

Traditional Uses, Phytochemical and Pharmacological Properties of *Dovyalis caffra*

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Abstract: *Dovyalis caffra* is a valuable indigenous African fruit tree widely cultivated throughout the world. The species is also traditionally used as herbal medicine to treat and manage human and animal diseases. This study reviewed ethnobotanical uses, phytochemical and pharmacological properties of *D. caffra*. Relevant information on the uses, phytochemistry and pharmacological properties of *D. caffra* was collected from electronic scientific databases such as ScienceDirect, SciFinder, PubMed, Google Scholar, Medline, and SCOPUS. Pre-electronic literature search of conference papers, scientific articles, books, book chapters, dissertations and theses were carried out at the University library. Literature search revealed that *D. caffra* is used as herbal medicine for amenorrhoea, heart pains, malaria, pain, wounds and as ethnoveterinary medicine. Phytochemical compounds identified from the species include alkaloids, amino acids, fatty acids, flavonoids, hydroxybenzoic acids, hydroxycinnamic acids, hydroxyhydrocinnamic acid, hydroxyphenylacetic acids, organic acids, phenolics, steroids, terpenoids and volatile compounds. Pharmacological studies revealed that *D. caffra* extracts and compounds have antimicrobial, antioxidant, antischistosomal, nematocidal and cytotoxicity activities. There is need for detailed scientific investigations aimed at elucidating the chemical, nutritional and toxicological properties of *D. caffra*.

Keywords: *Dovyalis caffra*, Salicaceae, southern Africa, sustainable development, traditional knowledge.

INTRODUCTION

Dovyalis caffra (Hook. f. & Harv.) Hook. f. is a widespread and horticulturally important southern African endemic plant species [1]. The species belongs to the family Salicaceae or willow family. The genus *Dovyalis* E. Mey. ex Am. is relatively small, mostly African genus comprising about 15 species of shrubs or relatively small trees, often thorny, with simple, alternate and exstipulate leaves [1,2]. In South Africa, the fruits of *D. caffra*, *D. rhamnoides* (Burch. ex DC.) Burch. & Harv. and *D. zeyheri* (Sond.) Warb. have commercial value as jelly, jam, dried, liqueurs, sweets and processed products [3]. The fruits of *D. caffra* are popular in South Africa [4-11] and are sold in informal markets in both rural and peri-urban areas of the country [6]. Okole and Odhav [12] argued that the fruits of *D. caffra* have potential for domestication and large-scale cultivation in tropical Africa based on the widespread utilization of the fruits. Based on the importance of *D. caffra* as a source of edible fruits, the species has been introduced in tropical East Africa, Australia, the Mediterranean and European countries [13,14]. According to Van Wyk and Gericke [6], *D. caffra* has been introduced in trial plantings in the Negev desert in Israel, but the thorns make commercial harvesting a difficult task. *Dovyalis caffra* is widely

cultivated throughout the world as a fruit tree and hedge plant and has become naturalized in some countries [13,14]. Research by Lubbe *et al.* [15] and de Bruin [16] revealed that *D. caffra* is managed in urban and peri-urban domestic gardens in the North West and Western Cape provinces of South Africa. *Dovyalis caffra* is receiving increasing research attention due to health benefits derived from the fruits. It is within this context that this study was carried out aimed at reviewing the ethnobotanical, phytochemical and pharmacological properties of *D. caffra*.

BOTANICAL PROFILE OF *D. CAFFRA*

The common English name of *D. caffra* is Kei apple, mainly because the species is abundant along the Kei river in the Eastern Cape province, South Africa [13,14,17]. The genus name *Dovyalis* is based on the Greek word for a spear, in reference to the straight and sharp spines associated with the species [13]. The specific name *caffra* is from the Hebrew word "kafri" meaning "person living on the land" and the name was often applied to plants indigenous to the eastern parts of South Africa in the previous centuries. The synonyms of *D. caffra* are *Aberia caffra* Hook. f. & Harv. and *A. edulis* T. Anderson [13,14,18]. *Dovyalis caffra* is indigenous to Africa's southern countries, including Mozambique, South Africa, Swaziland and Zimbabwe but now widely cultivated throughout the world and has become naturalized in certain countries [13,14]. The species has been recorded in open

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Table 1: Medicinal Uses of *D. caffra* in Southern Africa

