Journal of Medicinal Plants for Economic Development
ISSN: (Online) 2616-4809, (Print) 2519-559X

A review of the medicinal plants with immune-boosting potential

Authors:
Olaoluwa O. Olarewaju[1]
Olufunke O. Fajinmi[1]
Kuben K. Naidoo[1]
Georgina D. Arthur[1]
Roger M. Coopoosamy[1]

Affiliations:
[1]Department of Nature Conservation, Faculty of Natural Sciences, Mangosuthu University of Technology, Durban, South Africa

Corresponding author:
Olaoluwa Olarewaju,
ooolarewaju1@gmail.com

Dates:
Received: 09 Feb. 2022
Accepted: 08 Apr. 2022
Published: 07 Oct. 2022

How to cite this article:
Olarewaju, O.O., Fajinmi, O.O., Naidoo, K.K., Arthur, G.D. & Coopoosamy, R.M., 2022, 'A review of the medicinal plants with immune-boosting potential', *Journal of Medicinal Plants for Economic Development* 6(1), a158. https://doi.org/10.4102/jomped.v6i1.158

Background: Humanity is faced with various kinds of infections (viral, bacterial and fungal). The recent spread of coronavirus disease 2019 (COVID-19) has led the World Health Organization to declare the coronavirus disease outbreak as a global pandemic. Medical experts suggested that people with high immunity tend to survive the infection more than those with low immunity. Hence, people must boost their immunity by consuming more fruit and vegetable or medications with immune-boosting potential to survive any form of unforeseen infections.

Aim: This study aimed to review horticultural fruit, vegetables and medicinal plants with immune-boosting potentials that may be useful in drug formulations to combat infectious diseases.

Methods: A literature search was conducted on electronic databases such as Google Scholar, Scopus and Web of Science. Several terms and free text words were combined in an appropriate manner to perform the search. Identified articles were reviewed independently for eligibility and extract of information.

Results: The study highlighted medicinal and horticultural crops with the potential to combat the symptoms of Covid-19 such as cold, cough, chest pain and high fever. Details about how despite effective vaccines, respiratory infections such as asthma, tuberculosis, pneumonia and measles are causing significant death worldwide.

Conclusion: This review highlights the fact that pharmaceutical companies should be encouraged to maximise the use of medicinal plants suggested for drug formulation strategies and humans should consume more fruit and vegetables to boost their immune systems.

Contribution: The use of natural products is now receiving global attention against synthetic ones to combat infections and the recent COVID-19 outbreak has called for innovative methods of treating the disease and its symptoms. This review provided information about medicinal plants with immune-boosting potential that when consumed or used in drug formulations can boost immune systems against various forms of infections. Insights on how the burden of diseases can be reduced and healthy lifestyles enhanced naturally are provided for social and economic developments.

Keywords: horticultural fruit and vegetables; immunostimulatory; COVID-19 and its symptoms; human health; medicinal.

Introduction

A healthy person tends to have a good immune system that combats potential infectious diseases caused by insects, fungi, bacteria or viruses. The immune system is the natural defence mechanism against diseases whereby it can produce an unlimited variety of cells and molecules to inhibit the manifestation of a variety of infections and undesirable substances (Sharma et al. 2017). It plays a crucial role in guarding against most external disease-promoting factors and malicious cells using helper and suppressor cells and soluble products (Mirabeau & Samson 2012). The immune system may be compromised and may result in either sickness or even death in some cases as experienced in the recent outbreak of the coronavirus pandemic (Cucinotta & Vanelli 2020). However, to survive infections, medical experts advised the consumption of food items or medications capable of boosting the immunity of a compromised immune system to maintain the high level of immunity required for survival (Aman & Masood 2020).

Medicinal plants are natural resources used by many local communities since time immemorial for the treatment of infectious diseases and as natural immune boosters (Street & Prinsloo 2013). The international communities now understand and appreciate the important role of medicinal plants in healthcare systems amongst many other benefits (Geldenhuys & Mitchell 2006; Street &

Prinsloo 2013). The pharmacologically active compounds in medicinal plants and horticultural produce responsible for boosting or modulating the immune system, especially in immunocompromised body systems, are now of great interest, especially during coronavirus disease outbreak. Furthermore, many vegetables such as eggplants, potatoes, mushrooms and tomatoes provide alternative forms of quality nutrition because of their richness in natural substances and enzymatic systems that protect against oxidation and free radical attack during metabolism (Huang et al. 2010; Scalbert et al. 2005). They are also important sources of polyphenols that protect cells against oxidative damage and invariably provide immunity against infectious diseases associated with oxidative stress inflicted by free radicals (Huang et al. 2010; Meccariello & D'Angelo 2021). Thus, consumption of these vegetables will potentially enhance human immune systems against diseases such as coronavirus disease 2019 (COVID-19). Apart from the contribution of fruit and vegetables in stimulating the immune system of humans, several medicinal plants are used in the African traditional medicine system to boost the immune system and treat chest pain, cough, high fever and shortness of breath – these are some of the major symptoms associated with coronavirus and other respiratory diseases. In addition to their efficacy in treating these symptoms and helping to develop immunity, they have been used to treat other respiratory infections, such as measles, tuberculosis (TB) and influenza amongst others in Africa and other parts of the world.

Several viral infectious diseases have plagued the world and led to high mortality and morbidity rates. Viral infections such as measles, smallpox, chickenpox, hepatitis, TB and polio amongst others have left apparent scars on mankind, especially amongst Africans (Greenwood 2014; Tulchinsky & Varavikova 2014). Before the discovery of the measles vaccine in 1963, there was measles epidemic every 2–3 years and almost everyone had the infection during childhood, with 90% of individuals infected by the age of 10 years (Hendriks & Blume 2013; WHO 2009). In urban areas, measles epidemic would occur every 1–2 years affecting children between the ages of 1.5 and 2.5 years. Outbreaks were less frequent in the rural areas and infections were commonly recorded amongst children between the ages of 2.5 and 5.0 years (Cutts et al. 1991). Whilst traditional healers often come up with treatments of natural origin to combat these diseases during another wave of the pandemic, it is believed that the infection naturally provides lifelong immunity (Goodson et al. 2011) meaning that once infected with measles during childhood, it is most improbable to be reinfected during adulthood.

Although the measles vaccine was administered throughout Africa and measles incidence was drastically reduced (Centres for Disease Control and Prevention [CDCP] 2009), there are still measles outbreaks, with case fatality rates amongst young children as high as 5% – 10% during outbreaks (WHO 2009). This resulted in an estimated 28 000 measles-related deaths each year (CDCP 2009). By implication, measles remains a major public health problem in Africa to date (Goodson et al. 2011). The developing countries of Africa and Asia have the highest incidence of measles infections in the world (Onoja & Ajagbe 2020). Endemic areas are largely confined to the tropics where the transmission rises after rainy seasons (Onoja & Ajagbe 2020). To curb the infection and transmission of measles, several medicinal plants are now being used traditionally because of their therapeutic components that could modulate complex immune systems to prevent infections rather than just treating immune-related diseases (Jantan, Ahmad & Bukhari 2015). Many plants contain immunomodulatory compounds, such as lactones, alkaloids, flavonoids, polysaccharides, diterpenoids and glycosides, that make them useful as medicinal plants (Jantan et al. 2015). Table 1 displays a summary of some active ingredients responsible for the immune-boosting potentials of horticultural crops whilst Table 2 shows some diseases and infections that are currently being treated with the use of medicinal plants.

