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Research Paper

Use of Herbal Medicine in French Guiana: Influences and Challenges for Prevention Strategies in the Context of the COVID-19 Pandemic

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ABSTRACT

Introduction: In French Guiana, the COVID-19 pandemic was marked by very high levels of transmission in the population, low rates of hospitalisations and deaths, and high vaccine hesitancy. The use of traditional herbal remedies is very common in the population and understanding its influence as part of the population's healing strategy is important. We investigated the use of traditional remedies for the prevention or treatment of COVID-19 in French Guiana and its influence on vaccine hesitancy.

Methods: An online survey was conducted between April and May 2021 among 1 295 participants aged 18 years or older. Demographic characteristics, attitudes, and perceptions of the population about the pandemic, vaccination intentions and use of traditional remedies were collected through a standardised questionnaire.

The cited plants were collected and deposited at the Cayenne herbarium for identification.

Results: For combating COVID-19, 31.7% of people used traditional remedies while 71.4% reported usually treating themselves with remedies unrelated to COVID-19. A total of 604 use reports were recorded as 'anticoronavirus.' *Quassia amara* (Simaroubaceae) was the most frequently used species (153/604), representing 25.3% of the citations. Preventive use was more prevalent than curative use. Vaccine hesitancy was more common among people using traditional remedies.

Discussion/Conclusions: Several species commonly used in French Guiana such as *Quassia amara*, *Neurolaena lobata*, *Alpinia zerumbet*, and *Tinospora crispa* were found to be used in the context of COVID-19. Further studies would be useful to investigate qualitative and quantitative components of interest, mechanisms, and effects.

Introduction

French Guiana is a French overseas territory located in north-eastern South America, between Suriname and Brazil. It possesses a diverse medicinal flora, with 620 medicinal plants referenced in the traditional Guianese pharmacopoeias to date (Grenand, 2004). Traditional herbal remedies hold significant importance among the population in French Guiana (Tareau et al., 2017, 2020). Previous studies have revealed that people rely on phytoremedies, either alone or in combination, to combat infectious diseases, despite having access to free healthcare (Odonne et al., 2021a, 2011). French Guiana boasts a multiethnic population resulting from successive migration waves. As of 2019, this territory had a population of 281 678 inhabitants, with 29.8% of them being immigrants from neighbouring countries, primarily Suriname, Haiti, and Brazil (INSEE, 2022). This migration comes from neighbouring countries, mainly Suriname, Haiti, and Brazil. This cultural amalgamation of various ethnic groups such as Amerindians, Maroons, Creoles, Latin Americans, and Caribbean people contributes to the wide array of plant-based remedies available (Erarslan and Kultur, 2021; Fleury, 1991, 2007; Grenand et al., 2004; Odonne et al., 2017; Tareau, 2019; Tareau et al., 2021).

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Despite the fact that people worldwide commonly turn to phytotherapies and local remedies as initial solutions against COVID-19 (Pieroni et al., 2020; Vandebroek et al., 2020), no data regarding French Guiana's context are available as of yet. Numerous articles have been published on the use of medicinal plants against COVID-19 in Asia (Adhikari et al., 2021; Ang et al., 2020; Islam et al., 2020; Wang and Yang, 2021); however, to the best of our knowledge, none have been published within a South American context. Through molecular docking and simulation analysis, natural components of traditional Chinese medicine have been identified as potential lead molecules capable of interacting with components that block viral replication in SARS-CoV-2 (Alagu Lakshmi et al., 2020). Natural compounds may therefore serve as vital complementary tools in the fight against viruses (Islam et al., 2020). Additionally, randomised controlled trials have demonstrated the potential effects of combined herbal medicine and biomedicine on effective rates and symptom improvement (Pawar et al., 2021). However, similar to other 'promising' but ultimately inactive molecules during the pandemic, further high-quality randomised controlled trials are necessary to substantiate the effectiveness and identify adverse events associated with herbal medicine in COVID-19 treatment (Ang et al., 2020; Yu et al., 2022).

In the absence of effective treatment, authorities worldwide have mobilised to develop and provide access to vaccines through large-scale vaccination campaigns. However, attaining the goal of mass immunity presents numerous challenges. Even if vaccines are available and proven effective in reducing the risk of transmission, convincing a large portion of the population to receive vaccination is not an easy task. Vaccine hesitancy has become a growing global concern for more than a decade (Dubé et al., 2013; Larson et al., 2016). This concern prompted the World Health Organisation to include vaccine hesitancy, which does not necessarily entail a complete rejection of all forms of vaccination, in its list of 10 threats to global health in 2019 (World Health Organizations, 2019).

Among the various factors that may impact vaccination hesitancy (Dubé et al., 2013; Kestenbaum and Feemster, 2015), one hypothesis is that herbal medicine practices are a factor that may contribute to hesitancy in countries where there is sometimes a disparity between the use of medicinal plants and pharmaceuticals (Pugliese-Garcia et al., 2018).

The incorporation of ethnopharmacological knowledge can guide research towards the selection and pharmacochemical evaluation of relevant plants against the disease, providing a better understanding of attitudes towards biomedicine and vaccination, as well as identifying the communication needs in the realm of health. Therefore, the primary objective of this study is to describe the utilisation of traditional remedies for the prevention or treatment of COVID-19 in French Guiana and to investigate the relationship between the use of traditional remedies and vaccine hesitancy.

Materials and Method

Study Design and Recruitment

We implemented CAP-COVID, an online anonymized survey, to gather information on attitudes and perceptions regarding COVID-19 vaccination intentions among the population in French Guiana. The target population included individuals aged 18 years and above who were residing in French Guiana during the survey period. Participant recruitment took place from 26 April to 9 May 2021.

To promote the CAP-COVID survey, we utilised various public media platforms available in French Guiana such as radio, TV, and social networks. Advertisements were posted on platforms like Facebook and Twitter, as well as on the website of the Institut Pasteur of French Guiana. Additionally, the survey was shared via email. All individuals aged 18 years and older were invited to participate by completing the questionnaire.

The questionnaire was meticulously crafted by drawing inspiration from a French national-level questionnaire on vaccine intentions (Ward et al., 2020) and extensively tailored to suit the unique context of French Guiana. Its aim was to gather not only essential information about vaccine intentions but also to provide a comprehensive understanding of attitudes, practices, and behaviours concerning traditional remedies within the local population.

