal plant vendors. The age group of 31–44 years was particularly noteworthy as it represents the demographic most inclined to embrace traditional medicine and seek to reclaim traditional knowledge. In addition, a large number of informants had a university education. The high level of education among the majority of respondents indicates that, despite heightened awareness of the ongoing pandemic, the population continues to associate medicinal plants with the prevention and treatment of diseases exhibiting flu-like symptoms. Khadka et al. (2021) supported this finding, reporting that educated people had a preference for modern medicine, but during COVID-19, they used medicinal plants as an alternative medicine option. Gabon is very rich in plant biodiversity, and the knowledge of medicinal plants used to treat infections or conditions such as malaria or influenza is deeply rooted within the population, is transmitted from generation to generation, and is often shared by traditional healers with individuals seeking information. Consequently, when the

pandemic emerged, the Gabonese population likened it to a blend of malaria and flu due to the overlapping symptoms with COVID-19, including fever, joint and body ache, fatigue, coughing, and cold symptoms. Subsequently, people began treating these symptoms using plants commonly used to treat influenza and malaria. The study findings indicate that these specific symptoms were the most frequently treated by the population. Surveys conducted in different countries such as Bangladesh and South Africa also described these symptoms as the most commonly treated in their respective countries (Phumthum et al., 2021; Rafiqul Islam et al., 2021; Zondi and Ehaine, 2022). The remedies predominantly involved the use of barks and leaves, prepared through infusion, decoction, or maceration. Notably, steam baths emerged as the second most common mode of administration, a method traditionally employed in Gabon specifically for treating malaria. Other studies also mentioned steam baths or steam inhalation as modes of administration, arguing that this method has been used for decades as a home remedy for cold and pain (Rafiqul Islam et al., 2021; Mvogo Ottou et al., 2022; Zondi and Ehaine, 2022). The study also revealed that the majority of respondents had contracted COVID-19 and that only 3% of them did not take treatment based on medicinal plants. Among the remaining respondents who claimed to have never developed any symptoms, medicinal plants were used for prevention. These results suggest that medicinal plants may have provided protection against coronavirus infection for individuals who used them. Further research, including clinical trials, is necessary to confirm these findings and to determine the safety and efficacy of the plants. In a similar context, results from a study carried out in Peru on the use of medicinal plants for COVID-19 prevention and respiratory symptom treatment showed that most of their respondents did use plants for these purposes (Villena-Tejada et al., 2021).

Ethnobotanical surveys often employ various indexes to unveil or highlight medicinal plants that are most frequently used or deemed most beneficial for the treatment of a specific disease. These indexes help quantify and analyze the importance of different plant species within a particular cultural or ecological context. In the present study, the results indicated that several indexes, including RFC, UV, or RI, collectively highlighted the plants most frequently used for the prevention or treatment of COVID-19. Notably, *Annickia chlorantha*, *Allium* sp., *Citrus* sp., *Alstonia congensis*, *Zingiber officinale*, *Carica papaya*, *Staudtia kamerunensis*, *Mangifera indica*, *Combretum micranthum*, *Cymbopogon citratus*, *Newbouldia laevis*, *Ocimum gratissimum*, *Gymnanthemum amygdalinum*, *Musa x paradisiaca*, and *Artemisia annua* emerged as the most commonly cited. Surveys conducted worldwide documented the use of several of these plants in the prevention and/or treatment of the disease, regardless of geographical location, climate diversity, or the variability of flora in the different regions. Hence, plants like *Allium* sp., *Citrus* sp., *Zingiber officinale*, *Carica papaya*, *Mentha piperita*, *Cymbopogon citratus*, and *Ocimum* sp. were used in diverse regions such as Cameroon, Morocco, Iraq, Thailand, Nepal, and Turkey (Akbulut, 2021; Khadka et al., 2021; Phumthum et al., 2021; Abdulrahman et al., 2022; Mvogo Ottou et al., 2022). ICF and POPUT are indispensable tools in ethnopharmacological surveys, offering valuable insights into the consensus, popularity, and cultural significance of medicinal plants within a community (Asiimwe

TABLE 4 Active compounds from medicinal plants with potential anti-SARS-CoV activity.

