RESEARCH ARTICLE

Ethnobotanical survey of medicinal plants of bejaia localities from algeria to prevent and treat coronavirus (COVID-19) infection shortened title: phytomedicine to manage COVID-19 pandemic

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Abstract

The propagation of the COVID-19 pandemic in Algeria has pushed the population searching alternative therapies as preventives and treatment selections. The use of medicinal plants is a promising alternative solution to strengthen immunity and chase COVID-19. The aim of this study was to carry out an ethnobotanical survey in the Bejaia department (Algeria) to identify the plants used during the current pandemic. The study was conducted from February to May 2021. The interviews were conducted with 400 informants in order to assemble socio-demographic and floristic features of the respondents and used plants. The data analysis was performed by means of Relative Frequency of Citation (RFC), Family Importance Value (FIV), and Plant Part Value (PPV). 23 medicinal plants belonging to 12 families were adopted by the population of the Bejaia localities to prevent and treat COVID-19 infection. *Aloysia citriodora* Palau *(RFC = 0.248), Mentha spicata* L. *(RFC = 0.145), Citrus limon* (L.) Osbeck *(RFC = 0.135), Thymus vulgaris* L. *(RFC = 0.118), Zingiber officinalis* Roscoe *(RFC = 0.09), Artemisia herba-alba* Asso *(RFC = 0.065), and Eucalyptus globules* labill *(RFC = 0.063)* were the most cited species. The leaves of these plants which are used (65%) in the form of infusion (43.6%) are administered orally (95.03%) to treat and relieve certain symptoms of COVID-19. The current survey is the only one in the Bejaia department regarding the exploitation of medicinal herbs in the COVID-19 pandemic. These plants can be used as a platform to manage COVID-19.

Keywords COVID-19 · Ethnobotanical survey · Medicinal plants · Bejaia province · Algeria

Introduction

On January 30th, 2020, the World Health Organization (WHO) declared officially the COVID-19 that began in China in 2019 as a public health emergency of international concern. COVID-19 causes pneumonia characterized by flu-like symptoms: fever, cough, severe acute respiratory disorders, and death in some cases (Helali et al. 2020). Like other countries, Algeria was affected by the COVID-19 pandemic from February 25th, 2020. It recorded as of June 4th, 2021 a total of 130,361 people tested positive and more than 3,504 deaths since the start of the pandemic (http://www.covid19.sante.gov.dz).

The employment of plants to maintain human health is as old as mankind. Herbal prescriptions are employed for the treatment of several ailments, and the vast majority of people use these products as first-line remedies. Currently, attention has been drawn to claims by the traditional herbal medicine practitioners on the availability of herbal medicines for the prevention and cure of COVID-19. The need to search for African-based natural products was identified as potential anti-COVID-19 herbal remedies and natural compounds to be used as a home grown solution to the pandemic (Team et al. 2020).

Furthermore, neediness among populations, particularly between the intermediate and underprivileged peoples everely touched by the financial effect of obliged confinements, has conducted augmented attention in considering

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substitute selections of therapeutic herbals (Lim et al. 2021). Additionally, synthetic drugs are expensive and cause side effects, and thus safe and novel antiviral drugs are requested. Medicinal plants and their extracts have become a special substitute to prevent and treat COVID-19 infections. Moreover, herb-based antiviral substances have exposed distinguished results even in multiple clinical trials. Medicinal plants were investigated for antiviral activity against the different human viruses like Human Immunodeficiency Viruses (HIV) and influenza viruses (Adhikari et al. 2021). Hence, traditional drugs from various countries around the world have been studied for their therapeutic effect against SARS-COV-2 (Sharma et al. 2020).

Algeria conceals a remarkable floristic richness and the use of plants in herbal medicine is very old and since the coronavirus pandemic is spreading in our country, this recourse was multiplied and the interest shown by the population in the use of medicinal plants towards COVID-19 is increased (Beldi et al. 2021; Helali et al. 2020).

This study allowed us to observe and gather information concerning the diversity and richness of ethnobotanical information. The main objective is to know for the first time the medicinal plants used by the population of the localities of the Bejaia department (petite Kabylie) located in the North-East of Algeria to prevent and fight against COVID-19. The findings of the medicinal plants explored for therapeutic purposes in response to this pandemic in this province will be presented and analyzed.

Material and methods

Description of the study area

The department of Bejaia is located in the Northeast of Algeria at 220 km East of the Algerian capital Algiers., it is delimited by the Mediterranean Sea in the North, Bordj-Bou-Arreridj and Setif departments in the South, Jijel department in the East, and Bouira and Tizi-Ouzou departments in the West. Its approximate geographic location is 36° 45′ 21″ Northern latitude and 5° 05′ 03″Eastern longitude (Fig. 1). The total surface area of Bejaia is 3261 km^2 and its population was estimated at 978,050 inhabitants (DSP of the department of Bejaia, 2018).

