Pappea capensis Eckl. & Zeyh. (Sapindaceae): Evaluation of traditional and future potential uses

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Review

Abstract

Background: Pappea capensis has potential as a fruit plant on the basis of fruit size, palatability, yield, abundance and nutritional properties. But today, *P. capensis* it is a well-known medicinal plant throughout its distributional range, with local communities relying on its traditional *materia medica* for primary healthcare needs. The present review compiles existing information on traditional uses, chemical, pharmacological properties, and further use potential and applications of *P. capensis.*

Methods: Multiple searches on existing literature on the traditional, medicinal, phytochemistry and pharmacological properties of *P. capensis* were conducted in online databases such as Scopus, JSTOR, PubMed, Google Scholar and Science Direct as well as using pre-electronic literature sources obtained from the university library.

Results: This study showed that *P. capensis* is a multipurpose species used as food plant, source of firewood, timber and herbal medicine. *Pappea capensis* is used as medicinal plant against human and animal diseases in 11 countries, representing 55.0% of the countries where the species is indigenous. The chemical evaluation of the plant species revealed that it contains acids, alcohols, aliphatic, alkaloids, alkyl, amino acids, anthocyanidins, cardiac glycosides, cyanidins, cyclic esters, fatty acids, flavonoids, phenolics, phytol, phytosterols, saponins, tannins and terpenoids. The pharmacological evaluations showed that the crude extracts and phytochemical compounds isolated from the species demonstrated anthelmintic, antibacterial, antimycobacterial, antigonococcal, antifungal, anti-HIV, anticancer, antidiabetic, anti-inflammatory, antileishmanial, antioxidant, antiplasmodial, cardioprotective and molluscicidal.

Conclusiosn: Detailed ethnopharmacological evaluation of *P. capensis* focusing on its phytochemistry, pharmacological properties and toxicological evaluations, *in vivo* and clinical research are recommended.

Keywords: indigenous pharmacopeia, *materia medica, Pappea capensis*, traditional medicine, tropical Africa

Background

Pappea capensis Eckl. & Zeyh. (Figure 1) is a multipurpose tree with almost all of its different parts used as sources of various ecosystem services and goods that support human well-being and survival. *Pappea capensis* is a member of the Sapindaceae family, commonly known as the "soapberry" family. The common name "soapberry" is associated with species of the genus *Sapindus* Tourn. ex L. such as *S. drummondii* Hook. & Arn., *S. emarginatus* Vahl, *S. mukorossi* Gaertn., *S. saponaria* L. and *S. trifoliatus* L. (Dermer & Crews 1939, Langdon 1996, Díaz & Rossini 2012, Manjulatha et al. 2012, Asthana et al. 2017, Quigley et al. 2017, Xu et al. 2022). All these species contain saponin, a glucoside in the cavities of the flesh of their fruits which when shaken with water, forms a frothy detergent lather like soap (Dermer & Crews 1939, Langdon 1996, Díaz & Rossini 2012, Manjulatha et al. 2012, Asthana et al. 2017, Quigley et al. 2017, Xu et al. 2022). Similarly, in tropical Africa, *P. capensis* has a place in early ethnobotanical history as the species is traditionally used for soap production. Various species and varieties have in the past have been included in the genus *Pappea* Eckl. & Zeyh., but botanists now tend to consider it as a monotypic genus of one variable species *P. capensis* (Palmer & Pitman 1972).

Figure 1. *Pappea capensis*: A: a branch showing flowers (photo: BT Wursten) and B: fruits (photos: M Hyde)

The genus name "*Pappea"* is in honour of Karl (Carl) Wilhelm Ludwig Pappe (1803-1862), a Hamburg, German-born physician and plant collector who was the first Colonial Botanist and Professor at the Cape in South Africa (Palmer & Pitman 1972) and the specific name "*capensis*" means of the Cape (Palmer & Pitman 1972). The synonyms of *P. capensis* include *Nephelium capense* (Eckl. & Zeyh.) Baill., *Pappea capensis* Eckl. & Zeyh. var. *radkloferi* (Schweinf. ex Radlk.) Schinz, *P. fulva* Conrath, *P. radkloferi* Schweinf. ex Radlk., *P. radkloferi* Schweinf. ex Radlk. var. *angolensis* Schlecht., *P. schumanniana* Schinz, *P. ugandensis* Bak.f., *Sapindus capensis* (Eckl. & Zeyh.) Hochst. and *Sapindus pappea* Sond. (Exell 1966, Hedberg & Edwards 1990, Davies & Verdcourt 1998, Thulin 1999). The English common names of *P. capensis* include "bushveld cherry", "indaba tree", "jacket plum", "judgement tree" and "wild plum" (Palgrave 2002; Venter & Venter 2015). *Pappea capensis* is a small to medium-sized semi-deciduous to evergreen tree with intricately branched, spreading, round or somewhat flat on top crown. *Pappea capensis* has a clean, grey, bare, rather crooked, often lichen-covered stem which often peels off sporadically and grows to about 13 metres in height (Van Wyk & Van Wyk 2013). The branchlets are pale brown, usually hairy when young with longitudinally striated, smooth and dark grey bark with characteristic white patches. The bark of the species is pale grey to brownish in colour and smooth. *Pappea capensis* is monoecious with the flowers going through a distinct male phase followed by an equally distinct female phase (Fivaz & Robbertse 1993, Robbertse et al. 2011). The leaves are simple, oblong to circular in shape, spirally arranged and often crowded near the ends of branches. The leaves are leathery, rough and tough to the touch, dull green above and paler green below with many parallel lateral veins. The leaf apex and base are rounded with entire or closely spine-toothed leaf margins, particularly in juvenile plants. The flowers of *P. capensis* are pale yellow or greenish in colour, axillary and terminal with catkin-like racemes. The fruit is a furry green capsule, splitting to reveal a shiny black seed enclosed by a fleshy, orange-red or translucent appendage (Figure 1B). *Pappea capensis* has been recorded in Angola, Botswana, Democratic Republic of Congo (DRC), Djibouti, Eritrea, Eswatini, Ethiopia, Kenya, Malawi, Mozambique, Namibia, Oman, Rwanda, Somalia, South Africa, South Sudan, Sudan, Tanzania, Uganda, Yemen, Zambia and Zimbabwe (Exell 1966, Hedberg & Edwards 1990, Davies & Verdcourt 1998, Thulin 1999, Kilian et al. 2002, Darbyshire et al., 2015) (Figure 2). *Pappea capensis* has been recorded in evergreen montane woodland, bushveld, wooded grassland, valley bushveld, open woodland, termite mounds, riverine fringes and rocky outcrops at an altitude ranging from 30 m to 1740 m above sea level (Exell 1966, Hedberg & Edwards 1990, Davies & Verdcourt 1998, Kilian et al. 2002, Germishuizen & Meyer 2003).