Plant name	Active compounds	Mechanisms	References
<i>Ageratum conyzoides</i>	Chromene, hydroxamic acid, and apigenin	Inhibit SARS-CoV-2 main protease	Hariono et al. (2021)
<i>Allium cepa</i>	Oleanolic acid, quercitrin, peonidin progesterone, and 3-arabinoside	Inhibit SARS-CoV-2 main protease	Fitriani and Utami (2021)
<i>Allium sativum</i>	Alliin, S-propyl cysteine, S-allylcysteine, squalene, S-ethylcysteine, 1,4-dihydro-2,3-benzoxathiin 3-oxide, 1,2,3-propanetriyl ester, trans-13-octadecenoic acid, and methyl-11-hexadecenoate Fresh bulbs	Inhibit SARS-CoV-2 6LU7 protein Improvement in the general condition with the resolution of most of the symptoms after 2 days	Pandey et al. (2021) Belkessam et al. (2021)
<i>Aloe vera</i>	Feralolide, isoaloeresin, aloeresine, and aloin A	Inhibit SARS-CoV-2 main protease	Mpiana, et al. (2020)
<i>Annona muricata</i>	Roseoside, coreximine Javoricin, 5-(1-hydroxytridecyl)oxolan-2-one, arianacin, annomuricin A, annomuricin B, annomuricin C, muricatocin C, muricatacin, <i>cis</i> -annonacin, annonacin-10-one, and <i>cis</i> -goniothalamycin	Inhibit the main protease and spike protein Inhibit the spike protein	Adedotun et al. (2023) Prasad et al. (2021)
<i>Artemisia annua</i>	Scopoletin, arteannuin, and artemisinic acid	Inhibit the main protease and spike protein	Baggieri et al. (2023)
<i>Capsicum chinense</i>	Kaempferol, lutein, zeaxanthin, and quercetin	Inhibit main protease, ACE-2, and TMPRSS2 proteins	Rahmattullah et al. (2021)
<i>Carica papaya</i>	Papain, $\beta$ -cryptoxanthin, lycopene, lutein, $\beta$ -carotene, dichloro-9,10-diphenylanthracene-9,10-diol, lupeol Deoxyquercetin, riboflavin, kaempferol, catechin, deoxykaempferol, and apigenin	Inhibitory activity against main proteases of SARS-CoV-2, SARS-CoV, and MERS-CoV Inhibit 3-chymotrypsin-like protease, papain-like protease, RNA-dependent RNA-polymerase, endonuclease, and S1 and S2 regions of the spike protein	Nallusamy et al. (2021) Hariyono et al. (2021)
<i>Cissus quadrangularis</i>	Taraxerol and $\beta$ -amyrin	Inhibitory activity against main proteases of SARS-CoV-2, SARS-CoV, and MERS-CoV	Nallusamy et al. (2021)
<i>Citrus</i> sp.	Naringin, naringenin, hesperetin, hesperidin, nobiletin Obacunone, limonin, nomilin, hesperidin Sakuranetin, isosakuranetin, tetra- <i>o</i> -methylscutallerin, rutoside, eriodictoyl, quercetin, neoeriocitrin, diosmin, and diosmetin	Inhibit ACE2 receptor Virucidal activity on Vero E6-infected cells Inhibit SARS-CoV-2 main protease	Liu et al. (2022) Magurano et al. (2021) Mauludya et al. (2022) Khan et al. (2022)
<i>Cymbopogon citratus</i>	Tannic acid, isoorientin, luteolin, swertijaponin, chlorogenic acid, cymbopogonol, warfarin, citral diethyl acetal, citral acetate, kaempferol, and cyanidanol	Inhibit SARS-CoV-2 main protease	Ahmad et al. (2022)
<i>Gymnanthemum amygdalinum</i>	Veronicoside A, vernodalin and vernolide, vernomygdnin and 11, 13-dihydrovernodalin, and neoandrographolide	Inhibit SARS-CoV-2 main protease	Oladele et al. (2021)
<i>Mangifera indica</i>	Ellagic acid, epicatechin, gallic acid, mangiferin, kaempferol Amentoflavone, catechin, mangiferin, and kaempferol	Inhibit SARS-CoV-2 main protease Inhibitory activity against main proteases of SARS-CoV-2, SARS-CoV, and MERS-CoV	Haruna et al. (2021) Nallusamy et al. (2021)
<i>Moringa oleifera</i>	Catechin, ellagic acid, chlorogenic acid, quercetin, Myrecitin, and kaempferol Epicatechin, niazirin, glucotropaeolin, quercetin, apigenin, luteolin, rutin, kaempferol, isorhamnetin, myricetin, astragalol, marumosioid A, and moringyne	Inhibit SARS-CoV-2 main protease Inhibit the human TMPRSS2 protein	Haruna et al. (2021) Oyedara et al. (2021)
<i>Musa x paradisiaca</i>	Leucocyanidin, quercetin, sitoindoside-I, 6S-9R-roseoside, hydroxyanigorufone, and 1,2-dihydro-1,2,3-trihydroxy-9-[4-methylphenylphenalene]	Inhibit SARS-CoV-2 main protease	Harini and Gopal (2022)
<i>Ocimum gratissimum</i>	Luteolin, rosmarinic acid, chicoric acid, and myricetin	Inhibit SARS-CoV-2 main protease	Gyebi et al. (2021)
<i>Psidium guajava</i>	Gamma-sitosterol, peri-xanthenoxanthene-4,10-dione,2,8-bis(1-methylethyl) <i>P. guajava</i> extract supplementation	Inhibit main protease, papain-like protease, and spike and ACE2 receptor. Neutrophil/lymphocyte ratio reduction, PCR-based conversion time acceleration, and increase in the recovery rate of subjects with mild and asymptomatic COVID-19 infection in a single-blinded, randomized clinical trial	Fadilah et al. (2021) Heppy et al. (2023)
<i>Pycnanthus angolensis</i>	<i>Pycnanthuquinone</i> C and <i>pycnanthuquinone</i> A	Inhibit SARS-CoV-2 main protease	Chtita et al. (2022)

(Continued on following page)



TABLE 4 (Continued) Active compounds from medicinal plants with potential anti-SARS-CoV activity.