Medicinal use	Parts of the plant used	Country	References
Amenorrhoea	The thorns are mixed with roots of <i>Albizia brevifolia</i> Schinz, <i>Pterocarpus angolensis</i> DC. and <i>Brackenridgea zanguebarica</i> Oliv. and decoction taken orally	South Africa	[21,22]
Heart pains	The thorns are mixed with fruits of <i>Musa paradisiaca</i> L. and decoction taken orally	South Africa	[21,22]
Malaria	Root decoction taken orally	Kenya	[23]
Painful and swollen legs	Root decoction applied topically	Zimbabwe	[25]
Ethnoveterinary medicine	Fruits	Kenya	[24]

bushveld, scrubland, wooded grassland, edges of coastal forest, riverine thicket, often in *Acacia* woodland and frequently associated with termite mounds. The species is drought- and frost-resistant, can tolerate sea breezes and salt spray. *Dovyalis caffra* thrives in deep, well drained loamy or sandy soils in regions where mean annual rainfall is 800 to 1700 mm and altitude ranging from 15 m to 1370 m above sea level [13,14,18].

Dovyalis caffra is an evergreen shrub or a small tree which may grow to a height of 8 metres characterized by long, sharp thorns which are few on the main stem and more on side branches. The stem is either single, several or multiple and characterized by a greyish smooth bark which eventually flakes into square sections [14]. The leaves are leathery and glossy, dark green above, paler below, with lateral veins more visible above than below, hairless, narrowly obovate to broadly obovate-elliptic and arranged in clusters along the branches. The flowers have no petals, are small and inconspicuous, usually on dwarf spur-branchlets and creamy green in colour [14,17]. The male flowers occur in dense clusters, usually seen as a mass of stamens while female flowers are single and borne in small groups [14]. The fruit is spherical, bright yellow with an extremely tough skin with 5 to 15 seeds arranged in double rings in the centre [5].

TRADITIONAL USES OF *D. CAFFRA*

Dovyalis caffra is an important fruit tree with aromatic apricot-like fruits which are eaten raw by people and wild animals or cooked, and enjoyed as jelly, pickles, jam and alcoholic beverage [9,13,14]. Therefore, *D. caffra* is widely cultivated throughout the world, and in many areas of southern Africa, and garden plants have escaped and become naturalized in some cases [13,14]. The fruit is however, considered too acidic to be eaten directly from the tree. It is normally served as a dessert, where it is cut in half,

peeled, seeded, sprinkled with sugar and allowed to stand for a few hours before serving. *Dovyalis caffra* fruits are also added into fruit salads, made into syrups, shortcake, jam and jelly or made into dried fruit [4,19]. The fruit juice is mixed with porridge to make a kind of traditional pudding [20]. The fruits, roots and thorns of *D. caffra* are used as herbal medicines in Kenya, South Africa and Zimbabwe [21-25], see Table 1. Although *D. caffra* is exotic to Kenya, the species has been incorporated into traditional pharmacopoeia as herbal medicine for both humans and livestock [23,24], corroborating the general hypothesis that exotic plants are important in the provision of primary healthcare as traditional medicines to local communities in developing countries [26-28].

NUTRITIONAL AND PHYTOCHEMICAL COMPOSITION OF *D. CAFFRA*

The fruit pulp of *D. caffra* is highly nutritious by virtue of high amounts of carbohydrates, protein and vitamins (Table 2). Several amino acids and fatty acids (Table 2) have been identified from the fruit pulp of *D. caffra* [10,29,30]. Reference is also made to the recommended dietary allowance (RDA) representing the average daily intake of essential nutrients that are sufficient to meet the nutrient requirements of a health person (Table 2). The carbohydrates, protein, vitamins, amino acids and fatty acids identified from the fruit pulp of *D. caffra* imply that the species is essential in meeting the nutritional needs of local communities at risk of food insecurity, macro- and micronutrient malnutrition. Several phytochemical compounds such as alkaloids, flavonoids, hydroxybenzoic acids, hydroxycinnamic acids, hydroxyhydrocinnamic acid, hydroxyphenylacetic acids, organic acids, phenolics, steroids, terpenoids and volatile compounds have been identified from the fruits, leaves and seeds of *D. caffra* (Table 3). Minnaara *et al.* [31] argued that the fruits of *D. caffra* are bitter due to high concentration of malic acid which was determined to be 10.2 g/100g [11].

