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Review

A review of phylogeny, medicinal values, phytochemistry and toxicity of *Sarcophyte piriei* Hutch (Balanophoraceae)

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In recent years, plants have shown potential as sources of antimicrobial agents due to their immense phytochemical constituents, and there is a need to continuously search and develop potent antimicrobial agents to combat the growing threat of antimicrobial resistance worldwide. The challenges facing the utilization of ethnomedicine are lack of sufficient studies to ascertain their therapeutic use. *Sarcophyte* is a holoparasite plant and trophic guild parasite. Its native ranges from Southern parts of Ethiopia to South Africa. It has a vital medicinal value in managing various disorders. This review article purposes to offer a complete rundown literature regarding *Sarcophyte* genus: Phylogeny, medicinal values, phytochemistry and toxicity that have been outlined in diverse journals and articles. This review has been developed with the aid of books, articles, peer reviewed articles, theses, Google Scholar, Science Direct and validated internet sources. *Sarcophyte piriei* has been utilized customarily to manage a variety of disorders among Africans for ages. It is employed to treat diseases but is not limited to sores, bruises, sore throat, swollen glands, toothache, abdominal pain, diarrhoea, shingles, cancer, snake bites and menstrual disorders. Alkaloids, flavonoids, phenols, saponins, terpenoids and tannins have shown to be the major phytochemical constituents correlated with the antimicrobial properties of the holoparasite and contributed to the antibacterial prospects of the plant against *Staphylococcus aureus, Escherichia coli, Pseudomonas aeruginosa, Streptococcus pyogenes, Klebsiella pneumonia and Proteus mirabilis.* Its safety and toxicity have not been well established hence the need for evaluation. More studies are required to elucidate more phytochemical composition, medicinal values, efficacy, potency, safety and toxicity measures. *Sarcophyte* genus will provide a novelty in new remedies for the emerging antimicrobial resistance to conventional antimicrobial agents.

Key words: Balanophoraceae, *sarcophyte piriei,* phylogeny, phytomedicines, phytochemistry, toxicity.

INTRODUCTION

Infectious diseases are ranked among the top ten deadly diseases globally and antimicrobial resistance has reduced the effectiveness of antibiotics under clinical trial (WHO, 2020). Antimicrobial resistance endangers the successful prevention and treatment of an ever-increasing range of infections caused by bacteria, parasites, viruses and fungi.

Globally a problem with antimicrobial resistance need to be exploited for alternative management of infections caused by drug resistant strain to enable the attainment of the Sustainable Development Goal number three which requires that the Nations ensure all citizens have healthy lives and promotes the well-being for all citizens of all ages (Cocks and Dold, 2005); International Council for Science, 2015). The high number of sub-Saharan Africa population living below the stipulated economic line, lack of adequate health facilities and inadequate qualified medical practitioners has made this population to seek for plants as the mainframe of healthcare. Where conventional medicines are used, they are mixed with herbal concoctions with the mindset that prescribed drugs are likely to be ineffective (Kipkore et al. 2014). The irrational use of antibiotics has caused an increase in antimicrobial resistance, leading to high antimicrobial resistance related deaths across the whole world (Karuniawati et al., 2021).

Antimicrobial resistance problems can be overcome by a multi-target drug approach sustainable strategy because bacterial resistance to a single target antibiotic is rapid and resistance to new drug develops before reaching the market (Declan and Michaelal, 2020). Molecules derived from plants are potent multi-target for micro-organisms at different stages of the plant starting from germination to maturity because they undergo challenging defense mechanisms for their survival (Hannan et al., 2021; Taylor et al., 2019; Hossain et al., 2021). Plants are major segment of biodiversity and have greatly contributed to traditional medicine practice systems around the world with major case being primary health for the resource constrained society (Karunamoorthi et al., 2013). In addition, plants have resurgence in the United States with over 80% of the prescribed medicines in the market (Yuan et al., 2016). In the 21st Century plants have provided a lead for drugs that are offering a solution to communicable and non-communicable diseases in the era of rising antimicrobial resistance, challenge of having effective drugs for diseases like arthritis Alzheimer's diseases, scarcity of safe and affordable to manage diabetes, cancer and hypertension (Newman, 2013).

Plants with medicinal value have a rich history in the management of illness and are traced back to records in early human civilization. Approximately three quarter of the inhabitants in advancing countries are relying on herbs with medicinal value as a solution to their ailments(Cathrine and Nagarajan, 2011; Elujoba et al., 2005). Antibiotics that destroy or slow down the growth of bacteria have been used to manage infections since their discovery and introduction for therapeutic use. Antibiotics were expected to offer a long-term solution for the management of infections but due to their misuse there has been a sharp rise in antimicrobial resistance majorly from the commercial drugs hence microbial infections have not been eradicated completely and many resistant strains of bacteria and fungi have emerged (Khan et al., 2009).

Sarcophyte piriei is a potent medicinal plant used in traditional medicine that has not been investigated widely to ascertain the traditional claims. *S. piriei* is utilized in African folk medicine system to manage infectious diseases, cancer and pain in human beings. The therapeutic effects of *S. piriei* are due to a number of phytochemical constituents.

Antimicrobial activities of *S. piriei* or its metabolites have been reported (Mahammed et al., 2020; Mbakazi, 2022). However, the data on scientific studies to reveal the efficacy, safety and chemical composition of the *S. piriei* is not available.

This review aims to determine if *S. piriei* is a valuable lead compound for therapeutic development of investigational drug and if the phytochemical constituents of *S. piriei* are potential antimicrobial agents to overcome antimicrobial resistance. Additionally, this review provides comprehensive overview of published data regarding *S.e piriei*: phylogeny, medicinal values, phytochemistry and toxicity of *S. piriei.* Therefore, the current review will provide empirical data that will be analyzed to rationalize the use of the extracts from the plant to treat bacterial infections and also evaluate the safety and chemical components of *S. piriei*.

METHODOLOGY

This review has been developed with the aid of books, articles, peer reviewed articles, theses, Google Scholar, Science Direct and validated internet sources. The search phrases included: phylogeny of *Sarcophyte piriei,* medicinal values of *S. piriei*, phytochemistry of *S. piriei* and toxicity of *S. piriei*. The articles published from years 1992 to 2022 were considered in the review. The older literatures were valuable in the search for medicinal value of *S. piriei*. Relevant articles were accessed using inclusion and exclusion criteria.