Plant name	Active compounds	Mechanisms	References
<i>Syzygium aromaticum</i>	Campesterol, stigmasterol, cratogeolic acid, oleanolic acid, and bicornin Polysaccharides	Inhibit SARS-CoV-2 main protease Block SARS-CoV-2 replication	Abdelli and Hamed (2023) Jin et al. (2021)
<i>Xylopiya aethiopicia</i>	Phenolic compounds and essential oils Liriodenine, lycisamine, o-methylmoschatoline, oxoglucaine, and oxophoebine	Antiviral activity against SARS-CoV-1 and SARS-CoV-2 pseudoviruses infecting HeLa ACE-2 cells Inhibit SARS-CoV-2 main protease	Melo et al. (2021) Ogunyemi and Oderinlo (2022)
<i>Zingiber officinale</i>	Gingerenone-A, chlorogenic acid, and hesperidin Cyanin Thujopsene, zingiberol, Gamma-elemene, beta-elemene, and aromadendrene	Block the entry of SARS-CoV-2 through its ACE2 receptors, binding affinities to Mpro and S protein Inhibitory activity against main proteases of SARS-CoV-2, SARS-CoV, and MERS-CoV Inhibit human TMPRSS2 protein	Jahan et al. (2021) Nallusamy et al. (2021) Ogunyemi and Oderinlo (2022)

et al., 2021; Anwar et al., 2023). Their application enhances the understanding of traditional healthcare practices and guides scientific research efforts. In this regard, symptoms such as fever, cough, and fatigue, which displayed high index values, appeared to be well-managed by the population, who are knowledgeable about several plants that can alleviate these symptoms. These plants merit further investigation based on the specific symptoms they are reported to alleviate.

The study findings suggest that plants traditionally used in the treatment of malaria are potential candidates for drug development against coronaviruses. Notably, the species prominently cited in this study have undergone assessment for their antiplasmodial activity, both in animal models and *in vitro*, demonstrating significant potential for managing malaria (Afolabi and Oyewole, 2020; Tajbakhsh et al., 2021; Indradi et al., 2023). These plants include *Annickia chlorantha*, *Zingiber officinale*, *Alstonia congensis*, *Newbouldia laevis*, *Ocimum gratissimum*, *Gymnanthemum amygdalinum*, *Artemisia annua*, and *Carica papaya* (Cimanga et al., 2019; Abubakar et al., 2020; Assogba, 2020; Wang et al., 2020; Kshirsagar and Rao, 2021; Tajbakhsh et al., 2021). Furthermore, the same plants demonstrate noteworthy anti-inflammatory and immunomodulatory effects, which are particularly valuable in addressing the cytokine storm induced by COVID-19 (Omorieg and Pal, 2016; Eftekhar et al., 2019; Abubakar et al., 2020; Olaoye et al., 2021; Kshirsagar and Rao, 2021; Mezui et al., 2022; Kamelnie et al., 2023; Nishiitha et al., 2023; Ukwubile et al., 2023; Yuandani et al., 2023). In addition, plants such as *Z. officinale*, *Artemisia annua*, *Carica papaya*, *Citrus* sp., *Allium sativum*, and *Cymbopogon citratus* were assessed for their antiviral activity against SARS-CoV-2 (Belkessam et al., 2021; Haridas et al., 2021; Oladele et al., 2021; Thuy et al., 2021; Adel et al., 2022) (Table 4). Various studies, using molecular docking, cell-based assays, and clinical trials, were conducted to elucidate the mechanisms underlying the antiviral activity of the cited plants. Collectively, the findings of these studies suggest that all tested plants are potential putative inhibitors of the proliferation of SARS-CoV-2, ACE2 host receptor, and major protease. They impede the attachment, membrane fusion, and internalization of SARS-CoV-2 into host cells, as well as the viral replication and transcription processes. Furthermore, numerous trials currently investigate several promising and potent phyto-based formulations for the treatment of SARS-CoV-2 infections (Alam et al., 2021). These formulations include a range of bioactive metabolites, plant extracts,

functional foods, and plant-based preparations. For example, hesperidin, which is present in some of the plants described in our study (Table 4), is involved as primary therapy in a phase II trial (Alam et al., 2021). In addition, a preliminary trial of the effect of *Allium sativum* in patients with SARS-CoV-2 showed an improvement in the general condition with the resolution of most of the symptoms (fever, headache, asthenia, ageusia, anosmia, and diarrhea) (Belkessam et al., 2021).

Analysis of the data highlighted that all the plants described in Table 4 showing promising activity against SARS-CoV-2 are listed in Table 3 as components of the popular recipes used in the prevention and/or treatment of COVID-19. A combination of these plants with antiviral and anti-inflammatory effects in a recipe strengthens the hypothesis that these recipes could effectively prevent or treat the coronavirus infection, thereby sustaining their use by the Gabonese population. So, taken together, the results of the present study showed the potential of medicinal plants as independent therapies, complementary or alternative medicines for the management of symptoms associated with COVID-19.

A concern could be raised regarding the potential overharvesting of certain species such as *Annickia chlorantha*, *Allium* sp., *Citrus* sp., *Alstonia congensis*, *Zingiber officinale*, *Carica papaya*, *Staudtia kamerunensis*, *Mangifera indica*, *Combretum micranthum*, and *Cymbopogon citratus* due to increased demand during the pandemic. However, Gabon is predominantly covered by forest (over 80%), and most of these species are distributed across all regions of the country (Wakefield Adhya, 2024). This suggests that the overharvesting of these species during the pandemic may not have had a significant impact on their abundance. Nevertheless, it is important to develop conservation planning for species with significant bioactivity. Conservation efforts could include measures such as sustainable harvesting practices and community-based management initiatives to ensure the long-term viability of these species and their ecosystems.