TABLE 1: Summary of some horticultural crops and their active components.

SN	Crops	Active components	References
1	Soursop (*Annona* spp.)	Alkaloids	Yang et al. 2015
		Phenolics	Jiménez et al. 2014
		Megastigmanes	Matsushige et al. 2012
		Flavonol triglycerides	Nawwar et al. 2012
2	*Citrus* (*Citrus* spp.)	Flavonoid	Harborne & Williams 2000
		Carotenoids, phenolic acid, pectin and vitamin C	Wang et al. 2007
3	Garlic (*Allium sativum* L.)	Citric acid, ascorbic acid	González-Molina et al. 2010
		Sulphur-rich compounds	Wargovich et al. 1988
		Organo-selenium compounds	Cardelle-Cobas et al. 2010
4	Onions (*Allium cepa* L.)	Carbohydrate, Protein	Roy et al. 2018
		Protein, flavonoids and fibre	Lanzotti 2006
		Organosulphur compounds	Bystrická et al. 2013; Suleria et al. 2015
5	Carrot (*Daucus carota* L.)	Copper, zinc, iron, selenium and vitamins such as vitamins A, B_2, C and E	Bhaskaram 2002
		Carotenoids	Raiola et al. 2014

Note: Please see the full reference list of the article, Olarewaju, O.O., Fajinmi, O.O., Naidoo, K.K., Arthur, G.D. & Coopoosamy, R.M., 2022, 'A review of the medicinal plants with immune-boosting potential', *Journal of Medicinal Plants for Economic Development* 6(1), a158. https://doi.org/10.4102/jomped.v6i1.158, for more information.

Horticultural crops and their potential as an immune booster

Annona species

Annona spp. is a perennial, tap-rooted fruit tree that belongs to the Annonaceae family with a long history of medicinal value. Some of its common names include soursop, guanabana, sirsak, sugar apple and Graviola and the fruit tree is mostly distributed in tropical and subtropical regions of the world such as Nigeria and India but is native to the warmest tropical area of South and North America (Adewole & Caxton-Martins 2009). The fruit of the species such as *Annona muricate*, *Annona squamosa* and *Annona reticulata* are widely used in ethnomedicine to treat many diseases and ailments such as malaria, fever and worms in humans (Moghadamtousi et al. 2015). The fruit pulp is mostly eaten raw, whilst the fruit rind and seeds, fruit tree leaves, tree stem and root barks and other parts are usually

TABLE 2: Summary of some diseases and infections currently being treated with medicinal plants.

SN	Diseases and infections	Medicinal plants used	References
1	Snakebite, coughs associated with colds	*Echinacea* spp.	Bauer & Wagner 1991
2	Measles	*Momordica charantia* L.	As et al. 2009
		Citrus aurantifolia and *Hibiscus cannabinus* L.	Mustapha et al. 2013
		Nauclea latifolia S.	Okwu & Uchenna 2009
		Elytraria marginata Vahl, *Peperomia pellucida* L. Humb., Bonpl. and Kunth, *Vernonia amygdalina* Del., *Momordica charantia* L., *Newbouldia laevis* (P. Beauv.) Seem. ex Bureau and *Ocimum gratissimum* L.	Sonibare et al. 2009
		Momordica charantia	Fatoba et al. 2019
		Rauvolfia caffra Sond.	Hutchings 1996; McGaw et al. 2000
3	Chickenpox and measles	*Momordica charantia*	Appiah et al. 2018
4	Influenza and measles	*Lippia javanica*	Mitra 2012
5	Trauma, inflammations and infection	*Echinacea purpurea* L.	Gajalakshmi et al. 2012
6	Tuberculosis	*Clausena anisata, Haemanthus albiflos* and *Artemisia afra*	Lawal et al. 2014
		Artemisia afra	Buwa & Afolayan 2009; Makunga 2010; Semenya & Maroyi 2013
		Cannabis sativa	Hutchings 1996
		Knowltonia vesicatoria	Efange 2002
		Bolusanthus speciosus	WHO 2003
		Eucalyptus spp., *Ocimum suave, Persea americana* Mill., *Momordica foetida* Schum.	Tabuti et al. 2010
7	Mycobacterium tuberculosis	*Asparagus africanus* and *Ficus sur*	Madikizela et al. 2014
8	Flu	*Artemisia afra*	Buwa & Afolayan 2009; Makunga 2010; Semenya & Maroyi 2013
9	Measles and bronchial	*Clausena anisate*	Ajibesin et al. 2007; Hutchings 1996
10	Colds, bronchitis, tuberculosis, coughs, asthma and chest infections	*Leonotis leonurus*	Mdluli, Kaneko & Upton 2014
11	Tuberculosis, asthma	*Hypoxis hemerocallidea*	Makunga 2010
12	Influenza, cancer, tuberculosis and HIV infection	*Sutherlandia frutescens*	Giesbrecht 2001; Mills et al. 2005

Note: Please see the full reference list of the article, Olarewaju, O.O., Fajinmi, O.O., Naidoo, K.K., Arthur, G.D. & Coopoosamy, R.M., 2022, 'A review of the medicinal plants with immune-boosting potential', *Journal of Medicinal Plants for Economic Development* 6(1), a158. https://doi.org/10.4102/jomped.v6i1.158, for more information.

processed before consumption and they help to boost the immune system to combat diseases such as arthritis, diarrhoea, cystitis, diabetes, rheumatism and catarrh (Mishra et al. 2013; Yajid et al. 2018).

Many scientific investigations suggest that *Annona* spp. is rich in compounds and phytoconstituents such as alkaloids (Yang et al. 2015), phenolics (Jiménez et al. 2014), megastigmanes (Matsushige et al. 2012) and flavonol triglycerides (Nawwar et al. 2012), making it an immune-boosting candidate. Regular consumption of the fruit could boost the human immune system against diseases such as bacterial and viral diseases and is therefore recommended. An antioxidant study performed on aqueous and methanolic leaf extract of the plant revealed DNA protective effects against H_2O_2-induced toxicity (George et al. 2015). Whilst the ethanolic extract of *A. muricata* stem bark triggered a decrease in the lipid peroxidation induced by cold immobilisation stress in the brain of rats (Padma, Chansouria & Khosa 1997; Padma et al. 2001), an aqueous extract of the leaves was tested against a gastrointestinal parasite, *Haemonhus contortus* and the results were positive, with 89.08% and 84.91% toxicity against larva and eggs as indicated by the larva motility and egg hatch tests. Hence, a promising anthelminthic activity in the leaves was indicated (Ferreira et al. 2013). These reported results about *Annona* spp. present it as a candidate with immune-boosting effects in humans against the most infectious disease of viral, bacterial or fungal sources.