Hosted online through REDCap software, the questionnaire encompassed sociodemographic characteristics, behaviours, and perceptions of the population regarding the pandemic. It sought participants' opinions on the government and local authorities' management of the pandemic, vaccination intentions, attitudes and beliefs related to traditional remedies, the efficacy and safety of vaccines, as well as their perspectives on the contributions of science to humanity and their political opinions. The reliability of the questionnaire was evaluated through a pilot study involving a convenience sample of 20 individuals from the population of French Guiana. This assessment ensured the questionnaire's robustness and validity in accurately capturing data on attitudes, practices, and behaviours related to traditional remedies specific to the population. The participants completed the questionnaire in approximately 10 minutes.

To ensure accessibility to a wider audience, the questionnaire was translated into French, English, Spanish, and Portuguese and made available on the Pasteur Institute in French Guiana website.

Furthermore, individual interviews were conducted in July 2021 with a dozen residents of French Guiana who utilise medicinal plants. These interviews aimed to provide further clarification on the ethnomedicinal uses and perceptions presented in this article.

Statistical Analysis

We categorised the study participants into the following age groups: 18–24, 25–35, 35–44, 45–54, 55–64, 65–74, and > 75 years. Descriptive statistics were computed to analyse the use of traditional remedies based on age group, gender, place of birth, area of residence, socioprofessional categories, and type of health care insurance coverage.

Participants who responded 'yes' to the question: 'Do you usually take traditional remedies, Creole remedies to avoid getting sick or treat yourself when you are sick?' were considered phytotherapy users. Among phytotherapy users, we differentiated between preventive and curative users. We then identified the plants most frequently mentioned by consumers.

To mitigate biases associated with the study design and potential lack of representativeness of the study population, estimations were adjusted using official population demographics (INSEE, 2022). Weighted estimates were calculated by replicating the age and sex distribution, geographic area, and socioprofessional category in the population of persons aged 18 years and older residing in French Guiana.

For each variable, the raw numbers, their adjusted proportions, and their 95% confidence intervals were presented. Chi-square tests were performed to identify significant differences at the 0.05 level. Since most fields of the questionnaire were compulsory, no imputation of missing data was necessary. The analyses were carried out using the survey capabilities of Stata© 15.1 software (StataCorp, 2017).

Voucher Collection

Some of the mentioned plant species were collected from herbariums, except for plants used for culinary purposes, which are commonly found in stores and are difficult or impossible to collect. These specimens were then processed and deposited at the Cayenne IRD Herbarium for botanical identification. The taxonomic nomenclature used was the APG IV.

Results

A total of 1 295 individuals participated to the survey, consisting of 839 women and 456 men, with a mean age of 45.0 years. A comparison of the sociodemographic characteristics of the study sample with the census data revealed certain disparities. The sample showed an overrepresentation of women (64.8% vs 53.0% in the general population of French Guiana) and adults aged 35–44 years (59.7% vs 49.7% in French Guiana) while there was an underrepresentation of individuals aged 18–34 years (29.7% vs 40.2% in French Guiana). Furthermore, executive and higher intellectual professions (29.2% vs 5.2% in French Guiana) and employees (27.6% vs 15.4% in French Guiana) were overrepresented while those without professional activities were underrepresented (16.5% vs 45.9% in French Guiana). The sample also showed an overrepresentation of individuals living in Cayenne and its surroundings (72.8% vs 44.4% in French Guiana) whereas individuals living in the Maroni area were underrepresented (4.7% vs 29.8% in French Guiana) (Figure 1). To account for these differences, post-stratification weights were assigned to each participant in the analyses based on age, sex distribution, residence area, and socioprofessional category.

Use of Local Phytotherapy

At the time of the survey, 22.2% [16.1; 29.8] of participants believed they had COVID-19, 63.9% [56.4; 70.8] did not, and 13.9% [9.6; 19.9] were unsure.

The proportion of people who use local phytotherapy in non-COVID-19 situations was estimated at 71.4% [63.7; 78.1]. Nearly half of the individuals reported regular use (46.6% [39.5; 53.8]) and a quarter (24.9% [39.5; 53.8]) reported using it only occasionally. Women, individuals aged 18–24 or over 55, and those born in French Guiana were among the most frequent users (Table 1). Regarding COVID-19, only 31.7% [25.4–38.8] of people used medicinal plants against the SARS-CoV-2 virus, with 24.5% [20.3–29.3] using them for prevention and 8.6% [4.9–14.7] for curative treatment. Table 1 presents the use of medicinal plants both in general and during the COVID-19 crisis for curative and preventive purposes, categorised according to the sociodemographic characteristics of the respondents.

The use of herbal remedies was higher among women than among men (79.3% vs 64.6%, $P = 0.02$). Older individuals were particularly frequent users of herbal medicines, with 98.0 [92.2; 99.5] of those aged 75 and above claiming to use them. Pensioners and students were also significant users in line with the age distribution.

People born in French Guiana or abroad used more medicinal plants than people born in continental France or other French territories. People with a lower academic level used traditional remedies more often with 95.0% [89.9; 97.6] of individuals who had not attended school or who had only completed primary school reporting their use. According to our study, health insurance coverage, the number of chronic diseases, and SARS-CoV-2 infection status did not influence the use of remedies.

When examining preventive and curative use, gender did not significantly influence the use of herbal medicine.

Among consumers of preventive phytotherapies for COVID-19, older people were the most frequent users, with 72.4% [46; 88.9] of those aged 75 and above using them. People born in French Guiana or abroad used more preventive remedies than people born in continental France or French territories. We also noticed that 41% [25.3; 58.9] of retired people used preventive remedies. People living in Cayenne or on the coast, with lower qualifications and with at least two chronic pathologies at risk for COVID-19, used more preventive remedies. Health insurance coverage did not influence use. People with a history of a positive but asymptomatic SARS-CoV-2 infection were the most frequent users of medicinal plants as a preventive measure.

