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Traditional uses, phytochemistry and pharmacological activity of *Carpobrotus edulis*: A global perspective

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ABSTRACT

Carpobrotus edulis has widely been used in South Africa as a traditional medicine for a wide range of ailments and its pharmacological activities has been widely studied. The present review aims to provide a comprehensive literature overview regarding phytochemistry, traditional use, pharmacology and toxicology of different *Carpobrotus edulis* extracts. The review was compiled through a thorough literature search from authentic resources using data bases such as Google Scholar, PubMed, Web of Science, Scopus and Science Direct, peer reviewed articles, books and thesis. *Carpobrotus edulis* is an important medicinal plant used in ethno medicine for the treatment of tuberculosis and other respiratory infections, toothache and earache, facial eczema, wounds, burns, hypertension, and diabetes mellitus. Pharmacological studies performed on the fresh plant materials, crude extracts and various solvent extracts of *Carpobrotus edulis* validates the traditional medical use of the plant. Studies performed validate the use of *Carpobrotus edulis* extracts in antimicrobial, antiproliferative, and antioxidant therapy. *Carpobrotus edulis* also has proved to have anticholinesterase activity against acetylcholinesterase and butyrylcholinesterase. Information on therapeutic validation in wound healing, diabetes mellitus, hypertension, analgesia and gastrointestinal motility is scanty. To substantiate the traditional use of *C. edulis* in the aforementioned area, there is need for further experimental studies to validate its pharmacological use. The information on toxicology was also scanty however the available literature suggests that *C. edulis* extracts are non-toxic. The review article supports the folkloric use of the medicinal plant. However, in-depth studies evaluating the safety profile of *C. edulis* extracts are highly recommended.

Keywords: *Carpobrotus edulis*, phytochemistry, pharmacology, toxicology, traditional medicine.

INTRODUCTION

Traditional medicine is the most affordable and easily accessible treatment method in the primary healthcare system in developing countries. More so, traditional medicines are culturally acceptable in various societies [1]. Studies have revealed that about half of the African population regularly uses traditional medicine [2, 3]. Traditional medicine in developing countries therefore contributes directly to the socioeconomic status of the rural communities, as well as urban communities as of late. Africa has an extraordinary richness in its flora, amounting to several thousands of species. Researchers suggest that about 10% of Africa's flora is of medical importance and some of the plant species have been studied in biomedical research [4]. The genus *Carpobrotus* (Aizoaceae) has about 12 to 20 species which are very similar in appearance and their correct identification must be done by a taxonomist [5]. Most of these are endemic to South Africa but there are at least four Australian species and one South American species [6, 7]. Some species from this genus have important validated medicinal properties that can provide leads to drug development. Most of the species native to South Africa are used in traditional medicine and some of their pharmacological activities have been studied [8]. *Carpobrotus mellei* has antimicrobial activities against *Pseudomonas aeruginosa* and *Staphylococcus aureus.* A study by Springfield *et al.* [9] showed the antimicrobial activity of *Carpobrotus muirii* and *Carpobrotus quadrifidus* extracts against *Staphylococcus aureus* and *Mycobacterium smegmatis*. This paper reviews the traditional uses, phytochemical composition and pharmacological activities of *Carpobrotus edulis*.

The succulent plant *Carpobrotus edulis* commonly known as sea fig is a perennial ground creeping species native from South Africa that invades coastal habitats in many parts of the world. The plant was originally called *Mesembryanthemum edule* and it was renamed by Brown in 1926 and by Bolus in 1927 to *Carpobrotus edulis* [10]. *Carpobrotus* mainly inhabits sandy coastal habitats and can also be found inland in sandy to marshy places [11]. There is a continued significant risk of deliberate introduction as the plant is propagated for their ornamental properties.

Taxonomic Tree

Domain: Eukaryota

Kingdom: Plantae

Phylum: Spermatophyta

Subphylum: Angiospermae

Class: Dicotyledonae

Order: Caryophyllales

Family: Aizoaceae

Genus: Carpobrotus

Species: Carpobrotus edulis

Figure 1: The flowering *Carpobrotus edulis* plant. The picture was taken in Mount Pleasant, Harare in Zimbabwe and authentication done from Zimbabwe National Herbarium.

