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The *in vitro* pharmacological activities of 12 South African *Hermannia* species

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ABSTRACT

Hermannia species are widely used in traditional medicine in southern Africa, however no extensive study has been conducted on this genus. The acetone extracts of 12 indigenous *Hermannia* species (flowers, stems and leaves combined) were evaluated for various pharmacological activities. All investigated species displayed promising antimicrobial activity, with *Hermannia saccifera* being the most active against *Staphylococcus aureus* (MIC = 19.5 μg/ml), *Bacillus cereus* (MIC = 19.5 μg/ml) and *Enterococcus faecalis* (MIC = 125 μg/ml). Time-kill studies on *H. saccifera* against *S. aureus* indicated bacteriostatic activity at 1.25, 2.5 and 5.0%, and a concentration of 7.5% achieved complete bactericidal activity after 4 h. Ten of the 12 species indicated good free radical scavenging activity, with *H. cuneifolia* demonstrating the most promising activity in the 2,2-diphenyl-1-picrylhydrazyl ($DPPH^{\bullet}$:IC_{50} = 10.26 μg/ml) and 2,2′-azino-bis(3-ethyl-benzothiazoline-6-sulfonic acid) ($ABTS^{\bullet+}$/TEAC: IC_{50} = 10.32 μg/ml) assays. In addition, all species exhibited moderate anti-inflammatory activity in the 5-lipoxygenase assay with the exception of *H. cuneifolia* (IC_{50} = 15.32 μg/ml). Overall, the selected species were low in cytotoxicity, except for *H. saccifera* and *H. trifurca*. Several *Hermannia* species indicated promising *in vitro* biological activity which relate to their traditional use in treating a number of disease states.

1. Introduction

Traditional medicines form a significant part of the lives of many people around the world and in South Africa almost 60% of the population consult traditional healers in addition to the modern medical services available. Plants form a significant part of traditional healing and as such, select species of a traditionally used plant genus, *Hermannia*, were chosen for biological investigations to determine a scientific basis for the traditional use of these plants. *Hermannia* is a genus of the subfamily Byttnerioideae in the tribe Hermanieae of the family Malvaceae (previously Sterculiaceae), in which there are about 180 species worldwide. Eleven species occur in tropical Africa, three in America, one in Australia and about 162 species occur in southern Africa (Leistner, 2000).

The genus *Hermannia* has been utilized traditionally by a diversity of people such as the European, Tswana, Kwena, Southern Sotho, Xhosa and Zulu for a wide variety of uses such as fever, cough, respiratory diseases such as asthma, wounds, burns, eczema, stomach ache, as a purgative, diaphoretic, for heartburn, flatulence in pregnant women, colic and haemorrhoids. During the 18th century, *H. althaeifolia* was cultivated in Europe and was used medicinally as an aromatic tea against syphilis (Shearing, 1997). In addition, the Xhosa use a decoction of the root of *H. incana* for dysuria; while a decoction of the root of *H. salviifolia* is utilized as an old-fashioned European household remedy for convulsions. In addition, an ointment made from the plant together with *Lobostemon fruticosus* and

Abbreviations: $ABTS^{\bullet+}$, 2,2′-azino-bis(3-ethyl-benzthiazoline-6-sulfonic acid) cation radical; ATCC, American type culture collection; CFU, colony forming units; COX, cyclooxygenase; DMSO, dimethyl sulfoxide; $DPPH^{\bullet}$, 2,2-diphenyl-1-picrylhydrazyl radical; FLAP, 5-lipoxygenase activating protein; HPLC, high performance liquid chromatography; IC_{50}, concentration required to inhibit 50% cell growth/enzyme activity or scavenge 50% radical formation; INT, *p*-iodonitrotetrazolium; MIC, minimum inhibitory concentration; MTT, 3-[4,5-dimethylthiazol-2-yl]-2,5-diphenyl-2*H*-tetrazolium bromide; NCTC, National culture type collection; NDGA, nordihydroguaiaretic acid; TEAC, Trolox™ equivalent anti-oxidant capacity; TSA, tryptone soya agar.

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Psoralea decumbens is an old Cape remedy for "roos" (erysipelas or eczema). The Europeans apply an infusion or a decoction of *H. cuneifolia* to sores (Watt and Breyer-Brandwijk, 1962).