The use of traditional remedies for curative purposes did not change with age but was more pronounced among students (18.6% [6.8; 41.8]) and employees (9.5% [5.8; 15.3]) in association with a higher infection rate at the time of the study (students 25.3%, non-working 28.8%, and employees 24.5%). People born in French Guiana or abroad used medicinal plants for curative purposes more frequently than those born in metropolitan France or other overseas countries (12.9%, 10.7% vs 1.6% $P = 0.0049$). People with a history of SARS-CoV-2 infection or compatible symptoms were the main users of curative remedies.

Botany

Overall, 604 citations of plant species (use reports) were referenced, with an average of two citations per person (excluding null citations). The medicinal plants used as traditional remedies have been classified by frequency of use in Table 2, and the common names of each plant are translated into English (eng), French (fre), and Creole (krg). *Quassia amara*, a shrubby tree (2–8 m high) in the Simaroubaceae family, is the most commonly used plant in phytotherapy against COVID-19.

The common uses have all been determined according to Grenand (2004).

We also recorded 66 mentions (10.9%) of the term '*amer*,' which means bitter in French Guiana. This term refers to a category of multispecies alcoholic drinks prepared by macerating bitter plants in rum or vermouth. The commonly used plants in this category include *Aristolochia trilobata*, *Quassia amara*, *Geissospermum laeve*, *Momordica charantia,* and *Tinospora crispa* (Tareau, 2019).

During the survey, we collected five herbarium samples, which were sent to the Cayenne herbarium for identification.

The only species that we did not have access to was *Neurolaena lobata,* as it does not occur naturally in French Guiana but is found in the West Indies. However, *N lobata* is used in French Guiana in the form of syrup sold in drugstores, such as Virapic.

Preventive and Curative Use

The distribution of the most commonly used medicinal plants for preventive (a) and curative (b) purposes is presented in Figure 2. It can be observed that a wide variety of traditional remedies are used for both preventive and curative purposes, with a higher prevalence of preventive use.

In preventive use, many plants are used without one species predominating over the others, with nine species mentioned by over 80% of respondents. In curative medicine, *Tinospora crispa* was the most commonly used, followed by *Cinnamomum verum, Citrus aurantiifolia*, and *Quassia amara*. *T crispa* appeared to be primarily used for curative purposes, as the majority of users (77.3%) reported using it for curative rather than preventive purposes (32.9%).

Other species, such as *Curcuma longa*, *Zingiber officinale*, and *Neurolaena lobata*, were more commonly used for preventive rather than curative purposes.

Impact of the Use of Herbal Medicines on COVID-Vaccine Hesitancy

Table 3 shows that most consumers of local phytotherapy did not wish to be vaccinated. Among those hesitant to get vaccinated, the top reason for their reluctance was uncertainty about the vaccine's efficacy (77.3% [70.5–82.9]), followed by fear of side effects (53.0% [41.1–64.6]) and a preference for using herbal remedies (33.7% [25.5–43.1]). Additionally, 59.2% [47.2–69.8] of the participants expressed a complete lack of trust in local authorities' ability to manage the health crisis.

People who typically used herbal remedies (excluding COVID-19) were less likely to be vaccinated against COVID-19 (54.8% vs 77.0%, $P = 0.0013$). The majority of users of local phytotherapy believed that

Fig. 1. Map showing the main study locations for this survey and the division of the field into four zones.

the SARS-CoV-2 vaccine was not effective at all (89.4% [77.8; 95.3]). Furthermore, most of them perceived the vaccine to be not at all safe, meaning it had significant potential side effects (92.4%, $P = 0.0029$). Participants' level of vaccine information was not significantly correlated with the use of herbal remedies.

Among individuals using herbal remedies for preventive purposes, there were more unvaccinated people compared to vaccinated individuals (31.3% vs 13.8% $P < 0.0001$). The use of traditional remedies for preventive purposes was associated with negative vaccine intentions at 17.8% versus 9.1% ($P < 0.0010$) for positive vaccine intentions. A significant proportion of people using preventive remedies had a negative opinion about the effectiveness of the vaccine or were unsure about its effectiveness; 37.6% [26.4; 50.3] believed that the vaccine was not effective at all. The same pattern was observed regarding safety, with 39% [27.2; 52.3] perceiving it as not safe. Among users of preventive traditional remedies, 44% [34.3; 54.3] reported being uninformed about the vaccine.

In terms of curative use, the number of unvaccinated individuals was also high and the use of medicinal plants was correlated with vaccine hesitancy: 7% did not want to get vaccinated compared to 2.4% who wanted to be vaccinated or had not yet been vaccinated ($P = 0.0150$).

Discussion

French Guiana is one of the French territories that has been most affected by the COVID-19 epidemic, even though the impact on hospitalisations and deaths remains very low in this territory (Andronico et al., 2020; Flamand et al., 2021). However, despite the availability of free vaccines and significant efforts of cultural mediation to adapt to cultural difference, COVID-19 vaccination coverage in French Guiana is among the lowest observed in French and European territories due to highs level of vaccine hesitancy. It is worth noting that vaccination coverage for other older vaccines, such as DPT, is very high (92.9% in 2016 according to the French Public Health Agency (Santé Publique France, 2018).

In this context, it is interesting to study the practices of the population in response to this emerging disease. Phytotherapy, or the use of

Table 1
Factors associated with the use of local phytotherapy in COVID-19 (preventive and curative) N = 1 295.