Figure 2. Distribution of *Pappea capensis* in tropical Africa and Asia (map drawn using mapchart.net)

The seeds of *P. capensis* are roasted under the coals to make a sweetly scented, golden yellow, non-drying and fairly heavy oil which local people use for soap-making and lubrication (Palmer & Pitman 1972, Palgrave, 2002). In Kenya, the inner bark of *P. capensis* is used to make tea, its roots used in soup, tender shoots and young leaves are chewed, and the species is widely used as source of firewood, charcoal, timber, poles, furniture, tool handles and utensils (Maundu et al. 2005). In Tanzania, *P. capensis* is regarded as a food additive, added to milk and meat-based soups (Watt & Breyer-Brandwijk 1962, Heine et al. 1988, Johns et al. 1999, Kokwaro 2009, Roulette et al. 2018). *Pappea capensis* is regarded as an excellent fodder plant for game and domestic stock (Van Wyk 2008, Van Wyk & Van Wyk 2013). The fruits of *P. capensis* are regarded as pleasant-tasting and widely used as a fruit snack in tropical Africa (Palmer & Pitman 1972, Schmidt et al. 2017, Van Wyk & Gericke 2018). In South Africa, the sap of *P. capensis* fruits are collected and ground into jam, jelly, vinegar or allowed to ferment into a fairly potent alcohol and wine (Mabogo 1990, Van Wyk & Gericke 2018). The bark, leaves, seeds and stems of *P. capensis* are sold in informal herbal medicine markets in in Kajiado, Narok and Nairobi counties in Kenya as sources of traditional medicines (Mwaura et al. 2020). Similarly, in the Mpumalanga and Gauteng provinces in South Africa, the roots of *P. capensis* are sold in informal herbal medicine markets as sources of traditional medicines (Botha et al. 2001, Williams et al. 2001). In Southern Africa, *P. capensis* is regarded as important sources of traditional medicines and therefore, included in the monograph "Medicinal and magical plants of southern Africa: An annotated checklist" (Arnold et al. 2002). Therefore, the present review of *P. capensis* compiles information on its chemical and pharmacological properties, traditional and present uses and further use potential. This is a comprehensive scientific review aimed at providing baseline information and additional views that can enhance further research, cultivation, and use of this plant species.

Materials and Methods

Literature search on medicinal uses, phytochemistry and pharmacological properties of *P. capensis* throughout its distributional range in tropical Africa was conducted using online databases such as Scopus, JSTOR, Google Scholar, PubMed and Science Direct. In addition to this, pre-electronic sources such as books, journal articles, dissertation, book chapters, theses and other scientific articles obtained from the University library were used. Keywords used in the search included "biological activities of *Pappea capensis*", "pharmacological properties of *Pappea capensis*", "ethnobotany of *Pappea capensis*", "medicinal uses of *Pappea capensis*", "phytochemistry of *Pappea capensis*" and "traditional uses of *Pappea capensis*".

Results and Discussion

Medicinal uses of *Pappea capensis*

In traditional medicine, the bark, branches, fruits, kernels, leaves, oil, rootbark, roots, sap, seeds, stem bark and twigs of *P. capensis* have medicinal value and also used for magical or ritual purposes (Tables 1). The medicinal uses of *P. capensis* have been recorded in Botswana, Eritrea, Eswatini, Ethiopia, Kenya, Malawi, Mozambique, Rwanda, South Africa, Tanzania and Zimbabwe, representing 55.0% of the countries where the species is indigenous. The herbal concoctions prepared from the different parts of *P. capensis* are used as aphrodisiac, ethnoveterinary medicine, lucky and preventive charm, and as traditional medicines against cancer, nose bleeding, rheumatism, respiratory infections, malaria, eye problems, sexually transmitted diseases and gastro-intestinal problems (Table 1, Figure 3). Other medicinal applications of *P. capensis* recorded in two countries and supported by at least two references include the uses of the species as appetizer (Kiringe 2006, Makule 2015), purgative (Watt & Breyer-Brandwijk 1962, Palmer & Pitman 1972, Palgrave 2002, Hankey 2004, Schmidt et al. 2017, Dharani, 2019) and tonic (Watt & Breyer-Brandwijk 1962, Johns et al. 1994, 1999, Mhlongo & Van Wyk 2019), and traditional medicine against adnominal pain and general pain (Wild & Gelfand 1959, Makule 2015), backache (Kiringe 2006, Makule 2015), headache (Wild & Gelfand 1959, Eshete & Molla 2021) and skin problems (Watt & Breyer-Brandwijk 1962, Palmer & Pitman 1972, Hutchings et al. 1996, Palgrave, 2002, Hankey 2004, Schmidt et al. 2017, Nicosia et al. 2022). In Tanzania, the leaves of *P. capensis* are mixed with those of *Hoffmannanthus abbotianus* (O.Hoffm.) H.Rob., S.C.Keeley & Skvarla (family Asteraceae) as remedy for backache and chicken pox (Moshi et al. 2010). Similarly, in South Africa, the stem bark of *P. capensis* is mixed with the roots of *Euclea natalensis* A.DC. subsp. *angustifolia* F.White (Ebenaceae) and *Grewia hexamita* Burret (Malvaceae) as traditional medicines against infertility and menstrual problems (Chauke et al. 2015, Maroyi 2017).

Table 1. Medicinal uses of *Pappea capensis*

Mono-therapeutic applications	Plant parts used	Country or region	References
Adnominal pain and general pain	Not specified	Tanzania and Zimbabwe	Wild & Gelfand 1959, Makule 2015
Alopecia (hair loss)	Oil from seeds	South Africa	Watt & Breyer-Brandwijk 1962, Palmer & Pitman 1972, Hutchings et al. 1996, Palgrave 2002, Hankey 2004
Aphrodisiac	Bark and leaves	Kenya, Malawi, South Africa and Tanzania	Watt & Breyer-Brandwijk 1962, Gelfand et al. 1985, Mabogo 1990, Mulaudzi et al. 2011, Muthee et al. 2011, Makule et al. 2014, Makule 2015, Tshikalange et al. 2016, Pendota et al. 2017, Mwaura et al. 2020
Appetizer	Bark	Kenya and Tanzania	Kiringe 2006, Makule 2015
Backache	Bark	Kenya and Tanzania	Kiringe 2006, Makule 2015
Cancer	Bark, fruits, leaves and roots	Ethiopia, Kenya and Tanzania	Kipkore et al. 2014, Eshete & Molla 2021, Marealle et al. 2021
Colic	Not specified	Tanzania	Makule 2015