Table 2: Nutritional Composition of *D. caffra*

Nutritional composition	Values	Plant parts	Recommended Dietary Allowance (RDA)	References
Arabinose (%)	2.1	Fruit pulp	-	[33]
Ash (%)	7.45	Fruit pulp	-	[11]
Carbohydrates (%)	54.1	Fruit pulp	275g	[11]
Fat (g/100g)	0.4	Fruit pulp	78g	[34]
Fibre (%)	16.3	Fruit pulp	28g	[11]
Fructose (mg/g)	3.0 – 35.3	Fruit pulp	-	[10]
Galactose (%)	26.8	Fruit pulp	-	[33]
Galacturonic acid (%)	63.0	Fruit pulp	-	[33]
Glucose (mg/g)	1.21 – 15.06	Fruit pulp	-	[10]
Moisture (%)	15.5	Fruit pulp	-	[11]
Pectin (%)	3.7	Fruit pulp	-	[33,35]
Protein (%)	1.6 - 4.0	Fruit pulp	50g	[9,11]
Provitamin A (mg/100g)	71.8	Fruit pulp	-	[34]
Rhamnose (%)	0.3	Fruit pulp	-	[33]
Total sugar (mg/g)	6.0 – 50.1	Fruit pulp	50g	[10]
Vitamin B1 (thiamine (mg/100g)	0.01	Fruit pulp	1.1 – 1.2mg	[34]
Vitamin B2 (riboflavin (mg/100g)	0.05	Fruit pulp	1.1 – 1.3mg	[34]
Vitamin C (mg/100g)	83.0 – 275.9	Fruit pulp	75 – 90mg	[9,11,34,35]
Xylose (%)	1.4	Fruit pulp	-	[33]
Amino acids				
Alanine (mg/L)	70.0 – 117.0	Fruit pulp	-	[10]
γ-amino butyric acid (mg/L)	180.0 – 650.0	Fruit pulp	-	[10]
Arginine (mg/L)	3.0 – 8.3	Fruit pulp	-	[10]
Asparagine (mg/L)	75.0 – 3150.0	Fruit pulp	-	[10]
Aspartic acid (mg/L)	33.0 – 126.0	Fruit pulp	-	[10]
Cysteine (mg/L)	0.3 – 0.7	Fruit pulp	28 – 43	[10]
Glutamic acid (mg/L)	33.0 – 160.0	Fruit pulp	-	[10]
Glutamine (mg/L)	20.0 -76.0	Fruit pulp	-	[10]
Glycine (mg/L)	0.8 – 12.7	Fruit pulp	-	[10]
Histidine (mg/L)	1.2 – 9.2	Fruit pulp	21 – 32	[10]
Isoleucine (mg/L)	0.3 – 2.8	Fruit pulp	28 - 43	[10]
Leucine (mg/L)	2.3 – 23.2	Fruit pulp	63 – 93	[10]
Lysine (mg/L)	1.4 – 4.2	Fruit pulp	58 - 89	[10]
Ornithine (mg/L)	0.2 – 0.6	Fruit pulp	-	[10]
Phenylalanine (mg/L)	2.2 – 27.8	Fruit pulp	54 – 84	[10]
Proline (mg/L)	18.0 – 140.0	Fruit pulp	-	[10]
Serine (mg/L)	18.0 – 77.0	Fruit pulp	-	[10]
Threonine (mg/L)	3.6 – 8.8	Fruit pulp	32 – 49	[10]
Tyrosine (mg/L)	0.7 – 1.2	Fruit pulp	37 - 58	[10]
Valine (mg/L)	1.9 – 5.8	Fruit pulp	10	[10]

(Table 2). Continued.

Nutritional composition	Values	Plant parts	Recommended Dietary Allowance (RDA)	References
Fatty acids				
Arachidic acid (%)	0.38	Seed	0.1	[29]
Decenoic acid (%)	0.29	Seed	-	[29]
Docosanoic acid (%)	0.12	Seed	-	[29]
Docosenoic acid (%)	0.03	Seed	-	[29]
Eicosenoic acid (%)	0.16	Seed	-	[29]
Linoleic acid (%)	55.0	Seed	6.7	[29]
Linolenic acid (%)	0.58	Seed	1.4	[29]
Oleic acid (%)	12.2	Seed	-	[29]
Palmitic acid (%)	1.5 - 21.4	Seed and twig	-	[29,30]
Stearic acid (%)	9.2	Seed	-	[29]