	Usual medicinal plants use			COVID-19 preventive use			COVID-19 curative use		
	Total (N = 1 295)	Weighted proportion % CI 95%	*P* value	Total (N = 377)	Weighted proportion % CI 95%	*P* value	Total (N = 95)	Weighted proportion % CI 95%	*P* value
Gender									
Male	272	64.6 [51.7; 75.6]	0.0241*	127	22.4 [16.3; 30.1]	0.3475	35	10.6 [4.5; 22.8]	0.2762
Female	606	79.3 [72.4; 84.8]		250	26.8 [21.7; 32.6]		60	6.4 [4.3; 9.2]	
Age (years)									
18–24	93	81.4 [69.2; 89.5]	0.0303*	37	19.8 [12.8; 29.4]	< 0.0001*	13	14.1 [4.6; 35.8]	0.3254
25–34	156	60.3 [40.4; 77.3]		56	16.3 [10.2; 25.2]		19	7.3 [3.7; 14.1]	
35–44	214	62.7 [42.1; 79.6]		93	31.2 [20.2; 44.8]		25	5.5 [3.0; 10.1]	
45–54	191	62.4 [46.8; 75.8]		86	19.8 [13.6; 27.8]		25	7.3 [3.5; 14.3]	
55–66	135	80.5 [69.6; 88.2]		59	28.4 [19.8; 38.9]		8	5.6 [2.1; 14.0]	
65–74	71	82.3 [72.3; 89.2]		37	37.0 [23.9; 52.3]		4	4.1 [1.3; 11.4]	
> 75	18	98.0 [92.2; 99.5]		9	72.4 [46.0; 88.9]		1	5.0 [0.6; 29.8]	
Birthplace									
French Guiana	392	84.9 [71.7; 92.6]	< 0.0001*	207	28.6 [21.0; 37.6]	0.0081*	50	12.9 [5.9; 25.91]	0.0049*
France (except French Guiana)	349	51.4 [40.3; 62.4]		112	15.2 [10.7; 21.2]		25	1.6 [0.8; 3.016]	
Outside France	131	76.6 [66.4; 84.5]		54	30.7 [22.5; 40.3]		12	10.6 [6.1; 17.89]	
Residence area									
Cayenne area	639	76.3 [71.8; 80.2]	0.2744	281	30.5 [26.2; 35.3]	0.0144*	75	9.6 [6.9; 13.3]	0.3447
Other coastline	183	76.0 [65.8; 83.8]		75	30.3 [22.8; 39.0]		11	4.0 [1.7; 9.0]	
Maroni/Western interior	41	63.7 [42.8; 80.5]		15	14.1 [7.1; 26.0]		3	8.6 [1.6; 34.5]	
Oyapock/Eastern interior	15	59.3 [30.4; 83.0]		6	15.8 [5.8; 36.6]		6	24.1 [9.3; 49.4]	
Social/professional category						0.0367*			0.0244*
Farmers	5	87.9 [45.5; 98.4]	0.0395*	3	22.7 [6.5; 67.7]		0		
Craftsmen, shopkeepers, company managers	68	76.4 [59.1; 87.9]		26	24.5 [14.7; 38.0]		5	3.5 [1.4; 8.8]	
Executives, higher intellectual professions	256	67.8 [60.1; 74.7]		111	23.9 [18.6; 30.2]		9	3.7 [2.3; 5.8]	
Intermediate professions	80	58.2 [41.1; 73.4]		36	23.5 [14.4; 36.0]		21	2.5 [1.1; 5.8]	
Employees	242	76.4 [67.1; 83.8]		94	29.5 [21.9; 38.5]		35	9.5 [5.8; 15.3]	
Workers	9	45.4 [15.8; 66.0]		3	8.1 [2.1; 26.2]		13	3.8 [0.8; 17.1]	
Retired	73	86.7 [77.8; 92.4]		34	41.1 [25.3; 58.9]		2	3.8 [1.3; 17.1]	
Students	65	84.9 [73.0; 92.2]		25	19.4 [11.8; 30.3]		6	18.6 [6.8; 41.7]	
Other people without professional activities	80	68.8 [53.8; 80.7]		45	30.0 [20.6; 41.4]		4	6.2 [3.0; 12.3]	
Diploma									
Out-of-school/Elementary school	66	95.0 [89.9; 97.6]	0.0235*	38	45.3 [29.8; 61.8]	0.0164*	10	9.4 [4.5; 18.6]	0.0959
General Certificate of Secondary Education	124	66.8 [42.5; 84.6]		55	20.6 [12.3; 32.6]		16	6.4 [3.0; 13.4]	
High school diploma	173	79.1 [65.6; 88.2]		88	25.2 [16.7; 36.0]		21	14.9 [5.1; 36.4]	
Bachelor/Higher national diploma	339	63.8 [54.3; 72.4]		133	21.2 [15.8; 27.8]		33	4.9 [3.0; 8.0]	
Master's degree, doctorate	169	52.4 [37.2; 67.1]		62	15.7 [7.8; 29.2]		13	1.9 [0.9; 4.1]	
Health care coverage									
Standard social coverage	702	64.9 [56.2; 72.8]	0.1399	289	22.7 [18.2; 28.1]	0.3997	67	4.3 [3.0; 6.3]	0.0045*
None or specific health insurance for poor	147	78.9 [61.1; 90.0]		88	26.9 [19.3; 36.1]		28	14.2 [6.6; 28.1]	
Chronic pathology									
None	640	70.9 [62.2; 78.3]	0.5276	272	23.07 [18.7; 28.1]	0.0086*	68	9.0 [4.5; 17.2]	0.0298*
A chronic pathology	163	67.4 [42.3; 85.3]		64	19.83 [12.4; 30.2]		15	6.4 [2.9; 13.7]	
At least two chronic pathologies	75	82.6 [64.5; 92.6]		41	47.34 [28.9; 66.6]		12	9.1 [4.2; 18.7]	
Coronavirus infection status									
No	595	71.6 [63.4; 78.7]	0.9932	259	27.9 [22.4; 34.1]	0.0233*	0		< 0.001*
Yes, I had clinical symptoms	50	72.3 [40.7; 90.8]		23	8.3 [3.2; 19.5]		11	27.3 [7.4; 63.8]	
Yes, I had clinical symptoms and biological confirmation	84	69.5 [51.1; 83.2]		22	22.4 [13.2; 35.5]		20	45.6 [32.1; 59.8]	
Yes, I had biological confirmation and no symptom	16	79.6 [45.8; 94.7]		8	39.7 [18.3; 66.0]		4	15.8 [4.7; 41.6]	
Do not know	133	70.6 [39.1; 90.0]		65	24.1 [14.2; 37.8]		54	1.583 [0.4; 6.6]	

(*continued on next page*)

Table 1 (*continued*)

	Usual medicinal plants use			COVID-19 preventive use			COVID-19 curative use		
	Total (N = 1 295)	Weighted proportion % CI 95%	*P* value	Total (N = 377)	Weighted proportion % CI 95%	*P* value	Total (N = 95)	Weighted proportion % CI 95%	*P* value
Total		71.4 [63.7; 78.1]			24.5 [20.3; 29.3]			8.6 [4.8; 14.7]	

* p-value < 0.05 indicates statistical significance.

medicinal plants, is widespread in Amazonia, particularly in the French Guianese territory (Odonne et al., 2017). However, the specific uses of medicinal plants in the context of COVID-19 were not previously known.