## 4.1 Limitations

The online ethnobotanical survey fell short of the anticipated participant count, primarily attributed to participants' failure to share the survey link and a general lack of interest in responding to online surveys. Furthermore, the use of online surveys is not



common among the Gabonese population, resulting in responders who are likely to possess a certain level of education and understand the significance of the survey. This could lead to potential bias regarding the sociodemographic profile of the responders. Furthermore, a field-based study extended to all the regions of the country might cover responses from all levels and classes of people.

## 5 Conclusion

COVID-19 has emerged as the most prolonged and deadly coronavirus outbreak witnessed worldwide in the past 50 years. Despite extensive exploration of various treatments, no definitive solution has been identified, and vaccination efforts have encountered limitations in the face of evolving virus variants. Ethnobotanical surveys conducted worldwide have explored the potential of plants to alleviate COVID-19 symptoms, yielding positive results and encouraging the use of medicinal plants for coronavirus infection management. In Gabon, the country's relatively low rate of cases and fatalities has been attributed to the consumption of plants traditionally used to treat malaria and flu, both as a preventive measure and in the treatment of COVID-19. Further investigation into the mechanisms of these plants such as anti-inflammatory, antioxidant, antiviral, and immunomodulatory activities is crucial for the development of plant-based medicines that could effectively act during the early stages of SARS-CoV-2 infection. This research holds promise as a significant alternative in the preparation for the inevitable occurrence of future coronavirus epidemics in the coming years. Understanding and harnessing the potential of these medicinal plants may provide valuable tools for mitigating the impact of such outbreaks.

## Data availability statement

The original contributions presented in the study are included in the article/Supplementary Material; further inquiries can be directed to the corresponding author.

## References

- Abdelli, W., and Hamed, D. (2023). Molecular docking and pharmacokinetics studies of *Syzygium aromaticum* compounds as potential SARS-CoV-2 main protease inhibitors. *Trop. J. Nat. Prod. Res.* 7 (11), 5155–5163. doi:10.26538/tjnpr/v7i11.18
- Abdulrahman, M. D., Mohammed, F. Z., Hamad, S. W., Hama, H. A., and Lema, A. A. (2022). Medicinal plants traditionally used in the management of COVID-19 in Kurdistan region of Iraq. *Aro-The Sci. J. Koya Univ.* 10 (2), 87–98. doi:10.14500/aro.11042
- Abubakar, A., Ahmad, N. S., Akanya, H. O., Abdullahi, A., and Asmau, N. A. (2020). Antiplasmodial activity of total alkaloids and flavonoids of stem bark extracts of *Enantia chlorantha* in mice. *Comp. Clin. Pathol.* 29, 873–881. doi:10.1007/s00580-020-03138-4
- Adedotun, I. O., Abdul-Hammed, M., Towolawi, B. T., Afolabi, T. I., Mufutau, K. M., and Adegoke, H. M. (2023). Phytochemicals from *Annona muricata* (Sour Sop) as potential inhibitors of SARS-CoV-2 main protease (M<sup>pro</sup>) and spike receptor protein: a structure-based drug design studies and chemoinformatics analyses. *Phys. Sci. Rev.* doi:10.1515/psr-2022-0338
- Adel, A., Elnaggar, M. S., Albohy, A., Elrashedy, A. A., Mostafa, A., Kutkat, O., and et al., (2022). Evaluation of antiviral activity of *Carica papaya* leaves against SARS-CoV-2 assisted by metabolomic profiling. *RSC Adv.* 12 (51), 32844–32852. doi:10.1039/d2ra04600h
- Afolabi, O. J., and Oyewole, J. L. (2020). Antiplasmodial efficacy of Vernonia amygdalina in Albino mice infected with Plasmodium berghei. *Int. J. Pediatr. Res.* 6, 115. doi:10.23937/2469-5807/1510115
- Ahmad, T., Saif, R., Raza, M. H., Zafar, M. O., Zia, S., Shafiq, M., et al. (2022). Computational prediction of *Cymbopogon citratus* compounds as promising inhibitors of main protease of SARS-CoV-2. *Futur. Biotechnol.* 2 (01), 20–25. doi:10.54393/ftb.v2i01.23
- Akbulut, S. (2021). Medicinal plants preferences for the treatment of COVID-19 symptoms in central and Eastern Anatolia. *Kastamonu Univ. J. Forestr. Facult.* 21 (3), 196–207. doi:10.17475/kastorman.1048372
- Alam, S., Sarker, M. M. R., Afrin, S., Richi, F. T., Zhao, C., Zhou, J.-R., et al. (2021). Traditional herbal medicines, bioactive metabolites, and plant products against COVID-19: update on clinical trials and mechanism of actions. *Front. Pharmacol.* 12 (671498), 671498. doi:10.3389/fphar.2021.671498
- Anwar, T., Qureshi, H., Naeem, H., Shahzadi, S., Sehar, Z., and Hassan, R. (2023). Exploration of the wild edible plants used for basic health care by local people of Bahawalpur and adjacent regions, Pakistan. *Foods.* 12 (19), 3557. doi:10.3390/foods12193557
- Asiimwe, S., Namukobe, J., Byamukama, R., and Imanlingat, B. (2021). Ethnobotanical survey of medicinal plant species used by communities around

## Author contributions

MB: conceptualization, data curation, formal analysis, methodology, writing–original draft, and writing–review and editing. AM: conceptualization, data curation, formal analysis, investigation, methodology, and writing–review and editing. JM: formal analysis, investigation, resources, and writing–review and editing. SA: conceptualization, supervision, validation, visualization, and writing–review and editing. LM: conceptualization, methodology, resources, supervision, validation, and writing–review and editing.