Table 3: Phytochemical Composition of *D. caffra*

Phytochemical composition	Values	Plant parts	References
Alkaloids			
Aberiamine N ¹ pentyyl-10-(1,3-dimethylhexahydro-2-pyrimidinyl)-1-decanamine	-	Leaves	[36]
Aberiamine N ¹ [(E)-1-butenyl 17-dimethylcarboxamidoheptadecyl)amino}methyl]-N-1-methylacetamide	-	Leaves	[36]
Flavonoids			
Apigenin	-	Leaves	[36]
Apigenin-7-O-β-glucoside	-	Leaves	[36]
Anthocyanin (mg/kg)	40.2 – 90.8	Fruit pulp	[10]
Hesperidin (μg/g)	7.0 – 79.0	Fruit pulp	[11]
Luteolin (μg/g)	2.0 – 22.0	Fruit pulp	[11]
Luteolin	-	Leaves	[36]
Quercetin (mg/kg)	30.0 – 100.0	Fruit pulp	[10,11]
Rutin (μg/g)	6.0 – 26.0	Fruit pulp	[11]
Hydroxybenzoic acids			
Gallic acid (μg/g)	2.4 – 28.0	Fruit pulp	[5,11]
m - hydroxybenzoic acid (mg/L)	4.3 ± 0.12	Fruit pulp	[5]
Protocatechuic acid (μg/g)	95.1 – 292.0	Fruit pulp	[5,11,31]
α-resorcylic acid (mg/L)	0.6 ± 0.02	Fruit pulp	[5]
Salicylic acid (mg/L)	0.4 ± 0.02	Fruit pulp	[5]
Syringic (mg/L)	0.7 ± 0.03	Fruit pulp	[5]
Vanillic acid (mg/kg)	6.69 – 15.94	Fruit pulp	[5,10,11]
Hydroxycinnamic acids			
Caffeic acid (mg/L)	11.2 – 32.0	Fruit pulp	[5,11,31]
Chlorogenic acid (mg/L)	903.3 ± 4.7	Wine	[31]
p-coumaric acid (mg/L)	1.34 – 72.0	Fruit pulp	[5,10,11,31]
Coumarin (μg/g)	2.8 – 7.0	Fruit pulp	[11]
Ferulic acid (mg/L)	0.8 – 61.0	Fruit pulp	[5,11,31]
Sinapic acid (mg/L)	3.9 ± 0.6	Wine	[31]

(Table 3). Continued.

Phytochemical composition	Values	Plant parts	References
Hydroxyhydrocinnamic acid			
hydro-p-coumaric acid (mg/L)	0.4 ± 0.04	Fruit pulp	[5]
Hydroxyphenylacetic acids			
Catechin (µg/g)	196.0 – 292.0	Fruit pulp	[5,11]
p-hydroxyphenylacetic acid (mg/L)	10.6 ± 0.6	Fruit pulp	[5]
3-methoxy-4-hydroxyphenylacetic acid (mg/L)	6.2 ± 0.1	Fruit pulp	[5]
Organic acids			
Succinic acid (g/100g)	0.4	Fruit pulp	[11]
Malic acid (g/100g)	10.2	Fruit pulp	[11]
Citric acid (g/100g)	0.6	Fruit pulp	[11]
Oxalic acid (g/100g)	0.4	Fruit pulp	[11]
Lactic acid (g/100g)	0.3	Fruit pulp	[11]
Propionic acid (g/100g)	0.6	Fruit pulp	[11]
Phenolics			
Catechol (µg/g)	9.0 – 275.0	Fruit pulp	[11]
Chlorogenic acid (µg/g)	2270.0 – 2730.0	Fruit pulp	[11]
Cinnamic acid (µg/g)	1.0 – 2.0	Fruit pulp	[11]
Ellagic acid (µg/g)	24.0 – 41.0	Fruit pulp	[10,11]
Epicatechin (µg/g)	101.0 – 230.0	Fruit pulp	[11]
Ferulic acid (mg/kg)	4.2 – 12.3	Fruit pulp	[10]
4-hydroxytremulacin	-	Leaves and twigs	[37]
p-hydroxyphenylacetic acid (mg/kg)	4.7 – 17.3	Fruit pulp	[10]
Itoside A	-	Leaves and twigs	[37]
Isoferulic acid (µg/g)	30.0 – 41.0	Fruit pulp	[11]
3-Methoxy-4-hydroxyphenylacetic acid (mg/kg)	0.3 – 10.0	Fruit pulp	[10]
p-OH benzoic acid (µg/g)	9.0 – 61.0	Fruit pulp	[11]
Protocatechuic acid (mg/kg)	32.8 – 227.6	Fruit pulp	[10]
Pyrogallol (µg/g)	917.1 – 5070.0	Fruit pulp	[10,11]
Resveratrol (µg/g)	6.0	Fruit pulp	[11]
Rosmarinic acid (µg/g)	1.0 – 6.0	Fruit pulp	[11]
Syringic acid (mg/kg)	34.4 – 111.1	Fruit pulp	[10]
3,4,5-Trimethoxycinnamic acid	3.0 – 6.0	Fruit pulp	[11]
Steroids			
Δ ⁵ avenasterol (%)	7.0	Seed	[29]
Δ ⁷ avenasterol (%)	0.5	Seed	[29]
Campesterol (%)	4.9	Seed	[29]
β-clerosterol (%)	0.5	Seed	[29]
Methyl 11-(3-pentyl-2-oxiranyl)undecanoate (%)	1.2	Twig	[30]
2-monopalmitin (%)	11.0	Twig	[30]
1,3,12-nonadecatriene (%)	4.9	Twig	[30]
2-monostearoylglycerol (%)	6.5	Twig	[30]
Octadecyldimethylamine (%)	5.8	Twig	[30]