H. incana

H. althaeifolia

Most ethnobotanical literature refers to the extensive traditional use of *Hermannia* and thus, it is remarkable that limited research has been conducted on this genus. Very little information is available on the chemical constituents, pharmacology and cytotoxicity of *Hermannia* spp. Two papers have been published with regard to the antimicrobial, antimalarial and anti-inflammatory activity of *H. depressa* (Clarkson et al., 2004; Reid et al., 2005). Since this is the only species of *Hermannia* to be investigated, this pioneer evaluation of the possible activity was necessary to determine the potential pharmacological use of this ethnobotanical important genus.

2. Materials and methods

2.1. Plant collection and solvent extraction

Fresh plant material (leaves, flowers and stems) of 12 *Hermannia* species were collected from natural populations in the Cape region of South Africa). The taxonomy was confirmed by botanists (J. Vlok and J. Manning) and voucher specimens have been maintained at the Department of Pharmacy and Pharmacology at the University of the Witwatersrand in Johannesburg (Table 1).

The powdered plant material (consisting of all three plant parts) of each species was extracted using acetone at 40 °C for 3 h after which the solvent was filtered. This was repeated three times to maximize the extraction efficiency and the solvent was removed using a Büchi Rotavapor R-11.

2.2. Antimicrobial activity

2.2.1. Minimum inhibitory concentration assay

The *p*-iodonitrotetrazolim violet (INT) assay was used to determine the minimum inhibitory concentration (MIC) of the 12 plant extracts (Eloff, 1998). Extracts were resuspended in acetone and 1:1 serial dilutions prepared in water, were incubated along with cultures containing a final density of 1×10^6 CFU/ml. Eight cultures were used: *Staphylococcus aureus* (ATCC 12600), *Staphylococcus epidermidis* (ATCC 2223), *Enterococcus faecalis* (ATCC 29212), *Bacillus cereus* (ATCC 11778), *Klebsiella pneumoniae* (NTCC 9633), *Pseudomonas aeruginosa* (ATCC 9027), *Candida albicans* (ATCC 1023) and *Cryptococcus neoformans* (ATCC 90112). The plates were incubated at 37 °C for 24 h (bacteria) and 48 h (yeasts). To indicate bacterial growth, 40 μl of 0.4 mg/ml INT was added to all wells and left at ambient temperature for 6 h for the bacteria and 24 h for the yeasts. After which, the lowest concentration at which growth inhibition occurred was recorded (the first clear well). Ciprofloxacin was used as the positive control for the bacteria and amphotericin B for the yeasts.

2.2.2. Death kinetics assay

The inactivation broth death kinetic method described by Christoph and Stahl-Biskup (2001) was used to determine the antimicrobial activity of *H. saccifera* against *S. aureus* (ATCC 12600) over a 24-h period. *Staphylococcus. aureus* was cultured overnight at 37 °C on tryptone soya agar (TSA). The colonies were then diluted in sterile saline to yield a final inoculum with an optical density of 0.023 at 600 nm. Various concentrations of the acetone extracts (1.25, 2.5, 5.0 and 7.5%) were prepared in tryptone soya broth and incubated at 37 °C in a shaking water bath. The control excluded the extract. At various time intervals over a 24h period, aliquots were transferred to the inactivation broth containing 0.1% peptone, 5% lecithin and 5% yeast extract. Four serial dilutions were performed in saline. Samples of each dilution (100 μl) as well as from the inactivation broth were plated on TSA. The plates were incubated for 24 h at 37 °C, after which the colony forming units (CFU) were counted and death kinetics expressed as $\log_{10}$ CFU/ml.

H. saccifera

2.3. Cytotoxicity

Transformed human kidney epithelial (Graham) cells were used to test the cytotoxicity of the various plant extracts using the 3-(4,5-dimethylthiazol-2-yl)-2,5-diphenyl tetrazolium bromide (MTT) colorimetric microtitre plate method (Mosmann, 1983; Van Zyl and Viljoen, 2002). The cell suspension (0.25 million cells/ml) was plated out and incubated at 37 °C in 5% CO_2 for 6 h before the addi-

Table 1
The cytotoxic, anti-oxidant and anti-inflammatory activity of the 12 *Hermannia* species with their corresponding voucher numbers