The current paper reviews traditional uses, phytochemical composition and pharmacological activities of *Carpobrotus edulis*. The databases used for literature search include; Google Scholar, Web of Science, Scopus, Science Direct, Springer Link, Sci Finder and PubMed. The terminologies used in the review articles consists of Keywords such as "*Carpobrotus edulis*"; Ethnomedicinal"; "Ethopharmacological"; "Ethopharmacological"; "Phytochemical"; "Antibacterial"; "Antifungal"; "Antioxidant'; "Cytotoxicity"; and "toxicity'. The literature searched is categorized under headings with detail explanation under individual section as well as respective tables for summarization of data as follows;

Traditional uses

Carpobrotus edulis has widely been used in South Africa as a traditional medicine for a wide range of ailments. The fruits, leaves and flowers are medicinally used in different forms. Mostly the plant's leaves, fruits or flowers are chewed raw or boiled in water and orally taken as a medicine for various bacterial and fungal infections [12]. In Sub Saharan Africa, the boiled leaves of *Carpobrotus edulis* are used in treatment of tuberculosis and other respiratory infections [13]. *Carpobrotus edulis* leaves may have analgesic effect; the leaves are boiled in water for toothache and earache treatments. However, their antimicrobial effect may be responsible because most toothaches or earaches are caused by various colonizing microbes. The leaf juice, however, has traditionally proved to be effective in soothing pain caused by spider and tick bites [14]. Facial eczema, wounds, burns and various skin conditions are treated by either chewing *Carpobrotus edulis* leaves or by drinking boiled leaves [15]. Topical use of *Carpobrotus edulis* extracts in traditional medicine is not very common. The Xhosa-speaking people in the coastal areas of the Eastern Cape Province commonly administer aqueous and alcohol extracts to patients for the management of HIV/AIDS associated diseases [16, 17]. This plant also seems to be important in the treatment of chronic non-communicable diseases like hypertension and diabetes mellitus [18, 19, 20]. The leaves also have an acerbic antiseptic fluid orally taken as mouth gags for sore throat and mouth infection treatments [8]. The leaf is also boiled for treatment of intestinal worms, dysentery, diarrhea and different stomach aches [21, 22]. In Tunisia, the leaves are boiled in water for treatment of sinusitis, chilblains and vaginal thrush [14].

PHYTOCHEMISTRY

Phytochemical screening

Eman [23] performed the phytochemical screening of various succulent plants found in Egypt and *Carpobrotus edulis* was one of them. *Carpobrotus edulis* flowers were found to be the richest organ containing the highest amounts of all the measured phytochemicals except the leaf which had higher levels of tannins, anthraquinones and sulphates than the flowers (Table 1).

Table 1: Phytochemical screening of *Carpobrotus edulis* plant parts from Egypt [23].

Phytochemical group	Levels of phytochemicals in different plant parts		
	stems	leaves	flowers
Saponins	++	+	++
Chlorides	+	+	+
Sulphates	+	++	+
Coumarins	+	+	+
Flavonoids	+	++	+++
Alkaloids	+	+	++
Anthraquinones	++	++	+
Irodoids	-	-	-
Cyanogenic glycosides	+	+	+
Cardiac glycosides	++++	+++	++++
Carbohydrates and / or Glycosides	+	+	+
Unsaturated sterols and / or Triterpenoids	+	+	+
Tannins	++	+++	+++

Very highly present++++, highly present+++, moderately present ++, lowly present, not detected -

The stems were found to be rich in polyphenols and contained the highest total flavonoid content. As per the phytochemical screening findings of Eman [23], Van der Watt and Pretorius [24] reported that the leaves of *C. edulis* had high tannin content. Qualitative phytochemical screening of the *C. edulis* leaf extracts revealed the presence of secondary metabolites in aqueous, ethanol, acetone and hexane extracts.

Quantitative phytochemical analysis

The total polyphenol content found within the leaves of *C. edulis* varied significantly between other plant parts. Quantitatively, the leaf extract showed a significantly higher concentration of phenolic compounds compared to the stems and especially the roots [25]. There is no particular solvent that is known to extract all the compounds on its own from the plant because of the huge differences in the nature of phytochemical constituents found in a plant. Four solvents hexane, ethanol, acetone and water were used to extract C. *edulis* leaves to accommodate the range of polarities of the compounds present. The extracts were quantitatively analysed for phytochemicals. The acetone extracts had a high percentage of phenolic compounds and a considerable amount of alkaloids and proanthocyanidins in the aqueous extract [16].

Table 2: Phytochemical screening results of various extracts from *C. edulis* leaf [16].