PHYLOGENY

Sarcophyte piriei description

Taxonomy, distribution and morphology of Balanophoraceae

Balanophoraceae family is in the order of Santalales (Sandalwood) in accordance with Angiosperm Phylogeny

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Group IV system of classification (Angiosperm Phylogeny Group, 2016; Nickrent, 2020). The family consists 18 genera of over 100 species of root holoparasitic geophytes distributed pantropically (Britannica (Editors), 2017; Delprete, 2016; Gonzalez et al., 2019). The plants in Balanophoraceae family are characterized by underground tuberous body of rhizome-like ramifications, it forms a nearly spherical or lopsided lobed or subdivided subterranean corrugated or scaly tuber sometimes apportioned with stolon identical to “corm”. The tuberous rhizomes that exist as undergrounds stems for the Balanophoraceae species attach the roots of the host tree and are highly adapted haustoria to provide nutrients and water to the parasite from the host tree (Britannica (Editors), 2017).

Plants are herbs with extremely reduced morphological features devoid of stems, leaves and normal roots. The inflorescence of plants in Balanophoraceae family are lying on the earth’s surface with the overall appearance of a fungus tuber ensuing directly from the tuber or stolon accompanied with countless miniscule epicene flowers presenting with deep purple or pale yellow colours (Britannica (Editors), 2017).

Sarcophyte genus description

Sarcophyte is a Greek work denoting a ‘fleshy plant’, the terms *sarx*, connoting ‘flesh’ and phyton, designating ‘plant’. *Sarcophyte* has two subspecies: subsp. *piriei* and subsp*. sanguinea,* with difference being the fruity smell of subsp. *Sanguinea* (Sarcophyte sanguinea subsp. sanguinea | PlantZAfrica (http://pza.sanbi.org). Subsp. *piriei* was named after Dr J. H. H. Pirie who was a Medical staff and species collector in East African (Hyde et al., 2020). *S. piriei* attains a height of 40 cm with no smell. The stem tubers are unevenly lobed measuring 5-13 cm in length and a width of cm lobed. The holoparasite bracts are oval in shape and are un-subdivided. The male floral envelope sections range from two to four portions. The parts are extremely fleshy; the stamens varying from two to four with perianth chunk being more than half of the stamens. The *S. piriei* female flowers form bunches of between 0.4 - 1.5 cm in length with an ovoid to ± spherical (Hyde et al., 2020).

Sarcophyte piriei is reddish parasite with the reproductive organs of the male parasite and the female parasite located on separate plants. The large stem tubers are irregular and lack the ability for rhizome production. The leaves are arranged spirally, reduced in size and flat*.* The flowers are arranged in axis, development of the flowers is unisexual and greatly branched. During the budding and development of flowers the male parasitic plants bear flowers of 2 to 4 groups forming secondary branches which are short, under it the flowers are supported by a bract. The female parts of *S. pirie* plants bud flowers with branches of 5 to 12 sub-globular fleshy axis enclosed in a spathe of ± 200 clusters with a hollow style. The fruits are fleshy and multiple with globular berry. Globally two species arise in Africa (Hyde et al., 2020).

The *S. piriei* produce a fruity scented odour. The flowering male parts of the plant develop to a height or approximately 40 cm tall while the female parts of the plant attain a lower height, with pale bracts and purplish-red flowers. Male flowers attain tepals about twice the length of the stamens and produce smooth pollen grains. Maroyi (2017) treated *S. piriei* as a subspecies of *S. sanguinea*. The difference with the two species of *Sarcophyte* is depicted from the length of the stamen with *S. piriei* having about twice the length of tepals which produce a bad smell and wrinkled pollen grains (Thulin, 1993).

Sarcophyte piriei has the widest distribution area, from Ethiopia and Somalia south to Mozambique. The stamens are less than half as long as the perianth segments and the flowers are odourless or have a fruity smell. *Sarcophyte sanguinea* subsp. *sanguinea* occurs in Mozambique and eastern South Africa. It differs mainly from subsp. *piriei* in that the stamens are more than half as long as the perianth segments, and that the flowers have a putrid smell (Obiloma et al., 2019).

Sarcophyte piriei has several synonyms such as *Sarcophyte sanguinea* Sparrm*.* subsp *pirei* (Maroyi, 2017). The doubts expressed by Hemsley with regards to the *Sarcophyte* (Balanophoraceae) found in the Tropical East Africa which was mentioned by Engler as *Sarcophyte sanguinea* Sparrm. whether it really belonged to the species, since it indigenous to Grahams town and its environs in South Africa. Hemsley’s observation was that the male *Sarcophyte* inflorescence found in Cape Town appeared to be compound branched. The available material could not fully answer the question hence he accepted Engler’s determination. Of the two subspecies, though hardly encountered, subsp. *piriei* has been recorded in some parts of Kenya including Ruwenzori (Kibwezi), Kitobo (Taveta), Nairobi National Park, Kajiado and Mbeere South (Thulin, 2008; Luke, 2017; Muriuki, 2011).

Figure 1 shows the photograph of uprooted plant of *Sarcophyte piriei* Hutch showing the massive underground tuber and short stem with aerial flowering body.

The *Sarcophyte sanguinea* Sparrm, is an exceptional parasite found on the roots of *Acacia horrida*. The characteristic strong odour of *Sarcophyte* is similar to that of *Hydnora* as acknowledged by MacOwan and Clinton (2015). Further, he mentioned that the *Sarcophyte* needs protection from the infecting ticks and mites’ arachnids of the *Acaru*s genus and the order *Acarina.* The *Acarus scabiei* (also known as the Sarcophyte scabies) infects humans causing scabies and in dogs it causes mange disease (MacOwan and Clinton, 2015).