The relief of the Bejaia department is subdivided into three zones which are (i) mountainous zone which occupies 75% of its total area, (ii) the foothills zone which represents the intermediate zone between the plains and the mountains, and (iii) the plains zone composed of the plains of the Soummam valley and the coastal plain which separates the sea and the Babors chain. Bejaia is found in a temperate zone with a mild Mediterranean climate. However, its broken topography provides sharp local contrasts in both prevailing temperatures and incidence of rainfall. The coastal zone and the Soummam valley enjoy a rainy and mild climate in winters, dry and hot in summer. The climate of the mountain areas is characterized by a dry and hot summer and a rainy and cold winter (Statistical directory of the department of Bejaia).
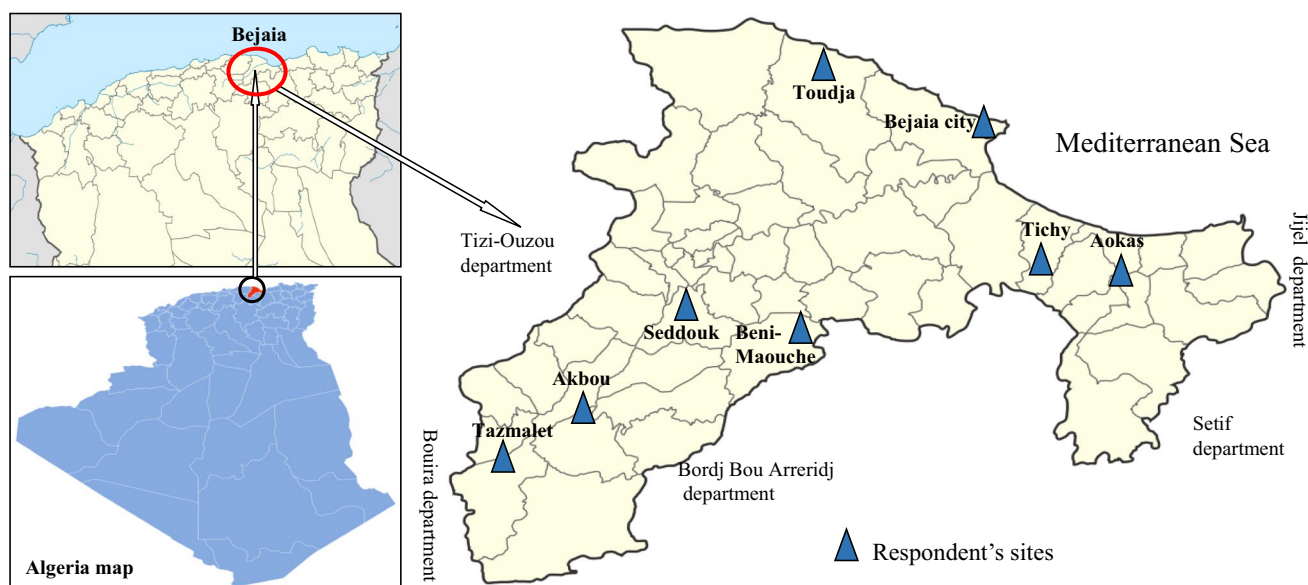

Fig. 1 Geographical location of the study area, Bejaia – Algeria

Ethnobotanical survey and data collection

With a view to assemble data on medicinal plants used to prevent and fight COVID-19 pandemic, an ethnobotanical survey was conducted from February 1st, to May 31th, 2021. This survey has been conducted in different regions of the Bejaia department. Eight sites were chosen, two in the North (Bejaia city and Toudja), two in the South (Beni-Maouche and Seddouk), two in the East (Tichy and Aokas), and two in the West (Akbou and Tazmalet) (Fig. 1).

This study was carried out by a series of trips over the eight regions during which we carried out 400 interviews with many different people (men and women of different age categories) chosen randomly, and participants had to complete the questionnaire strictly anonymously. The approach of those interviewed was based on dialogue in the local language (Kabyle).

An established questionnaire, which includes specific questions on the informants and the medicinal plants used was adopted. The information relating to the persons interviewed are age, gender, level of education, family situation, socioeconomic level and living environment. The data conerning the medicinal plants are name of plants (vernacular and latin names), parts used, method of preparation, mode of use, duration of treatment, plant efficiency, origin of the information, and side effects of the plants.

A list of the vernacular names of the medicinal plants cited by the respondents was made. The taxonomic identification of plants and the definitive determination of their Latin names and their names in Kabyle were based on documents: The medicinal plants of Kabylie (Aït Youssef et al. 2006)**.** The family names of the plants have been classified in alphabetical order based on the APGIII system (Angiospermes Phylogeny Groupe) [APG III, 2009].

Data analysis

The data was processed by Excel software and the obtained results were processed by the simple methods of descriptive statistics. Besides, analysis of ethnobotanical data was achieved using the Relative Frequency of Citation (RFC), the Family Importance Value (FIV), and the Plant Part Value (PPV).

Relative frequency of citation (RFC)

Relative Frequency of Citation (RFC) has been estimated to evaluate the local importance of each species. It is given by the Frequency of Citation (FC, the number of informants mentioning the use of the species) divided by the total number of informants in the survey (N).

$$\text{Relative frequency of citation (RFC)} = \frac{FC}{N}$$

This index varies from 0, when no informants refer to the plant species as useful, to 1, in the case when there are a maximum number of informants that consider a plant taxon useful (Orch et al. 2020).