Citrus species

Citrus (*Citrus* spp.) belongs to the Rutaceae family and grows as large shrubs or small trees with edible fruit. The genus comprises several species such as *Citrus maxima* (Pomelo) and *Citrus reticulata* (Mandarin orange) and hybrids such as *Citrus limon* (Lemon) and *Citrus paradisi* (Grapefruit), which contain important active phytochemicals that contribute to the boosting of human immune systems when consumed regularly (Wang, Chuang & Ku 2007). Flavonoid is one of the fruit's major components, which has a vast array of biological effects in enhancing human immune systems to fight against diseases and disorders such as inflammation, oxidation and microbial activities (Harborne & Williams 2000). Other constituents of citrus that boost human immunity include carotenoids, phenolic acid, pectin and vitamin C (Wang et al. 2007). *Citrus limon* is an important medicinal fruit that is rich in vitamin C, citric acid, ascorbic acid and other active components (González-Molina et al. 2010) responsible for enhancing immunity against microbial infections. The peel of the fruit is also potent against these infections (Astani, Reichling & Schnitzler 2011; Hernawan et al. 2015; Ramadan et al. 2015).

Garlic and onions

Garlic (*Allium sativum* L.) and onions (*Allium cepa* L.) are vegetables of the same genus with an ancient history of culinary and medicinal value. They both have been classified under the family Liliaceae (Cardelle-Cobas et al. 2010) but are now placed under Amaryllidaceae after a re-evaluation of their taxonomic position by the Angiosperm Phylogeny Group (APG III 2009; Mirabeau & Samson 2012). Garlic has been useful in decreasing serum cholesterol and triglyceride levels hindering platelet accumulation and boosting immunity against bacterial, viral, fungal and parasitic infections (Lanzotti 2006; Matsuura 2001). The biological activities and immune-boosting potential of garlic are attributed to its high sulphur-rich compounds (Wargovich et al. 1988), which are believed to work in synergy with other compounds such as organo-selenium compounds (Cardelle-Cobas et al. 2010). Garlic is undoubtedly a prominent vegetable with high

immune potential and hence its consumption is recommended. It could be used as a spice whilst cooking or chopped and mixed with honey before consumption. The function of the immune system can be modified by garlic to disrupt the potential activities of several diseases and viral infections in the body (Cardelle-Cobas et al. 2010). Although the main component behind the immune-boosting activities of garlic is not yet known, different studies have identified carbohydrate, protein and many low-molecular-weight sulphur compounds as active ingredients of garlic (Cardelle-Cobas et al. 2010; Liu et al. 2018; Roy et al. 2018). It is also rich in phosphorus, potassium, sulphur, zinc, calcium, magnesium, sodium and vitamins (Agarwal 1996).

Similarly, onion is a perennial herbaceous plant, which is rich in vitamin C, selenium, sulphur compounds and zinc. It is usually used as spices in the daily preparation of most cuisines around the world and contains protein, flavonoids and fibre (Lanzotti 2006). Onions have high antioxidant properties with antiviral functions (Griffiths et al. 2002) and can be found in almost every region of the world, including Africa, Europe and North America (Suleria et al. 2015). The bulb makes an important vegetable that can be consumed raw, cooked or processed into different products but is mostly used as food preparation and culinary agent (Corzo-Martínez & Villamiel 2012). The bioactive compounds responsible for the characterisation of onion as an immune-boosting vegetable include organosulphur compounds (diallyl sulphide and diallyl sulfoxide), peptides, proteins and flavonoids (Bystrická et al. 2013; Suleria et al. 2015).

Carrot

Daucus carota L. is a common vegetable that belongs to the Umbelliferae family (Cherng, Chiang & Chiang 2008). It is sometimes used as spices and is rich in various nutrients that have immune-boosting functions. These nutrients include copper, zinc, iron, selenium and vitamins A, B_2, C and E (Bhaskaram 2002). The dietary intake of carotenoids, especially vitamin A, helps in maintaining the normal function of the immune system (Sommer & Vyas 2012). Frequent consumption of carrots can enhance the immune system (Sun, Mihyang & Song 2001) and provide preventive and curative functions against bacterial, fungal and viral infections (Bae et al. 2000; Chiang 2003) as it contains many bioactive compounds such as flavonoids, coumarins and carotenoids (Duke 1992).

Carotenoids that are also referred to as tetraterpenes are fat-soluble pigments and they include provitamin A carotenoids such as β-carotene and β-cryptoxanthin and non-provitamin A carotenoids such as lutein and lycopene (Raiola et al. 2014). These compounds protect plants against photodamage (Rao & Rao 2007). More than 600 carotenoids have been identified in nature, of which around 40 are naturally present in food included in the human diet (Gerster 1997). The health benefits of carotenoids are related to their antioxidant ability, immune system stimulation and antitumor activity (Ciccone et al. 2013; González-Vallinas et al. 2013; Maiani et al. 2009). Digested purple carrot extract has the potency of decreasing oxidative DNA damage by up to 20.7% to protect colon cells against reactive oxygen species (ROS) stress (Olejnik et al. 2016). Lycopene can increase the expression of differentiation-related proteins, such as cell surface antigen (CD14), oxygen burst oxidase and chemotactic peptide receptors (Sharoni et al. 2004). Carrot possesses a diverse range of phytochemicals such as phenolic compounds, polyacetylenes and ascorbic acid serving as immune-boosting agents against microbial infections (Ahmad et al. 2019).

Tomatoes

Scientific reports have indicated that carotenoid intake from tomatoes is the most significant nutritional contribution of the fruit, and hence the highest weight in the index of antioxidant nutritional value is attributed to carotenoids content (Frusciante et al. 2007). Tomatoes contain 8 μg – 40 μg per gram fresh weight of the compound lycopene and around 80% of the total dietary intake of this carotenoid (Kong & Ismail 2011; Renju, Kurup & Saritha Kumari 2014). Research has shown that field-grown tomatoes contain higher levels of lycopene, with a range of 5.2 mg/100 g to 23.6 mg/100 g fresh weight (FW) compared with greenhouse-grown tomatoes (0.1 mg/100 g FW and 10.8 mg/100 g FW) (Sahlin, Savage & Lister 2004). In fresh tomatoes, lycopene is normally found in *trans*-conformation, whilst heat, light, acids, oxygen and digestion can cause conversion into the more bioactive *cis*-form (Boileau, Boileau & Erdman 2002). Lycopene is the major compound in tomato fruit responsible for its strong antioxidative role, which is associated with its ability to act as free radical scavengers from reactive oxygen species produced by partial reduction of oxygen (Friedman 2013). Tomato's protective capacity is usually attributed to lycopene (Raiola et al. 2014). However, tomato products contain other compounds such as vitamins A, B and E (Raiola et al. 2014).