As demonstrated by Tareau et al. (2020), the practice of herbal medicine is thriving in French Guiana, with over 70% of respondents claiming to consume medicinal plants. However, our study reveals that the primary profile of herbal remedy users consists of women over 55 years of age or young individuals, often students, aged 18–24 years, who were born in French Guiana.

The prominence of women as custodians of herbal medicine knowledge, primary actors in the transmission process, and the first users of medicinal plants is not surprising, as previous studies on the transmission of ethnobotanical knowledge have also observed this pattern (Lozada et al., 2006; Quinlan and Quinlan, 2007; Tareau et al., 2017; Torres-Avilez et al., 2016; Voeks, 2007; Voeks and Leony, 2004). The relatively high usage among young individuals can be explained by the presence of parents at home, as the transmission of knowledge in herbal medicine in French Guiana is primarily vertical (intergenerational) and intrafamilial (Tareau et al., 2020). Parents and grandparents administer herbal medicines to their children as long as they reside in the same household, and it is postulated that once the child leaves the family home, this type of use may temporarily decline. The use of medicinal plants as a preventive measure is more prevalent among elderly individuals, who are the most vulnerable population to infection. Students and employees, who are also the most susceptible to infection, are the primary users of plants for curative purposes, suggesting a shift in local medicinal practices. Preventive use is more significant among individuals who have received biological confirmation but show no symptoms, likely indicating contact cases who are infected but asymptomatic. Contact with an infected person may encourage the use of traditional remedies as a means of self-protection. On the other hand, curative use is more common among individuals who have received biological confirmation and/or exhibit symptoms. The use of herbal remedies, therefore, depends on the individual's proximity to the disease and their knowledge of the therapeutic effects of local medicinal plants.

Botanical Discussion

The most commonly used plants are those with a bitter species. This organoleptic characteristic holds significant therapeutic importance in Creole ethnomedicinal beliefs, as it is considered to have a ‘blood cleansing’ effect (Grenand et al., 2004; Tareau, 2019; Vilayleck, 2002), potentially capable of destroying the virus. Among the species most frequently mentioned in the survey (Table 2), four have a bitter taste: *M charantia*, *N lobata*, *Q amara,* and *T crispa*. Plants growing in yards and wastelands often exhibit qualitative defence mechanisms through the production of molecules with high biological activities, such as terpenes and alkaloids, which play a protective role against pathogens or predators and are crucial for their survival (Billing and Sherman, 1998; Jadhav et al., 1981). Interestingly, these highly pharmacologically active plants are also widely used in many pharmacopoeias (Leonti et al., 2013; Stepp and Moerman, 2001; Voeks, 2004), illustrating the pragmatism of folk medicines that leverage the natural defences of plants in human therapeutic healthcare, forming tripartite coevolutionary interactions between humans, plants, and pathogens (Etkin, 2003).

The prominent use of *Q amara* is noteworthy. This species, originally from Central America and naturalised in French Guiana in the 18th century, is traditionally employed by local populations for its antimalarial properties (Houël, 2011; Odonne et al., 2021b). The partial symptomatic analogy between malaria and COVID-19 likely explains the choice of this species for prevention and treatment of the latter disease.

However, the selection of this species is probably also influenced by the excitement surrounding hydroxychloroquine and the controversy

Table 2
Referencing of plants > 1% of citations.

Species Family	Common names	Herbarium voucher number	Part used	Common uses (Grenand, 2004)	Citation frequency	% citations
Quassia amara L. Simaroubaceae	Bitter wood (eng) *Quina de Cayenne* (fre) *Kwachi* (krg)	GF/MAT 001 GF/MAT 002	Leaves/bark	Fever Deworming	153	25.3%
Neurolaena lobata (L.) Clas, Asteraceae	Jackass bitters (eng) *Herbe à pique* (fre) *Zeb a pik* (krg)		Leaves	Fever Flu Malaria	73	12.1%
Citrus aurantiifolia (Christm.) Swingle Rutaceae	Lime (eng) *Citron vert* (fre) *Sitron* (krg)		Juice/bark	Conjunctivitis, sore, and plantar mycosis ear pain Flu	38	6.3%
Alpinia zerumbet (Pers) B.L. Burtt & R.M. Sm Zingiberaceae	Shell ginger (eng) *Gingembre cannelle* (fre) *Atoumo/katrépis* (krg)	GF/MAT 005	Flowers/ leaves/roots	Flu	36	6.0%
Zingiber officinale Roscoe Zingiberaceae	Ginger (eng) *Gingembre* (fre) *Jenjanm* (krg)		Rhizome	Digestive disorder Antinausea	36	6.0%
Allium sativum L. Amaryllidaceae	Garlic (eng) *Ail* (fre) *Lay* (krg)		Bulb	Fever Intestinal parasites Digestive disorder Skin affection	25	4.1%
Tinospora crispa (L.) Hook. F. & Thomson Menispermaceae	*Liane amère* (fre) *Lyann anmèr* (krg)	GF/MAT 004	Stems	Antimalarial Antidiabetic	24	4.0%
Momordica charantia L. Cucurbitaceae	Bitter gourd (eng) *Concombre amer* (fre) *Sorosi* (krg)	GF/MAT 003	Fruits Aerial parts	Antiseptic Antiparasitic Antidiabetic	11	1.8%
Allium cepa L Amaryllidaceae.	Onion (eng) *Oignon* (fre) *Lonyon* (krg)		Bulb	Flu state Oral candidiasis	11	1.8%
Syzygium aromaticum (L.) Merr & L.M. Myrtaceae	Clove (eng) *Clou de girofle* (fre) *Jirò̀f* (krg)		Dry flower buds	Dental pain	11	1.8%
Curcuma longa L. Zingiberaceae	Turmeric (eng) *Curcuma* (fre) *Tjitjima* (krg)		Rhizome	Cataplasm	10	1.7%
Cinnamomum verum J.Presl Lauraceae	Cinnamon (eng) *Cannelle* (fre) *Kannel* (krg)		Bark		9	1.5%
Cymbopogon citratus (DC.) Stapf Poaceae	Lemongrass (eng) *Citronnelle* (fre) *Sitronnel* (krg)		Leaves	Digestive disorder Flu	7	1.2%

surrounding this molecule. There is indeed a double confusion within the population, first between *Q amara* and quinine (Odonne et al., 2021b), and according to the field surveys conducted, between quinine and hydroxychloroquine, which was claimed to be effective against COVID-19 and highly publicised among a portion of the population. *Q amara* actually contains quassinoids (unrelated to quinoline alkaloids) that confer antimalarial activity in preclinical studies (Cachet et al., 2009; Houël et al., 2009).