Diabetes	Leaves	Kenya	Karau et al. 2012a,b
Eye problems (impending blindness, night blindness and sore eyes)	Leaves	Malawi, Mozambique, South Africa and Zimbabwe	Gelfand et al. 1985, Mabogo 1990, Palgrave, 2002, Hankey 2004, Mulaudzi et al. 2011, Pendota et al. 2017, Nicosia et al. 2022
Fertility problems	Stem bark	Kenya	Kimondo et al. 2015, Mwaura et al. 2020
Fever	Not specified	Tanzania	Makule 2015
Gastro-intestinal problems (constipation, diarrhoea, digestive disorders, enhance digestion, dysentery, indigestion, stomachache and stomach disorders)	Bark, fruits, kernels, leaves, roots, sap, seeds and stem bark	Ethiopia, Kenya, Mozambique, Rwanda, South Africa and Tanzania	Watt & Breyer-Brandwijk 1962, Harjula 1980, Hutchings et al. 1996, Kiringe 2006, Kokwaro 2009, Semenya & Maroyi 2012, Chauke et al. 2015, Kimondo et al. 2015, Makule 2015, Bigirimana et al. 2016, Dharani 2019, Mwaura et al. 2020, Eshete & Molla 2021, Nicosia et al. 2022
Gout	Not specified	Tanzania	Makule 2015
Gynecological problems	Leaves	Eritrea	Yemane et al. 2018
Headache	Bark and leaves	Ethiopia and Zimbabwe	Wild & Gelfand 1959, Eshete & Molla 2021
Hepatisis	Bark and leaves	Ethiopia	Eshete & Molla 2021
Internal swelling	Not specified	East Africa	Kokwaro, 2009
Liver diseases	Bark	Ethiopia	Usman et al., 2022
Lucky and preventive charm	Bark and roots	Botswana, Eswatini, South Africa and Zimbabwe	Gelfand et al. 1985, Hedberg & Staugård 1989, Hankey 2004, Singwane & Shabangu 2012
Malaria	Bark, branches and twigs	Ethiopia, Kenya, South Africa and Tanzania	Koch et al. 2005, Njoroge & Bussmann 2006, Bapela et al. 2014, Makule 2015, Asnake et al. 2016
Menstrual problems	Bark and leaves	Ethiopia	Eshete & Molla 2021
Mouth ulcers	Leaves	Tanzania	Augustino & Gillah 2005
Nose bleeding	Leaves	Botswana, South Africa and Zimbabwe	Gelfand et al. 1985, Hedberg & Staugård 1989, Hutchings et al. 1996, Hankey 2004
Postpartum haemorrhage	Bark	Kenya	Kaingu et al. 2011, Makule et al. 2014, Makule 2015
Purgative	Oil from seed	East Africa and South Africa	Watt & Breyer-Brandwijk 1962, Palmer & Pitman 1972, Palgrave 2002, Hankey 2004, Schmidt et al. 2017, Dharani, 2019
Respiratory infections (chest complaints, Sore throat and whooping cough)	Roots, rootbark and stem bark	Kenya, Mozambique and South Africa	Hutchings et al. 1996, Hankey 2004, Karau et al. 2012a,b, Semenya & Maroyi 2019a, b, c, 2020, Nicosia et al. 2022
Rheumatism (arthritis and joint pains)	Bark, fruits, leaves, roots and stem bark	Eritrea, Kenya and Tanzania	Kiringe 2006, Wambugu et al. 2011, Kipkore et al. 2014, Makule 2015, Yemane et al. 2018
Sexually transmitted infections (gonorrhoea and venereal diseases)	Bark and leaves	Botswana, Ethiopia, South Africa and Tanzania	Mabogo 1990, Hutchings et al. 1996, Palgrave, 2002, Hankey 2004, Mulaudzi et al. 2011, Makule 2015, Pendota et al. 2017, Mathibela et al. 2019, Eshete & Molla 2021
Skin problems (ringworm and tinea capitis)	Oil from seeds	Mozambique and South Africa	Watt & Breyer-Brandwijk 1962, Palmer & Pitman 1972, Hutchings et al. 1996, Palgrave, 2002, Hankey 2004, Schmidt et al. 2017, Nicosia et al. 2022
Snake bite	Bark and leaves	Ethiopia	Eshete & Molla 2021
Tonic	Branches	South Africa and Tanzania	Watt & Breyer-Brandwijk 1962, Johns et al. 1994, 1999, Mhlongo & Van Wyk 2019
Toothache	Bark and leaves	Ethiopia	Eshete & Molla 2021
Urinary problems	Not specified	Tanzania	Makule 2015

Vaginal ulcers	Leaves	South Africa	Masevhe et al. 2015
Wounds	Roots	Tanzania	Marealle et al. 2021
Ethnoveterinary medicine (indigestion in goats, internal parasites, purging cattle and reproductive problems)	Bark, leaves and roots	East Africa, Ethiopia and South Africa	Hutchings et al. 1996, Palgrave 2002, Mphahlele et al. 2016, Chitura et al. 2019, Dharani 2019, Oda et al. 2024
Multi-therapeutic applications			
Backache and chicken pox	Leaves mixed with those of *Hoffmannanthus abbotianus* (O.Hoffm.) H.Rob., S.C.Keeley & Skvarla (family Asteraceae)	Tanzania	Moshi et al. 2010
Infertility and menstrual problems	Stem bark mixed with roots of *Euclea natalensis* A.DC. subsp. angustifolia F.White (Ebenaceae) and *Grewia hexamita* Burret (Malvaceae)	South Africa	Chauke et al. 2015, Maroyi 2017
Menstrual problems	Stem bark mixed with roots of *Euclea divinorum* Hiern (Ebenaceae) and *G. hexamita*	South Africa	Chauke et al. 2015