There is increasing evidence to indicate a relationship between the consumption of antioxidant-rich foods and the incidence of obstructive airway disease (Reyes-Munguía et al. 2016). The consumption of fresh fruit has been related to healthy pulmonary function both cross-sectionally (Butland, Fehily & Elwood 2000; Cook et al. 1997; Strachan et al. 1991; Tabak et al. 1999) and longitudinally (Reyes-Munguía et al. 2016). Consumption of fruit has also been linked to reduced prevalence of respiratory symptoms, particularly airway obstruction, such as wheeze (Butland, Strachan & Anderson 1999; Forastiere 2000). Studies have shown a positive relationship between plasma nutrient levels and respiratory health as a link between pulmonary function and plasma vitamin C, (Hu & Cassano 2000; Ness et al. 1996), vitamin A (Chuwers et al. 1997; Morabia et al. 1990), vitamin E (Hu & Cassano 2000), and β-carotene (Chuwers et al. 1997; Hu & Cassano 2000). Furthermore, lower incidence of bronchitis and wheeze has been attributed to high plasma levels of vitamin C (Schwartz & Weiss 1990).

Medicinal plants with immune-boosting potentials used for viral diseases and symptoms related to COVID-19

Medicinal plants used for the treatment of measles in Africa

Several medicinal plants have been used to treat measles in Africa. For instance, finely powdered particles prepared from the whole plant of *Allium cepa* L. and *Allium sativum* L. are taken orally with cow's milk to treat measles amongst the Keffi people of Nigeria. The leaves of *Citrus aurantifolia* and *Hibiscus cannabinus* L. are independently made into powder and taken orally with cow milk for a few days to treat measles (Mustapha, Owuna & Uthman 2013). In Peru, leaves and aerial parts of *Momordica charantia* L. are utilised for measles treatment (As et al. 2009). The succulent ripe fruit of *Nauclea latifolia* S. is used in the treatment of measles and as a prophylactic against measles epidemics by the Ibo people of Nigeria. It is prepared by roasting ripe fruit in a pot over a hot firewood flame till the whole fruit is well-cooked (Okwu & Uchenna 2009).

Frequently used medicinal plants for the treatment of measles in the Ijebu area of Ogun State in southwest Nigeria include *Elytraria marginata* Vahl, *Peperomia pellucida* L. Humb., Bonpl. and Kunth, *Vernonia amygdalina* Del., *M. charantia* L., *Newbouldia laevis* (P. Beauv.) Seem. ex Bureau, and *Ocimum gratissimum* L. (Sonibare, Moody & Adesanya 2009). Whilst Cucurbitaceae species are the most frequently mentioned (Sonibare et al. 2009), *Citrullus colocynthis* L. Schrad. seeds, *Momordica augustisepala* L. bark and *M. charantia* L. have also been mentioned in the treatment of measles (Sonibare et al. 2009). *Lagenaria breviflorus*, referred to as 'Itagiri' in Yoruba, is a potent antiviral plant. The fruit of 'Itagiri' is commonly used to ward off viral diseases such as chickenpox and measles in Nigeria by placing it under the bed.

Amongst the several medicinal plants used for the treatment of viral infections in Africa, *M. charantia* is often used globally in various pharmaceutical products to treat viral diseases and their symptoms. The plant is traditionally used against chickenpox and measles in Togo and is topically applied to treat fever and measles in the Ejisu-Juaben Municipality of Ghana (Appiah et al. 2018). *Kedrostis foetidissima* (Jacq.) Cogn. is mixed with silverfish, boiled and given to children to drink to treat measles in communities around Mabira central forest reserve in Uganda (Tugume et al. 2016). In Southwest Nigeria, the leaves of *M. charantia* are boiled in water and the decocted material is used to bathe every day and night until the measles is cured (Fatoba et al. 2019). However, in Cameroon water macerate and palm wine macerate are used to treat measles and chickenpox, respectively (Ngono Ngane et al. 2011). The bark of *Rauvolfia caffra* Sond. (Quinine tree) is applied topically to treat measles in South Africa (Hutchings 1996; McGaw, Jäger & Van Staden 2000). The aromatic herb *Lippia javanica* leaf infusions are commonly used as a tea for the treatment of influenza and measles in Africa (Mitra 2012). *Momordica charantia* L. has been reported to contain many potent antiviral activities (Pongthanapisith et al. 2013) because its proteins strongly inhibit several viruses such as hepatitis B virus, dengue virus, herpes simplex virus and human immunodeficiency virus (Bourinbaiar & Lee-Huang 1996; Jiratchariyakul et al. 2001; Tang et al. 2012; Waiyaput et al. 2012). *Momordica charantia* L. possessed effective antiviral activity to a broad range of influenza A subtypes including H1N1, H3N2 and H5N1 (Pongthanapisith et al. 2013). In Uganda, leaves of *Momordica foetida* Schum. are reported to be used by traditional medicine practitioners for the treatment of TB and it is amongst the most frequently mentioned plant for the treatment of the disease (Tabuti, Kukunda & Waako 2010). Therefore, the plant may be considered a legendary medicinal plant. Other plants that have been found helpful in the treatment of TB include *Eucalyptus* spp. (leaves), *Ocimum suave* (leaves), *Persea americana* Mill. (leaves), *Acacia hockii* De Wild. (Stem bark), *Zanthoxylum chalybeum* Engl. (Root) (Tabuti et al. 2010) and *Warburgia salutaris* (G. Bertol.) Chiov. (Root and bark).

Warburgia species are used to treat cold, cough, sore throat, fever and respiratory ailments (Maroyi 2014), throat infections (Jansen & Mendes 1984) and chest complaints (Gertner 1938). In Kenya, *W. salutaris* bark is chewed and juice swallowed or bark is mixed with animal fat and rubbed on the chest to treat chest pain (Kiringe 2006; Wamalwa 2005). In Kenya and Tanzania, the bark is chewed and juice is swallowed for the treatment of cough (Kiringe 2006; Masinde 2010). In South Africa, *W. salutaris* is sold in tablet form to treat bronchitis, chest infections and ulcers (Botha, Witkowski & Shackleton 2004). As a traditional remedy for cough, powdered bark of *W. salutaris* and leaves of *Cannabis sativa* L. (Cannabaceae) are smoked as a herbal remedy for cough (Hutchings 1996). *Warburgia salutaris* is used as an expectorant for colds, sinus clearing, pneumonia, headache and cough (Van Wyk & Gericke 2000; Watt & Breyer-Brandwijk 1962).