Phytochemicals	Aqueous	Ethanol	Acetone	Hexane
Phenolics	+++	+++	+++	++
Flavonoids	+	+	+	+
flavonols	+	+	+	+
Proanthocyanidins	+++	+++	+++	+++
Tannins	+++	+++	+++	++
saponins	++	++	++	+
alkaloids	++	++	++	+

Highly present+++, moderately present -++, lowly present +

Tannins and saponins were major constituents in the ethanol extract and flavonoids and flavonols were at a higher concentration in the hexane extract (Table 3).

Table 3: Quantitative analysis of the phytochemical evaluated from the leaf of *C. edulis* [16].

Phytochemicals	Amount of phytochemical compounds (mg/g)			
	Aqueous	Ethanol	Acetone	Hexane
Phenols	517.71±0.40	330.87±0.04	557±0.23	64.14±0.15
Flavonoids	0.29±0.01	0.28±0.01	0.65±0.04	1.19±0.04
Flavonols	0.05±0.001	0.05±0.001	0.23±0.05	0.19±0.03
Proanthocyanidins	896.7±0.05	115.28±0.007	753.87±0.02	134.91±0.01
Tannins	461±0.07	489±0.28	384±0.14	64±0.14
Saponins	34±0.21	45±0.26	11±0.071	2±0.035
Alkaloides	45±0.06	38±0.02	31±0.021	3±0.014

Values are expressed as mean± standard deviation of the mean (n=3).

In Comparison to *Mesembryanthemum crystallinum*, a plant in the same family with *Carpobrotus edulis*, the determination of the flavonoids in the plant extracts revealed a higher content in in *C. edulis* (116.16 ± 3.34 µg/mg) in comparison with *M. crystallinum* (4.85 ± 0.9 µg/mg). *C. edulis* extract (104.69 ± 0.48 µg/mg) also had higher phenol content than *M. crystallinum* (23.89 ± 0.27 µg/mg) [14]. Seasonal variation in the phytochemical composition of *Carpobrotus edulis* extracts were evaluated by Choekoe *et al.* [26]. The prevalence of phytochemicals within the autumn leaf debris samples, regardless of the extracting solvent used, suggests that there is a higher concentration of phytochemicals within the leaf tissue of the plant during autumn and less of them are being circulated around the plant.

Phytochemical identification

Martins *et al.* [27] used a 1D, 2D NMR and MS investigations to identify compounds known as triterpens (β-amyrin, uvaol and oleanolic acid), monogalactosyldiacylglycerol, catechin, epicatechin and procyanidin B5 from methanol *C. edulis* extracts. Phenolic composition was also analysed and revealed the presence of sinapic acid, luteolin7-o-glucoside, hyperoside, ferrulic acid isorhamnetin-o- rutinoside, allergic acid and isoquercitrin from hydroethanolic and aqueous extracts of *C. edulis* [24, 28]. Omoruyi *et al.* [29] using the GC-Ms analysis investigated the chemical composition of *C. edulis* in hexane, acetone and ethanol. The identified phyto-constituents are displayed in tables 4, 5 and 6 below.

Table 4: Phyto-constituents identified in the hexane extract of *C. edulis* [29].

Retention-time	Compounds	Formula
3.9	2-Pentadecanone, 6,10,4- trimethyl	$C_{18}H_{36}O$
4.5	7-Methyl-Z-tetradecen-1-ol acetate	C17H32O2
5	Heptacosane	C27H56
5.3	1-Heptatriacotanol	C37H76O
5.54	n-Octyl-5-oxoheptadecanamide	C25H49NO2
5.75	Dodecanoic acid	C12H24O2
7.78	Phytol	C20H40O
8.6	Dibutyl phthalate	C16H22O4
8.67	n-hexadecanoic acid	C14H28O2
8.93	2-tertbutyle cyclohexylpropylphosphonofluoridate	C13H26FO2P
10.55	2-Pyrrolidinone, 1-(9-octadecenyl)	C22H41NO
11.47	Pyrrolidine, 1-(1-oxo-7,10-hexadecadienyl)	C20H35NO
13.96	Nonacosane	C29H60
4.331	4,8,12,16-Tetramethylheptadecan-4-olide	C21H40O2
18.09	2,6,10,14,18,22-Tetracosahexaene, 2,6,10,15,19,23-hexamethyl	C30H50
19	Octadecanoic acid	C18H36O2
19.87	cis-13-Octadecenoic acid	C18H34O2
8.6	Tetradecanoic acid	C14H28O2
20.6	Tetratriacontane	C34H70
21.62	9,12-Octadecadienoic acid (Z,Z)-2 3-dihydroxypropyl ester	$C18H32O_2$
24.07	9,12,15-Octadecatrienoic acid, 2,3-dihydroxypropyl ester, (Z,Z,Z)	C21H36O4
27.08	Eicosanoic acid	C20H40O2
32.4	α-Amyrin	C30H50O
34.87	1-Heptatriacotanol	C37H76O
40.57	9,19-Cyclolanost-24-en-3-ol, acetate, (3β)	C32H52O2
48.09	Lupeol	C30H50O
56.05	17-(1,5-Dimethylhexyl)-10,13-dimethyl-2,3,4,7,8,9,10,11,12,13,14,15,16,17-tetradecahydro-1Hcyclopenta[a]phenanthren-3-ol	C27H46O
57.35	Vitamin E	C29H50O2
58.06	17-(1,5-Dimethylhexyl)-2,3-dihydroxy-10,13-dimethyl-1,2,3,7,8,9,10,11,12,13,14,15,16,17-tetradecahydrocyclopenta[a]phenanthren-6-one	C27H44O3
59.83	4,4,6a,6b,8a,11,11,14b-Octamethyl-1,4,4a,5,6,6a,6b,7,8,8a,9,10,11,12,12a,14,14a,14b-octadecahydro-2H-picen-3-one	C30H48O