The South African plant collector Clemenz Heinrich

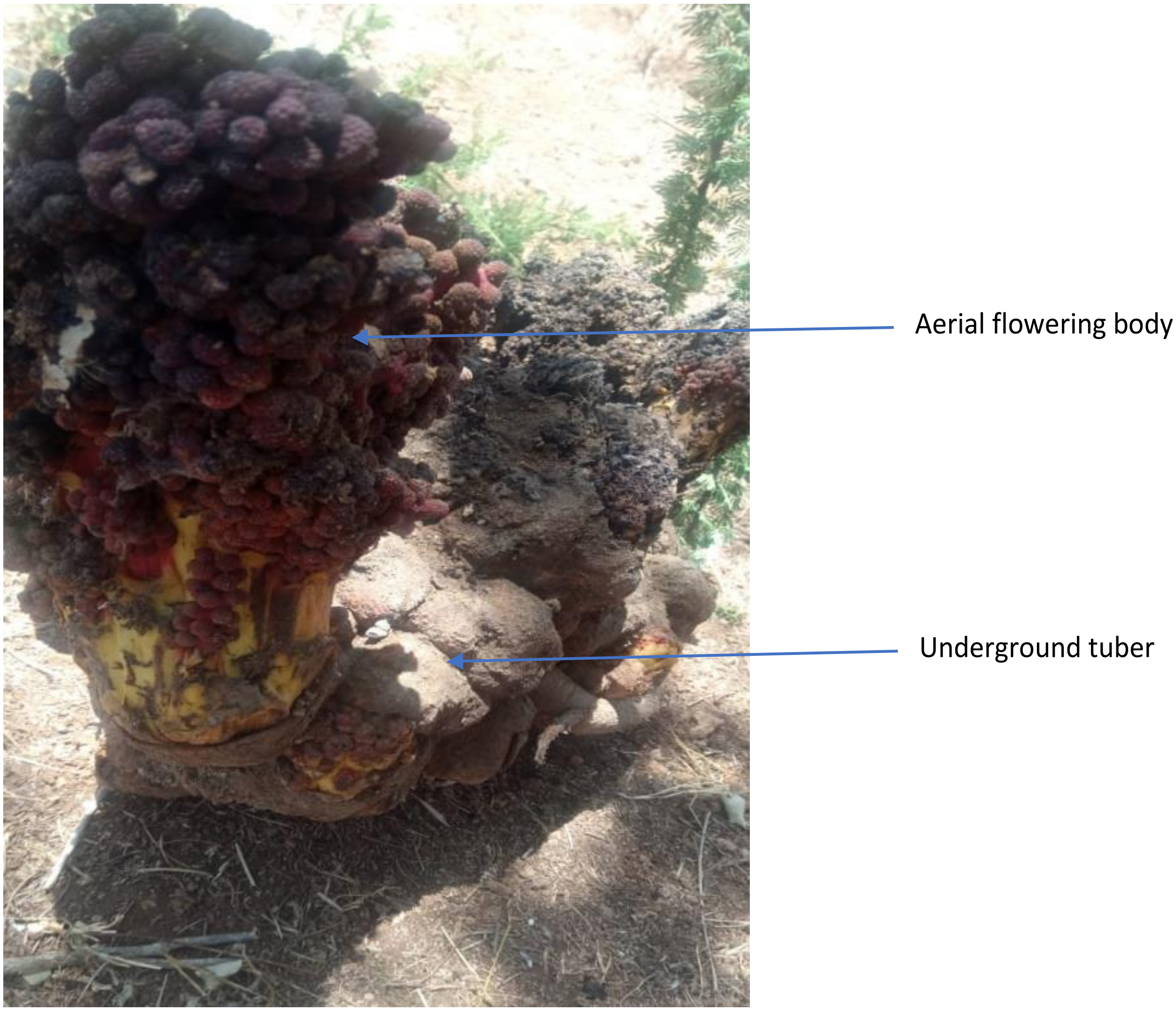

Figure 1. Photograph of uprooted plant of *Sarcophyte piriei* Hutch showing the massive underground tuber and short stem with aerial flowering body. Taken by Dennis Opwoko at Rwagiri village, in Mbeere South, on 3rd Oct. 2021.
Source: Authors 2023

Wehdeman made *Sarcophyte* drawing of a species named after him (*Ichthyosma wehdemanii* Schlechtd.) and afterwards abated to *Sarcophyte sanguinea* Sparrm (MacOwan and Clinton, 2015; Glen and Germishuizen, 2010).

Taxonomy

Kingdom: Plantae
Phylum: Tracheophyte
Class: Magnoliopsida
Order: Santalales
Family: Balanophoraceae
Genus: Sarcophyte Sparrm.
Variety: Sarcophyte piriei Hutch; Sarcophyte sanguinea subsp.

Traditional names

The traditional names of *Sarcophyte piriei* have been documented in literature from different countries namely: South Africa (Isizulu), Somali and Kenya (Mbeere) recorded by the respective countries. Different names of *S. piriei* are given in Table 1.

PHYTOMEDICINAL VALUE OF THE PLANT

Ethnomedical uses, phytochemistry and biological properties of Balanophoraceae

Large percentage of plant species in the Balanophoraceae family are commonly employed in indigenous medicine systems to manage HIV related

Table 1. Different names of *Sarcophyte piriei.*

Country	Name
South Africa (Isizulu)	Wolwekos, Ihlule and Umavumbuka
Somali	Diinsi
Kenya (Mbeere)	Ibatikanthi

Source: (Sarcophyte sanguinea subsp. sanguinea | PlantZAfrica (http://pza.sanbi.org).

diarrhea, dysentery, skin diseases and mycoses (Akram and Cassandra, 2019; Chinsembu and Hedimbi, 2010; Ignacimuthu et al., 2006). Asthma, fertility, sexual potency and male impotence are also treated using plant species of Balanophoraceae (Bussmann and Glenn, 2010; Lumlerdkij, 2018). *Sarcophyte* forms a sizeable genus in the Balanophoraceae family, it is exceedingly studied genus on the basis of both phytochemical and biological properties (She et al., 2010). Mostly, phenylpropanoids, triterpenoids and sterols have been isolated. Antioxidant, anti-inflammatory, analgesic and hypouricemic activities have been mostly reported. Other reported activities include anti-HIV, cytotoxic, hypoglycaemic and alcoholic sobering (Fang et al., 2018; Wang et al., 2012).

Genus *Sarcophyte* Sparrm phytomedicine uses

Herbal medicine recipe containing *Sarcophyte* include the following: *Cladostemon kirkii* roots have been concurrently taken with the roots of *Elephantorrhiza elephantina, Sarcophyte piriei* Hutch., leaves of *Senecio serratuloides* DC, bark of *Ficus sur* Forssk. whole plant, parts of *Ranunculus multifidus* and bulb of *Drimia delagoensis* utilized topically for the management of sores (Nickrent, 2020). *E. elephantina* root have been formulated into a decoction for oral administration incorporating *Sarcophyte sanguinea* Sparm. ssp. *piriei* (Hutch.) and other plant preparations has been employed for the treatment of shingles (Kipkore et al. 2014). *Sarcophyte piriei* and the extracts obtained from *Commiphora myrrha* have been in practices of traditional medicine for the management of wounds and infections (Mahammed et al., 2020).

The rhizomes of *Sarcophyte piriei* (Balanophoraceae) has been utilized in managing inflammation (Jachak and Jain, 2006).