(Table 3). Continued.

Phytochemical composition	Values	Plant parts	References
β -sitosterol (%)	84.1	Leaves and seed	[29,36]
β -sitosterol-3-O- β -glucoside	-	Leaves	[36]
Δ^7 stigmasterol (%)	0.5	Seed	[29]
2-tetradecanone (%)	25.5	Twig	[30]
Terpenoids			
α -amyrin	-	Leaves	[36]
β -amyrin	-	Leaves	[36]
β -carotene (mg/kg)	1.4 – 4.8	Fruit pulp	[10]
Carotenoids (μ g/g)	59.9	Fruit pulp	[11]
Volatile compounds			
Acetic acid (%)	0.3 – 13.4	Fruit pulp	[9]
1-butanamine (%)	0.1 – 2.7	Fruit pulp	[9]
1-butanol (%)	0.9 – 4.6	Fruit pulp	[9]
Butyl hexanoate (%)	0.3 – 1.1	Fruit pulp	[9]
Butyl acetate (%)	0.3 – 1.8	Fruit pulp	[9]
Butyl butanoate (%)	0.4 – 2.0	Fruit pulp	[9]
Ethanol (%)	1.1 – 5.6	Fruit pulp	[9]
Ethyl-2-butenate (%)	1.5 – 2.9	Fruit pulp	[9]
Ethyl-2-hexanoate (%)	0.5 – 4.5	Fruit pulp	[9]
Ethyl acetate (%)	2.1 – 15.7	Fruit pulp	[9]
2-Ethyl hexadecyl hexanoate (%)	0.1 – 0.7	Fruit pulp	[9]
Ethyl hexanoate (%)	7.6 – 19.5	Fruit pulp	[9]
Ethyl octanoate (%)	0.2 – 4.0	Fruit pulp	[9]
1-heptadecanol (%)	0.2 – 2.1	Fruit pulp	[9]
1-hexanol (%)	0.2 – 1.7	Fruit pulp	[9]
2-hexenal (%)	0.5 – 5.7	Fruit pulp	[9]
(Z)-3-hexen-1-ol (%)	0.1 – 17.8	Fruit pulp	[9]
3-hexen-1-ol acetate (%)	0.4 – 5.6	Fruit pulp	[9]
Hexyl acetate (%)	0.2 – 1.8	Fruit pulp	[9]
Hexyl butanoate (%)	1.1 – 5.5	Fruit pulp	[9]
Isopropyl palmitate (%)	0.1 – 1.0	Fruit pulp	[9]
2-methylpropyl benzoate (%)	0.1 – 3.1	Fruit pulp	[9]
Mono (2-ethylhexyl)-1,2-benzene dicarboxalate (%)	0.2 – 5.5	Fruit pulp	[9]
1-Nonadecene (%)	0.1 – 1.4	Fruit pulp	[9]
1-propanol (%)	0.8 – 4.4	Fruit pulp	[9]
n-propyl acetate (%)	0.5 – 1.0	Fruit pulp	[9]
Propyl butanoate (%)	0.5 – 1.3	Fruit pulp	[9]
3-pyridine-carboxylic acid (%)	0.1 – 2.7	Fruit pulp	[9]
4-tetradecyl-5-fluoro benzoate (%)	0.1 – 1.2	Fruit pulp	[9]
Undecyl benzoate (%)	1.2 – 1.6	Fruit pulp	[9]

These phytochemicals such as alkaloids, flavonoids and phenolics have various health benefits such as antioxidant, anti-microbial, anti-inflammatory, cancer preventive, anti-diabetic and antihypertensive properties [32].