Table 5: Phyto-constituents found in theacetone extract of *C. edulis* [29].

Retention Time	Compounds	Formula
4.51	7-Methyl-Z-tetradecen-1-ol acetate	C17H32O2
5.113	6,6-Dimethyl-10-methylene-1-oxa-spirodecane	C12H20O
5.3	1-Heptatriacotanol	C37H76O
6.09	Dodecanoic acid	C12H24O2
6.286	17-Pentatriacontene	C35H70
7.78	Phytol	C20H40O
8.6	Tetradecanoic acid	C14H28O2
8.67	n-Hexadecanoic acid (dibutyl ester)	C14H28O2
12.86	n-Hexadecanoic acid (bis-2-ethylhexyl ester)	C16H32O2
13.96	Nonacosane	C29H60
43.5	α-Amyrin	C30H50O
48.09	Lupeol	C30H50O

Table 6: Phyto-constituents found in the ethanol extract of *C. edulis* [29].

Retention time	Compounds	Formula
32.4	β-Amyrin	C30H50O
42.918	α-Amyrin	$C30H_{50}O$
48.09	Lupeol	C30H50O

PHARMACOLOGICAL ACTIVITY

Antimicrobial activity

Antibacterial activity

The antimicrobial activity of *C. edulis* extracts has been extensively researched. The phytochemicals have showed considerable activity against various microbes. The compounds isolated by Van der Watt and Pretorius [24] demonstrated remarkable antibacterial activity against the gram negative *Moraxella catharalis* as well as gram positive cocci, *Staphylococcus epidermidis* and *staphylococcus aureus*. A phenolic compound, hyperoside and a flavonone glycoside called neohesperidin also demonstrated activity against Pseudomonas *aeruginosa.* The growth of *Bacillus subtilis* and *Streptococcus pneumonia* colonies were only inhibited by a phenolic compound called ferrulic acid.

Methanol extracts of *C. edulis* however revealed no antibacterial activity against the methicillin resistant *Staphylococcus aureus* or against the multidrug resistant *Mycobacterium tuberculosis* [30]. These extracts however are able to impede bacterial growth once phagocytosed by monocyte derived human macrophages. Seasonal variation in the antimicrobial activity of *C. edulis* against *Pseudomonas aeruginosa*, *Enterococcus feacalis*, *Escherichia coli* and *Staphylococcus aureus* was also evaluated [26]. The minimum inhibitory concentration values for the spring extracts were lower than those of the autumn extracts suggesting that the spring extracts were more effective against all the test organisms. When the total activity was taken into account, the autumn extracts however revealed higher efficacy than the spring extracts. *Carpobrotus edulis* aqueous leaf extract demonstrated noteworthy antibacterial activity against *Mycobacterium aurum*. The ethanolic extract showed significant activity against *staphylococcus aureus, Bacillus cereus, S* and *Mycobacerium aurum* but showed weak activity against *Klebsiella pnuemoniae* and Escherichia *coli* [13]. Among the solvents evaluated, the ethanolic extract showed the weakest antibacterial activity in comparison to both the dichloromethane and water extracts. Meddeb *et al.* [28] also confirmed the reports that *C. edulis* leaf extracts has high antibacterial properties, particularly against the Gram positive *Staphylococcus aureus* and *Bacillus cereus* strains.