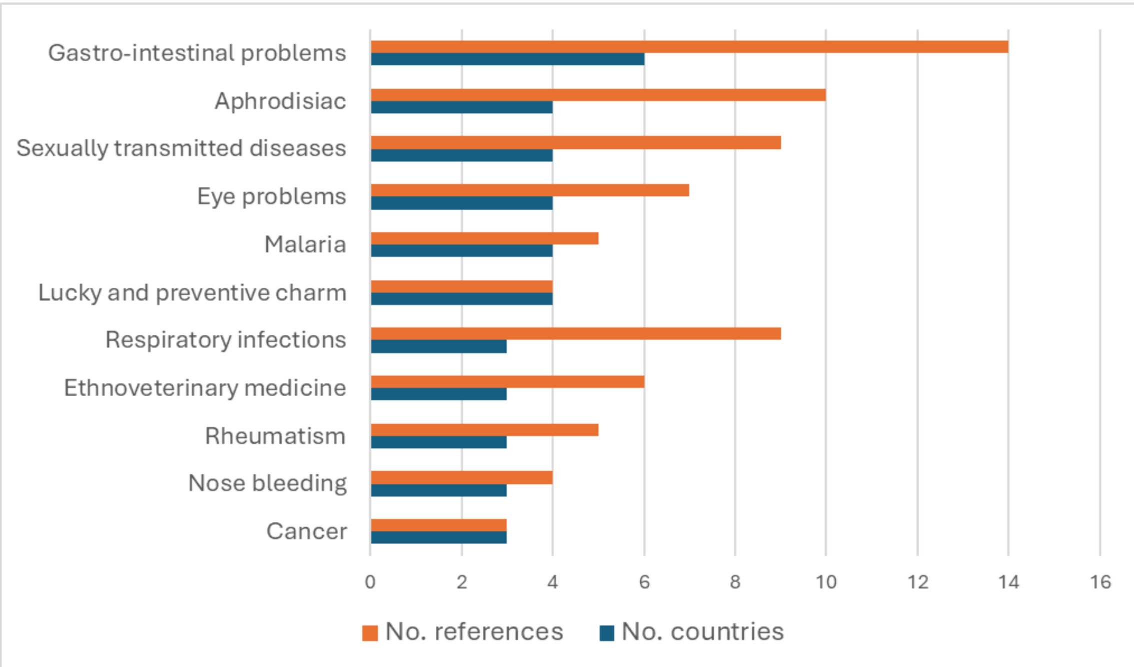

Figure 3. Main diseases and ailments treated and managed using *Pappea capensis* extracts

Phytochemical and pharmacological properties of *Pappea capensis*

The fruits of *P. capensis* are used as a snack and analyses of the nutritional value of the species (Table 2) show that the fruits are a better source of energy, minerals such as calcium, copper, iron, magnesium, manganese, phosphorus, potassium, sodium, zinc and classic nutrients such as fibre, protein and vitamins than a commercial fruit crop, mango, *Mangifera indica* L. Furthermore, different parts of *P. capensis* have been reported to contain acids, alcohols, aliphatic, alkaloids, alkyl, amino acids, anthocyanidins, cardiac glycosides, cyanidins, cyclic esters, fatty acids, flavonoids, phenolics, phytol, phytosterols, saponins, tannins and terpenoids (Tables 2 and 3). Some of these phytochemical compounds may be responsible for the biological activities associated with the species which include anthelmintic, antibacterial, antimycobacterial, antigonococcal, antifungal, anti-HIV, anticancer, antidiabetic, anti-inflammatory, antileishmanial, antioxidant, antiplasmodial, cardioprotective and molluscicidal.

Table 2: Nutritional composition of *Pappea capensis* and *Mangifera indica* L.

Nutrients	***P. capensis***	***M. indica***	**References**
Aluminium (mg/100 g)	354.1-897.4	-	Karau et al. 2012a
Arsenic (mg/100 g)	2.66-3.12	-	Karau et al. 2012a
Ash (g/100g)	0.7-3.42	0.34-0.52	Wehmeyer 1986, Maldonado-Celis et al. 2019, Sibiya et al. 2021
Calcium (mg/100g)	11.2	7.0-21.0	Wehmeyer 1986, Maldonado-Celis et al. 2019
Carbohydrates (g/100g)	25.0	16.2-17.2	Maldonado-Celis et al. 2019, Sibiya et al. 2021
Chromium (mg/100 g)	2.35-5.55	-	Karau et al. 2012a
Cobalt (mg/100 g)	2.62-2.78	-	Karau et al. 2012a
Copper (mg/100g)	0.28	0.04-0.32	Wehmeyer 1986, Maldonado-Celis et al. 2019
Dry matter (g/100 g)	91.38-91.54	-	Karau et al. 2012b
Energy kj/100g	163.31	62.1-190.0	Maldonado-Celis et al. 2019, Sibiya et al. 2021
Fat (g/100g)	5.11	0.3-0.53	Maldonado-Celis et al. 2019, Sibiya et al. 2021
Fibre (g/100g)	16.51-19.11	0.9-1.1	Karau et al. 2012b, Maldonado-Celis et al. 2019, Sibiya et al. 2021
Iron (mg/100g)	0.58–2.9	0.09-0.9	Wehmeyer 1986, Maldonado-Celis et al. 2019
Lead (mg/100 g)	0.16-0.18	-	Karau et al. 2012a
Lipid (g/100 g)	0.67-1.13	0.30-0.53	Karau et al. 2012b, Maldonado-Celis et al. 2019
Magnesium (mg/100g)	11.6	8.0-38.0	Wehmeyer 1986, Maldonado-Celis et al. 2019
Manganese (mg/100g)	0.32-6.68	0.03-0.12	Karau et al. 2012a, Maldonado-Celis et al. 2019
Mercury (mg/100 g)	0.56-0.76	-	Karau et al. 2012a
Moisture (g/100g)	45.63-89.0	78.9-82.8	Wehmeyer 19862, Maldonado-Celis et al. 2019, Sibiya et al. 2021
Molybdenum (mg/100 g)	13.02-13.74	-	Karau et al. 2012a
Nickel (mg/100 g)	1.10-1.30	-	Karau et al. 2012a
Phosphorus (mg/100g)	15.1	10.0-23.0	Wehmeyer 1986, Maldonado-Celis et al. 2019
Potassium (mg/100g)	250.0	120.0-617.0	Wehmeyer 1986, Maldonado-Celis et al. 2019
Protein (g/100g)	0.7	0.36-0.40	Osuga et al. 2006, Maldonado-Celis et al. 2019, Sibiya et al. 2021
Selenium (mg/100 g)	0.29	0.6	Karau et al., 2012a, Maldonado-Celis et al. 2019
Sodium (mg/100g)	1.56	0-4.0	Wehmeyer 1986, Maldonado-Celis et al. 2019
Vanadium (mg/100 g)	0.43-1.14	-	Karau et al., 2012a
Vitamin A (retinol)	-	-	Karau et al., 2012a
Vitamin B1 (thiamine) (mg/100g)	-	0.01-0.04	Karau et al., 2012a, Maldonado-Celis et al. 2019
Vitamin B3 (nicotinamide)	-	-	Karau et al., 2012a
Vitamin C (ascorbic acid) (mg/100g)	-	13.2-92.8	Karau et al. 2012a, Maldonado-Celis et al. 2019
Vitamin E) (α, β, γ and ō-tocopherol)	-	-	Karau et al., 2012a, Muruthi et al. 2023a, b
Zinc (mg/20 g dry mass)	0.03-0.3	0-0.15	Wehmeyer 1986, Maldonado-Celis et al. 2019
Fatty acids			
Hexadecanoic acid or palmitic acid	-	-	Maldonado-Celis et al. 2019, Makhoahle 2022, Muruthi et al. 2023a, b
Heptadecanoic	-	-	Maldonado-Celis et al. 2019, Muruthi et al. 2023b
Cis-10-Heptadecenoic	-	-	Maldonado-Celis et al. 2019, Muruthi et al., 2023b
Octadecanoic acid or stearic acid	-	-	Maldonado-Celis et al. 2019, Muruthi et al. 2023a, b
6-Octadecanoic acid	-	-	Muruthi et al. 2023a, b
12-octadecenoic acid	-	-	Muruthi et al. 2023b
Oleic acid	-	-	Maldonado-Celis et al. 2019, Muruthi et al. 2023a, b
Pentadecanoic	-	-	Muruthi et al. 2023b
Tetracosanoic acid or lignoceric acid	-	-	Maldonado-Celis et al. 2019, Muruthi et al. 2023b
Tetradecanoic acid	-	-	Muruthi et al. 2023b
Non-essential amino acids			
Alanine (g/100g)	0.41	0.08	Maldonado-Celis et al. 2019, Sibiya et al. 2021
Arginine (g/100g)	0.51	0.03	Maldonado-Celis et al. 2019, Sibiya et al. 2021
Aspartic acid (g/100g)	0.75	0.07	Maldonado-Celis et al. 2019, Sibiya et al. 2021
Glutamic acid (g/100g)	1.10	0.1	Maldonado-Celis et al. 2019, Sibiya et al. 2021