The second most frequently mentioned species during the survey, *N lobata*, was mainly used through a commercially available syrup called Virapic. This phytoremedy has experienced a significant increase in local consumption in recent months due to a notable 'mediatic visualisation effect' (Leonti, 2011). However, there is a lack of scientific and peer-reviewed publications confirming the antiviral or immune-enhancing activity of the extracts of this plant or its food supplement.

Furthermore, we observed that several species (*A sativum*, *A zerumbet*, *C aurantiifolia*, *C citratus*, *C verum*, *T crispa*) frequently mentioned in this study are widely used in Creole home remedies to treat various flu-like conditions (Grenand, 2004; Tareau, 2019). The use of these species is symptomatological, as they are employed to combat fever and respiratory disorders, which align with the main symptoms of a SARS-CoV-2 infection.

Lastly, a large number of species mentioned in the study (*Allium* spp., *C aurantiifolium*, *C verum*, *C longa*, *S aromaticum*, *Z officinale*) appear to be globally used as both food and medicinal plants (Etkin, 2003). Throughout the world, many plants fulfil both therapeutic and nutritional purposes, becoming an integral part of a food-care continuum that is central to most 'traditional' medicines (Etkin, 2008, 2000; Ogle et al., 2003; Pieroni et al., 2006; Pieroni and Price, 2006). The multifunctionality (Pieroni et al., 2006) of these species, which have a dual purpose, culinary and therapeutic, has undoubtedly contributed to their wide dissemination across different tropical regions (Benett and Prance, 2000; Voeks, 2004).

Herbal Medicine Versus Vaccination?

During the study, overall vaccination coverage in French Guiana remained low, the lowest in France and among French territories. Interestingly, one of the significant reasons cited in our study, by individuals who were reluctant to be vaccinated, was the use of traditional remedies (33.7%). Furthermore, they expressed a negative opinion regarding the effectiveness and safety of the SARS-CoV-2 vaccine, which has also been observed among healthcare workers in French Guiana (Vignier et al., 2021). These findings align with the popularity

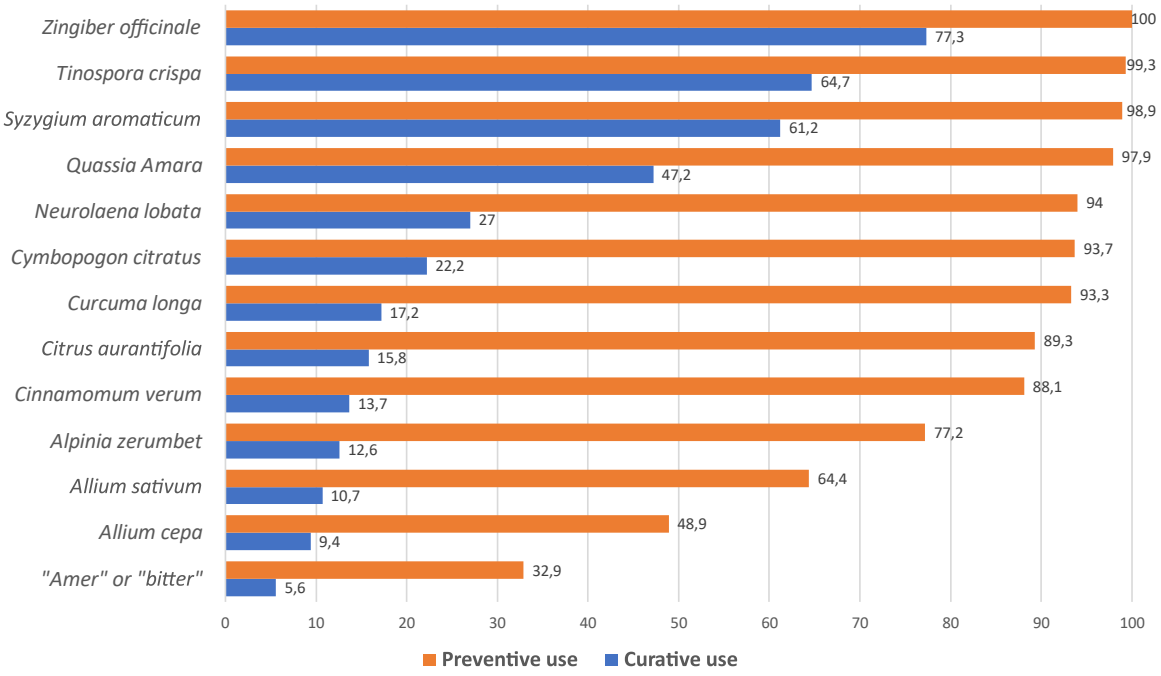

Fig. 2. Distribution of preventive and curative uses of the most cited medicinal plants among users (%).

and trust placed in medicinal plants in French Guiana, as well as the resulting usage patterns (Tareau et al., 2020). This high level of trust in herbal medicines and its widespread use seems to be in opposition to vaccination and partly hinders its acceptance among the population. Considering this significant public health issue, one recommendation for local health authorities would be to tailor vaccination campaigns to align with phytotherapeutic habits of the population in French Guiana, presenting them as complementary strategies rather than conflicting ones. It is quite paradoxical to observe that in a context where medical pluralism, notably between biomedicine and the various local ethnomedicines, appears to be the norm (Tareau, 2019), the use of plants is sometimes perceived by the population as an alternative they are familiar with, unlike the COVID-19 vaccine that they are unfamiliar with. However, it should be noted that the primary cause of COVID-19 vaccine hesitancy was a lack of trust in the vaccine, as indicated by 77.3% of the participants. Herbal medicine cannot be the sole factor, as the mistrust of the overseas populations towards the authorities plays a crucial role. In this sense, beyond concerns of efficacy and safety, choosing herbal medicine may indicate allegiance to French Guiana while expressing defiance towards mainland France.