Martins *et al.* [27] isolated numerous compounds from *C. edulis* and evaluated them for antibacterial activity against multidrug-resistant (MDR) bacteria. Oleanolic acid, a pentacyclic triterpenoid demonstrated strong activity against several bacterial strains. Another pentacyclic triterpene, Uvaol displayed the most effective modulation of efflux activity by multidrug-resistant Gram-positive strains. The activities of numerous compounds isolated from *C. edulis* were evaluated against multidrug-resistant (MDR) bacteria [27]. Oleanolic acid displayed good antibacterial activity against several bacterial strains with uvaol displaying the most effective modulation of efflux activity by MDR Gram positive strains. *C. edulis* found on the Tunisian coast also displayed notable antibacterial activity against *Pseudomonas aeruginosa, Escherichia coli* and *Staphylococcus aureus* [14].

Antifungal activity

Essential oils were extracted from fresh leaves of *C. edulis* for antifungal activity evaluation. Four solvents; hexane, acetone, water and ethanol were also used to extract fresh *C. edulis* leaves that were also tested for antifungal activity. The essential oils proved to be more effective in inhibiting fungal growth compared to extracts from the four listed solvents. These essential oil extract revealed antifungal activity against *Candida krusei, Candida albican, Candida glabrata Candida rugosa,* and *Cryptococcus neoformans* with minimum inhibitory concentration ranges of 0.02- 0.31 mg/ml [29]. The antifungal activity of the isolated essential oils was comparable to standard antifungal agents, nystatin and amphotericin B which were used as controls in the experiment. Hexane extracts were also effective against all the five fungal isolates while acetone extracts were only effective against *C. krusei* at 0.04mg/ml. The results are consistent with those of Wilfred *et al.* [17] when the effects of the acetone extracts of *arctotis arctotoides* on the growth of some opportunistic fungi associated with HIV/AIDS were evaluated. Ethanol and aqueous extracts had no considerable antifungal activity. Aqueous extracts could not inhibit the growth of the five fungi isolates, even at the highest concentration of 5mg/ml [29].

Antioxidant activity

Chokoe *et al.,* [26] evaluated the seasonal variation in the antioxidant activity of *C. edulis* extracts. The ethyl acetate, acetone and methanol extract reportedly had an antioxidant compound which was more evident in the autumn extracts. The antioxidant activity of *C. edulis* growing in the Tunisian coast was also evaluated [14]. A higher *C. edulis* antioxidant activity, concentration of up to 2mg/ml, in the DPPH assay compared to *Mesembryanthemum crystallinum* was reported [14]. A higher proportion of flavonoids and phenols may be responsible for such an outstanding antioxidant activity. *Carpobrotus edulis* had even a higher antioxidant activity than that of butylated hydroxyanisole, a synthetic antioxidant. The antioxidant activity of *C. edulis* was also evaluated by Omoruyi *et al.* [16] and found out that the ethanol and aqueous extracts demonstrated the best antioxidant activity.

Falleh *et al.* [25] extensively evaluated the antioxidant activity of *C. edulis*. The antioxidant properties and phenolic compounds of *C. edulis* were characterized in the root, stem and the leaf. The aerial parts of the plants were reported having higher antioxidant activity than the roots. The aerial parts had the highest polyphenolic content compared to the roots, explaining the higher antioxidant activity. All studied organs had a significantly higher activity of butylated hydroxytoluene, with maximal efficiency for stems followed by leaves then roots. In the characterization of polyphenols responsible for the strong antioxidant properties of *C. edulis* using LC/ESI-MS/MS, the methanol extract from the leaf, root and stem showed the highest scavenging activity against ABTS and DPPH radicals [31]. The leaf extract mainly contained procyanidins and the stem extracts mostly had propelargonidins responsible for the potent antioxidant activity. Despite methanol extracts being richer in total polyphenol content compared to the ethanol, the latter had higher antioxidant activity than the former.