The Local women in KwaZulu-Natal Province (South Africa) have used the stem tuber to manage gastrointestinal infections and wounds. The other ethnomedicinal utilization of the *Sarcophyte* is management of swollen glands, upper respiratory tract infections and menstrual disorders. The *Sarcophyte* preparations are also applied topicals for toothache and bruises. In Tanzania a decoction of the Sarcophyte is taken orally for the management of cancer (Kipkore et al., 2014).

Sarcophyte piriei stem tuber preparations is employed in Somalia for the management of menstrual disorders, toothache, infections, abdominal pain and gastrointestinal infections (Thulin, 1993). *S. piriei* Ibatikanthi (Mbeere) in Kenya is utilized for Snake bites (Kiura, 2011: Medicinal trees in smallholder agroforestry systems, https://www.worldagroforestry.org). In South Africa Xhosa speaking communities use *Sarcophyte piriei* for the treatment of acne and skin blemishes (Cocks and Dold, 2005).

Sarcophyte sanguinea stem tubers are traded and used for ethnomedicine in South Africa. The plant in Zulu and Xhosa is implicated in the management of piles, menstrual problems, diarrhea, acne, arresting bleeding and stomach cramps (Williams et al., 2011). In Muthi Market *S. sanguinea* is used in the treatment of diarrhea (Nkwanyana, 2022).

Ethnobotanical analysis on the plants utilized for the management of sexually transmitted infections was carried out with the aim of documenting the knowledge of the natives of the northern part of Maputaland in South Africa. *Sarcophyte sanguinea* subsp. *Sanguinea* was recorded for its use in the treatment of venereal diseases (Ignacimuthu et al., 2006; De Wet et al., 2012). The boiled stem of *S. Sanguinea* in water and the administered dose is determined by the severity of the condition and it is taken orally for the management of warts and genital sores in northern Maputaland (Karunamoorthi et al., 2013).

Sarcophyte sanguinea Sparrm., whole plant is implicated in the treatment of diarrhea and dysentery as an infusion and decoction preparations (Olajuyigbe and Afolayan, 2012). The *Sarcophyte piriei* Hutch has been described to treat sore, shingles, acne, skin eruptions (De Wet et al., 2013). The decoction of tuberous stem of *S. piriei* has been exploited to relieve toothache in addition to abdominal pain (Ogundaini et al., 1996). According to a team of herbalists and traditional medicine practitioners of Mbeere South subcounty in Embu County (Karunamoorthi et al., 2013) extracts of *S. piriei* tuber, locally known as Ibatikanthi, is used to treat cancer in Kenya. In addition, the extracts of *S. piriei* tubes find application in the folk for stomach disorders along with snake bites (Muriuki, 2011).

In King William’s Town, South Africa, *Sarcophyte sanguinea* is referred to as mavumbuka. Orally if is utilized in the management of chronic diarrhea, persistent cramps, its boiled extract is used for detoxification and its paste formulation is topically administered on the skin for the treatment of acne and skin complaints. To the contrary, the idea of edible *Sarcophyte* genus is repulsive among the South African communities (Karunamoorthi et al., 2013). *S. sanguinea* is used in Eastern Cape Town for ethno-veterinary in the treatment of black quarter disease of livestock and management of paratyphoid in cattle (Mthi et al., 2018). The people in Mtubatuba, South Africa believe the *S. sanguinea* could help them get jobs with most people seeking jobs at Richard Bay utilizing it (Sustainability Today (https://books.google.co.ke).

Phytochemistry

Sarcophyte species are rich of phytochemicals as evident from a variety of studies. These phytochemicals have nourished *Sarcophyte* with its medicinal application over the years. The phytochemicals constituents in *Sarcophyte* include: flavonoids, terpenoids, alkaloids, saponin, tannins and phenolics.

Saponins, tannins, flavonoids and terpenoids are well known to have significant inhibitory actions against bacteria and fungi (Hayek et al., 2013). The mechanism of act of plant products are distinct, the cytoplasmic membrane is common site of action for secondary metabolites. The secondary metabolites act through cell lysis causing the leakage of cellular contents and subsequently cell death (da Silva et al., 2013).

Secondary metabolites

Two bioflavonoids have been isolated from *Sarcophyte piriei* and have shown anti-inflammatory activity. The flavone glycosides, diinsininol and diinsinin were isolated from the rhizome with one known flavanone glycoside, naringenin 5-glucoside. Their structures were elucidated spectroscopically as: 5,7,3‘,4‘-tetrahydroxyflavanyl-7-O-β-glucosyl-(4β-8;2β-O-7)-eriodictyol and 5,7,3‘,4‘-tetrahydroxyflavanyl-7-O-β-glucosyl-(4β-8;2β-O-7)-naringenin respectively.The compounds were tested and have shown the ability to inhibit prostaglandin synthesis (5,7,3’,4’-Tetrahydroxy-8-prenylflavone | C20H18O6 - PubChem. (https://pubchem.ncbi.nlm.nih.gov). The *S. piriei* has biflavanoids essential for anti-inflammatory activity (Ogundaini et al. 1996).

The isolation forms the free form of the exocarpic acid ever isolated. The other plants of the holoparasite also contain constituents like triandrin, naringenin, *trans-p*-coumaraldehyde eriodictyol and D-pinitol (1D-4-*O*-methyl chiro inositol) (Lovina et al., 1992).

The methanolic extract of *Sarcophyte sanguinea* subsp. *piriei* (Hutch.) B assayed by the use Gas-chromatography time-of-flight mass spectrometry (GC/TOF-MS) has shown the presence of phthalic acid, di(oct-3-yl) ester, 3-O-methyl-d-glucose and 5-aminoimidazole-4-carboxamide-1-ád-ribofuranosyl 5′-monophosphate (Mbakazi et al., 2022).

S. piriei showed positive results for the presence of the secondary metabolites tested and they included: alkaloids, tannins, flavonoids, saponins, polyphenols and terpenoid are given in Table 2.

Phenols

Phenolic compounds like polyphenols, flavonoids and tannins act through the disruption of the cell membrane and cell wall of the micro-organism (Taguri et al., 2006). Phenolic compounds also penetrate the bacterial cells consequently coagulating the intracellular contents (Tian et al., 2009).

Saponins

Saponins exhibit antimicrobial property as a result of lipophilic portion in its structure. The lipophilic contain sapogenin or aglycon. The hydrophilic core of the saponin contains one or more sugars (Costa et al., 2010).