Pharmacological Discussion

It is necessary to study the effectiveness of these plants and their preparations on the immune system and on SARS-CoV-2, although conducting such experiments is complex due to the intricate interactions between the virus, immunity, and plant molecules.

The plant predominantly used among our survey participants is *Q amara. In vitro* and *in vivo* studies have shown antimalarial activity against *Plasmodium berghei* and *Plasmodium falciparum,* compared to chloroquine used as a control (Bertani et al., 2006). The extract of *Q amara* also exhibits an *in vitro* anti-inflammatory effect by reducing the production of nitric oxide (**NO**), a proinflammatory mediator (Verma et al., 2010). Recent literature on the antiviral activity of quassinoids may provide clues for other antiviral activities of *Q amara* constituents, thus warranting further serious research in this field, despite the well-known cytotoxicity of these compounds (Fukamiya et al., 1992; Houël et al., 2009; Woo et al., 2019). No data on antiviral activity have been found in the literature. *Neurolaena lobata* and *Alpinia zerumbet*, despite their potential for anti-inflammatory action and symptomatic effects, are more commonly used as preventive measures. *In vitro* studies have shown that extracts of *N lobata* reduce tumour necrosis factor alpha (**TNF-α**) levels in THP-1 monocytes, resulting in a 72.2% inhibition of TNF-α production compared to the stimulated vehicle control, demonstrating an anti-inflammatory effect. This activity has been attributed to the presence of five sesquiterpene lactones (Walshe-Roussel et al., 2013). TNF-α is an inflammatory cytokine produced by macrophages/monocytes during acute inflammation, and it plays a role in signalling events that can lead to necrosis or apoptosis (Idriss and Naismith, 2000).

A zerumbet exhibits anti-inflammatory effects on the NF-κB signalling pathway, a proinflammatory transcription factor (Mitchell et al., 2016), and it may ameliorate oxidative stress in the NOS-NO signalling pathway. A study has shown its potential use against atherosclerosis (Xiao et al., 2020). The anti-inflammatory effect of *A zerumbet* is attributed to the inhibition of NO production, with an IC_{50} value of 63.9 ± 15.6 μg/mL. Several lactones present in extracts of this plant have been identified as responsible for this effect (Nishidono et al., 2020). The anti-inflammatory effects of these two plants could be explored in the immediate antiviral response to SARS-COV-2. TNF-α and NF-κB are potential determinants of the immediate immune response to SARS-CoV-2 (Bonny et al., 2020).

Some of the most commonly used species include *C aurantiifolia, A sativum,* and *Z officinale*, which are well-known plants used in food and have more extensively studied pharmacological activities. The antiviral and anti-inflammatory effects of *A sativum* have long been recognised (El-Saber Batiha et al., 2020); garlic contains numerous compounds that have the potential to influence immunity (Percival, 2016). It has been hypothesised that garlic may be beneficial in reversing some of the signs and symptoms observed in COVID + patients, improving or recovering the diminished or lost sense of taste, increasing the number of Treg cells, cytotoxic and helper T cells, decreasing leptin, leptin receptor, and PPAR-γ levels, preventing inhibition of CD4 + CD25 + FoxP3 + Treg cells, decreasing IL-6 levels, stimulating NK cells, and suppressing TNF-α and C-reactive protein (Donma and Donma, 2020).

A clinical trial on 32 patients demonstrated the benefits of *Z officinale* in acute respiratory distress syndrome. An enteral diet

Table 3
Vaccination against COVID-19 and use of herbal remedies.

	Plant users in general			COVID-19 preventive users of herbal remedies			COVID-19 curative users of herbal remedies		
	Total (N = 878)	Weighted proportion % CI 95%	*P* value	Total (N = 377)	Weighted proportion % CI 95%	*P* value	Total (N = 95)	Weighted proportion % CI 95%	*P* value
Already vaccinated against COVID-19									
Yes	296	54.8 [45.7; 63.6]	0.0013*	93	13.8 [9.7; 19.3]	< 0.0001*	18	3.8 [1.7; 8.1]	0.0219*
No	582	77.0 [66.7; 84.8]		284	31.3 [25.0; 38.5]		77	11.3 [6.1; 20.1]	
Vaccine intention									
Yes or have yet to be vaccinated	493	63.7 [55.3; 71.3]		176	9.1 [7.0; 11.8]		44	2.4 [1.5; 3.8]	
No	385	79.0 [64.2; 88.8]	0.0653	201	17.8 [14.0; 22.3]	0.0010*	51	7.0 [3.3; 14.3]	0.0150*
Confident of vaccine effectiveness									
Yes, absolutely	58	57.8 [42.7; 71.5]		23	18.6 [9.9; 32.1]		2	3.6 [0.9; 13.7]	
Yes, rather	256	60.3 [47.4; 71.9]	0.0375*	83	16.4 [10.8; 24.1]	0.0411*	16	3.7 [1.7; 7.9]	0.1225
No, rather not	167	68.5 [44.3; 85.6]		78	30.7 [18.3; 46.5]		25	15.9 [4.5; 43.2]	
Not at all	211	89.4 [77.8; 95.3]		113	37.6 [26.4; 50.3]		36	14.0 [8.4; 22.6]	
Do not know	186	76.7 [64.8; 85.4]		78	28.6 [20.1; 38.9]		16	6.3 [3.2; 12.3]	
Confident of vaccine safety									
Yes, absolutely	56	55.2 [41.0; 68.5]		27	25.39 [15.3; 39.1]		4	5.4 [1.7; 15.9]	
Yes, rather	246	62.1 [47.9; 74.6]	0.0029*	73	13.63 [8.6; 20.9]	0.0062*	17	12.9 [3.5; 37.3]	0.4757
No, rather not	154	60.0 [37.8; 78.7]		77	28.57 [16.8; 44.3]		20	6.2 [2.9; 12.6]	
Not at all	239	92.4 [82.0; 97.0]		124	39.04 [27.2; 52.3]		40	12.2 [7.2; 19.8]	
Do not know	183	80.3 [70.0; 87.7]		76	32.68 [23.6; 43.3]		14	6.4 [3.0; 13.1]	
Well informed about vaccine									
Yes, absolutely	169	71.1 [61.0; 79.5]		72	31.97 [23.42; 51.0]		12	6.5 [2.9; 13.7]	
Yes, rather	335	70.5 [61.2; 78.4]	0.2989	124	24.72 [18.9; 31.7]	0.0221*	24	6.0 [3.3; 10.6]	0.3055
No, rather not	164	65.9 [45.0; 82.0]		68	19.77 [11.2; 32.5]		23	12.1 [3.2; 36.4]	
Not at all	165	87.4 [77.0; 93.5]		95	44.06 [34.3; 54.3]		31	16.6 [10.1; 26.1]	
Do not know	45	68.1 [40.4; 87.1]		18	21.22 [9.4; 41.3]		5	4.5 [1.3; 14.7]	