Antiproliferative activity

Carpobrotus edulis extracts are purportedly reported to have antiproliferative activity. Compounds isolated from the *C. edulis* leaf extracts using methanol water and hexane were evaluated for their antiproliferative effects on mouse lymphoma parental cells and human MDR1-transfected mouse lymphoma cells. All the compounds isolated reduced the proliferation of both cell lines. Catechin, Oleanolic acid and Uvaol were some of the isolated compounds and their antiproliferative effect was more significant in the parental cell lines. The multidrug resistant cell line was sensitive to epicatechin and monogalactosydiacylglycerol (MDGD) [32]. In all the isolated compounds, Uvaol had the most efficacious antiproliferative activity and is a potential lead in the reversal of multidrug resistance. Alkaloids from the family Aizoaceae have purported anticancer activity, even though the species of this family have invited minimal attention. Ordway *et al.* [33] revealed that *C. edulis* extract is non-toxic at concentrations that inhibit a verapamil sensitive efflux pump of L5178 mouse T cell lymphoma cell line thereby making these multidrug resistant cells sensitive to anticancer drugs.

Hydroethanolic and aqueous extracts of *C. edulis* were also reported to have cytotoxic effects against HCT116 cells, a human colon cancer cell line [34]. The ethanol-water extracts were more effective with substantial reduction in cell viability after 24 hours of incubation.

Neurological activity

The results from Custódio *et al.* [35] reveal that *C. edulis* has anticholinesterase activity against acetylcholinesterase and butyrylcholinesterase. *Carpobrotus edulis* is thus considered a potential lead in future research and alternative therapy for the management of neurological conditions associated with decreased acetylcholine levels in the brain.

Toxicology of *C. edulis*

A selected number of *Carpobrotus* species with medicinal properties were tested for cytotoxicity using the brine shrimp lethality test. The aqueous extract of *Carpobrotus mellei* and tthe methanol extract of *Carpobrotus quadrifidus* showed the highest activity than *Carpobrotus edulis* and other species tested [36]. Akhalwaya *et al.* [37] investigate the cytotoxicity of indigenous South African medicinal plants used to treat oral infections. *Carpobrotus edulis* is one of the medicinal plants tested and was considered non- toxic with percentage mortality rate of 47.43% at 24 hour and 48.06% at 48 hours. Cock and Van Vuuren [38] also found out that aqueous and methanol extracts of *C. edulis* are either non-toxic, or of low toxicity in the brine shrimp lethality bioassay.

Dugesia sicula Lepori, 1948, a freshwater planarian was used to investigate the effect of aqueous-acetone *C. edulis* extracts on regeneration. Morphological changes were evident on microscopic analysis of *Dugesia sicula Lepori* in ordinary medium containing phenolic extracts at non-toxic concentrations. The study suggests that *C. edulis* polyphenols can have harmful effects on the development of stem cells [28]. *Carpobrotus edulis* polyphenols can therefore have ecotoxicological impact on the planarians' physiology in the environment.

CONCLUSIONS AND PERSPECTIVES

An extensive literature survey has revealed that *Carpobrotus edulis* is an important medicinal plant used in ethno medicine for the treatment of tuberculosis and other respiratory infections, toothache and earache, facial eczema, wounds, burns, hypertension, and diabetes mellitus. Pharmacological studies performed on the fresh plant materials, crude extracts and various solvent extracts of *Carpobrotus edulis* validates the traditional medical use of the plant. Studies mainly focused on evaluation of the antimicrobial, antiproliferative, antioxidant and neurological activity of the plant extracts. State of the art pharmacological and toxicological methods have been used to evaluate the activity of *C. edulis* as reported in the current review. A significant proportion of studies also focused on phytochemical evaluation of the plant extract using different solvent systems and methods. The majority of the reported pharmacological studies aimed at validating its traditional uses. It is evident that the antibacterial properties have been extensively studied by various research groups globally. However, experimental evidence in wound healing, diabetes mellitus, hypertension, analgesia and gastrointestinal motility is greatly missing. To substantiate the traditional use of *C. edulis* in the aforementioned area, there is need for further experimental studies to validate its pharmacological use. There is little information reported on the safety profile of *C. edulis* extracts. The extensive use of *C. edulis* in traditional medicine may be posing a toxicological hazard to the exposed population. Studies evaluating the safety profile of *C. edulis* extracts are highly recommended.