Hypoxis hemerocallidea (African Potato)

African potato is a legendary African endemic medicinal plant with immunostimulatory activities, and it is one of the most popular medicinal plants in the South African traditional medicine system. This is because of its extensive use by the South African people for human immunodeficiency virus (HIV) and Acquired immunodeficiency syndrome (AIDS) symptoms and opportunist infections. Traditionally, it is used for the treatment of TB, asthma and several other conditions (Hutchings 1996; Makunga 2010; Mills et al. 2005; Van wyk & Gericke 2000) and as an immunostimulatory agent (Drewes et al. 2008). The corms of *Hypoxis hemerocallidea* are being used for immune-related illnesses, which include common cold, flu, cancer and HIV and AIDS (Mills et al. 2005). The extracts of the corm of African Potato are used to make decoctions, which are taken as tonics against TB, testicular tumours, other cancers and HIV and AIDS (Drewes et al. 2008). Within the genus, two species, *H. hemerocallidea* and *Hypoxis colchicifolia,* are predominantly known and

utilised as African traditional remedies and in preparation of herbal tinctures and teas (Mills et al. 2005).

Hypoxis hemerocallidea is used in South Africa as an immunostimulant for HIV and AIDS patients by the primary healthcare community (Albrecht et al. 1995; Mills et al. 2005) with a daily dose of 2400 mg of the raw plant assumed to be effective (Albrecht et al. 1995). Albrecht et al. (1995) researched the effectiveness of African Potato by administering a methanolic extract of *H. hemerocallidea* to HIV patients for over 2 years during the mid-1990sand found that the CD4+ lymphocyte counts in these patients remained stable, whilst the serum p24 HIV antigen decreased and there was a decrease in expression of the HLA-DR CD8+ lymphocyte activation marker (Albrecht et al. 1995). The HLA-DR CD8+ is used to identify T-lymphocytes and high levels are observed in HIV infection (Viallard et al. 2006). The study revealed the potent pharmacological activities of rooperol relevant to cancer, inflammation and HIV (Albrecht et al. 1995). The active components of *H. hemerocallidea* include rooperol (Matyanga et al. 2020). There is indirect evidence that sterols and sterolins in the root of *H. hemerocallidea* have the potential to enhance immunity (Bouic & Lamprecht 1999; Bouic et al. 2001). Apart from *Hypoxis*, *Sutherlandia* is another highly sought-after medicinal plant used for HIV and AIDS treatment and is endorsed by the South African Ministry of Health for HIV management (Mills et al. 2005).

Sutherlandia frutescens: A gem in the Southern African traditional medicine

Sutherlandia frutescens has been used in the treatment of a variety of symptoms and conditions, which include influenza (Giesbrecht 2001; Van Wyk & Albrecht 2008), cancer, TB and HIV infection (Giesbrecht 2001; Mills et al. 2005). *Sutherlandia frutescens* has a long history of use in the Southern African traditional medicine system and the leaves are the most economically important parts even though other parts above ground are useful (Makunga 2010). Its therapeutic effects are based on its unique ability to help the human body activate its immunity to fight against diseases and mental and emotional stress (Prevoo et al. 2004). *Sutherlandia frutescens* is distributed globally through Internet sources that claim it to be an effective immunity booster (Minocha et al. 2011).

A crude polysaccharide-enriched fraction isolated from a decoction of *S. frutescens* has an immunostimulatory activity, which resulted in the activation of macrophages through TLR4 receptors and the NF-κB signalling pathway (Lei et al. 2015). This fraction increased the production of nitric oxide, ROS and inflammatory cytokines/chemokines by macrophages: a cell with an essential role in shaping innate immune responses in the host (Lei et al. 2015). The hot water extracts of *S. frutescens* are rich in plant polysaccharides and comprise several glucose and galacturonic acid units with a pectin-like structure (Zhang et al. 2014). These polysaccharides promote complement fixation, which is a feature of the innate immune response (Zhang et al. 2014). The immunomodulatory properties of the polysaccharides present in the water extracts of *S. frutescent* validate its traditional use in South Africa.

L-canavanine (2-amino-4-guanidinooxybutyric acid) is the most important nonprotein amino acid found in the leaves of *Sutherlandia*. L-canavanine is a structural analogue of L-arginine and a natural insecticide. As a result of its close similarity to arginine, it can interfere with arginine metabolism and be incorporated into proteins and thus lead to the formation of dysfunctional proteins (Mitri et al. 2009). Canavanine has been reported to be a potent anticancer agent (Swaffar et al. 1994; Tsirigotis et al. 2001) and has antiviral activity against influenza and retroviruses (Green 1992).

Siphonochilus aethiopicus (Schweinf.) B. L. Burtt is commonly known as African ginger or wild ginger. It is one of the most important medicinal plant species that grows in South Africa and is only found in Mpumalanga and the Northern Province and has become extinct in KwaZulu-Natal (Makunga 2010). It also grows in Zimbabwe, Malawi and Zambia (Watt & Breyer-Brandwijk 1962). The rhizomes and roots are used to treat a variety of ailments, which include malaria, headache, candida, pain, coughs, colds, asthma, influenza (Fouche, Van Rooyen & Faleschini 2013; Hutchings 1996; Makunga 2010; Van Wyk & Albrecht 2008), flu, wheezing of the chest and sinus problems (Fouche et al. 2013).

Pelargonium sidoides

Pelargonium sidoides DC. is native to the coastline regions of South Africa and Lesotho (Gurib-Fakim et al. 2010). *Pelargonium sidoides* species contribute significantly to the traditional medicine system of the Southern African region as it has an ancient history in the traditional healing practices (Kolodziej 2008). In the early part of the 20th century, a man named Charles Henry Stevens from South Africa was treated by a traditional health practitioner who claimed that he cured his TB using a natural remedy that contained *P. sidoides* (Gurib-Fakim et al. 2010). Stevens referred to TB medicine as 'Umckaloabo', a name that is still being used to date (Gurib-Fakim et al. 2010). Subsequently, Charles tried to introduce 'Stevens' Consumption Cure' for sale in Great Britain (Brendler & Van Wyk 2008; Helmstädter 1996; Kolodziej 2008; Taylor, Maalim & Coleman 2005).

In the first half of the 20th century, a product derived from the root of *P. sidoides* was used in Europe for the treatment of TB (Gurib-Fakim et al. 2010). Brendler and Van Wyk (2008) summarised the history of the commercial development of 'Umckaloabo' in Europe. Clinical trials have demonstrated the efficacy of aqueous-ethanolic formulation of *P. sidoides* extracts (EPs® 7630) in the treatment of respiratory tract disorders such as bronchitis and sinusitis and tonsillitis (Kolodziej 2011). The trial has been approved as a medicinal product for the treatment of patients with acute bronchitis, common cold, rhinosinusitis, tonsillopharyngitis or chronic obstructive pulmonary disease (Agbabiaka, Guo & Ernst 2008; Matthys et al. 2013). Well-documented therapeutic

effects of *P. sidoides* in infectious conditions of the respiratory tract led to the modern formulation of the roots of *P. sidoides*, EPs® 7630, which is exclusively contained in Umckaloabo® and marketed by Spitzner Arzneimittel, Ettlingen, Germany (Kolodziej 2011).