Flavonoids

Flavonoids show antibacterial activity against both gram-positive and gram-negative bacteria through the inhibition of DNA gyrase and effect on bacterial energy metabolism (Coppo and Marchese, 2014; Daglia, 2012; Cushine and Lamb, 2005; Njume et al., 2009). The six subfamilies of flavonoids include: flavones, flavanols, flavanones, isoflavonoids, flavonols and anthocyanidins inhibit the PriA helicase activity of *S. aureus* and interaction of *K. pneumoniae* DNA B helicase with dNTPs. The flavones have platelet-activating factor-induced exocytosis (Hammond et al., 2016). A natural product exocarpic acid (13 *E*-octadecene-9,11-diynoic acid) obtained from both the male and female holoparasite of *Sarcophyte sanguinea* is the major component of the stem tubers. It also forms the major composition of the constituents of the inflorescences of the *Sarcophyte* genus from the isolation.

Naringenin

Naringenin is a flavonone with antimicrobial activity exhibited through repression of many pathogenicity genes and down-regulation of other genes flagella and inhibiting their motility (Vikram et al., 2011). Naringenin antimicrobial property against *P. aeruginosa* is by reduction of acyl homoserine lactones production

Table 1. Phytochemical composition of *Sarcophyte piriei.*

Phytochemical constituent	Reference
Alkaloids	Mahammed et al., 2020
Flavonoids	Mahammed et al., 2020
Phenolics	Mahammed et al., 2020
Saponins	Mahammed et al., 2020
Terpenoids	Mahammed et al., 2020
Tannins	Mahammed et al., 2020
Flavone glycosides	https://pubchem.ncbi.nlm.nih.gov
Diinsininol	https://pubchem.ncbi.nlm.nih.gov
Diinsinin	https://pubchem.ncbi.nlm.nih.gov
Naringenin 5-glucoside	https://pubchem.ncbi.nlm.nih.gov
Biflavanoids	(Ogundaini et al. 1996)
Flavones	Hammond et al., 2016
Exocarpic acid	Lovina et al., 1992
Triandrin	Lovina et al., 1992
Naringenin	Lovina et al., 1992
Trans-p-coumaraldehyde	Lovina et al., 1992
D-pinitol	Lovina et al., 1992
Phthalic acid	Mbakazi et al., 2022
Di(oct-3-yl) ester	Mbakazi et al., 2022
3-O-methyl-d-glucose	Mbakazi et al., 2022
5-aminoimidazole-4-carboxamide-1-ád-ribofuranosyl 5′-monophosphate	Mbakazi et al., 2022

Source: (Mahammed et al. 2020; https://pubchem.ncbi.nlm.nih.gov; Hammond et al. 2016; Lovina et al. 1992; Ogundaini et al. 1996; Mbakazi et al. 2022).

(Vandeputte et al., 2011).

Tannins

Tannins antimicrobial activity is through several mechanism of action including: complexation of metal ions, inhibition of extracellular microbial enzymes and deprivation of substrates (Buzzin et al., 2008; Njume et al., 2009).

Alkaloids

Alkaloids are naturally occurring cyclic ring organic compounds containing nitrogen in a negative oxidative state. Alkaloids have been shown to act through efflux pump activity as reputed antibacterial functionality (Khameneh et al., 2019).

Terpenes

Terpenes of isoprenoids form part of the most diverse family of natural products. The mechanism of action of terpenes is associated with lipophilic characteristics. Monoterpenes act on cell membranes to interfere with the fluidity and permeability. Terpenes also affect protein and respiration chain (Paduch et al., 2007)

ANTIMICROBIAL ACTIVITY

Sarcophyte piriei exhibited remarkable antibacterial properties against the experimental microorganisms with the zones of inhibition giving a diameter of ≥8 mm. The *S. piriei* ethanolic and methanolic extracts showing a minimum zone of inhibition diameter of 10 ± 2 mm and a maximum zone of inhibition diameter of 24.9 ± 0.9 mm as displayed in Table 3.

The minimum inhibitory concentration of *Sarcophyte piriei* methanolic and ethanolic extracts.

The bacteria *Klebsiella pneumoniae was* used to test the MIC value using the *Sarcophyte piriei* ethanolic extract. The repeatedly obtained values for MIC using the *S. piriei* ethanolic extract was 62.5 mg/mL, the sequence being in the order of: 31.50 mg/mL and 125.00 mg/mL, 15.6 mg/mL, 7.81 mg/mL, 250.00 mg/mL (Mahammed et al., 2020). *S. piriei* had MIC value at a concentration of 62.50 mg/mL and the results are provided in Table 4.

S. piriei inhibited the growth of the bacteria tested; both

Table 2. The showing Mean zone of inhibition against test organisms of *Sarcophyte piriei* methanolic and ethanolic extracts at 500 mg/ml (Mahammed et al., 2020).

Test organism	Mean inhibition zone of *Sarcophyte piriei* extracts (Mean ± SD mm)		
	Methanolic extract	Ethanolic extract	Control (Gentamicin 10 μg/disc)
Staphylococcus aureus	12.3 ± 1.5	16.7 ± 2.5	26 ± 0.3
Escherichia coli	15.3 ± 2.5	14 ± 2.3	28 ± 0
Pseudomonas aeruginosa	13.2 ± 0.4	15 ± 1.2	26 ± 0.5
Streptococcus pyogenes	14.2 ± 2.2	15.9 ± 1.9	28 ± 0.1
Klebsiella pneumonia	12.2 ± 1.2	18.1 ± 1.3	27 ± 0.4
Proteus mirabilis	13 ± 0.1	16 ± 1.5	26 ± 0.2

Source: (Mahammed et al. 2020)

Table 3. The mic values of the five selected medicinal plants extracts against test organisms using broth dilution methods (Mahammed et al., 2020).

Test organism	MIC of plant extract (mg/ml)	
	Methanolic extract	Ethanolic extract
Staphylococcus aureus	250	125
Escherichia coli	250	15.6
Pseudomonas aeruginosa	62.5	62.5
Streptococcus pyogenes	31.2	125
Klebsiella pneumonia	125	250
Proteus mirabilis	125	62.5

Source: (Mahammed et al. 2020).

methanolic and ethanolic *S. piriei* extracts exhibited antibacterial properties at varied concentrations. The results depict the presence of secondary metabolites responsible for the inhibitory activity arresting the growth of the tested microorganisms. *S. piriei* portrayed dominant antibacterial properties against *Staphylococcus aureus* with the minimum inhibitory concentration values of 15.6 mg/mL. Conversely, *S. piriei* methanolic extracts conveyed antibacterial activity *S. aureus* and *Escherichia coli* at minimum inhibition concentration of 250 mg/mL (Mahammed et al., 2020).