REFERENCES

1. Peltzer K, Friend-du Preez N, Ramlagan S, Fomundam H. Use of traditional complementary and alternative medicine for HIV patients in KwaZulu-Natal, South Africa. BMC public health. 2008; 8:255.
2. Mahomoodally MF. Traditional medicines in Africa: an appraisal of ten potent African medicinal plants. Evidence-Based Complementary and Alternative Medicine. 2013.
3. Oreagba IA, Oshikoya KA, Amachree M. Herbal medicine use among urban residents in Lagos, Nigeria. BMC Complementary and Alternative medicine. 2011; 11:117.
4. Gurib-Fakim A, Mahomoodally MF. African Flora as Potential Sources of Medicinal Plants: Towards the Chemotherapy of Major Parasitic and Other Infectious Diseases: A Review. Jordan Journal of Biological Sciences. 2013; 147:1-8.
5. Roiloa SR, Rodríguez-Echeverría S, de la Pena E, Freitas H. Physiological integration increases the survival and growth of the clonal invader Carpobrotus edulis. Biological Invasions. 2010; 12:1815-1823.
6. Maltez-Mouro S, Maestre FT, Freitas H. Weak effects of the exotic invasive Carpobrotus edulis on the structure and composition of Portuguese sand-dune communities. Biological invasions. 2010; 12:2117-2130.
7. Novoa A, González L, Moravcová L, Pyšek P. Effects of soil characteristics, allelopathy and frugivory on establishment of the invasive plant Carpobrotus edulis and a co-occuring native, Malcolmia littorea. PLoS One. 2012; 7:e53166.
8. Van Wyk BE, De Wet H, Van Heerden FR. An ethnobotanical survey of medicinal plants in the southeastern Karoo, South Africa. South African Journal of Botany. 2008; 74:696-704.
9. Springfield EP, Amabeoku G, Weitz F, Mabusela W, Johnson Q. An assessment of two Carpobrotus species extracts as potential antimicrobial agents. Phytomedicine. 2003; 10:434-9.
10. O'Rourke E, Lysaght L. Risk assessment of Carpobrotus edulis. 2014.
11. Campoy JG, Acosta AT, Affre L, Barreiro R, Brundu G, Buisson E, González L, Lema M, Novoa A, Retuerto R, Roiloa SR. Monographs of invasive plants in Europe: Carpobrotus. Botany Letters. 2018; 165:440-75.
12. Steenkamp V, Fernandes AC, Van Rensburg CE. Screening of Venda medicinal plants for antifungal activity against Candida albicans. South African Journal of Botany. 2007; 73:256-8.
13. Buwa LV, Afolayan AJ. Antimicrobial activity of some medicinal plants used for the treatment of tuberculosis in the Eastern Cape Province, South Africa. african Journal of Biotechnology. 2009; 8:23.
14. Ibtissem B, Abdelly C, Sfar S. Antioxidant and antibacterial properties of Mesembryanthemum crystallinum and Carpobrotus edulis extracts. Adv Chem Eng Sci. 2012; 2:359-65.
15. Van Wyk BE. The potential of South African plants in the development of new food and beverage products. South African Journal of Botany. 2011; 77:857-68.
16. Omoruyi BE, Bradley G, Afolayan AJ. Antioxidant and phytochemical properties of Carpobrotus edulis (L.) bolus leaf used for the management of common infections in HIV/AIDS patients in Eastern Cape Province. BMC Complementary and Alternative Medicine. 2012; 12:215.
17. Otang WM, Grierson DS, Ndip RN. The effect of the acetone extract of *Arctotis arctotoides* (Asteraceae) on the growth and ultrastructure of some opportunistic fungi associated with HIV/AIDS. International journal of molecular sciences. 2011; 12:9226-35.
18. Rocha MI, Rodrigues MJ, Pereira C, Pereira H, da Silva MM, da Rosa Neng N, *et al.* Biochemical profile and in vitro neuroprotective properties of *Carpobrotus edulis* L., a medicinal and edible halophyte native to the coast of South Africa. South African journal of botany. 2017; 111:222-231.