This herbal treatment is well sought after in European countries, the Commonwealth of the Independent States, the Baltic States and Mexico (Kolodziej 2007; Kolodziej & Kiderlen 2007). EPs® 7630 is the most widely investigated extract of the plant that revealed its potent antiviral activity, which inhibits the replication of respiratory viruses and the enzymes haemagglutinin and neuraminidase (Kolodziej 2011). The high local and international demands for *P. sidoides* herbal mixtures have proven that traditionally utilised herbal medicines could provide the basis for the development of a modern and innovative phytopharmaceutical that meets vital requirements such as quality, safety and efficacy for an evidence-based therapy (Kolodziej 2011). The immunomodulatory activity of *P. sidoides* is assumed to be a result of the combination of phenolic compounds and the numerous coumarins (Brendler & Van Wyk 2008). The main constituents of EPs 7630 include coumarins (e.g. umckalin) and flavanols (polyphenols) (Kolodziej 2007). According to Kayser, Kolodziej and Kiderlen (2001), the high content of gallic acid and its methyl ester in *P. sidoides* and its active extracts have been identified to be responsible for the immunomodulatory property of this herbal medicine (Kayser et al. 2001).

Turmeric: A therapeutic wonder from the spice cupboard and pharmacological activities of its active ingredient (Curcumin)

Turmeric is a widely used spice derived from the rhizomes of *Curcuma longa* L. belonging to the ginger family (Prasad & Aggarwal 2011). It has been used as a dietary spice (Ruby et al. 1995). Curcumin does not possess any nutritive value but has nevertheless been utilised often as turmeric powder since Vedic times or even earlier and is assumed to be pharmacologically safe (Jagetia & Aggarwal 2007). Percentages of volatile and non-volatile oils, proteins, fats, minerals, carbohydrates, curcuminoids and moisture content of ground, the dried rhizome depends on the geographical location and environmental conditions in which the plant is grown (Catanzaro et al. 2018). Commercially available curcumin is a combination of three molecules referred to as curcuminoids (Catanzaro et al. 2018; Ruby et al. 1995; Singh & Khar 2006). Curcumin is the most represented (60% – 70%), followed by demethoxycurcumin (20% – 27%) and bisdemethoxycurcumin (10% – 15%) (Catanzaro et al. 2018). Human consumption of curcumin as a dietary spice ranges up to 100 mg/day (Ammon & Wahl 1991) and a clinical trial indicated that humans could tolerate a dose of curcumin as high as 12 g/day, without any toxic side effects (Cheng et al. 2001; Lao et al. 2006). Curcuminoids have different degrees of potency, efficacy and stability, with no clear supremacy of curcumin over the other two compounds or the whole mixture (Goel, Kunnumakkara & Aggarwal 2008). Apart from curcuminoids, other active components of turmeric include sesquiterpenes, diterpenes and triterpenoids (Abdel-Lateef et al. 2016). Curcumin is the main active content of turmeric and is responsible for its yellow colour. As a result of the various pharmacological activities of curcumin, several studies have investigated its therapeutic effect on various diseases and infections (Boroumand, Mahmoudinasab & Saadat 2018). Several studies have reported that curcumin from *Curcuma longa* has a wide range of medicinal and immunomodulatory properties (Afolayan et al. 2019). The protective effect of curcumin as an antioxidant on astrocytes has been investigated as oxidative stress plays a key role in most neurodegenerative diseases (Boroumand et al. 2018).

There is a possibility that curcumin could inhibit oxidative damages caused by chronic stress in vital organs, including the brain, liver and kidney (Boroumand et al. 2018). It has been established that curcumin plays this vital role by maintaining the superoxide dismutase and glutathione peroxidase activity in addition to reversing the stress-induced inhibition of catalase (Boroumand et al. 2018). These activities of curcumin could ultimately reduce lipid peroxidation and, hence, ameliorate the negative effect of chronic stress on tissues (Samarghandian, Farkhondeh & Samini 2017). Curcumin is traditionally known for its anti-inflammatory effects and has been reported to be a potent immunomodulatory agent that can modulate the activation of T cells, B cells, macrophages, neutrophils, natural killer cells and dendritic cells (Allam 2009; Jagetia & Aggarwal 2007). Supplementation in rabbit diet with curcumin (2, 4 and 6 g/kg) significantly increased the serum levels of immunoglobulin G and M, thus signifying the ability of curcumin to improve immune functions (Alagawany, Ashour & Reda 2016).

Studies on mice spleen immunised with sheep red blood cells established various immunostimulatory activities of curcumin, which include an increase in total white blood cell count, circulating antibody titter and plaque-forming cells (Antony, Kuttan & Kuttan 1999). Curcumin raised bone marrow cellularity, α-esterase positive cells and phagocytic activity of macrophages (Antony et al. 1999). Churchill et al. (2000) reported that curcumin treatment stimulates the proliferation of B cells in the mucosa of the intestine of C57BL/6J-Min/+ (Min/+) mice, thus indicating its immunostimulatory activity. Curcumin affects several autoimmune diseases because of its ability to modulate immune cells and immune cell cytokines (Jagetia & Aggarwal 2007). Curcumin is expected to be helpful in the therapy of autoimmune disorders as inflammation plays a crucial role in most autoimmune diseases (Jagetia & Aggarwal 2007).

Several reports have highlighted that curcumin may have therapeutic potential against AIDS (Jagetia & Aggarwal 2007). Curcumin's mode of action in the suppression of replication of HIV is through inhibition of HIV long

terminal repeat (Barthelemy et al. 1998) and HIV protease (Sui et al. 1993), inhibition of HIV-1 integrase (Mazumder et al. 1995; Vajragupta et al. 2005), inhibition of p300/CREB binding protein-specific acetyltransferase and the repression of acetylation of histone/nonhistone proteins and histone acetyltransferase-dependent chromatin transcription (Balasubramanyam et al. 2004). Curcumin treatment before and after the onset of sepsis could reduce tissue injury and mortality and decrease TNF-α expression in septic rats (Siddiqui et al. 2006). Curcumin could reverse the post-transplant lymphoproliferative disorder commonly associated with the use of cyclosporine in the process of organ transplant (Ranjan et al. 1998).