Organic extracts of *Sarcophyte sanguinea* have proved to possess sufficient antimicrobial activity. The organic and aqueous extracts of *S. sanguinea* indicated notable activity against *Neisseria gonorrhoeae*. The organic extract of *S. sanguinea* showed inhibitory activity against the growth *Gardnerella vaginalis* (Karunamoorthi et al., 2013).

Genus Sarcophyte pharmacological interactions and toxicity

Sarcophyte Sanguinea has been shown to possess the herb-drug interaction with the interaction being exhibited by the high inhibitory activity on the enzyme isoform CYP3A4 (Ramulondi, 2017). There were no toxicity studies that could be found in the literature for *S. sanguinea* and *S. piriei*. Future studies on the toxicity or side effects associated with this important medicinal plant will be undertaken to lift the lid on their safety and prospects as used traditionally (Ndhlala et al., 2022).

CONCLUSION

This review has revealed that *Sarcophyte* genus portray considerable ethnomedicinal utilization being applied extensively in the management of a variety of ailments including infectious diseases. Various crude extracts have exhibited antibacterial, antifungal, antiparasitic and antiviral activities. *Sarcophyte piriei* phytochemical constituents are potent modulators of antimicrobial resistant bacteria. Phenolic compounds exhibit antimicrobial activity through the disruption of cell membrane and the cell wall. Saponins act by penetrating the cells as a result of the lipophilic structure.

Flavonoids act via inhibition of the DNA gyrase and affecting bacterial energy metabolism. Naringenin antimicrobial activity act by suppression of pathogenicity genes. Tannins antimicrobial mechanism of action include: inhibition of extracellular microbial enzymes, deprivation of substrates and complexation of metal ions. Alkaloids act through efflux pump activity putative functionality. Terpenoids interfere with the cell membrane permeability and fluidity. Further studies need to be carried out on the plants extracts for structural elucidation and identification of additional phytochemicals. Despite the small number of toxicity studies carried out on these plants and some lacking any toxicity studies, immense analysis is required to ascertain their safety and efficacy of the plants in ethnomedicinal use, especially on their hepatotoxicity and carcinogenicity in humans. This review has shown that there are inadequate studies on phytochemicals, medicinal values and toxicity of *Sarcophyte piriei*. Hence, the need for more studies since *S. piriei* could aid in combating antimicrobial resistance menace when processed and used correctly.

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CONFLICT OF INTERESTS

The authors have not declared any conflicts of interests.

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REFERENCES

Akram MS, Cassandra L (2019). Quave. Medicinal Plants as a Reservoir of New Structures for Anti-infective Compounds. In: Ahmad I, Ahmad S, Rumbaugh KP, eds. Antibacterial Drug Discovery to Combat Multi-Drug-Restistant: Natural Compounds, Nanotechnology and Novel Synthetic Sources. Springer Nature Singapore Pte Ltd., pp. 1-680. doi:10.1007/978-981-13-9871-1

Angiosperm Phylogeny Group (2016). An update of the Angiosperm Phylogeny Group classification for the orders and families of flowering plants: APG IV. Botanical Journal of Linnean Society 181(1):1-20. doi:doi:10.1111/boj.12385

Britannica (Editors) (2017). 'Balanophoraceae". Encyclopedia Britannica. https://www.britannica.com/plant/Balanophoraceae.

Bussmann RW, Glenn A (2010). Medicinal plants used in Northern Peru for reproductive problems and female health. Journal of Ethnobiology and Ethnomedicine 6:1-12. doi:10.1186/1746-4269-6-30

Buzzin P, Arapitsas P, Goretti M, Branda E, Turchetti B, Pinelli P (2008). Antimicrobial and antiviral activity of hydrolysable tannins Minirev. Medicinal Chemistry 8(12):1179-1187

Cathrine L, Nagarajan NP (2011). Preliminary Phytochemical Analysis and Antibacterial Activity of Leaf Extracts of *Vitex Leucoxylon* L. F. International Journal of Current Pharmaceutical Research ISSN-3(2):2-4.

Chinsembu KC, Hedimbi M (2010). IJBMBR Ethnomedicinal plants and other natural products with anti-HIV active compounds and their putative modes of action. International Journal of Biotechnology and Molecular Biololgy 1(6):74-91.

Cocks M, Dold AP (2005). Imbhola yesiXhosa traditional Xhosa cosmetics: Published online.

Coppo E, Marchese A (2014). Antibacterial activity of polyphenols? Current Pharmaceutical and Biotechnology 15(4):380-390

Costa DA, Chaves MH, Silva WCS, Costa CLS (2010). Chemical constituents, total phenols and antioxidant activity of Sterculiastriata St. Hil. Acta Amazonica 40:207-212. 10.1590/S0044-59672010000100026

Cushine TT, Lamb AJ (2005). Antimicrobial activity of flavonoids. International Journal of Antimicrobial Agents 26(5):343-356

Da Silva LCN, Sandes JM, de Paiva MM, de Araújo JM, Figueiredo RCBQD (2013). Anti-Staphylococcus aureus action of three Caatinga fruits evaluated by electron microscopy. Natural Products Research. 27(6):1492-1496. 10.1080/14786419.2012.722090

Daglia M (2012). Polyphenols as antimicrobial agents Current Opinion in Biotechnology 23(2):174-181

De Wet H, Nciki S, van Vuuren SF (2013). Medicinal plants used for the treatment of various skin disorders by a rural community in northern Maputaland, South Africa. Journal of Ethnobiololgy and Ethnomedicine 9(1):1-10. doi:10.1186/1746-4269-9-51/FIGURES/3

De Wet H, Nzama VN, Van Vuuren SF (2012). Medicinal plants used for the treatment of sexually transmitted infections by lay people in northern Maputaland, KwaZulu-Natal Province, South Africa. South African Journal of Botany 78:12-20. doi:10.1016/J.SAJB.2011.04.002

Declan AG, Michaela W (2020). Multitarget approaches against multiresistant superbugs. ACS Infectious Diseases 6(6):1346-1365. DOI: 10.1021/acsinfecdis.0c00001

Delprete PG (2016). A New Species of Lophophytum and the First Report of Lathrophytum (Balanophoraceae) from the State of Goiás, Central Brazil Published by: Springer on behalf of Royal Botanic Gardens. Kew Bulletin 59(2):291-295.

Elujoba AA, Odeleye OM, Ogunyemi CM (2005). Traditional medicine development for medical and dental primary health care delivery system in Africa. African Journal Traditional Complementary and Alternative Medicine 2:46-61.