Species/controls	Voucher number	Cytotoxicity $IC_{50} \pm$ S.D. (μg/ml)	Anti-oxidant activity		Anti-inflammatory activity	
			DPPH assay	ABTS assay	5-Lipoxygenase assay	
			$IC_{50} \pm$ S.D. (μg/ml)		% Inhibition with 100 μg/ml	$IC_{50} \pm$ S.D. (μg/ml)
H. althaeifolia L.	JV 2834	>200	14.73 ± 0.79	11.86 ± 0.64	56.53 ± 0.23	nd
H. cuneifolia Jacq. var. *cuneifolia.*	JV 2828	>200	10.26 ± 0.29	10.32 ± 0.34	100.0 ± 0.00	15.32 ± 5.49
H. flammula Harv.	JV 2832	>200	18.91 ± 1.13	19.56 ± 0.24	44.77 ± 0.96	nd
H. holosericea Jacq.	JV 2827	>200	14.16 ± 1.39	11.89 ± 0.13	56.4 ± 2.63	nd
H. incana Cav.	JV 2829	>200	16.57 ± 0.54	10.63 ± 0.18	47.26 ± 0.02	nd
H. involucrata Cav.	JV 2831	>200	23.32 ± 0.18	18.78 ± 0.62	44.66 ± 1.46	nd
H. lavandufolia L.	JV 2835	>200	26.35 ± 1.02	22.05 ± 0.62	27.69 ± 3.16	nd
H. muricata Eckl. and Zeyh.	JV 2833	>200	29.21 ± 1.96	21.62 ± 0.91	32.11 ± 0.87	nd
H. saccifera (Turcz.) K. Schum	JV 2830	61.40 ± 4.56	15.41 ± 0.65	12.94 ± 0.56	45.80 ± 4.65	nd
H. salviifolia L. f.	JV 2836	>200	>100	109.49 ± 0.26	41.38 ± 0.62	nd
H. scabra Cav.	AV 1165	>200	15.40 ± 0.43	12.77 ± 0.20	33.07 ± 0.00	nd
H. trifurca L.	AV 1166	75.61 ± 6.11	42.66 ± 0.35	41.74 ± 0.99	51.97 ± 2.23	nd
Controls		136.06 ± 4.06[a]	2.46 ± 0.01[b]	2.96 ± 0.001[c]	100.0 ± 0.00[d]	2.39 ± 0.71[d]

nd: unable to determine at concentrations tested.
[a] Quinine.
[b] Ascorbic acid.
[c] Trolox™.
[d] Nordihydroguaiaretic acid.

tion of the extracts (12.5–200 μg/ml). The plates were incubated for 44 h, after which MTT was added to each well. After a further 4 h incubation period, culture medium was aspirated and DMSO added to stop the reaction and to solubilize the formazan crystals. The absorbances were read at 540 and 690 nm using a microplate reader (Labsystems iEMS Reader MF) and Ascent® software. The results were expressed as percentage cellular viability of the drug- and cell-free controls. The concentration required to inhibit 50% cell growth (IC_{50} values) were obtained from log sigmoid dose–response curves using the Enzfitter® software. The extracts were tested in triplicate.

2.4. Anti-oxidant activity

2.4.1. 2,2-Diphenyl-1-picrylhydrazyl ($DPPH^{\bullet}$) assay

The quantitative measurement of the radical scavenging properties of the extracts was carried out using the $DPPH^{\bullet}$ assay with ascorbic acid as the reference compound (Shimada et al., 1992). The $DPPH^{\bullet}$ (Sigma–Aldrich) prepared in HPLC grade methanol was plated with 100 μg/ml for all the extracts in triplicate wells and those with activity less than 100 μg/ml were serially diluted (6.25–100 μg/ml). After an incubation period of 30 min at room temperature in the dark, the absorbances were read at 550 nm. The IC_{50} values (i.e. the concentration of sample required to scavenge 50% of the DPPH radical) were determined using the Enzfitter® software. The anti-oxidant activity of each plant extract was done in triplicate.