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## Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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- Mabira and Mpanga Central Forest Reserves, Uganda. *Trop. Med. Health* 49 (52), 52. doi:10.1186/s41182-021-00341-z
- Assogba, M. (2020). Usage traditionnel d'*Artemisia annua*: intérêt et limites dans le traitement du paludisme. *Sci. Pharm.* 75.
- Baggieri, M., Gioacchini, S., Borghonovo, G., Catinella, G., Marchi, A., Picone, P., et al. (2023). Antiviral, virucidal and antioxidant properties of *Artemisia annua* against SARS-CoV-2. *Biomed. Pharmacother.* 168, 115682. doi:10.1016/j.biopha.2023.115682
- Belkessam, N., Messafeur, A., Abderrahmane, R., Abdelkrim, K., and Ghanassi, F. Z. (2021). Etude préliminaire de l'effet de l'ail (*Allium sativum* L.) chez des malades atteints du SARS-CoV-2/preliminary study of the effect of garlic (*Allium sativum* L.) in patients with SARS-CoV-2. *Alger. J. Health Sci.* 3 (2), 9–14.
- Belmouhoub, M., Aberkane, B., and Bachir bey, M. (2021). Ethnopharmacological survey on medicinal plants used by Algerian population to prevent SARS-CoV-2 infection. *Ethnobot. Res. Appl.* 22, 1–13. doi:10.32859/era.22.38.1-13
- Chebaibi, M., Boust, D., Bourhia, M., Baammi, S., Salamatullah, A. M., Nafidi, H. A., et al. (2022). Ethnobotanical study of medicinal plants used against COVID-19. *Evidence-Based Complementary Altern. Med.* 2022, 2085297. doi:10.1155/2022/2085297
- Chitita, S., Fouedjou, R. T., Belaidi, S., Djoumbissie, L. A., Ouassaf, M., Qais, F. A., et al. (2022). *In silico* investigation of phytoconstituents from Cameroonian medicinal plants towards COVID-19 treatment. *Struct. Chem.* 33, 1799–1813. doi:10.1007/s11224-022-01939-7
- Cimanga, R. K., Nsaka, S. L., Tshodi, M. E., Mbamu, B. M., Kikweta, C. M., Makila, F. B., et al. (2019). *In vitro* and *in vivo* antiparasitodal activity of extracts and isolated constituents of *Alstonia Congensis* root bark. *J. Ethnopharmacol.* 242, 111736. doi:10.1016/j.jep.2019.02.019
- Cordoba-Tovar, L., Ríos-Geovo, V., Largacha-Viveros, M. F., Salas-Moreno, M., Marrugo-Negrete, J. L., Ramos, P. A., et al. (2022). Cultural belief and medicinal plants in treating COVID 19 patients of Western Colombia. *Acta Ecol. Sin.* 42 (5), 476–484. doi:10.1016/j.chnaes.2021.10.011
- da Silva, A. M., Horsth, A. L., Timóteo, E. D., Faria, R. J., Bazoni, P. S., Meira, E. F., et al. (2023). Use of medicinal plants during COVID-19 pandemic in Brazil. *Sci. Rep.* 13, 16558. doi:10.1038/s41598-023-43673-y
- Eftekhari, N., Moghimi, A., Mohammadian Roshan, N., Saadat, S., and Boskabady, M. H. (2019). Immunomodulatory and anti-inflammatory effects of hydro-ethanolic extract of *Ocimum basilicum* leaves and its effect on lung pathological changes in an ovalbumin-induced rat model of asthma. *BMC Complement. Altern. Med.* 19 (1), 349. doi:10.1186/s12906-019-2765-4
- Fadilah, F., Erlina, L., Paramita, R. I., Istiadi, K. A., and Handayani, R. R. D. (2021). Active constituents and molecular analysis of *Psidium guajava* against multiple protein of SARS-CoV-2. *Res. Sq.* doi:10.21203/rs.3.rs-271919/v1
- Fitriani, I., and Utami, W. (2021). Potential phytochemical inhibitor from *Allium cepa* for the medication of COVID-19 using in-silico approach. *Al Kim. J. Ilmu Kim. Terap.* 4 (2), 80–87. doi:10.19109/alkimia.v4i2.7459
- Gyebi, G. A., Elfiky, A. A., Ogunyemi, O. M., Ibrahim, I. M., Adegunloye, A. P., Adebayo, J. O., et al. (2021). Structure-based virtual screening suggests inhibitors of 3-Chymotrypsin-Like Protease of SARS-CoV-2 from *Vernonia amygdalina* and *Ocimum gratissimum*. *Comput. Biol. Med.* 136, 104671. doi:10.1016/j.combiomed.2021.104671