Fang L, He TT, Wang X, Zhou J (2018). Isolation and purification of galloyl, caffeoyl, and hexahydroxydiphenoyl esters of glucoses from Balanophora simaoensis by high-speed countercurrent chromatography and their antioxidant activities in vitro. Molecules 23(8). doi:10.3390/molecules23082027

Glen HF, Germishuizen G (2010). Botanical exploration of southern Africa. Botanical Exploration South Africa. Published online.

Gonzalez AM, Sato HA, Marazzi B (2019). Embryology in helosis cayennensis (Balanophoraceae): Structure of female flowers, fruit, endosperm and embryo. Plants 8(3). doi:10.3390/plants8030074

Hammond JW, Lu SM, Gelbard HA (2016). Platelet activating factor enhances synaptic vesicle exocytosis via PKC, elevated intracellular calcium, and modulation of synapsin 1 dynamics and phosphorylation. Frontiers in Celularl Neuroscience. 9(JAN2016):505. doi:10.3389/FNCEL.2015.00505/BIBTEX

Hannan MA, Rahman MA, Sohag AA, Uddin MJ, Dash R, Sikder MH, Rahman MS, Timalsina B, Munni YA, Sarker PP, Alam M. Black cumin (Nigella sativa L.) (2021). A comprehensive review on phytochemistry, health benefits, molecular pharmacology, and safety. Nutrients 13(6):1784.

Hayek SA, Gyawali R, Ibrahim SA (2013). Antimicrobial natural products" in Microbial Pathogens and Strategies for Combating them: Science, Technology and Education, edition A. Méndez-Vilas (Badajoz: FORMATEX) pp. 910-921.

Hyde MA, Wursten BT, Ballings P, Coates Palgrave M (2020). Flora of Zimbabwe. Flora of Zimbabwe. Published online.

Ignacimuthu S, Ayyanar M, Sankara K. Sivaraman (2006). Ethnobotanical investigations among tribes in Madurai District of Tamil Nadu (India). Journal of Ethnobiololgy and Ethnomedicine 2:1-7. doi:10.1186/1746-4269-2-25

International Council for Science (2015). Review of Targets for the Sustainable Development Goals: The Science Perspective:Paris: International Council for Science (ICSU). United Nations. 8-10 p.

Jachak SM, Jain R (2006). Current status of target-based antimycobacterial natural products. Antiinfect Agents Medicinal

Chemistry 5(2):123-133. doi:10.2174/187152106776359011

Karunamoorthi K, Jegajeevanram K, Vijayalakshmi J, Mengistie E. Traditional Medicinal Plants (2013b). A Source of Phytotherapeutic Modality in Resource-Constrained Health Care Settings. Journal of Evidence-Based Complementary & Alternative Medicine 18(1):67-74. doi:10.1177/2156587212460241

Karuniawati H, Hassali MAA, Suryawati S, Ismail WI, Taufik T, Hossain MS (2021). Assessment of Knowledge, Attitude, and Practice of Antibiotic Use among the Population of Boyolali, Indonesia: A Cross-Sectional Study. International Journal of Environmental Research and Public Health 18(16):8258. https://doi.org/10.3390/ijerph18168258

Khameneh B, Iranshahy M, Soheili V (2019). Review on plant antimicrobials: a mechanistic viewpoint. Antimicrobial Resistance and Infection Control 8:118. https://doi.org/10.1186/s13756-019-0559-6

Khan R, Islam B, Akram M (2009). Antimicrobial Activity of Five Herbal Extracts Against Multi Drug Resistant (MDR) Strains of Bacteria and Fungus of Clinical Origin. Published online: 586-597. doi:10.3390/molecules14020586

Kipkore W, Wanjohi B, Rono H, Kigen G (2014). A study of the medicinal plants used by the Marakwet Community in Kenya. Journal Ethnobiology Ethnomedicine 10(1):1-22. doi:10.1186/1746-4269-10-24

Kiura JM (2011). Medicinal trees in smallholder agroforestry systems: assessing some factors influencing cultivation by farmers East of Mt. Kenya | World Agroforestry | Transforming Lives and Landscapes with Trees. Accessed August 16, 2022. https://www.worldagroforestry.org/publication/medicinal-trees-smallholder-agroforestry-systems-assessing-some-factors-influencing-0

Lovina LAC, Staden J Van, Hutchings A (1992). Exocarpic acid and other compounds from tubers and inflorescences of Sarcophyte sanguinea. Phytochemistry 31(11):3929-3931. doi:10.1016/S0031-9422(00)97556-3

Luke Q (2017). Plants of Conservation Interest of the Nairobi National Park. doi:10.13140/RG.2.2.13794.12487

Lumlerdkij N (2018). Thai Traditional Medicine as a Source for Cancer Prevention: From Local Concepts to the Discovery of Potential Chemopreventive Extracts. PhD Thesis. University College of London.

MacOwan P, Clinton GP (2015). The Correspondence of Peter MacOwan (1830 - 1909) and George William Clinton (1807 - 1885). Accessed September 6, 2022. https://www.researchgate.net/publication/286912846_The_Correspondence_of_Peter_MacOwan_1830_-_1909_and_George_William_Clinton_1807_-_1885

Mahammed A, Mitiku H, Mohammed J (2020). In vitro antibacterial activity of selected medicinal plants extract used in traditional treatment of common human wound infection in Fafan zone, Somali region, Ethiopia. International Journal of Herbal Medicine 8(6):6-11.

Maroyi A (2017). Elephantorrhiza elephantina: Traditional Uses, Phytochemistry, and Pharmacology of an Important Medicinal Plant Species in Southern Africa. Evidence-based Complementary and Alternative Medicine. doi:10.1155/2017/6403905

Mbakazi Y, Kappo AP, Soyingbe OS (2022l). GC/TOF-MS-based phytochemical analysis, in vitro antiproliferative effects, antioxidant, and antibacterial activity of *Sarcophyte sanguinea* subsp. *piriei* (Hutch.) B. Hansen. South African of Journal Botany 150:752-758. doi:10.1016/J.SAJB.2022.08.003

Mthi S, Rust JM, Morgenthal TL, Moyo B (2018). Journal of Medicinal Plants Research An ethno-veterinary survey of medicinal plants used to treat bacterial diseases of livestock in three geographical areas of the Eastern Cape Province, South Africa 12(18):240-247. doi:10.5897/JMPR2017.6444

Muriuki J (2011). Medicinal Trees in Smallholder Afroforestry Systems: Assessingsome Facors Influencing Cultivation by Some Farmers East of Mount Kenya University of Natural Resources and Applied Life Sciences Vienna.