Family importance value (FIV)

The Family Importance Value (FIV) pinpoints the relevance of medicinal plant families. It is assessed by the number of informants mentioning the family (FC familly) divided by total number of species in each family (Ns).

$$\text{Family importance value (FIV)} = \frac{FC\,\text{family}}{Ns}$$

Family use value is a culturally significant index that can be applied to ethnobotany to calculate the biological value of the plant taxon (Orch et al. 2020).

Plant part value (PPV)

The Plant Part Value (PPV) is determined to estimate the relevance of each employed part of the plant by the respondents, it corresponds the sum of reported uses per part of the plant (RUplant part) divided by the number of reported uses of all parts of the plant (RU) (Orch et al. 2020).

$$\text{Plant part value (PPV)} = \frac{RU\,\text{plant part}}{RU}$$

Results and discussion

Socio-demographic characteristics of the respondents

Four hundred informants between the ages of 20 and 80 years cooperated in the survey. The fluctuation regarding age, gender and education of the respondents has relevant involvements with medicinal cognizance (Table 1).

Table 1 Demographic characteristics of the informants ($n = 400$)

Variables	Categories	Number of Informants	(%)
Age	18–30	152	38.00
	[30–40]	99	24.75
	[40–50]	76	19.00
	[50–60]	47	11.75
	>60	24	06.50
Gender	Male	156	39.00
	Female	244	61.00
Family situation	Married	218	54.00
	Single	182	45.50
Academic level	Illiterate	27	06.75
	Primary	24	06.00
	Average	39	09.75
	Secondary	76	19.00
	University	234	58.50
Habitat	Urban	224	56.00
	Rural	176	44.00

Concerning age, people aged from 18 to 30 are the most frequent users of medicinal plants (38%) during the pandemic period. However, the lowest rate was noted among the elderly persons (ˆ 60 years) with a percentage of only 6.5%. On a national scale, similar results were recorded where people aged from 18 to 30 (60%) use plants more to prevent and fight against the coronavirus and are familiar with traditional herbal medicine compared to other age groups. Likewise, the lack of interest in herbal medicine is marked among the elderly for this pandemic (Helali et al. 2020).

In terms of gender, it is women who have acquired a good knowledge of medicinal species (61%) compared to men (39%). These values are consistent with the findings of Hamdani and Houari (2020) and Helali et al. (2020), who showed that 74% and 80% of Algerian women employed plants against 20.79% and 20% of men, respectively (Hamdani and Houari 2020; Helali et al. 2020). Women are the best informed and most involved in the knowledge and use of medicinal plants. Moreover, among the questioned persons, 54% were married and 45.5% were single. Indeed, it is the married people who have distinct tasks in ancestral health care delivery, particularly as parents. This is in agreement with the report of Kadri et al. (2019) who showed that married persons hold 88% of the traditional usage of plants in the department of Adrar in Algeria (Kadri et al. 2019).

Regarding the level of education, the majority of respondents have a university level (58.5%). People with secondary education have also an important percentage (19%), while people with an average and primary levels or illiterate represent 9.75%, 6%, and 6.75%, respectively. In the same line, in recent reports Helali et al. (2020) and Hamdani and Houari (2020) stated that 90% and 92%, respectively of phytotherapy users in other departments of Algeria have high education level (Hamdani and Houari 2020; Helali et al. 2020).

The residents surveyed in Bejaia regions revealed that of 56% of them were from urban areas against 44% who live in rural regions. Unlike the ethnobotanical study carried out in the Beni Mellal-Khènifra region from Morocco, Zahir et al. (2020) found that rural participants are the main consumers of medicinal plants since the rural population keeps good contact with nature (Zahir et al 2020). This can be explained by the fact that the majority of people affected with the COVID-19 virus are found in densely populated areas (urban).

Floristic analysis

As for therapeutic practices (Table 2), 23.75% of the population use traditional medicine, 67.25% prefer to combine traditional and modern medicines while 9% use modern ones. These findings confirm the results achieved in the North of Algeria by Hamdani and Houari (2020) who demonstrated that 91.2% of persons believe in the therapeutic efficacy of medicinal plants to treat COVID-19, and 60% of the participants in the survey believe that herbal remedies improve the health of patients, and can be used as a preventive treatment, against 3% who disapprove of the use of herbal medicine (Hamdani and Houari 2020). Concurrently, 57.75% of informants opt for the use of plants for their effectiveness, 9.25% for their easy acquisition, and 21.5% for their low cost compared to drug treatments, while 8.75% indicated that traditional medicine is better than modern medicine. According to Orch et al. (2020), the elevated expense of contemporary health therapies, their secondary impacts, and the disadvantageous socio-economic circumstances of inhabitance, are the main elements that drive people to take large employment of medicinal plants (Orch et al. 2020).