- Haridas, M., Sasidhar, V., Nath, P., Abhithaj, J., Sabu, A., and Rammanohar, P. (2021). Compounds of *Citrus medica* and *Zingiber officinale* for COVID-19 inhibition: *in silico* evidence for cues from ayurveda. *Futur J. Pharm. Sci.* 7 (1), 13. doi:10.1186/s43094-020-00171-6
- Harini, R., and Gopal, V. (2022). *In silico* studies on the phytoconstituents of *Musa paradisiaca* for Sars Cov-2 main protease inhibitory activity. *J. Adv. Pharmacol.* 2 (1), 7.
- Hariono, M., Hariyono, P., Dwiastuti, R., Setyani, W., Yusuf, M., Salin, N., et al. (2021). Potential SARS-CoV-2 3CLpro inhibitors from chromene, flavonoid and hydroxamic acid compound based on FRET assay, docking and pharmacophore studies. *Results Chem.* 3 (21), 100195. doi:10.1016/j.rechem.2021.100195
- Hariyono, P., Patramurti, C., Candarasari, D., and Hariono, M. (2021). An integrated virtual screening of compounds from *Carica papaya* leaves against multiple protein targets of SARS-Coronavirus-2. *Results Chem.* 3, 100113. doi:10.1016/j.rechem.2021.100113
- Haruna, I. U. H. N. D., Sunday, S. J., Tolulope, P. S., Tajudeen, O. J., Adeola, A., and Jamilu, B. D. (2021). In-silico analysis of the inhibition of the SARS-CoV-2 main protease by some active compounds from selected African plants. *J. Taibah Univ. Med. Sci.* 16 (2), 162–176. doi:10.1016/j.jtumed.2020.12.005
- Heppy, F., Mulyana, R., Afrainin, S. N., and Tjandrawinata, R. R. (2023). The effect of *Psidium guajava* Leaves' extract for mild and asymptomatic corona virus Disease-19. *Saudi Pharm. J.* 31 (4), 592–596. doi:10.1016/j.jsps.2023.02.012
- Indradi, R. B., Muhaimin, M., Barliana, M. I., and Khatib, A. (2023). Potential Plant-Based New Antiplasmodial Agent Used in Papua Island, Indonesia. *Plants.* 12, 1813. doi:10.3390/plants12091813
- Jahan, R., Paul, A. K., Bondhon, T. A., Hasan, A., Jannat, K., Mahboob, T., et al. (2021). *Zingiber officinale*: ayurvedic uses of the plant and *in silico* binding studies of selected phytochemicals with Mpro of SARS-CoV-2. *Nat. Prod. Commun.* 16 (10), 1934578X2110317–13. doi:10.1177/1934578X211031766
- Jin, C., Feng, B., Pei, R., Ding, Y., Li, M., Chen, X., et al. (2021). Novel pectin from crude polysaccharide of *Syzygium aromaticum* against SARS-CoV-2 activities by targeting 3CLpro. *bioRxiv.* 38. doi:10.1101/2021.10.27.466067
- Kamelnia, E., Mohebbati, R., Kamelnia, R., El-Seedi, H. R., and Boskabady, M. H. (2023). Anti-inflammatory, immunomodulatory and anti-oxidant effects of *Ocimum basilicum* L. and its main constituents: a review. *Ira. J. Basic. Med. Sci.* 26 (6), 617–627. doi:10.22038/IJBMS.2023.67466.14783
- Khadka, D., Dhamala, M. K., Li, F., Aryal, P. C., Magar, P. R., Bhatta, S., et al. (2021). The use of medicinal plants to prevent COVID-19 in Nepal. *J. Ethnobiol. Ethnomed* 17 (1), 26. doi:10.1186/s13002-021-00449-w
- Khan, J., Sakib, S. A., Mahmud, S., Khan, Z., Islam, M. N., Sakib, M. A., et al. (2022). Identification of potential phytochemicals from *Citrus Limon* against main protease of SARS-CoV-2: molecular docking, molecular dynamic simulations and quantum computations. *J. Biomol. Struct. Dyn.* 1 (12), 10741–10752. doi:10.1080/07391102.2021.1947893
- Kshirsagar, S. G., and Rao, R. V. (2021). Antiviral and immunomodulation effects of *Artemisia*. *Med. Kaunas. Lith.* 57 (3), 217. doi:10.3390/medicina57030217
- Liu, W., Zheng, W., Cheng, L., Li, M., Huang, J., Bao, S., et al. (2022). Citrus fruits are rich in flavonoids for immunoregulation and potential targeting ACE2. *Nat. Prod. Bioprospect.* 12 (4), 4. doi:10.1007/s13659-022-00325-4
- Magurano, F., Sucameli, M., Picone, P., Micucci, M., Baggieri, M., Marchi, A., et al. (2021). Antioxidant activity of citrus limonoids and investigation of their virucidal potential against SARS-CoV-2 in cellular models. *Antioxidants* 10 (11), 1794. doi:10.3390/antiox10111794