2.4.2. 2,2′-Azino-bis(3-ethyl-benzthiazoline-6-sulfonic acid) ($ABTS^{\bullet+}$) scavenging assay

The radical scavenging activity of all extracts was determined using the $ABTS^{\bullet+}$ assay, i.e. the Trolox™ equivalent anti-oxidant capacity (TEAC) assay (Miller et al., 1993; Van den Berg et al., 1999). The radical scavenging activity was quantitated by reacting the ABTS radical cation ($ABTS^{\bullet+}$) with the extract/control. The mixture was heated for 4 min, after which the absorbance was read at 734 nm on a Specord® 40 spectrophotometer. Measurements were performed in triplicate. Ethanol and methanol were used as negative controls, while Trolox™ (6-hydroxy-2,5,7,8-tetramethylchromon-2-carboxylic acid) (Sigma–Aldrich) was used as the positive control. The percentage inhibition was plotted as a function of the concentration and using the straight line equation, the concentration that produced 50% decolourisation (IC_{50} value) was determined. The scavenging activity of the extracts were compared to Trolox™ and each plant extract tested in triplicate.

2.5. Anti-inflammatory activity

The anti-inflammatory activity of the extracts was determined by inhibiting the activity of 5-lipoxygenase, resulting in the inhibition of prostaglandin and leukotriene synthesis (Sircar et al., 1983; Evans, 1987). Test samples (100 μg/ml) were dissolved in 2.73% (w/w) Tween® 20 in DMSO and mixed with 0.1 M potassium phosphate buffer (pH 6.3) and linoleic acid (≥99%, Fluka). The reaction was initiated by the addition of 50 U of 5-lipoxygenase (Cayman) prepared in 0.1 M potassium buffer (pH 6.3; 4 °C). The increase in absorbance at 234 nm was recorded for a period of 10 min using a Specord 40 spectrophotometer utilizing Winaspect® software. The percentage inhibition of the enzyme activity was calculated by comparison with the controls (Tween® 20/DMSO mixture) and the IC_{50} value (concentration at which 50% of the enzyme was inhibited) was determined for those extracts with adequate inhibition. The experiment was conducted in duplicate. Nordihydroguaiaretic acid (NDGA) was used as the positive control.

3. Results and discussion

3.1. Antimicrobial activity

The crude extracts of all 12 plants with the exception of *Hermannia flammula* displayed inhibitory effects on the selected test organisms and this activity was shown to be a concentration-dependant inhibitory effect (Table 2). Most values ranged between 2 and 4 mg/ml with only *H. flammula* indicating limited activity against *C. albicans* and *S. aureus* with values of greater than 16 and 8 mg/ml, respectively. In addition, *H. althaeifolia*, *H. holosericea* and *H. scabra* produced MIC values of 8 mg/ml against *E. faecalis*. Aligiannis et al. (2001) proposed a classification for plant materials based on MIC results as follows: strong inhibitors—MIC up to 0.5 mg/ml; moderate inhibitors—MIC between 0.6 and 1.5 mg/ml; weak inhibitors above 1.6 mg/ml. Thus, while most extracts do possess potential antimicrobial activity, many exhibit weak activity. However, a few species indicated moderate activity. In addition, *H. cuneifolia*, *H. involucrata*, *H. muricata* and *H. salviifolia* have indicated

Table 2
Antimicrobial activity for *Hermannia* species

Species/controls	Antimicrobial activity (mg/ml)							
	S. aureus	*S. epidermidis*	*E. faecalis*	*B. cereus*	*K. pneumoniae*	*P. aeruginosa*	*C. albicans*	*C. neoformans*
H. althaeifolia	4	4	8	4	4	4	4	1
H. cuneifolia	2	2	4	2	2	2	4	0.5
H. flammula	8	4	4	2	2	4	>16	4
H. holosericea	2	2	8	2	2	2	4	2
H. incana	2	2	4	2	2	1	8	1
H. involucrata	2	2	4	2	2	1	2	0.5
H. lavandufolia	4	2	4	2	2	1	4	4
H. muricata	2	4	4	2	2	2	4	0.5
H. saccifera	0.0195	1	0.125	0.0195	2	2	1	0.5
H. salviifolia	2	2	4	2	1	0.5	2	1
H. scabra	4	2	8	1	1	0.5	2	0.5
H. trifurca	4	4	4	6	3	1	4	1
Control	0.0025[a]	0.0006[a]	0.0013[a]	0.0006[a]	0.0013[a]	0.00002[a]	0.0025[b]	0.003[b]

[a] Ciprofloxacin.
[b] Amphotericin B.

strong activity against either *P. aeruginosa* or *C. neoformans*. For *H. scabra*, good activity (0.5 mg/ml) was noted against both organisms.