19. Davids D, Gibson D, Johnson Q. Ethnobotanical survey of medicinal plants used to manage high blood pressure and type 2 diabetes mellitus in Bitterfontein, Western Cape Province, South Africa. Journal of ethnopharmacology. 2016; 194:755-766.
20. Al-Faris NA, Al-sawadi AD, Alokail MS. Effect of samh seeds supplementation (Mesembryanthemum forsskalei Hochst) on liver enzymes and lipid profiles of streptozotocin (STZ)-induced diabetic Wistar rats. Saudi journal of biological sciences. 2010; 17:23-28.
21. Semenya SS, Maroyi A. Medicinal plants used by the Bapedi traditional healers to treat diarrhoea in the Limpopo Province, South Africa. Journal of ethnopharmacology. 2012; 144:395-401.
22. Bisi-Johnson MA, Obi CL, Kambizi L, Nkomo M. A survey of indigenous herbal diarrhoeal remedies of OR Tambo district, Eastern Cape Province, South Africa. African Journal of Biotechnology. 2010; 9:8.
23. Eman AA. Phytochemical screening on different plant parts of some succulent plants of Egypt. New York Sci J. 2011; 4:15-18.
24. Van der Watt E, Pretorius J C. Purification and identification of active antibacterial components in *Carpobrotus edulis* L. Journal of Ethnopharmacology. 2001; 76:87-91.
25. Falleh H, Ksouri R, Medini F, Guyot S, Abdelly C, Magné C. Antioxidant activity and phenolic composition of the medicinal and edible halophyte *Mesembryanthemum edule* L. Industrial Crops and Products. 2011; 34: 1066-1071.
26. Chokoe PK, Masoko P, Mokgotho MP, Howard RL, Mampuru LJ. Does seasonal variation influence the phytochemical and antibacterial properties of *Carpobrotus edulis*?. African Journal of Biotechnology. 2008; 7:22.
27. Martins A, Vasas A, Viveiros M, Molnár J, Hohmann J, Amaral L. Antibacterial properties of compounds isolated from *Carpobrotus edulis*. International journal of antimicrobial agents. 2011; 37:438-444.
28. Meddeb E, Charni M, Ghazouani T, Cozzolino A, Fratianni F, Raboudi F. *et al*. Biochemical and Molecular Study of *Carpobrotus edulis* Bioactive Properties and Their Effects on Dugesia sicula (Turbellaria, Tricladida) Regeneration. Applied biochemistry and biotechnology. 2017; 182: 1131-1143.
29. Omoruyi BE, Afolayan AJ, Bradley G. The inhibitory effect of *Mesembryanthemum edule* (L.) bolus essential oil on some pathogenic fungal isolates. BMC complementary and alternative medicine. 2014; 14:168.
30. Martins M, Ordway D, Kristiansen M, Viveiros M, Leandro C, Molnar J, Amaral L. Inhibition of the *Carpobrotus edulis* methanol extract on the growth of phagocytosed multidrug-resistant Mycobacterium tuberculosis and methicillin resistant *Staphylococcus aureus.* Fitoterapia. 2005; 76:96-99.
31. Falleh H, Oueslati S, Guyot S, Dali AB, Magné C, Abdelly C, Ksouri R. LC/ESI-MS/MS characterisation of procyanidins and propelargonidins responsible for the strong antioxidant activity of the edible halophyte *Mesembryanthemum edule* L. Food Chemistry. 2011; 4:1732-1738.
32. Martins A, Vasas A, Schelz ZS, Viveiros M, Molnár J, Hohmann J, Amaral L. Constituents of *Carpobrotus edulis* inhibit P-glycoprotein of MDR1-transfected mouse lymphoma cells. Anticancer research. 2010; 30:829-835.
33. Ordway D, Hohmann J, Viveiros M, Viveiros A, Molnar J, Leandro C, *et al*. *Carpobrotus edulis* methanol extract inhibits the MDR efflux pumps, enhances killing of phagocytosed S. aureus and promotes immune modulation. Phytotherapy Research. 2003; 17:512-519.
34. Hafsa J, Hammi KM, Khedher MRB, Smach MA, Charfeddine B, Limem K, Majdoub H. Inhibition of protein glycation, antioxidant and antiproliferative activities of *Carpobrotus edulis* extracts. Biomedicine & Pharmacotherapy. 2016; 84: 1496-1503.
35. Custódio L, Ferreira AC, Pereira H, Silvestre L, Vizetto-Duarte C, Barreira L, *et al.* The marine halophytes *Carpobrotus edulis* L. and *Arthrocnemum macrostachyum* L. are potential sources of nutritionally important PUFAs and metabolites with antioxidant, metal chelating and anticholinesterase inhibitory activities. Botanica marina. 2012; 55:281-288.
36. Jooste CS. Brine shrimp lethality test and acetylcholine esterase inhibition studies on selected South African medicinal plants (Doctoral dissertation, University of the Western Cape). 2012.
37. Akhalwaya S, van Vuuren S, Patel M. An in vitro investigation of indigenous South African medicinal plants used to treat oral infections. Journal of ethnopharmacology. 2018; 210:359-371.
38. Cock IE, Van Vuuren SF. Anti-Proteus activity of some South African medicinal plants: their potential for the prevention of rheumatoid arthritis. Inflammopharmacology. 2014; 22:23-36.

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