PHARMACOLOGICAL PROPERTIES OF *D. CAFFRA*

Various extracts of *D. caffra* and compounds isolated from the species exhibited pharmacological activities such as antimicrobial [38-40], antioxidant

[5,10,11], antischistosomal [41], nematocidal [42] and cytotoxicity [30,43] activities.

Antimicrobial Activities

Preliminary assessment of antimicrobial activities of fruit, leaf, root, stem and twig extracts of *D. caffra* against *Candida albicans*, *Escherichia coli*, *Klebsiella aerogenes*, *Mycobacterium phlei*, *Pseudomonas aeruginosa*, *Salmonella typhi* and *Staphylococcus aureus* conducted by Zaki [38] revealed that the fruit, root and stem extracts exhibited antimicrobial activities against the tested pathogens while leaves and twigs showed no activities. Similarly, Basile et al. [39] evaluated antibacterial activities of fruit skin, pulp, seed, leaf and stem extracts of *D. caffra* against *Enterococcus faecalis*, *Escherichia coli*, *Klebsiella pneumoniae*, *Proteus mirabilis*, *Pseudomonas aeruginosa*, *Salmonella typhi*, *Staphylococcus aureus* and *Streptococcus pyogenes* using the broth-dilution method with benzyl penicillin sodium, cefotaxime sodium and tetracycline hydrochloride as positive controls. All the extracts showed activities except leaves, with minimum inhibitory concentration (MIC) values ranging from 1.0 µg/ml to 512 µg/ml [39]. El-Zaher et al. [40] evaluated the antifungal activities of fruit extracts of *D. caffra* against *Candida albicans*, *Malassezia furfur* and *Microsporum canis*. The extract showed activities against all the tested pathogens with high inhibitory activities against *Candida albicans* with zone of inhibition ranging from 14.0 to 30 mm [40].

Antioxidant Activities

Loots et al. [5] evaluated the antioxidant activities of *D. caffra* crude fruit pulp extracts using the oxygen radical absorbance capacity (ORAC) assay and the ferric reducing antioxidant potential (FRAP) assay. The extracts showed antioxidant activities with ORAC and FRAP values of 43.9 ± 1.3 mmol/L TEs and 6100 ± 191 µmol/L AA equivalents [5]. Loots et al. [5] also determined the antioxidant potential of polyphenols such as catechin, 3-methoxy-4-hydroxyphenylacetic acid, p-hydroxyphenylacetic acid, hydro-p-coumaric acid, caffeic acid, ferulic acid, p-coumaric acid, m-coumaric acid, syringic, protocatechuic acid, α-resorcylic acid, gallic acid, vanillic acid, m-hydroxybenzoic acid, salicylic acid by determining the trolox equivalent antioxidant capacity (TEAC) and total antioxidant activity (TAA). The TEAC values ranged from 0.04 mM to 3.01 mM while TAA values ranged from 0.10 µM to 900.8 µM [5]. Mpai et al. [10] evaluated the antioxidant activities of *D. caffra* crude fruit pulp extracts using the 1,1-diphenyl-2-

picrylhydrazyl (DPPH) radical scavenging assay and FRAP assay. The extracts showed antioxidant activities with half maximal inhibitory concentration (IC₅₀) values ranging from 0.23 µg/mL to 0.62 µg/mL and the TEAC values ranged from 17.0 µmol TEAC/g to 50.0 µmol TEAC/g [10]. Taher et al. [11] evaluated the antioxidant activities of *D. caffra* extracts using the DPPH radical scavenging assay, nitric oxide (NO) scavenging ability and reducing power test. The extracts exhibited activities, the IC₅₀ values for DPPH assay ranged from 32.3 µg/mL to 187.1 µg/mL while IC₅₀ values for the NO assay ranged from 120.8 µg/ml to 208.3 µg/ml which was comparable to IC₅₀ value of 104.1 µg/ml exhibited by the control, quercetin. The *D. caffra* extracts were effective in reducing Fe³⁺/ferricyanide complex to Fe²⁺ form and this ability was comparable to that of the control, gallic acid [11].