H. flammula

The highest activity, however, was obtained by *H. saccifera* with a MIC of 19.5 μg/ml against both *S. aureus* and *B. cereus* and a MIC of 0.125 mg/ml against *E. faecalis*. The high activity against *S. aureus* is promising and noteworthy in light of the existence of *S. aureus* strains that are highly resistant to available antimicrobial agents (Lechner et al., 2004). Essop (2005) reported the isolation of *E*-17,19-diacetoxy-15-hydroxylabda-7,13-diene from *H. saccifera* and recorded an MIC value of 23.6 μg/ml for this compound against *S. aureus*. Although the activity was less than that of the crude extract (MIC = 19.5 μg/ml), this labdane compound clearly contributes to the antimicrobial activity. To date, *H. depressa* is the only species of *Hermannia* to be investigated for antimicrobial activity. The ethanol and ethyl acetate extracts resulted in inhibitory values ranging from 0.78 to 3.13 mg/ml against *S. aureus*; but was more active against *Bacillus subtilis* with the values ranging from 0.78 to 3.90 mg/ml (Reid et al., 2005). In comparison, *H. saccifera* has a much greater antimicrobial activity than any other *Hermannia* species tested (Table 2).

Due to the very low MIC value of *H. saccifera* against *S. aureus* (ATCC 12600), the antimicrobial activity was further characterized using death kinetic assays to determine whether *H. saccifera* possessed bactericidal activity over time (Fig. 1). An initial decrease in viable cell counts for all concentrations including the control was observed. After the first 30 min the viable colony count for the control increased and the antibacterial activity of all concentrations was noticeable after 60 min of exposure time. The activity of the extract is concentration-dependant resulting in a reduction of colony forming units. All concentrations exhibited antibacterial activity over time with most concentrations achieving at least a 4–5 $\log_{10}$ reduction in bacterial count after 8 h. Extract concentrations of 1.25, 2.5 and 5.0%, indicated bacteriostatic activity with an initial decrease in viable cell counts. The 7.5% extract achieved complete bactericidal activity after 4 h. Regrowth of microorganisms did not occur at any concentration being investigated within the 24 h test period (Fig. 1).

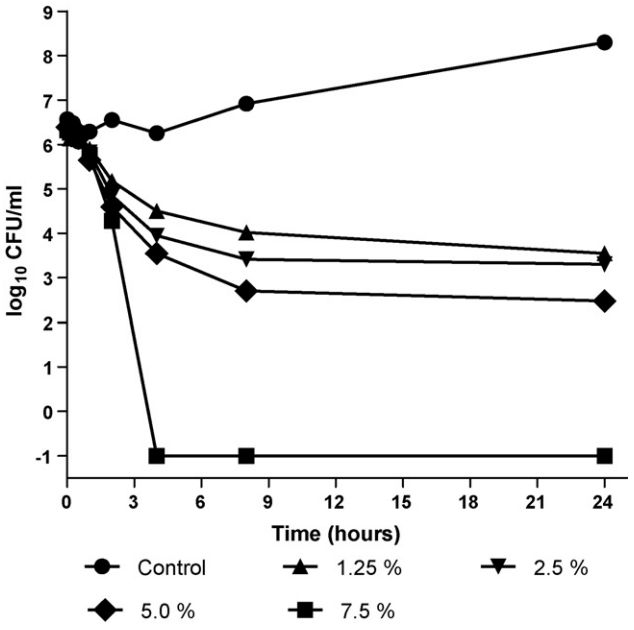

Fig. 1. Death kinetics of *Staphylococcus aureus* exposed to various concentrations of *H. saccifera* over 24 h.

3.2. Cytotoxicity

Overall, 10 of the *Hermannia* species possessed low cytotoxicity with IC_{50} values greater than 200 μg/ml (Table 1). Only two species, namely *H. saccifera* and *H. trifurca* were more toxic than the others with IC_{50} values of 61.40 ± 4.56 and 75.61 ± 6.11 μg/ml, respectively. The possibility that the increased cytotoxicity of *H. saccifera* may influence the promising antimicrobial activity should be considered.