Glycine (g/100g)	0.38	0.034	Maldonado-Celis et al. 2019, Sibiya et al. 2021
Proline (g/100g)	0.34	0.03	Maldonado-Celis et al. 2019, Sibiya et al. 2021
Serine (g/100g)	0.46	0.035	Maldonado-Celis et al. 2019, Sibiya et al. 2021
Tyrosine (g/100g)	0.22	0.016	Maldonado-Celis et al. 2019, Sibiya et al. 2021
Essential amino acids			
Histidine (g/100g)	0.63	0.019	Maldonado-Celis et al. 2019, Sibiya et al. 2021
Isoleucine (g/100g)	0.29	0.029	Maldonado-Celis et al. 2019, Sibiya et al. 2021
Leucine (g/100g)	0.48	0.05	Maldonado-Celis et al. 2019, Sibiya et al. 2021
Lysine (g/100g)	0.77	0.07	Maldonado-Celis et al. 2019, Sibiya et al. 2021
Methionine (g/100g)	0.14	0.008	Maldonado-Celis et al. 2019, Sibiya et al., 2021
Phenylalanine (g/100g)	0.30	0.03	Maldonado-Celis et al. 2019, Sibiya et al. 2021
Threonine (g/100g)	0.31	0.016	Maldonado-Celis et al. 2019, Sibiya et al. 2021
Valine (g/100g)	0.37	0.04	Maldonado-Celis et al. 2019, Sibiya et al. 2021

Table 3. Phytochemical composition of *Pappea capensis*

Phytochemical compound	**Formula**	**Plant part**	**Reference**
1-Dodecanol	$C_{12}H_{26}O$	Wood	Makhoahle 2022
1-Tridecene	$C_{13}H_{26}$	Wood	Makhoahle 2022
2-Propenoic acid	$C_9H_8O_3$	Wood	Makhoahle 2022
2-Tetradecyloxyethanol	$C_{16}H_{34}O_2$	Wood	Makhoahle 2022
4-Ethylbenzaldehyde	$C_9H_{10}O$	Wood	Makhoahle 2022
1,3-Di-tert-butylbenzene	$C_{14}H_{22}$	Wood	Makhoahle 2022
2-Tetradecyloxyethanol	$C_{16}H_{34}O_2$	Wood	Makhoahle 2022
2,4-Di-tert-butylphenol	$C_{14}H_{22}O$	Wood	Makhoahle 2022
2,6-dimethoxyphenol	$C_8H_8O_3$	Stem bark	Muruthi et al. 2023b
3-(1-methylethyl)-phenol	$C_9H_{12}O$	Stem bark	Muruthi et al. 2023b
3,4,5, Trimethoxycinnamic acid	$C_{12}H_{14}O_5$	Leaves	Gaichu et al. 2023
4-Ethylbenzaldehyde	$C_9H_{10}O$	Wood	Makhoahle 2022
4-Hydroxy-4-methyl-2-pentanone	$(CH_3)_2C(OH)CH_2COCH_3$	Wood	Makhoahle 2022
4-hydroxycinnamonic acid	$C_9H_8O_3$	Stem bark	Muruthi et al. 2023a, b
5-(Hydroxymethyl)furfural	$C_6H_6O_3$	Wood	Makhoahle 2022
Acetic acid	CH_3CO_2H	Wood	Makhoahle 2022
α and β-Amyrin	$C_{30}H_{50}O$	Stem bark	Muruthi et al. 2023a, b
Apigenin	$C_{15}H_{10}O_5$	Stem bark	Muruthi et al. 2023a, b
Bornanone / camphor	$C_{10}H_{16}O$	Stem bark	Muruthi et al. 2023a, b
Benzothiazole	C_7H_5NS	Wood	Makhoahle 2022
Betulin	$C_{30}H_{50}O_2$	Leaves and stem bark	Muruthi et al. 2023a, b
Butanoic acid	$C_4H_8O_2$	Wood	Makhoahle 2022
Caffeic acid	$C_9H_8O_4$	Leaves	Gaichu et al. 2023
Campesterol	$C_{29}H_{50}O$	Stem bark	Muruthi et al. 2023a, b
β-Carotene	$C_{40}H_{56}$	Leaves and stem bark	Karau et al. 2012a
Catechin	$C_{15}H_4O_6$	Stem bark	Muruthi et al. 2023a, b
Chlorogenic acid	$C_{16}H_{18}O_9$	Leaves	Gaichu et al. 2023
α-copaene	$C_{15}H_{24}$	Stem bark	Muruthi et al. 2023a, b
m and p-Coumaric acid	$C_9H_8O_3$	Leaves	Gaichu et al. 2023, Muruthi et al. 2023a, b
β-Cryptoxanthin	$C_{40}H_{56}O$	Leaves and stem bark	Karau et al. 2012a
p-Cymene	$C_{10}H_{14}$	Stem bark	Muruthi et al. 2023a, b
Docosane	$C_{22}H_{46}$	Wood	Makhoahle 2022
Dodecane	$CH_{10}CH_3$	Wood	Makhoahle 2022
Dodecyl ester	$C_{22}H_{44}O_2$	Wood	Makhoahle 2022
Ellagic acid	$C_{14}H_6O_8$	Leaves and stem bark	Gaichu et al. 2023, Muruthi et al. 2023a, b
Epichatechin	$C_{15}H_4O_6$	Leaves and stem bark	Pendota et al. 2017, Tajuddeen et al. 2021, Gaichu