Botanical families most represented in the study area

A total of 23 medicinal plant species belonging to 12 botanical families were employed by the population of the department of Bejaia from Algeria in the prevention and treatment of COVID-19. The different species are displayed in alphabetical order and for each plant, the family, scientific name, the vernacular name, the local name, the part used, the preparation method adopted by the local population, and the FC, RFC, and FIV data were given (Table 3). The most represented family, in terms of the number of species, was Lamiaceae (8 species); other families accounted for only 1 or 2 species. Our results are similar to those recorded by El Alami et al. (2020) who

Table 2 Data related to the floristic analysis

	Distribution	Number of informants	(%)
Therapeutic practices	Traditional medicine	95	23.75
	Modern medicine	269	09.00
	Both medecines	36	67.25
Phytoterapy reasons	Effectiveness	231	57.75
	Easy acquisition	37	09.25
	Low cost	86	21.50
	Traditional medicine is better	35	08.75
Condition of preparations	Fresh	254	71.34
	Dried	203	57.02
	After treatment	11	03.08
Methodes of preparation	Infusion	178	50.00
	Decoction	136	38.20
	Cooked	35	09.83
	Raw	28	07.86
	Pressing	22	06.17
	Powder	17	04.77
	Maceration	10	02.8
Administration mode	Orally	351	98.59
	Inhalation	34	09.55
	Massage	11	03.08
	Rinsing	8	02.24
Acquisition of phytoterapy	Heritage, media	281	78.93
	Refer to herbalists	59	16.57
	Medical advice	14	03.93
Efficacy of phytotherapy	Improvement	243	68.25
	Cure	128	35.95
	Ineffective	10	02.80
Side effects of phytotherapy	Without side effects	337	94.66
	With side effects	63	05.34

identified 23 species belonging to 11 botanical families used by the Moroccan population during the spread of the COVID-19 pandemic (El Alami et al. 2020). Belhaj and Zidane (2021) and Helali et al. (2020) found also that Lamiaceae was most prevalent to prevent infection with COVID-19 (Belhaj and Zidane 2021; Helali et al. 2020).

Depending on the FIV (Fig. 2), the 6 extremely mentioned families were Verbenaceae (FIV = 0.248), Zingeberaceae (FIV = 0.09), Rutaceae (FIV = 0.07), Myrtaceae (FIV = 0.059), Lamiaceae (FIV = 0.050), and Asteraceae (FIV = 0.039); it means that they are predominant in the prevention and treatment of COVID-19 infection.

Relative frequency of citation

A high relative citation frequency (RCF) was determined to emphasize the relevance of ancestral knowledge; RCF was attributed to the more advisable plant species by the Bejaia localities people, so these plants have an elevated level of usage. Between these species, seven plants from six botanical families are commonly adopted by the population of Bejaia localities to prevent and treat COVID-19 infection. It is about: *Aloysia citriodora* Palau (RFC = 0.248), *Mentha spicata* L. (RFC = 0.145), *Citrus limon* (L.) Osbeck (RFC = 0.135), *Thymus vulgaris* L. (RFC = 0.118), *Zingiber officinalis* Roscoe (RFC = 0.09), *Artemisia herba-alba* Asso (RFC = 0.065), and *Eucalyptus globules* labill (RFC = 0.063).

Zingiber officinale Roscoe and *Eucalyptus globulus* labill were cited by Belhaj and Zidane (2021) as plants capable of modulating voices related to immune system enhancement and progression of the pathogenesis of various pathologies towards COVID-19 (Belhaj and Zidane 2021). Villena-Tejada et al. (2021) identified ginger and eucalyptus among the most utilized plants to treat and prevent of the respiratory symptoms related to COVID-19 in Cusco, Peru (Villena-Tejada et al. 2021). Moreover, the most mentioned plant

Table 3 List of active medicinal plants used to the prevention and treatment of COVID-19 infection in Bejaia localities from Algeria

Family	Latin name	Kabyle name	Common name	Part used	Fc	RFC	FIV
Amaryllidaceae	*Allium sativum* L	Thiskkerth	Garlic	Bulbs	6	0.015	0.01
	Allium cepa L	Lvssel	Onion	Bulbs	2	0.005	
Anacardiaceae	*Pistacia lentiscus* L	Thidekt	Lentiscus	Leaves and fruits	3	0.008	0.008
Apiaceae	*Pimpinella Anisum* L	Habetlhlawa	Green anise	Fruits	1	0.003	0.003
Asteraceae	*Artemisia herba-alba* Asso	Chih	White wormwood	Aerial part	26	0.065	0.039
	Matricaria chamomilla L	Babounej	Chamomile	Inflorescence	5	0.013	
Lamiaceae	*Lavandula stoechas* L	Amezir	Lavender	Leaves and flowers	1	0.003	0 .050
	Rosmarinus officinalis L	Iklil	Rosemary	Leaves	9	0.023	
	Ocimum basilicum L	Lhveq	Basil	Leaves and stems	8	0.02	
	Melissa officinalis L	Ifrezizwi	Lemon balm	Leaves	1	0.003	
	Mentha spicata L	Naanaa	Spearmint	Leaves	58	0.145	
	Origanum vulgare L	Zaatar	Oregano	Leaves	33	0.083	
	Thymus vulgaris L	Ziitra	Thyme	Leaves	47	0.118	
	Salvia officinalis L	Merimya	Sage	Leaves	3	0.008	
Lauraceae	Cinnamomun verum J. Presl	Lqerfa	Cinnamon	Bark	4	0.01	0.01
Myrtaceae	Eucalyptus globules labill	Kalitous	Eucalyptus	Leaves	25	0.063	0.059
	Syzigium aromaticum (L.) Merr & L.M Perry	Izouran n'tiv	Clove	flower buds	22	0.055	
Oleaceae	*Olea europaea* L	Azemour	Olive	Fruits	11	0.028	0.028
Pinceae	*Pinus halepensis* Mill	Thaydha	Aleppo pine	Latex	3	0.008	0.008
Rutaceae	*Citrus x limon* (L.) Osbeck	Lqares	Lemon	Fruits	54	0.135	0.07
	Citrus sinensis (L.) Osbeck	Ccina	Orange	Fruits	2	0.005	
Verbenaceae	*Aloysia citriodora* Palau	Tizana	Verbena	Leaves	99	0.248	0.248
Zingeberaceae	*Zingiber officinalis* Roscoe	Zanjabil	Ginger	Rhizomes	36	0.09	0.09