3.3. Anti-oxidant activity

Most species possessed promising anti-oxidant activity in both the $DPPH^{\bullet}$ and $ABTS^{\bullet+}$ assays, with *H. cuneifolia* being the most active (10.26 ± 0.29 and 10.32 ± 0.34 μg/ml in the $DPPH^{\bullet}$ and $ABTS^{\bullet+}$ assays, respectively). There was only a fourfold difference between this latter activity and the positive controls (ascorbic acid and Trolox™) indicating the potential for the isolation of compounds that contributed to this favourable activity. Ten of the 12 species possessed activity ranging from 10 to 30 μg/ml, with *H. trifurca* indicating moderate activity and *H. salviifolia* displaying limited activity in both assays (Table 1).

While the selected plant species indicate promising free radical scavenging activity, it must be noted, however, that there are a number of mechanisms by which anti-oxidants may function. The cascade leading to oxidative damage is complex and only free radical scavenging activity has been explored. The mechanism of anti-oxidant action can include suppressing reactive oxygen species formation, either by inhibition of enzymes or by chelating trace elements involved in free-radical production, scavenging reactive species and up-regulating or protecting anti-oxidant defenses (Van Acker et al., 1996). While these plants do possess chain breaking potential, a selection of assays may provide a more complete indication for the extent of anti-oxidant activity and therefore, assays such as the hydrogen peroxide, thiobarbituric acid reactive substances (TBARS), as well as iron chelation assays may further define their anti-oxidant ability.

3.4. Anti-inflammatory activity

The use of *Hermannia* species for inflammatory conditions is validated by the inhibitory effects of the 12 plant species against the 5-lipoxygenase enzyme (Table 1). At a concentration of 100 μg/ml, all but *H. cuneifolia* displayed moderate activity with the inhibitory effects ranging from 27.69 to 56.53%. *H. cuneifolia* inhibited 50% of the 5-lipoxygenase activity at a concentration of 15.32 ± 5.49 μg/ml, in comparison to Trolox™ (2.39 ± 0.71 μg/ml). Essop (2005) isolated four compounds, 5,8-dihydroxy-6,7,4′-trimethoxyflavone, cirsimaritin, lupeol and β-sitosterol from various species which inhibited the 5-lipoxygenase enzyme by 51.97, 33.86, 42.5 and 2.13%, respectively. This indicates that while these compounds do contribute to the activity of the extracts they are not individually responsible for any significant activity. Conclusive evidence would be required by investigating the effects of these plants on other enzymes involved in the inflammation pathway, such as cyclooxygenase (COX)-1 and -2 or phospholipase A_2. This is warranted as *H. depressa* has previously been shown to display good inhibition of the COX-1 enzyme where, the dichloromethane extract (500 μg/ml) inhibited between 78% and 81% of enzyme activity (Reid et al., 2005). In addition, the inhibition of leukotrienes by the plant extracts may also be related to the inhibition of the 5-lipoxygenase activating protein (FLAP). Studies have indicated that cells, which contain 5-lipoxygenase and not FLAP, are unable to biosynthesize leukotriene products unless provided with a large excess of exogenous arachidonic acid substrate and thus the plant may exhibit this mechanism of action. Further, the direct inhibition of leukotriene D_4 itself cannot be eliminated as this is another possible mechanism of action for the modulation of the pathway (Young, 1999).

Other than NDGA, the only plant extract to inhibit 100% enzyme activity at a concentration of 100 μg/ml, was *H. cuneifolia* which yielded an IC_{50} value of 15.32 ± 5.49 μg/ml which is only sixfold less effective than NDGA. Anti-oxidant and anti-inflammatory activities are often related (Fernandes et al., 2004), thus the promising activities of *H. cuneifolia* could produce bioactive compounds that may be useful in treating inflammation, as well as conditions that would benefit from free radical scavenging.

4. Conclusions

Biological investigations indicated that certain species of *Hermannia* displayed promising antimicrobial, anti-oxidant and anti-inflammatory activity. Thus, the biological activity observed in *Hermannia* species provides a scientific basis for the use of the plants in traditional medicines with each facet of activity contributing to the ultimate therapeutic benefit of the plant.