Antischistosomal Activities

Yousif et al. [41] evaluated the antischistosomal activities of methanolic leaf and twig extracts of *D. caffra* by assessing viability of *Schistosoma mansoni* mature worms in culture medium after exposure for 24 hours to extracts bioassayed at 100 µg/mL with praziquantel (0.1 µg/mL) as a positive control. The extracts exhibited activities with LC₅₀ and LC₉₀ (lethal concentration that causes 50% or 90% death of parasite, respectively) values of 24.3 µg/ml and 43.9 µg/ml, respectively [41].

Nematocidal Activities

Nyoni et al. [42] assessed the nematocidal effects of acetone and aqueous root extracts of *D. caffra* against *Meloidogyne javanica*. The extracts were screened on nematode inoculated tomato variety red khaki (*Solanum lycopersicum* L.) at a rate of 30 ml per plant with fenamiphos (nema-cur 400g/l) used as a positive control at a rate of 30 ml per plant. The extracts reduced the formation of root knot galls by 32% to 60% [42]. These findings revealed that *D. caffra* extracts have potential as nematocides and the species can be used by resource poor rural farmers to suppress and control the attack of tomato plants by nematodes.

Cytotoxicity Activities

Moustafa et al. [43] evaluated cytotoxicity activities of methanol branch extracts of *D. caffra* against four human cancer cell lines namely breast (MCF-7), colon (HCT-116), hepatocellular (HepG 2) and lung (A-549) using the *in vitro* (MTT) test with doxorubicin as a positive control. The extracts exhibited activities with

LC₅₀ values ranging from 20.3 µg/ml to 71.8 µg/ml and selectivity index values of 0.9 to 3. The LC₅₀ values exhibited by *D. caffra* extracts were comparable to LC₅₀ values of 21.6 µg/ml to 37.6 µg/ml exhibited by doxorubicin, the control [43]. Moustafa *et al.* [30] evaluated cytotoxicity activities of methanol branch extracts of *D. caffra* against four human cancer cell lines namely breast (MCF-7), colon (HCT-116), hepatocellular (HepG 2) and lung (A-549) using the *in vitro* (MTT) test. The extracts exhibited activities with LC₅₀ values ranging from 23.9 µg/ml to 90.1 µg/ml and selectivity index values ranging from 0.4 to 1.5.

Toxicity Activities

In the toxicity experiments using Albino rats, research carried by Gomaa *et al.* [44] demonstrated that the aqueous and alcoholic fruit extracts of *D. caffra* caused death through acute heart failure. Similarly, Taher *et al.* [11] evaluated the acute, subacute and chronic toxicity of *D. caffra* whole fruit extracts by oral route in male and female Sprague Dawley Wistar rats at levels of 1000, 3000 and 6000 mg/kg body weight and these single oral doses were introduced at a rate of 20 mL/kg body weight. The authors recorded no mortalities, therefore, *D. caffra* extract is safe, the median lethal dose (LD₅₀) value for its oral administration in male and female rats was more than 6000 mg/kg body weight. No abnormal macroscopic changes and histological changes were recorded for liver and kidney tissues due to *D. caffra* extract treatments [11].

Other Pharmacological Activities

Pharmacological research using Albino rats carried by Gomaa *et al.* [44] demonstrated that the aqueous and alcoholic fruit extracts of *D. caffra* produced transient increase in the depth of respiration, marked prolonged stimulation of the ventricular contractions and inhibited uterine contractions at the different stages of the sex cycle [44].

CONCLUSION

Dovyalis caffra is widely used as a food plant throughout the world and also as herbal medicine in tropical Africa. Documentation of the food value and ethnopharmacological properties of the species is important as this information is required for further research on the species. The present study showed that there are still some research gaps in the phytochemistry, pharmacological and toxicological properties of the species. Further rigorous research is

required aimed at evaluating the phytochemical properties of the fruit pulp in relation to other edible fruits. Detailed toxicological research aimed at assessing the safety of edible fruits, compounds and crude extracts of *D. caffra* are required.

AUTHORS' CONTRIBUTIONS

I declare that this work was done by the author named in this article.

CONFLICT OF INTEREST

No conflict of interest is associated with this work.

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