Fig. 2 Family Importance value (FIV) of medicinal plants used in the prevention and treatment of Covid-19 infection by the population of Bejaia localities from Algeria
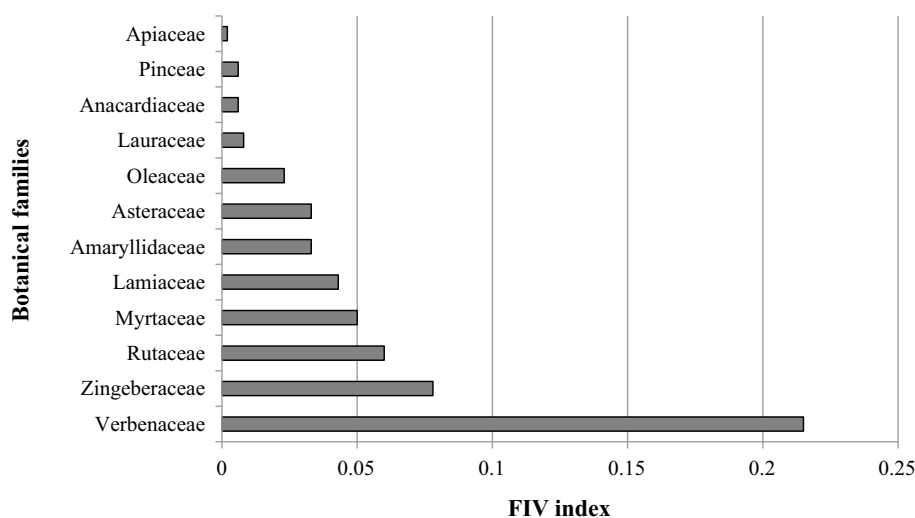
was *Eucalyptus globulus* Labill in the COVID-19 prevention and treatment in Morocco. Other species such as *Artemisia annua* L., *Thymus vulgaris* L., *Citrus limon* (L.) Osbeck*,* and *Zingiber officinale* Roscoe were also used (Orch et al. 2021).

These species are known for their richness in various bioactive substances such as phenolic acids, flavonoids, essential oils, alkaloids, glycosides, aromatic constituents, carotenoids, and many other anti-infectious compounds. Different studies established that the cited plants in this current survey offer significant effects against the virus in clinical and experimental studies (Table 4).

Table 4 The principal active compounds and the biological effects of medicinal plants used to prevent and treat infection caused byCOVID-19 in Bejaia localities from Algeria

Family	Latin name	Principal active compounds	Immunomodulatory and Anti-viral activities
Amaryllidaceae	*Allium sativum* L	Thiosulfinates (Alliin), ajoenes, sulfides, vitamins, flavonoids, minerals, saponins, sapogenins, phenolic compounds, nitrogen oxides, amides and proteins (Martins et al. 2016)	Inhibition of spontaneous and induced TNF-α secretion of pro-inflammatory cytokines and chemokines (Martins et al. 2016)
	Allium cepa L	Phenolic acids, flavonoids, anthocyanins, dipropyl disulfideand, dipropyl trisulfide, organo-sulfuric compounds, S-alk(en)yl-L-cysteine sulfoxides (Teshika et al. 2019)	Treat wasting syndrome, especially associated with AIDS, and/or to lengthen the latency period of HIV infection, and/or to delay the latent phase of AIDS (Goren 2002)
Anacardiaceae	*Pistacia lentiscus* L	Terpenoids, non-cannabinoid terpenoids, anthocyanins, fatty acids, phenolic acids, flavonoids, sterols, and tannin derivatives (Milia et al. 2021)	Its extract significantly reduced the production of IL-1β from ATP- or H₂O₂-activated cells. It inhibited the development of granuloma and the serum level of TNF-α and IL-6 in reply to the irritants (Milia et al. 2021)
Apiaceae	*Pimpinella Anisum* L	Volatile oils, fatty acids, coumarins, flavonoids, phenolic acids, terpenoids, lignin-carbohydrate protein complexes (Shojaii and Abdollahi Fard 2012)	Its essential oil prevents infection of COVID-19 virus and treats mild infections (Nasir and Yabalak 2021)
Asteraceae	*Artemisia herba-alba* Asso	Sesquiterpene lactones, flavonoids, phenolic acids and essential oils (Mohamed et al. 2010)	The herbal extract from Artemisia have shown remarkable antiviral activity in a cell-based stay against the SARS-CoV (Li et al. 2005)
	Matricaria chamomilla L	Sesquiterpenes, flavonoids, coumarins, and polyacetylenes (Singh et al. 2011)	Its ethanolic extract inhibites the growth of Herpes and poliovirus (Murti et al. 2012)