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References

Aligiannis, N., Kalpotzakis, E., Mitaku, S., Chinou, I.B., 2001. Composition and antimicrobial activity of the essential oils of two *Origanum* species. Journal of Agricultural and Food Chemistry 40, 4168–4170.

Clarkson, C., Maharaj, V.J., Crouch, N.R., Grace, O.M., Pillay, P., Matsabisa, M.G., Bhagwandin, N., Smith, P.J., Folb, P.I., 2004. *In vitro* antiplasmodial activity of medicinal plants native to or naturalized in South Africa. Journal of Ethnopharmacology 92, 177–191.

Christoph, F., Stahl-Biskup, E., 2001. Death kinetics of *Staphylococcus aureus* exposed to commercial tea tree oils. Journal of Essential Oil Research 13, 98–102.

Eloff, J.N., 1998. A sensitive and quick microplate method to determine the minimal inhibitory concentration of plant extracts for bacteria. Plant Medica 64, 711–713.

Essop, A.B., 2005. The Biological Activity and Phytochemistry of Selected *Hermannia* species. M.Sc. Dissertation. University of the Witwatersrand, South Africa.

Evans, A.T., 1987. Actions of cannabis constituents on enzymes of arachidonate metabolism, anti-inflammatory potential. Biochemical Pharmacology 36, 2035–2037.

Fernandes, A., Cromarty, A.D., Albrecht, C., Jansen van Renburg, C.E., 2004. The antioxidative potential of *Sutherlandia frutescens*. Journal of Ethnopharmacology 95, 1–5.

Lechner, D., Stavri, M., Oluwatuyi, M., Pereda-Miranda, R., Gibbons, S., 2004. The anti-staphylococcal activity of *Angelica dahurica* (Bai Zhi). Phytochemistry 65, 331–335.

Leistner, O.A., 2000. Seed Plants of Southern Africa: Families and Genera. Strelitzia, vol. 10. National Botanical Institute, Pretoria.

Miller, N.J., Rice-Evans, C.A., Davies, M.J., Gopinathan, V., Milner, A., 1993. A novel method for measuring antioxidant capacity and its application to monitoring the antioxidant status in premature neonates. Clinical Science 84, 407–412.

Mosmann, T., 1983. Rapid colorimetric assay for cellular growth and survival: application to proliferation and cytotoxicity assays. Journal of Immunological Methods 65, 55–63.

Reid, K.A., Jäger, A.K., Light, M.E., Mulholland, D.A., Van Staden, J., 2005. Phytochemical and pharmacological screening of Sterculiaceae species and isolation of antibacterial compounds. Journal of Ethnopharmacology 97, 285–291.

Shearing, D., 1997. Karoo: South African Wild Flower Guide, vol. 6. Botanical Society of South Africa, RSA.

Shimada, K., Fujikawa, K., Yahara, K., Nakamura, T., 1992. Antioxidative properties of Xanthan on the autooxidation of soybean oil in cyclodextrin emulsion. Journal of Agricultural and Food Chemistry 40, 945–946.

Sircar, J.C., Shwender, C.J., Johnson, E.A., 1983. Soybean lipoxygenase inhibition by nonsteroidal anti-inflammatory drugs. Prostaglandins 25, 393–396.

Van Acker, S.A.B.E., Van den Berg, D.J., Tromp, M.N.J.L., Griffioen, D.H., Van Bennekom, W.P., Van der Vijgh, W.J.F., Bast, A., 1996. Structural aspects of antioxidant activity of flavonoids. Free Radical and Biological Medicine 20, 331–432.

Van den Berg, R., Haenen, G.R.M.M., Van den Berg, H., Bast, A., 1999. Applicability of an improved Trolox equivalent antioxidant capacity (TEAC) assay for evaluation of antioxidant capacity measurements of mixtures. Food Chemistry 66, 511–517.

Van Zyl, R.L., Viljoen, A.M., 2002. *In vitro* activity of *Aloe* extracts against *Plasmodium falciparum*. South African Journal of Botany 68, 106–110.

Watt, J.M., Breyer-Brandwijk, M.G., 1962. The Medicinal and Poisonous Plants of Southern and Eastern Africa, second ed. Livingstone, London, UK.

Young, R.N., 1999. Inhibitors of 5-lipoxygenase: a therapeutic potential yet to be fully realized? European Journal of Medicinal Chemistry 34, 671–685.