			et al. 2023, Muruthi et al. 2023a, b
Ferulic acid	$C_{10}H_{10}O_4$	Leaves	Gaichu et al. 2023
Furan	C_4H_4O	Twigs	Mabuza et al. 2022
Gallic acid	$C_7H_6O_5$	Leaves	Gaichu et al. 2023
Gentisic acid	$C_7H_6O_4$	Leaves	Gaichu et al. 2023
Isoferulic acid	$C_{10}H_{10}O_4$	Leaves	Gaichu et al. 2023
Furan	C_4H_40	Twigs	Mabuza et al. 2022
Furfural	$C_5H_4O_2$	Wood	Makhoahle 2022
Heneicosane	$C_{21}H_{44}$	Wood	Makhoahle 2022
Hesperidin	$C_{28}H_{34}O_{15}$	Leaves	Gaichu et al. 2023
Hexadecane	$C_{16}H_{34}$	Wood	Makhoahle 2022
Homovanillyl alcohol	$C_9H_{12}O_3$	Stem bark	Muruthi et al. 2023b
Kaempferol	$C_{15}H_{10}O_6$	Stem bark	Muruthi et al. 2023a, b
Kaempferol-3-O-arabinopyranoside	$C_{20}H_{18}O_{10}$	Leaves	Tajuddeen et al. 2021; Gaichu et al. 2023
Kaempferol hexoside	$C_{21}H_{20}O_{11}$	Leaves	Gaichu et al. 2023
Lauryl acetate	$C_{14}H_{28}O_2$	Wood	Makhoahle 2022
Lutelion	$C_{15}H_{10}O_6$	Stem bark	Muruthi et al. 2023a, b
Myricetin	$C_{15}H_{10}O_8$	Leaves	Gaichu et al. 2023
Phenol,2,4-bis(1,1dimethylethyl)	$C_{17}H_{30}OSi$	Stem bark	Muruthi et al. 2023b
Phenol,2,5-bis(1,1dimethylethyl)	$C_{17}H_{30}OSi$	Stem bark	Muruthi et al. 2023b
Phenol,34,5-trimethoxy	$C_9H_{12}O_4$	Stem bark	Muruthi et al. 2023b
Pentadecane	$C_{15}H_{32}$	Wood	Makhoahle 2022
Phytol	$C_{20}H_{40}$	Stem bark	Muruthi et al. 2023a, b
Protocatechuic acid	$C_7H_6O_4$	Leaves	Gaichu et al. 2023
Quercetin	$C_{21}H_{20}O_{11}$	Leaves and stem bark	Tajuddeen et al. 2021, Gaichu et al. 2023, Muruthi et al. 2023a, b
Quercitrin 3-O-β-D-glucoside	$C_{21}H_{20}O_{12}$	Leaves	Tajuddeen et al. 2021
Quercetin-3 glucoside	$C_{21}H_{19}O_{12}$	Leaves	Gaichu et al. 2023
Quercetin-3-O-rhamnoside	$C_{21}H_{20}O_{11}$	Stem bark	Pendota et al. 2017, Gaichu et al. 2023, Muruthi et al. 2023a, b
Quercetin-3-O-α-L-rhamnoside	$C_{21}H_{20}O_{11}$	Leaves	Gaichu et al. 2023
Quercetin-3-O-β-arabinopyranosyl	$C_{21}H_{20}O_{12}$	Leaves	Gaichu et al. 2023
Quercetin-3-O-β-D-L-glucosyl	$C_{24}H_{22}O_{15}$	Leaves	Gaichu et al. 2023
Quercetin-3-O-β-D-L-glucoside	$C_{21}H_{20}O_{12}$	Leaves	Gaichu et al. 2023
Quercetin-3-O-β-D-G-glucoside	$C_{21}H_{20}O_{12}$	Leaves	Gaichu et al. 2023
(R or S)-2,3-Butanediol	$C_4H_{10}O_2$	Wood	Makhoahle 2022
Rhamnetin	$C_{16}H_{12}O_7$	Leaves	Gaichu et al. 2023
Rutin	$C_{27}H_{30}O_{16}$	Stem bark	Muruthi et al. 2023a, b
β-Sitosterol	$C_{30}H_{48}O$	Stem bark	Muruthi et al. 2023a, b
Squalene	$C_{30}H_{50}$	Stem bark	Muruthi et al. 2023a, b
Stigmast-4-en-3-one	$C_{29}H_{48}O$	Stem bark	Muruthi et al. 2023a, b
Stigmast-7-en-3-ol	$C_{29}H_{50}O$	Stem bark	Muruthi et al. 2023a, b
Stigmasterol	$C_{29}H_{48}O$	Stem bark	Muruthi et al. 2023a, b
Tetradecane	$C_{14}H_{30}$	Wood	Makhoahle 2022
Vanilin	$C_8H_8O_3$	Stem bark	Muruthi et al. 2023b

Anthelmintic activities

Mphahlele et al. (2016) and Chitura et al. (2019) evaluated the anthelmintic activities of aqueous extracts of *P. capensis* bark by assessing *Haemonchus contortus* egg hatch inhibition, larval development inhibition and larval mortality assays at concentration levels of 2.5 mg/ml, 5.0 mg/ml and 7.5 mg/ml with thiabendazole®) as a positive control. The extracts demonstrated larval mortality similar to the commercial drug after 72 hours of incubation (Mphahlele et al., 2016; Chitura et al., 2019).