Table 4 (continued)

Family	Latin name	Principal active compounds	Immunomodulatory and Anti-viral activities
Lamiaceae	*Lavandula stoechas* L	Flavonoids, catechic tannins, sterols, coumarins, leucoanthocyans, mucilage and fatty acids (Ez zoubi et al. 2020)	The regulation of inflammatory precursors, including matrix metalloproteinase 9, inductible nitric oxide synthase, cyclooxygenase 2, and pro-inflammatrory cytokines (Ez zoubi et al. 2020)
	Rosmarinus officinalis L	Phenolic compounds, di- and triterpenes and essential oils (Andrade et al. 2018)	Its extract at 40 µg/mL caused 65% inhibition of HSV-2 plaques. It completely inhibited HSV-1 and HSV-2 plaque formation at 50 µg/mL (Al-Megrin et al. 2020)
	Ocimum basilicum L	Essential oils, phenolic acids and flavonol-glycosides, fatty acids (Singh et al. 2019)	Its alcoholic extract inhibits ZIKV replication in vero E6 cells. It inhibit the virus at the step of attachment and entry into the host cell (Singh et al. 2019)
	Melissa officinalis L	Hydroxycinnamic acid derivatives, tannins, flavonoids, monoterpene glycosides, sesquiterpenes, triterpenes and volatile oils (Miraj et al. 2016)	Its extract demonstrated a high virucidal activity against HSV-1, even at very low concentrations of 1.5 µg/mL (Miraj et al. 2016)
	Mentha spicata L	Essential oils, phenolic compounds (rosmarinic acid), carotenoids (Brahmi et al. 2017)	Its aqueous extract exhibits anti-viral potential against porcine parvovirus in vitro by efficiently killing them and control their multiplication in cells (WeiLi et al. 2011)
	Origanum vulgare L	Phenolic glycosides, flavonoids, tannins, sterols and high amounts of terpenoids (Pezzani et al. 2017)	Treatment of hepatitis A virus with its essentail oils at 0.5% resulted in slight decrease of its infectivity with the maximum reduction of less than 0.4 log $TCID_{50}$ (50% tissue culture infective dose)/mL (Pezzani et al. 2017)
	Thymus vulgaris L	Essentail oils (thymol, carvacrol), flavonoids and phenolic compounds such as rosmarinic acid (Hosseinzadeh et al. 2015)	Its extracts has shown inhibitory activity against Herpes simplex virus type 1 (HSV-1), type 2 (HSV-2) (Hosseinzadeh et al. 2015)
	Salvia officinalis L	Essential oils, phenolic acids, flavonoid glycosides, estrogenic substances, phenolic glycosides (Miraj and Kiani 2016)	Two new diterpenoids, safficinolide and sageone, which showed antiviral activity, were isolated from its aerial parts (Miraj and Kiani 2016)
Lauraceae	*Cinnamomunverum* J. Presl-a	essential oil, polyphenol, trans cinnamaldehyde, cinnamic acid and A-type and B-type procyanidins (Singh et al. 2021)	Its extract has significantly inhibited the pepsin enzyme which further upregulated the inhibition of HIV protease. A significant IC_{50} value obtained at the concentration of 56.08 ± 0.87 µg/mL (Singh et al. 2021)

Table 4 (continued)