- Mauludya, N. B., Tallei, T. E., Ginting, B., Idroes, R., Illian, D. N., and Faradilla, M. (2022). Analysis of flavonoid compounds of Orange (*Citrus sp.*) peel as anti-main protease of SARS-CoV-2: a molecular docking study. *IOP Conf. Ser. Earth. Environ. Sci.* 951 (1), 012078. doi:10.1088/1755-1315/951/1/012078
- Mehraeen, E., Najafi, Z., Hayati, B., Javaherian, M., Rahimi, S., Dadras, O., et al. (2022). Current treatments and therapeutic options for COVID-19 patients: a systematic review. *Infect. Disord. Drug Targets* 22 (1), e260721194968. doi:10.2174/1871526521666210726150435
- Melo, C., Perdomo, R., Yerima, F., Mahoney, O., Cornejal, N., Alsaidi, S., et al. (2021). Antioxidant, antibacterial, and anti-SARS-CoV activity of commercial products of *Xylopia* (*Xylopia aethiopia*). *J. Med. Act. Plants.* 10 (1), 11–23. doi:10.7275/9baf-e988
- Mezui, C., Kuissi, M. M., Fanta, S. Y., Amang, P. A., Daptousia, D., Emakoua, J., et al. (2022). Analgesic, anti-inflammatory and non-ulcerogenic properties of *Annickia chlorantha* aqueous stem bark extract. *Discov. Phytom.* 9 (1), 184–192. doi:10.15562/phytomedicine.2022.186
- Mpiana, P. T., Tshibangu, D. S., Kilembe, J. T., Gbolo, B. Z., Mwanangombo, D. T., Inkoto, C. L., et al. (2020). Identification of potential inhibitors of SARS-CoV-2 main protease from *Aloe vera* compounds: a molecular docking study. *Chem. Phys. Lett.* 754 (2020), 7. doi:10.1016/j.cplett.2020.137751
- Murakami, N., Hayden, R., Hills, T., Al-Samkari, H., Casey, J., Del Sorbo, L., et al. (2023). Therapeutic advances in COVID-19. *Nat. Rev. Nephrol.* 19 (1), 38–52. doi:10.1038/s41581-022-00642-4
- Mvogo Ottou, P. B., Fogang, C. W. S., Ndiang, Z., Biyon, J. B. N., Mokake, S. E., Mbezo, F. B., et al. (2022). Assessment of resilience of aromatic plants during the COVID-19 pandemic in Douala, Cameroon. *J. Drug Deliv. Ther.* 12 (5), 8–19. doi:10.22270/jddt.v12i5.5580
- Naceiri, M. H., Bouyahya, A., Naceiri Mrabti, N., Jaradat, N., Doudach, L., and Faouzi, M. E. A. (2021). Ethnobotanical survey of medicinal plants used by traditional healers to treat diabetes in the Taza region of Morocco. *Evidence-Based Complement. Altern. Med.* 2021 (5515634), 5515634. doi:10.1155/2021/5515634
- Nallusamy, S., Mannu, J., Ravikumar, C., Angamuthu, K., Nathan, B., Nachimuthu, K., et al. (2021). Exploring phytochemicals of traditional medicinal plants exhibiting inhibitory activity against main protease, spike glycoprotein, RNA-dependent RNA polymerase and non-structural proteins of SARS-CoV-2 through virtual screening. *Front. Pharmacol.* 12 (667704), 667704. doi:10.3389/fphar.2021.667704
- Ndhlovu, P. T., Asong, J. A., Omotayo, A. O., Otang-Mbeng, W., and Aremu, A. O. (2023). Ethnobotanical survey of medicinal plants used by indigenous knowledge holders to manage healthcare needs in children. *PLoS ONE* 18 (3), e0282113. doi:10.1371/journal.pone.0282113
- Nishitha, A., Sindhu, R., and Anjali, S. (2023). Comparative evaluation of anti-inflammatory and antioxidant property of *Carica papaya* leaf and seed extract—an *in vitro* study. *J. Popul. Ther. Clin. Pharmacol.* 30 (14), 11–18. doi:10.47750/jptcp.2023.30.14.002
- Ogunyemi, B. T., and Oderinlo, O. O. (2022). In-silico investigation of oxoaporphine alkaloids of *Xylopia aethiopia* against SARS-COV-2 main protease. *AROC Nat. Prod. Res.* 2 (1), 01–12. doi:10.53858/arocnpr02010112
- Oladele, J. O., Oyeleke, O. M., Oladele, O. T., and Oladiji, A. T. (2021). Covid-19 treatment: investigation on the phytochemical constituents of *Vernonia amygdalina* as potential Coronavirus-2 inhibitors. *Comput. Toxicol.* 18 (2021), 100161. doi:10.1016/j.comtox.2021.100161