Antibacterial activities

Mukanganyama et al. (2011) assessed the antibacterial activities of ethanol extracts of *P. capensis* bark and leaves against *Bacillus subtilis*, *Bacillus cereus*, *Escherichia coli*, *Staphylococcus aureus* and *Pseudomonas aeruginosa* using the disk agar diffusion method with ampicillin as a positive control. The extracts exhibited activities against *Staphylococcus aureus* and *Pseudomonas aeruginosa* with zone of inhibition values ranging from 1.0 mm to 2.0 mm (Mukanganyama et al., 2011). Mulaudzi et al. (2011) evaluated the antibacterial activities of aqueous, acetone, dichloromethane and petroleum ether extracts of *P. capensis* leaves against *Staphylococcus aureus, Klebsiella pneumoniae, Bacillus subtilis* and *Escherichia coli* using the microdilution method with neomycin as the positive control. The extracts demonstrated activities against the tested pathogens with the minimum bactericidal concentration (MIC) values ranging from 0.1 mg/ml to >12.5 mg/ml (Mulaudzi et al., 2011). Pendota et al. (2017) assessed the antibacterial activities of hexane, dichloromethane, ethyl acetate and butanol extracts of *P. capensis* leaves and the phytochemical compounds quercetin-3-O-rhamnoside and epicatechin isolated from the species against *Bacillus subtilis, Staphylococcus aureus, Escherichia coli* and *Klebsiella pneumoniae* using the microdilution assay with neomycin as a positive control. Both the extracts and phytochemical compounds exhibited activities against the tested pathogens with MIC values ranging from 0.39 mg/ml to 125.00 mg/ml (Pendota et al., 2017).

Antimycobacterial activities

Mukanganyama et al. (2011) assessed the antimycobacterial activities of ethanol extracts of *P. capensis* leaves against *Mycobacterium aurum* using the disk agar diffusion method with ampicillin as a positive control. The extracts exhibited activities against the tested pathogen with the MIC and minimum bactericidal concentration (*MBC*) value of 0.31 mg/ml (Mukanganyama et al. (2011).

Antigonococcal activities

Mulaudzi et al. (2011) assessed the antigonococcal activities of acetone, dichloromethane and petroleum ether extracts of *P. capensis* leaves against *Neisseria gonorrhoeae* by determining the clear zones of inhibition with ciprofloxacin as a positive control. The extracts exhibited weak to moderate activities with percentage inhibition ranging from 44.0% to 65.0% (Mulaudzi et al., 2011). Pendota et al. (2017) assessed the antigonococcal activities of hexane, dichloromethane, ethyl acetate and butanol extracts of *P. capensis* leaves and the phytochemical compounds quercetin-3-O-rhamnoside and epicatechin isolated from the species against *Neisseria gonorrhoea* using the microdilution assay with ciprofloxacin as a positive control. Both the extracts and phytochemical compounds exhibited activities against the tested pathogen with inhibition ranging from 44.0% to 72.0% (Pendota et al., 2017).

Antifungal activities

Mukanganyama et al. (2011) assessed the antifungal activities of ethanol extracts of *P. capensis* bark and leaves against *Candida albicans* and *Candida mycoderma* using the disk agar diffusion method with fungazole as a positive control. The extracts exhibited activities against the tested pathogens with zone of inhibition values ranging from 1.0 mm to 3.5 mm (Mukanganyama et al., 2011). Mulaudzi et al. (2011) evaluated the antifungal activities of aqueous, acetone, dichloromethane and petroleum ether extracts of *P. capensis* leaves against *Candida albicans* using the microdilution method with amphotericin B as a positive control. The extracts exhibited activities against the tested pathogen with MIC and minimum fungicidal concentration (MFC) values ranging from 0.2 mg/ml to 6.25 mg/ml and 0.78 mg/ml to 12.5 mg/ml, respectively (Mulaudzi et al., 2011). Pendota et al. (2017) assessed the antifungal activities of hexane, dichloromethane, ethyl acetate and butanol extracts of *P. capensis* leaves and the phytochemical compounds quercetin-3-O-rhamnoside and epicatechin isolated from the species against *Candida albicans* using the microdilution assay with amphotericin B as a positive control. Both the extracts and phytochemical compounds exhibited activities against the tested pathogen with MIC values ranging from 0.39 mg/ml to 62.50 mg/ml (Pendota et al., 2017). Machaba et al. (2024) evaluated the antifungal activities of acetone, methanol, dichloromethane, water and hexane extracts of P. capensis leaves against *Candida albicans*, *Aspergillus fumigatus* and *Cryptococcus neoformans* using the microdilution assay with amphotericin B as the positive control. The extracts exhibited activities against the tested pathogens with MIC values ranging from 0.02 mg/ml to 1.25 mg/ml (Machaba et al., 2024).

Anti-HIV activities

Mulaudzi et al. (2011) assessed the anti-HIV activities of water and methanol extracts of *P. capensis* leaves against the non-radioactive HIV-1 reverse transcriptase colorimetric ELISA kit with kaletra and combivir as positive controls. The extracts exhibited activities with inhibition percentage of 70.0% at 1.0 mg/ml and half maximal inhibitory concentration (IC_{50}) values ranging from 0.05 mg/ml to 0.1 mg/ml, which were comparable to IC_{50} values of 0.06 mg/ml to 0.3 mg/ml exhibited by the positive control (Mulaudzi et al., 2011).

Anticancer activities

Makhoahle & Mashele (2021) evaluated the anticancer activities of agueous and dichloromethane/methanol (1:1) extracts against colon (HCT116), breast (MCF7) and prostate (PC30) cancer cells using *in vitro* Sulforhodamine B (SRB) assay with parthenolide as a positive control. The extracts exhibited activities with IC_{50} values ranging from 6.25 µg/ml to 12.52 µg/ml which were comparable to 0.81 µg/ml to 2.22 µg/ml demonstrated by the positive control (Makhoahle & Mashele, 2021). Muruthi et al. (2023b) evaluated the anticancer activities of aqueous, ethyl acetate and dichloromethane extracts of *P. capensis* stem bark against human breast (HCC 1395) and prostate (DU145) cancer cell lines using using 2,3-bis-(2-methoxy-4-nitro-5-sulfophenyl]-2-htetrazolium-5-carboxyanilide salt (XTT) calometric assay with doxorubicin as a positive control. The extracts exhibited activities against the cancer cells with the IC_{50} values ranging from 5.00 µg/ml to 12.67 µg/ml (Muruthi et al. 2023b).

Antidiabetic activities

Karau et al. (2012b) evaluated the antidiabetic activities of aqueous and ethyl acetate extracts of *P. capensis* leaves and stem bark in alloxanized diabetic BALB/c mice. The extract induced hypoglycemic activities in a dose independent manner (Karau et al., (2012b). Ngai et al. (2017) evaluated the antidiabetic activities of dichloromethane and methanolic extracts of *P. capensis* leaves and stem bark on alloxan-induced diabetic male albino rats. The extracts showed hypoglycaemic activities by reducing blood sugar levels of alloxan-induced diabetic rats within the treatment period of seven days (Ngai et al., 2017).