Family	Latin name	Principal active compounds	Immunomodulatory and Anti-viral activities
Myrtaceae	*Eucalyptus globules* labill	Essential oils (phloroglucinol-sesquiterpenes), eucalyptin, monoterpenes (phenols, oleanolic acid, flavonoids, alkaloids, and tannins (Chandorkar et al. 2021)	Tereticornate A isolated from *E. globulus* (IC$_{50}$: 0.96 μg/mL) showed the strongest activity in the anti-HSV-1 assay. Cypellocarpin C isolated also from *E. globulus* (EC$_{50}$: 0.73 μg/mL) showed the most potent anti-HSV-2 activity (Brezáni et al. 2018)
	Syzigiumaromaticum (L.) Merr& L.M Perry	Carbohydrates, terpenoids, glycosides, steroids, sterols, tannins and phenolic compounds, saponins, alkaloids, flavanoids, cardiac glycosides, ketones, aldehydes (Kaur and Kaushal 2019)	Its extract was highly active at inhibiting replication of the hepatitis C virus (Hussein et al. 2000)
Oleaceae	*Olea europaea* L	Lipids, flavonoids (luteolin, apigenin, rutin), anthocyanins, secoiridoid phenols (Guo et al. 2018)	Its aqueous leaves extract showed anti-viral potential against new castle disease virus by restricting replication (Concentration: 1000 μg/mL) (Salih et al. 2017)
Pinceae	*Pinus halepensis* Mill	Terpenoids, fatty acids, steroids, phenolic acids, flavonoids, aldehydes, hydrocarbons, ketones, carboxylic acids, resin acids, phthalates, glaucids, alcohols, and proteins (El Omari et al. 2020)	Its extracts inhibited Sindbis virus at a minimum concentration of 1.5 μg/mL and poliovirus at 6.5 μg/mL (Mouhajir et al. 2001)
Rutaceae	*Citrus x limon* (L.) Osbeck	Flavonoids, limonoids, essentail oils, phenolic acids, coumarin compounds, carboxylic acids, a complex of B vitamins, ascorbic acid, fatty acids, carotenoids, Tocopherols (Klimek-Szczykutowicz et al. 2020)	Hesperidin from this species may be used for the development of anti-SARS-CoV-2 drugs as a treatment regime of COVID-19 (Utomo and Meiyanto 2020) Inhibition of replication of Herpes simplex (Klimek-Szczykutowicz et al. 2020)
	Citrus sinensis (L.) Osbeck	Flavonoids, steroids, hydroxyamides, alkanes, fatty acids, coumarins, carbohydrates, carbamates and alkylamines, carotenoids and volatile compounds elements (Favela-Hernández et al. 2016)	The treatment of cells with its extract prior to infection with CoV decreases the replication of the virus. IL-8 secretion was very low at early time points after infection. The virus load decreased when its extract was added to CoV infected cells (Ulasli et al. 2014)
Verbenaceae	*Aloysia citriodora* Palau	Flavonoids, anthocyanins, the essential oils (monoterpenoids, sesquiterpenoids, fatty alcohols, ketones), lignans, and triterpenes (Bahramsoltani et al. 2018)	Cytokines/inflammatory markers, such as IL-12 levels in the relapsing–remitting type, and IFN-γ levels in all types of multiple sclerosis (MS) patients were reduced. The concentrations of the anti-inflammatory cytokine, IL-4 and IL-10, were increased in the secondary progressive MS patients (Bahramsoltani et al. 2018)
Zingeberaceae	*Zingiber officinalis* Roscoe	Vitamin C, nicotinic acid, vitamin A, carotenoids, flavonoids, tannin, terpenes, phenolic compounds, phytosterols amadaldehyde, paradole, gingerdiols, gingerdiacetates, gingerenones, 6-gingersulfonic acid, diterpens, gingerglycolipids A, B and C, volatile oils (Zhukovets and Özcan 2020)	Its aqueous extract was effective against HRSV-induced plaque formation on airway epithelium by blocking viral attachment and internalization (San Chang et al. 2013)

Parts used

To formulate therapeutic remedies employed to prevent and treat COVID-19 infection, different parts of the mentioned species are managed (leaves, stems, fruits, flowers, rhizomes, tubers,.). The determination of the PPV use index demonstrated that the leaves are the most employed parts in medicinal preparation with a PPV index = 0.582, then stems (PPV = 0.161), and fruits (PPV = 0.154). The rhizomes, latex, flowers, tubers, and seeds are exploited to a lesser degree (Fig. 3). The aerial parts are the most used in medicinal preparations, and the dominance of the leaves usage was confirmed in the study of Helali et al. (2020) carried out in another region of Algeria (Helali et al., 2020). The frequency of use of the aerial parts of the plant can be explained by the ease and speed of their harvest, but also by the fact that they are the seat of photosynthesis and sometimes of storage of secondary metabolites responsible for the biological properties of the plant (Orch et al. 2020).

Method of preparation and administration

To administrate the bioactive substances included in herbal medicine, the habitants of Bejaia localities exert different modes of preparation for the prevention and treatment of COVID-19 infection. The most commons are infusion (50%) and decoction (38.20%), followed by cooking (9.83%), rawness (7.86%), pressing (6.17%), powdering (4.77%), and maceration (2.8%). These results are in agreement with the findings of other ethnobotanical studies which have found that infusion and decoction are the most cited methods of preparation, which was explained by their ease of achievement (Helali et al. 2020). Likewise, Hamdani and Houari

(2020) discovered that the infusion was the most frequent method of use (74%) among the North Algerian population during the COVID -19 pandemic (Hamdani and Houari 2020).

The ethnobotanical study revealed that most of the prepared recipes are prescribed orally (98.59%) because it represents the simplest, effective and rapid route of administration followed by inhalation (9.55%), massage (3.08%), and rinsing (2.24%). Similar results are found in another ethnobotanical study developed by El Alami et al. (2020) who found that infusion or decoction of parts of Lamiaceae and Asteraceae species, infusion of seeds of Apiaceae species, the decoction of rhizomes of *Zingiber officinale* Roscoe and *Alpinia officinarum,* and powder obtained after drying young twigs of Cupressaceae species are administered orally. In addition, the bulbs of the Liliaceae species, are also taken orally but the hot infusion of *Eucalyptus globules* labill is used by inhalation (Al Alami et al. 2020).