Ndhlala AR, Thibane VS, Masehla CM, Mokwala PW (2022). Ethnobotany and Toxicity Status of Medicinal Plants with Cosmeceutical Relevance from Eastern Cape, South Africa. Plants 11(11):1451. https://doi.org/10.3390/plants11111451

Newman GMC (2013). Natural products: A continuing source of novel drug leads. Biochimica et Biophysica Acta 1830(6):3670-3695. doi:10.1038/jid.2014.371

Nickrent DL (2020). Parasitic angiosperms: How often and how many? Taxonomy 69(1):5-27. doi:10.1002/tax.12195

Njume C, Afolayan A, Ndip R (2009). An overview of antimicrobial resistance and the future of medicinal plants in the treatment of Helicobacter pylori infections African Journal of Pharmacy and Pharmacology 3(13):685-699.

Nkwanyana MN. An ethnobotanical and antidiarrhoeal investigation of plants used traditionally in the Maputaland area homesteads Published online 2013. Accessed September 6, 2022. http://uzspace.unizulu.ac.za/xmlui/handle/10530/1260

Obiloma AA, Madu WC, Osuji GO, Ampim PA, Weerasooriya AD, Carson LE (2019). Terpene-Rich Medicinal Plant Spices for Flavoring of Processed Tropical Food. American Journal Plant Sciences 10(4):572-577. doi:10.4236/AJPS.2019.104041

Ogundaini A, Farah M, Perera P, Samuelsson G, Bohlin L (1996). Isolation of two new antiinflammatory biflavanoids from *Sarcophyte piriei.* Journal of Natural Products 59(6):587-590. doi:10.1021/np960386k

Olajuyigbe OO, Afolayan AJ (2012). Ethnobotanical survey of medicinal plants used in the treatment of gastrointestinal disorders in the Eastern Cape Province, South Africa. Journal of Medicinal Plants Research 6(18):3415-3424. doi:10.5897/JMPR11.1707

Paduch R, Kandefer-Szerszen M, Trytek M, Fiedurek M, Terpenes J (2007). Substances useful in human healthcare. Archivum Immunology and Therapeutic Experiments 55(5):315-27.

Ramulondi M (2017). Toxicology and herb-drug interaction of selected anti-hypertension plants used by lay persons in Northern KwaZulu-Natal (South Africa). Published online 2017. Accessed September 6, 2022. http://uzspace.unizulu.ac.za/xmlui/handle/10530/1590

Hossain S, Urbi Z, Karuniawati H, Mohiuddin RB, Moh Qrimida A, Allzrag AMM, Ming LC, Pagano E, Capasso R Andrographis paniculata (Burm. f.) Wall. ex Nees (2021). An Updated Review of Phytochemistry, Antimicrobial Pharmacology, and Clinical Safety and Efficacy. Life 11(4):348. https:// doi.org/10.3390/life11040348

Sarcophyte sanguinea subsp. sanguinea | PlantZAfrica. Accessed August 16, 2022. http://pza.sanbi.org/sarcophyte-sanguinea-subsp-sanguinea

She GM, Hu JB, Zhang YJ, Yang CR (2010). Phenolic constituents from Rhopalocnemis phalloides with DPPH radical scavenging activity. Pharmaceutical Biology 48(1):116-119. doi:10.3109/13880200903032757

Sustainability Today - Google Books. Accessed September 6, 2022. https://books.google.co.ke/books?hl=en&lr=&id=WKlXrzH1uagC&oi=fnd&pg=PA45&dq=Ndawonde,+B.+G.,+Dlamini,+E.+T.,+%26+Imenda,+S.+N.+(2012).+Indigenous+knowledge,+women+and+issues+of+sustainable+development.+WIT+Transactions+on+Ecology+and+the+Environment,+167,+45-54.&ots=LQG0lVokMn&sig=1ffSVvWfDm2FncBDs7KrfG2NbVs&redir_esc=y#v=onepage&q&f=false

Taguri T, Tanaka T, Kouno I (2006). Antibacterial spectrum of plant polyphenols and extracts depending upon hydroxyphenyl structure. Biological and Pharmaceutical Bulletin 29:2226–2235. 10.1248/bpb.29.2226

Taylor WF, Yanez M, Moghadam SE, Moridi Farimani M, Soroury S, Ebrahimi SN, Tabefam M, Jabbarzadeh E (2019). 7-epi-Clusianone, a multi-targeting natural product with potential chemotherapeutic, immune-modulating, and anti-angiogenic properties. Molecules 24(23):4415.

Thulin M, Royal (1993). Botanic Gardens K. Flora of Somalia. Published online. Accessed August 16, 2022. https://press.uchicago.edu/ucp/books/book/distributed/F/bo9855185.html

Thulin M (2008). Sarcophyte piriei Hutch. [family Balanophoraceae]. Http://plants.jstor.org/stable/105555/al.ap.specimen.k000430580. Published online 2006:1-4.

Tian F, Li B, Ji B, Zhang G, Luo Y (2009). Identification and structure–activity Relationship of gallotannins separated from Galla chinensis. LWT-Food Science and Technology 42(7):1289-1295. 10.1016/j.lwt.2009.03.004

Vandeputte OM, Kiendrebeogo M, Rasamiravaka T, Stevigny C, Duez P, Rajaonson S (2011). The flavanone naringenin reduces the production of quorum sensing-controlled virulence factors in Pseudomonas aeruginosa PAO1 Microbiology 157(7):2120-2132

Vikram A, Jesudhasan PR, Jayaprakasha G, Pillai SD, Jayaraman A, Patil BS (2011). Citrus flavonoid represses Salmonella pathogenicity island 1 and motility in *S. Typhimurium* LT2 International Journal of Food and Microbiology 145(1):28-36.

Wang X, Liu Z, Qiao W, Cheng R, Liu B, She G (2012). Phytochemicals and biological studies of plants from the genus Balanophora. Chemistry Central Journal 6(1):11-18. doi:10.1186/1752-153X-6-79

World Health Organization (WHO) (2020). Antimicrobial resistance, https://www.who.int/news-room/fact

Williams VL, Falcão MP, Wojtasik EM. Hydnora abyssinica (2011): Ethnobotanical evidence for its occurrence in southern Mozambique. South African Journal of Botany 77(2):474-478. doi:10.1016/J.SAJB.2010.09.010

Yuan H, Ma Q, Ye L, Piao G (2016). The traditional medicine and modern medicine from natural products. Molecules 21(5).