Artemisia: A genus of highly referred medicinal plants across the world

Artemisia ('Sage Brush' or 'Wormwood') is a medicinal plant genus popularly used in folk medicine and as food in many cultures since time immemorial (Roy, Krishnan & Roy Roy 2018). *Artemisia* is a genus of diverse and economically important species, with more than 500 species reported globally (Abad et al. 2012; Bora & Sharma 2011; Obistioiu et al. 2014), which are mainly found in Asia, Europe and North America (Abad et al. 2012; Bishop et al. 1996; Bora & Sharma 2011; Obistioiu et al. 2014). The over 500 species of *Artemisia* are majorly perennial herbs dominating the vast steppe communities of Asia (Nigam et al. 2019). The genus is distributed in all continents except Antarctica with a preference for the Northern Hemisphere and a low degree in the Southern Hemisphere (Vallès et al. 2011). Asia has the highest number of species, with 150 accessions from China, 174 from the former Soviet Union, about 50 reported from Japan, 35 species were found in Iran and about 30 in Italy (Nigam et al. 2019). Several *Artemisia* species have uses in various fields, such as medicine (antihelminthic and antimalarial activities), food (edible plants, condiments and ingredients of beverages, the most famous being absinth) and ornaments (Vallès et al. 2011). The genus is from the tribe Anthemideae and comprises important medicinal plants, which are being given great phytochemical attention because of their biological and chemical diversity and essential oil production (Abad et al. 2012). *Artemisia* has a broad spectrum of bioactivity, owing to the presence of several active ingredients or secondary metabolites, which work through various modes of action (Nigam et al. 2019). *Artemisia* essential oils contain a variety of volatile components, which include terpenoids, phenylpropanoids and aliphatic compounds (Sharifi-Rad et al. 2017). Traditionally, *Artemisia* species are often utilised in the treatment of different diseases including malaria, hepatitis, cancer, inflammation and infections by fungi, bacteria and viruses (Abad et al. 2012; Willcox 2009). Several species of the genus *Artemisia* have been reported to display a variety of *in vitro* pharmacological activities and have also demonstrated immunostimulatory activities through different pathways. *Artemisia annua* C. Winkl. extract and leaf powder increase the performance, cellular and humoral immunity of broilers (Gholamrezaie Sani et al. 2013). The purified polysaccharide fractions of *Artemisia selengensis* Turcz. and *Artemisia iwayomogi* Kitam. exhibited immunomodulatory and antitumour properties (Koo et al. 1994) and extended the survival of murine spleen cells *in vitro* (Lee et al. 1993). The immunomodulatory effects evaluated by splenocyte proliferation and the cytokine secretion proposed that the polysaccharides fractions from *Artemisia argyi* Levl. et Vant. leaves are good immune stimulators (Lan et al. 2010). The immunomodulatory activity of plants has been attributed eventually to the presence of various phytochemicals (Ambwani 2013; Cundell 2014). *Artemisia selengensis* Turcz. polysaccharides displayed immunostimulatory and antioxidant activities with potential application in functional foods (Wang et al. 2020). Amongst the *Artemisia* species, *A. annua* C. Winkl. has received significant attention. It is a well-known anti-fever herbal medicine and was first described in traditional Chinese medicine 1000 years ago. Artemisinin, the active compound of *A. annua* and its derivatives dihydroartemisinin (DHA), artemether and artesunate have been reported to be effective in the treatment of malaria (Zhang et al. 2020). The efficacy of DHA has also been investigated for the treatment of lupus erythematosus, indicating its possibility to balance the immune response in immunocompromised individuals (Zhang et al. 2020). Apart from the anti-parasitic activity of artemisinin and its derivatives, they can also actively modulate the immune system directly to the advantage of the host (Zhang et al. 2020).

Artemisinin is a major bioactive compound isolated from *Artemisia* (Ferreira et al. 2010). Artemisinin is a terpene lactone well known as one of the most effective antimalarial agents even against drug-resistant strains (Ferreira et al. 2010). The presence of artemisinin has been reported in many *Artemisia* species (Hamidi et al. 2018; Mannan et al. 2011; Pellicer et al. 2018; Salehi et al. 2018). Artemisinin is one of the most promising natural products studied in the past two decades (Efferth et al. 2008) because of its potent antiviral activity (Kshirsagar & Rao 2021). It was established that artesunate inhibits the replication of human cytomegalovirus AD169 and other strains; and herpes simplex virus type 1 *in vitro* (Efferth et al. 2002). Human cytomegalovirus is a major opportunistic disease in immunocompromised individuals such as AIDS patients and transplant recipients. It is a common cause of congenital infection, which often leads to developmental abnormalities and hearing loss (Mocarski et al. 2007). The report showed that other herpesviruses from all subfamilies (α, β and γ) are likewise sensitive to artesunate (Efferth et al. 2002; Kaptein et al. 2006). Artesunate displayed anti-Hepatitis B virus (HBV) activity (Romero et al. 2005). Despite the safety or effectiveness of the available vaccine against HBV, the infection caused by this virus continues to be a major health challenge globally (Hou, Liu & Gu 2005). Paeshuyse et al. (2006) reported that artemisinin, a popular antimalaria drug, inhibited Hepatitis C virus (HCV) replicon replication in a dose-dependent manner. Hemin, an iron donor, inhibits HCV replicon replication through inhibition of the viral

polymerase (Fillebeen et al. 2005). Combination therapy of artemisinin and hemin had a distinct synergistic antiviral activity without affecting host cells (Efferth et al. 2008). Artesunate demonstrates activity against HIV-1 (Efferth et al. 2002).

Echinacea purpurea: A highly utilised North American endemic plant

Echinacea spp. is a highly sought-after herbal remedy in the United States of America. Traditionally it is utilised by the native Americans as snakebite and anti-infective remedy to treat cough associated with cold (Bauer & Wagner 1991). It has been claimed to have high immunostimulatory activity through its action as an immune promoter (Ernst 2002). It is known to improve respiratory infections, sore throats and other symptoms (Perrone et al. 2012). *Echinacea angustifolia*, *Echinacea pallida* and *Echinacea purpurea* are the three major species of *Echinacea* utilised in traditional medicine or formation of nutraceuticals in the United States of America and Europe (Borchers et al. 2000). The most common active ingredients of *Echinacea* are alkamides and caffeic acid derivatives polysaccharides and lipoproteins (Pietta et al. 1998). The activation of macrophages and polymorphonuclear neutrophils immune cells are the most frequently reported pharmacological activities of *Echinacea* (Goel et al. 2005; Sullivan et al. 2008).

Echinacea purpurea L. is one of the most important medicinal herbs with vast pharmacological and aesthetic properties (Gajalakshmi, Vijayalakshmi & Devirajeswari 2012). In 2005, *E. purpurea* was highly ranked amongst botanical supplements in the United States of America. Its roots and subterranean stems were used by the North Americans to treat trauma and alleviate symptoms of inflammation and infection (Gajalakshmi et al. 2012). *Echinacea purpurea* L. showed good immunoregulatory, anti-inflammatory and antioxidant activities (Lee et al. 2009; Zhai et al. 2007) without any symptoms of hypersensitivity or side effects during a clinical trial (Saunders, Smith & Schusky 2007). Other active components of the plant are flavonoids, essential oils and polyacetylenes (Thygesen et al. 2007). Amongst these, caffeic acid derivatives and alkamides have been established to have immunoregulation effects (Matthias et al. 2008). The root of *E. purpurea* was commonly used in different parts of the world to stimulate the immune system (Redondo 2000) and for the treatment of respiratory infections and malignant tumours traditionally (Burger et al. 1997; Elsässer-Beile et al. 1996; Percival 2000). It stimulates the immune system by increasing the production and activation of leukocytes, lymphocytes, monocytes and cytokines (Kim, Waters & Burkholder 2002) and the non-specific cellular and humoral immunity (Gajalakshmi et al. 2012). *Echinacea purpurea* is popularly used for the treatment of common cold, coughs, bronchitis, influenza and inflammation of mouth and pharynx and ranks in the second position in sales of over-the-counter herbal products (Barrett 2003; Barrett, Vohmann & Calabrese 1999; Blumenthal no date; Robbers & Tyler 1999). *Echinacea purpurea* is a perennial plant native to North America, used by the Delaware Indians for the treatment of venereal diseases and Plain Indians for the treatment of respiratory infections and fever (Tyler 1992).