Conditions of medicine preparation

Most usually, the population claimed that they favor the part of the fresh herb than the dried part for cure elaboration. In the survey regions, most remedies (71.34%) were developed from fresh parts, followed by their dried form (57.02%) and only 3.08% indicated that they use the plants after treatment. Similar results were revealed in an ethnobotanical study achieved by Orch et al. (2021). They revealed that 70.8% of the plants are used fresh while 29.2% are utilised in dried form (Orch et al. 2021). The habituation of Bejaia habitants on fresh matters is predominantly thanks to the efficiency of fresh plants in cure since the amounts are not wasted prior to usage in comparison with the dried herbs.

Fig. 3 Plant part used in the prevention and treatment of Covid-19 infection by the population of Bejaia localities from Algeria
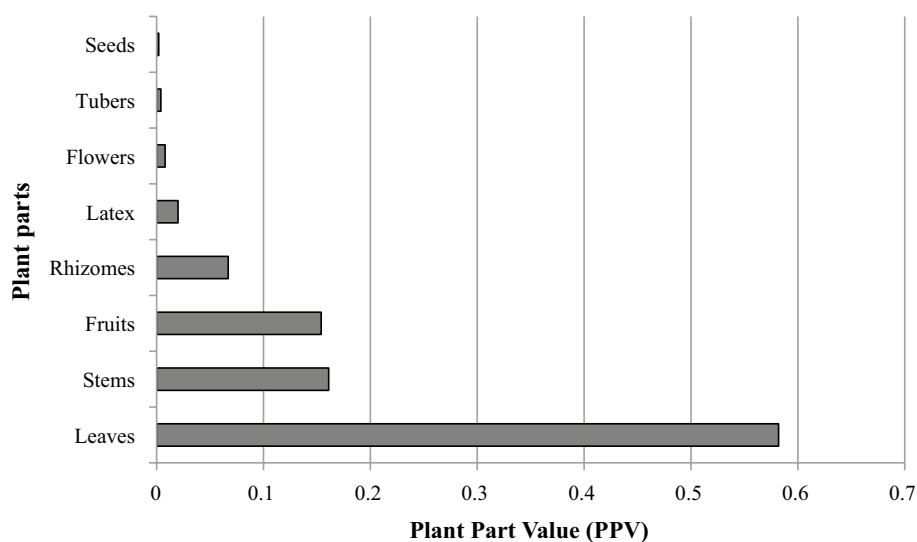
Origin of information on medicinal plants

Regarding the therapeutic application of medicinal herbs, 78.93% of people had their knowledge through family transmission or by consulting websites, books or through the media, 16.57% of the population refer to herbalists and only 3.93% sought medical advice. These results join those of Helali et al. (2020) recorded in northern Algeria and which indicate that 95% of medicinal plants users had their knowledge through family transmission, some consult books, and the internet and only 5% have recourse to the advice of an herbalist (Helali et al. 2020).

Effectiveness and side effects of the plants

According to the results obtained, 68.25% of the responses estimate an improvement against 35.95% who believe that medicinal plants allow a cure, while only 2.80% find that these plants are ineffective. This representativeness has also been observed, with some differences, in similar ethnomedicinal surveys conducted in other regions of Algeria. Hamdani and Houari (2020) showed that 60% of herbal medicine users believe that herbal remedies improve the health of patients with COVID-19 and can be used as a preventive treatment (Hamdani and Houari 2020).

Regarding side effects, out of all the results obtained, 94.66% of the Bejaia localities population found that the medicinal plants used did not cause any side effects. These results are confirmed by Helali et al. (2020) in a study carried out in Algeria and which recorded that 60% of surveyed persons revealed the absence of side effects regarding the use of medicinal plants during the COVID-19 pandemic (Helali et al. 2020).

Conclusion

The findings of this survey revealed a high demand of the population of Bejaia localities to medicinal remedies towards the global pandemic (COVID-19). Most of the plants used by the population during this pandemic are applied to fight many respiratory tract infections that cause manifestations similar to those of COVID-19. The identified species are known for their richness in different secondary metabolites which can have antimicrobial and even antiviral effects. So, the medicinal plants having high RFC must be further assessed for phytochemical and pharmaceutical analysis to identify their active constituents for any drug extraction.

However, there is increasing use of herbal products and herbal medicines globally with the belief that herbal medicines are always "safe" and carry no risk because they are from natural sources but it is important to know that there are concerns regarding medicinal plants and their ability to produce adverse effects.

The current survey allowed highlights the ignorance of certain users of medicinal plants concerning the modalities and their contraindications. Therefore, special attention should be given to the conservation and use of these medicinal plants, by fully documenting traditional medicinal knowledge as well as by carrying out phytochemical validation of the reported plants.

Declarations

Ethical statement This article does not contain any studies involving animals performed by any of the authors. This article does not contain any studies involving human participants performed by any of the authors.

Conflict of interest Fatiha Brahmi has no conflict of interest. Yassmina Iblhoulen has no conflict of interest. Hanane Issaadi has no conflict of interest. Mahmoud Fahmi Elsebai has no conflict of interest. Khodir Madani has no conflict of interest. Lila Boulekbache-Makhlouf has no conflict of interest.

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