supplemented with ginger in acute respiratory distress syndrome patients may enhance gas exchange and potentially decrease the duration of mechanical ventilation and length of stay in intensive care units (Vahdat Shariatpanahi et al., 2013).

Furthermore, the prevalent use of *T crispa* for curative purposes aligns with its potential antiviral action. Molecular modelling studies have been conducted to identify new compounds that can bind to the SARS-CoV-2 Mpro. *In silico* analysis of isolated compounds obtained from the methanol extract of *T crispa* indicated that certain selective compounds have the potential to modify the activity of SARS-CoV-2 Mpro (Rakib et al., 2020). Additionally, another *in silico* study demonstrated that the tyramine-Fe complex of *T crispa* exhibits better potential anti-inflammatory activity compared to tyramine alone, aspirin, and ibuprofen (Widodo, 2021). However, it is important to exercise caution and not hastily conclude that *in vitro* or *in silico* activity implies improved clinical outcomes. While many herbal remedies used in French Guiana contain molecules with effects on immunity and pathogens, including SARS-CoV-2, there is still a lack of substantial evidence regarding their preventive or curative efficacy. Emphasising the biological activity and 'promising' virtues of plants in the public discourse may serve as validation for the use of unproven remedies. However, it is crucial to acknowledge that a preventable disease that has claimed numerous lives requires a more evidence-based approach, especially considering the overwhelming evidence supporting the effectiveness of life-saving vaccines.

Limitations

The survey population may be overrepresented by employees, managers, and individuals who are educated, literate, and of high socioeconomic status, potentially indicating a higher level of politicisation. It also excluded populations less connected to social networks, smartphones, or the internet. For instance, individuals residing in the most remote areas along the Maroni and Oyapock rivers (Figure 1), where internet access is limited, accounted for only 4.8% and 1.9% of our study population, respectively, despite representing 29.8% and 25.7% of the French Guiana population along the Maroni and Oyapock rivers (INSEE, 2022).

To address this underrepresentation, estimates were computed by applying weights based on sex, age groups, geographical areas, employment characteristics, and status (e.g., telework, unemployed, retired, etc.) obtained from official demographics.

Moreover, there is uncertainty in identifying botanical species, as they were mentioned with different vernacular names in written form. However, most of these species are well-known, minimising the risk of confusion.

We did not gather information regarding the preparation methods and dosage. Participants' ethnic groups were not recorded, and it is unknown whether the traditional knowledge shared is based on a specific culture or a combination of multiple ethnic groups. The survey was not translated into all languages spoken in French Guiana, and it is not accessible to illiterate individuals.

Considering the topic of alternative medicines, it is possible that respondents may not have disclosed everything. They might have refrained from sharing 'well-kept' group recipes due to concerns about biopiracy, looting, and similar issues.

Conclusion

French Guiana is a unique French territory, characterised by a rich biodiversity and diverse ethnocultural practices. The use of Guianese phytotherapies is widespread among the local populations and has emerged as an important strategy in combating the emergence of COVID-19. Observational studies on local practices offer a significant opportunity to generate hypotheses about potential active phytochemicals. To deepen our understanding of the therapeutic potential of these phytochemicals and pave the way for the development of innovative treatments, further research investigations are necessary. *In vitro* preclinical and clinical studies on extracts of *N lobata, A zerumbet*, *T crispa*, or *Q amara*, which are commonly used plants against COVID-19, could provide valuable insights into their therapeutic potential. However, the COVID-19 crisis has unfortunately highlighted a significant and potentially harmful division between traditional and modern medicine, reflecting a complex interplay of health beliefs, distrust of authorities, and ingroup/outgroup dynamics that impact public health.

Ethical approval

Data were collected in accordance with French and European legislation for the protection and security of personal data. No directly identifiable information was collected, and it was not possible to feasible to re-identify individuals by cross-referencing their responses.

The research was determined to be exempt under 45CFR46 by the Institut Pasteur IRB (IRB00006966) on 4 May 2021. The complete dataset can be made available upon request, subject to prior determination of the terms and conditions of the request and in adherence to the relevant regulations.

Author contributions

Glwadys Forsans: Data curation, Formal analysis, Investigation, Visualization, Writing original draft. **Marc-Alexandre Tareau:** Conceptualization, Formal analysis, Funding acquisition, Investigation, Methodology, Writing – original draft, Writing – review & editing. **Leïla Ramiz:** Data curation, Formal analysis, Investigation, Methodology, Writing – review & editing. **Christelle Alves Sarmento:** Data curation, Investigation, Project administration, Writing – review & editing. **Nathalie Clément:** Project administration, Writing – review & editing. **Anaïs Perilhou:** Project administration, Writing – review & editing. **Nicolas Vignier:** Writing – review & editing. **Guillaume Odonne:** Funding acquisition; Writing – review & editing. **Mathieu Nacher:** Writing – review & editing. **Claude Flamand:** Conceptualization, Formal analysis, Funding acquisition, Methodology, Project administration, Supervision, Writing – original draft, Writing – review & editing.

Declaration of Competing Interest

The authors declare no conflicts of interest regarding the publication of this research article. We have no financial or personal relationships that could potentially bias our work or be perceived as influencing the outcome of this study. We have no competing interests related to employment, consultancies, honoraria, stock ownership, or any other financial relationships that could be perceived as a conflict of interest. This article is an honest representation of our research findings, and we have followed all ethical guidelines and regulations pertaining to the conduct and reporting of our study.

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