Anti-inflammatory activities

Mulaudzi et al. (2013) evaluated the anti-inflammatory activities of dichloromethane, 80% ethanol, petroleum ether and water extracts of *P. capensis* leaves against the cyclooxygenase (COX-1 and COX-2) enzymes. All extracts exhibited activities against COX-1 with percentage inhibition of at least 70.0% while dichloromethane and petroleum ether extracts exhibited with percentage inhibition of at least 80.0% against COX-2 (Mulaudzi et al., 2013).

Antileishmanial activities

Monzote et al. (2014) evaluated the antileishmanial activities of methanol extract of *P. capensis* against *Leishmania amazonensis* using the anti-mastigote and anti-promastigote assays with amphotericin B and pentamidine as positive controls. The extract exhibited activities with IC_{50} value of < 12.5 µg/ml (Monzote et al., 2014).

Antioxidant activities

Karau et al. (2012a) evaluated the antioxidant activities of methanol extracts of *P. capensis* leaves and stem bark using the β-carotene bleaching method with butylated hydroxylated toluene (BHT) as a positive control. The leaves and stem bark exhibited *in vitro* antioxidant activities of 54.82% and 46.04%, respectively which were comparable to 59.10% exhibited by the BHT (Karau et al., 2012a). Pendota et al. (2017) assessed the antioxidant activities of hexane, dichloromethane, ethyl acetate and butanol extracts of *P. capensis* leaves and the phytochemical compounds quercetin-3-O-rhamnoside and epicatechin isolated from the species using 2,2–diphenyl–1–picryl hydrazyl (DPPH) free radical scavenging assay and β-carotene-linoleic acid model with ascorbic acid and BHT as positive controls. Both the extracts and the phytochemical compounds exhibited activities with half maximal effective concentration (EC_{50}) values ranging from 3.35 µg/ml to 158.0 µg/ml (Pendota et al., 2017). Kimondo et al. (2019) evaluated the antioxidant activities of aqueous and methanol extracts of *P. capensis* stem bark using the DPPH free radical scavenging assay with ascorbic acid as the positive control. The aqueous and methanol extracts exhibited weak activities with IC_{50} values of 215.00 µg/ml and 378.62 µg/ml, respectively in comparison with 50.32 µg/ml exhibited by the positive control (Kimondo et al., 2019). Ngai et al. (2019) evaluated the antioxidant activities of dichloromethane: methanolic extracts of *P. capensis* leaves and stem bark using the DPPH free radical scavenging, hydrogen peroxide scavenging and total reducing power assays. The extracts exhibited dose-dependent activities (Ngai et al., 2019). Muruthi et al. (2023a) evaluated the antioxidant activities of aqueous and organic extracts of *P. capensis* leaves using ferric reduction, Iron chelating, hydroxyl radical, and DPPH free radical scavenging assays. The extracts exhibited concentration dependent activities (Muruthi et al., 2023a).

Antiplasmodial activities

Koch et al. (2005) evaluated the antiplasmodial activities of chloroform extracts of *P. capensis* inner bark against a chloroquine-sensitive (D6) strain of *Plasmodium falciparum* using a semiautomated microdilution technique with chloroquine as positive control. The extract showed weak activities with IC_{50} value of >10.00 µg/ml (Koch et al., 2005).

Mokoka et al. (2013) evaluated the antiplasmodial activities of dichloromethane:methanol (1:1) extracts of *P. capensis* leaves and roots using the [^{3}H]-hypoxanthine incorporation assay using *Plasmodium falciparum* as the test organism with chloroquine as the positive control. The leaf and root extracts exhibited weak antiplasmodial activities with IC_{50} values of 9.67 µg/ml and 5.30 µg/ml, respectively which were higher than 0.003 µg/ml exhibited by the positive control (Mokoka et al., 2013). Similarly, Bapela et al. (2014) evaluated antiplasmodial activities of dichloromethane extract of *P. capensis* twigs using the [^{3}H]-hypoxanthine incorporation assay using chloroquine sensitive (NF54) strain of *Plasmodium falciparum* as the test organism. The extract showed activities with IC_{50} value of 5.47 µg/ml in comparison to 0.003 µg/ml exhibited by the positive control (Bapela et al., 2014). Bapela et al. (2019) evaluated antiplasmodial activities of dichloromethane and methanol extracts of *P. capensis* twigs using the [^{3}H]-hypoxanthine incorporation assay against the chloroquine sensitive (NF54) strain of *Plasmodium falciparum*. Both extracts exhibited activities with IC_{50} values of 5.47 µg/ml and 24.8 µg/ml, respectively (Bapela et al., 2019). Tajuddeen et al. (2021) evaluated the antiplasmodial activities of methanol extracts of *P. capensis* leaves and the compounds quercetin 3-O-arabinopyranoside, quercitrin, kaempferol 3-O-arabinopyranoside and quercitrin 3-O-β-D-glucoside isolated from the species against the chloroquine-sensitive 3D7 *Plasmodium falciparum* using the parasite lactate dehydrogenase assay. The methanol extract and the phytochemical compounds inhibited the viability of *Plasmodium falciparum* (Tajuddeen et al., 2021). Mabuza et al. (2022) evaluated the antiplasmodial activities of dichloromethane, methanol and water mixture of *P. capensis* twigs using the using the [^{3}H]-hypoxanthine incorporation assay against the *Plasmodium falciparum* (NF54) and chloroquine as the standard drug. The extract exhibited activities with the best IC_{50} value of 2.59 µg/ml in comparison of 0.0035 µg/ml exhibited by the positive control (Mabuza et al. 2022).

Cardioprotective activities

Gaichu et al. (2023a,b) evaluated the cardioprotective activities of aqueous extracts of *P. capensis* leaves in salbutamol-induced Wistar albino rats with myocardial infarction. The extracts exhibited dose-dependent cardioprotective activities (Gaichu et al., 2023a,b).

Molluscicidal activities

Ndabambi et al. (2015) evaluated the molluscicidal activities of methanol extract of *P. capensis* stem bark against *Lymnaea natalensis* and *Helisoma duryi* with niclosamide as positive control. The extract exhibited weak activities with a 48 hour median lethal concentration (LC_{50}) value of 51.0 mg/l and maximum lethal concentration (LC_{90}) value of 87.0 mg/l (Ndabambi et al. 2015).

Conclusion

The present review provides a summary of the traditional uses, medicinal applications, chemical and pharmacological properties of *P. capensis*. Such ethnopharmacological studies are important for plant species widely used as traditional medicines as assessing their phytochemistry, pharmacological properties and toxicological evaluations is important. But detailed studies focusing on toxicity and safety, mechanisms of action *in vivo* and clinical research aimed at corroborating the traditional medical applications of *P. capensis* are recommended.

Declarations

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