- Olaoye, I. F., Oso, B. J., and Aberuagba, A. (2021). Molecular mechanisms of anti-inflammatory activities of the extracts of *Ocimum gratissimum* and *Thymus vulgaris*. *Avicenn. J. Med. Biotech.* 13 (4), 207–216. doi:10.18502/ajmb.v13i4.7206
- Omogregje, E. S., and Pal, A. (2016). Antiplasmodial, antioxidant and immunomodulatory activities of ethanol extract of *Vernonia amygdalina* del. leaf in Swiss mice. *Avicenna J. Phytomed.* 6 (2), 236–47.
- Oyedara, O. O., Agbedahunsi, J. M., Adeyemi, F. M., Juárez-Saldivar, A., Fadare, O. A., Adetunji, C. O., et al. (2021). Computational screening of phytochemicals from three medicinal plants as inhibitors of transmembrane protease serine 2 implicated in SARS-CoV-2 infection. *Phytomed. Plus.* 1 (4), 100135. doi:10.1016/j.phyplu.2021.100135
- Panahi, Y., Gorabi, A. M., Talaei, S., Beiraghdar, F., Akbarzadeh, A., Tarhriz, V., et al. (2023). An overview on the treatments and prevention against COVID-19. *Virology* 20 (1), 23. doi:10.1186/s12985-023-01973-9
- Pandey, P., Khan, F., Kumar, A., Srivastava, A., and Jha, N. K. (2021). Screening of potent inhibitors against 2019 novel coronavirus (Covid-19) from *Allium sativum* and *Allium cepa*: an in-silico approach. *Biointerface Res. Appl. Chem.* 11 (1), 7981–7993. doi:10.33263/BRIAC111.79817993
- Phumthum, M., Nguanchoo, V., and Balslev, H. (2021). Medicinal plants used for treating mild Covid-19 symptoms among Thai Karen and Hmong. *Front. Pharmacol.* 12, 699897. doi:10.3389/fphar.2021.699897
- Prasad, S. K., Pradeep, S., Shimavallu, C., Kollur, S. P., Syed, A., Marraiki, N., et al. (2021). Evaluation of *Annona muricata* Acetogenins as potential anti-SARS-CoV-2 agents through computational approaches. *Front. Chem.* 8, 624716. doi:10.3389/fchem.2020.624716
- Rafiqul Islam, A. T. M., Ferdousi, J., and Shahinozzaman, M. (2021). Previously published ethno-pharmacological reports reveal the potentiality of plants and plant-derived products used as traditional home remedies by Bangladeshi COVID-19 patients to combat SARS-CoV-2. *Saudi. J. Biol. Sci.* 28 (11), 6653–6673. doi:10.1016/j.sjbs.2021.07.036
- Rahman, M. M., Masum, M. H. U., Wajed, S., and Talukder, A. (2022). A comprehensive review on COVID-19 vaccines: development, effectiveness, adverse effects, distribution and challenges. *Virusdisease* 33 (1), 1–22. doi:10.1007/s13337-022-00755-1
- Rahmattullah, N., Arumingtyas, E. L., Widyananda, M. H., Ahyar, A. N., and Tabroni, I. (2021). Bioinformatics analysis of bioactive compounds of four capsicum species against SARS-CoV-2 infection. *Int. J. Adv. Biol. Biomed. Res.* 9 (4), 298–319. doi:10.22034/ijabbr.2021.139183.1335
- Soheili, M., Khateri, S., Moradpour, F., Mohammadzadeh, P., Zareie, M., Mortazavi, S. M. M., et al. (2023). The efficacy and effectiveness of COVID-19 vaccines around the world: a mini-review and meta-analysis. *Ann. Clin. Microbiol. Antimicrob.* 22 (1), 42. doi:10.1186/s12941-023-00594-y
- Tajbakhsh, E., Kwenti, T. E., Kheyri, P., Nezaratzade, S., Lindsay, D. S., and Khamesipour, F. (2021). Antiplasmodial, antimalarial activities and toxicity of African medicinal plants: a systematic review of literature. *Malar. J.* 20, 349. doi:10.1186/s12936-021-03866-0
- Thuy, B. T. P., Nhan, V. D., Quang, N. M., Duoc, N. T., and Tat, P. V. (2021). Evaluation of SARS-CoV-2 inhibition of some compounds in *Cymbopogon citratus* oil combining docking and molecular dynamics simulations. *Vietn. J. Chem.* 59 (6), 790–799. doi:10.1002/vjch.202100022
- Ukwubile, C. A., Ikpefan, E. O., Dibal, M. Y., Umeano, V. A., Menkiti, D. N., Kaosi, C. C., et al. (2023). Pharmacognostic profiles, evaluation of analgesic, anti-inflammatory and anticonvulsant activities of *Newbouldia laevis* (P. Beauv.) Seem. ex Bureau leaf and root extracts in Wistar rats. *J. Ethnopharmacol.* 314, 116632. doi:10.1016/j.jep.2023.116632
- Villena-Tejada, M., Vera-Ferchau, I., Cardona-Rivero, A., Zamalloa-Cornejo, R., Quispe-Florez, M., Frisancho-Triveño, Z., et al. (2021). Use of medicinal plants for COVID-19 prevention and respiratory symptom treatment during the pandemic in Cusco, Peru: a cross-sectional survey. *PLoS ONE* 16 (9), e0257165. doi:10.1371/journal.pone.0257165
- Wakefield Adhya, S. (2024). Inspiring the world through action. The nature conservancy. Available at: <https://www.nature.org/en-us/what-we-do/our-insights/perspectives/gabon-30-30-leading-conservation/> (Accessed June 26, 2024).
- Wang, W. T., Liao, S. F., Wu, Z. L., Chang, C. W., and Wu, J. Y. (2020). Simultaneous study of antioxidant activity, DNA protection and anti-inflammatory effect of *Vernonia amygdalina* leaves extracts. *PLoS ONE* 15 (7), e0235717. doi:10.1371/journal.pone.0235717
- Yuandani, J. I., Haque, M. A., Rohani, A. S., Nugraha, S. E., Salim, E., Septama, A. W., et al. (2023). Immunomodulatory effects and mechanisms of the extracts and secondary compounds of *Zingiber* and *Alpinia* species: a review. *Front. Pharmacol.* 14, 26. doi:10.3389/fphar.2023.1222195
- Zondi, L. P., and Ehaine, S. (2022). Perspectives of the rural communities of Impendle, Bulwer, and Kokstad in South Africa using ethnomedicinal plants to cure flu and associated symptoms in the advent of COVID-19. *Int. J. Indig. Herb. Drug.* 7 (3), 62–75. doi:10.46956/ijhd.v7i3.312