Other commonly used medicinal plants for respiratory infections and viral diseases

A variety of active components in tubers of *Dioscorea batatas* have been reported to exhibit immunomodulatory activities (Oh & Lim 2009; Su et al. 2011). These phytochemicals include mucopolysaccharide, dioscorin, diosgenin, batatasins and glycoproteins. A storage protein (Dioscorin) from the tuber of the plant has been shown to exhibit systemic and mucosal immunomodulatory activities *in vivo* after oral administration (Liu & Lin 2009). Dioscorins can enhance the production of CD4 þ, CD8 þ and CD19 þ cells in the spleen (Lin et al. 2009). The mucopolysaccharide in *D. batatas* could increase Interferon-gamma (IFN-g) production in treated splenocytes, suggesting its ability to induce cell-mediated immune responses (Choi, Koo & Hwang 2004). Research has shown that a 50% – 75% ethanol-partitioned fraction of tuber extract of *D. batatas* may have immunogenic activities (Su et al. 2011). Ginseng is well known as an immune modulator (Choi et al. 2004; Jie, Cammisuli & Baggiolini 1984; Kitts & Hu 2000; Scaglione et al. 1990). Roots (mostly), stems and leaves of ginseng and their extracts have been used for the maintenance of immune homeostasis and to enhance resistance to illness or microbial attacks (Kang & Min 2012).

Leonotis leonurus, commonly known as Wild dagga or Lion's ear, is widespread throughout the eastern part of South Africa (Newman & Cragg 2007) and has a variety of medicinal uses, which include treatment of colds, bronchitis, TB, coughs, asthma and chest infections (Nsuala, Enslin & Viljoen 2015). The herbal decoction can be used internally to treat coughs, colds, influenza and bronchitis, whilst leaf infusions are used to treat hepatitis (Makunga 2010). The organic extracts of this plant displayed more than 99% growth inhibition of *Mycobacterium tuberculosis* (Saleem et al. 2010), which justifies its traditional use.

Knowltonia vesicatoria (Ranunculaceae) is a South African plant traditionally utilised for the treatment of TB. The compounds 5-(hydroxymethyl) furan-2(5H)-one and 5-(hydroxymethyl) dihydrofuran-2(3H)-one were isolated from the plant and these compounds demonstrated antimycobacterial activity, which validates the traditional use of the plant to treat TB. Many bioactive compounds have been reported to be active against drug-sensitive *M. tuberculosis* (Efange 2002). *Bolusanthus speciosus* (Fabaceae) is widely distributed in subtropical South Africa, Botswana, Zimbabwe, Mozambique and Zambia. The dried inner bark of the tree is often used in the treatment of TB (WHO 2003).

Existing diseases and infections currently being treated by medicinal plants in Africa

Tuberculosis

Tuberculosis is a highly contagious and dangerous lung disease for which medicinal plants have been used in its treatment in Africa. Although it is not a viral infection, it has left terrible scars of anguish and pain in the lives of the African people, with very high incidences in the Southern African Development Community countries because of HIV and AIDS infections leading to high mortality rates. South Africa has the seventh highest incidence of TB in the world and the second highest in Africa and the fifth highest burden of drug-resistant TB cases globally (National Department of Health 2011). A survey by Lawal, Grierson and Afolayan (2014) revealed 30 plants belonging to 21 families that are commonly used by traditional healers in the Eastern Cape region of South Africa for the treatment of TB. *Clausena anisata*, *Haemanthus albiflos* and *Artemisia afra* were the leading set of investigated plants (Lawal et al. 2014). In other parts of South Africa, several medicinal plants are being used for the treatment of TB and its symptoms. Traditional healers in Amathole District in the Eastern Cape province use *A. afra* to treat flu and TB, and it is also utilised by the Zulu people for the same purpose amongst others (Buwa & Afolayan 2009; Makunga 2010; Semenya & Maroyi 2013). Amongst the Zulu people, infusion of *Cannabis sativa* is inhaled in the process of the traditional treatment of TB (Hutchings 1996). Madikizela et al. (2014) documented *Asparagus africanus* and *Ficus sur*, which showed positive results against *M. tuberculosis*. *Clausena anisata* is used for the treatment of measles and bronchial problems in Nigeria. Its leaves are used for the treatment of respiratory ailments (Ajibesin et al. 2007; Hutchings 1996). Similarly, there is the widespread use of *C. anisata* for the treatment of TB in Nkonkobe Municipality (Lawal et al. 2014).

Conclusion

Nature has bestowed a variety of health-benefiting food and medicinal plants on humanity. These natural resources could help maintain good health and boost the body immune system. In the past, viral or bacterial infections have affected humanity severely. However, cures for these diseases or infections and their symptoms were discovered from plant origin. Hence, the plant kingdom is a hub for natural therapeutic compounds. Whilst some of the active therapeutic compounds available in the plant have been fully developed into usable products, ongoing research and future research will lead to the discovery of more therapeutic compounds. However, consumption of the horticultural fruit mentioned in this review could help maintain a good immune system to protect mankind against infectious diseases, such as coronavirus. Nonetheless, in-depth research into the antivirus potential of the medicinal plants reported in this review, especially those with antiviral and antibacterial activities against respiratory infections, could offer a pathway to the discovery of medicinal plants combined with active ingredient(s) that can combat COVID-19 and its symptoms. This review has highlighted a variety of medicinal plants traditionally used for fever, cough, chest pain, flu, sore throat and respiratory infections. These are some of the COVID-19 symptoms. Hence, it will be worthwhile to investigate the antiviral activities of these plants or a combination of these against the disease. This could lead to innovative discoveries towards the formulation of a plant-based cure for COVID-19, which is currently ravaging the world.

Acknowledgements

The authors would like to acknowledge Mangosuthu University of Technology for postdoctoral funding.

Competing interests

The authors have declared that no competing interest exists.

Authors' contributions

With the submission of this manuscript, the authors would like to undertake that this work is originally put together by the authors and no part thereof has been submitted or published elsewhere. All authors agreed with the contents of the manuscript and its submission to the journal. All authors have contributed significantly to the work. No part of the research has been published in any form elsewhere.

Ethical considerations

This article followed all ethical standards for research without direct contact with human or animal subjects.

Funding information

This research received no specific grant from any funding agency in the public, commercial or not-for-profit sectors.

Data availability

Data sharing is not applicable to this article as no new data were created or analysed in this study.

Disclaimer

The views and opinions expressed in the article are those of the authors and do not necessarily reflect the official policy or position of any affiliated agency of the authors.

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