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MINI-REVIEW ARTICLE

Garcinia livingstonei T. Anderson: A Potential Source for Bioactive Constituents

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Abstract: *Garcinia livingstonei* T. Anderson (African mangosteen) is a member of family Clusiaceae and is native to South Africa. It is distributed from Malaysia to the Philippines, Burma and India. The plant is used traditionally in the treatment of diarrhea. It contains various chemical constituents belonging to biflavonoids, benzophenones and xanthones. *Garcinia livingstonei* is reported to possess beneficial pharmacological activities as anti-oxidant, anti-bacterial, anti-viral and cytotoxicity. This review aims at summarizing the available literature on the botanical features, phytochemical, ethnomedicinal and pharmacological activities of *Garcinia livingstonei.*

Keywords: *Garcinia livingstonei*, morphological features, traditional uses, nutritive value, phytoconstituents, pharmacological activity.

1. INTRODUCTION

For thousands of years, natural compounds, mostly from plants, have been the mainstay of traditional medicine. They also have been the source of lead compounds for modern medicine [1]. *Garcinia livingstonei* belongs to the family Clusiaceae. Genus *Garcinia* includes more than 250 species distributed in the tropical and temperate regions of Southeast Asia, Central and South America [2, 3]. It is a dioecious evergreen tree with leathery leaves in opposite pairs or whorls and polygamous flowers. The fruit is edible, juicy with a slightly acidic and sweet apricot-like flavor and can be fermented to produce alcoholic beverages [4-7]. Traditionally, different parts of this plant are used for the treatment of cough, fever, parasitic diseases, toothache [8, 9] in addition to treatment of abdominal pains during pregnancy and aid in childbirth [10, 11]. Several secondary metabolites were reported in *Garcinia* species, including xanthones, flavonoids, benzophenones, lactones and phenolic acids [12]. *G. livingstonei* T. Anderson is a rich source of biflavonoids, benzophenones and xanthones [4, 13, 14]. *G. livingstonei* was reported to exhibit several therapeutic benefits, including anti-oxidant, anti-human immunodeficiency virus (HIV), anti-bacterial in addition to inhibition of melanin formation (skin whitening) which is beneficial in cosmetic preparation. Isolated compounds from *G. livingstonei* showed melanin inhibitory activity which increased activity of the plant as a cosmetic agent [4, 15, 16]. The aim of this review is to highlight the importance of this plant and its phytoconstituents.

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2. MORPHOLOGICAL AND MICROSCOPICAL FEATURES

G. livingstonei is a dioecious evergreen tree. It reaches 10-16 meters in height, glabrous with three lateral branches at the node. Leaves are bluish-green in color, coriaceous and petiolate. The texture is leathery or waxy, and the arrangement is opposite pairs or whorls. Lamina shape varies from lanceolate to oblanceolate, obovate, oblong or orbicular. Margin is shallowly crenated. Apex is emarginate, apiculate or round to acute. Base is crenate to round. Fruits are orange-yellow, orange to reddish-orange in color, obovoid to globose in shape, filled with yellow latex, 1-2 seeded, having thin skin and its diameter is 10-40 mm. Flowers are polygamous, have long pedicels, they consist of fascicles; the axils of the older leaves have from five to fifteen or more, while old wood has from four to twenty, 35 mm in length, with five to eight obovate to orbicular petals that is greenish-white to pale yellow in color having longitudinal glandular lines orange to reddish in color; and four unequal sepals which are arranged in two opposite and decussate pairs. Stamens are free and numerous in male flowers and embedded in a fleshy cushion which is the result of united fasciclodes. Staminodes are few in the female flowers and embedded in a fleshy fasciclodal ring beneath the ovary, which is globose; locules number is two or three enclosed in a fleshy and bi-lobed stigma. Seeds number is one or two, 1.5 to 2 cm in length, and the shape of the seeds is cylinder or plano-ovoid. Outer bark of *G. livingstonei* is grey, but underneath the superficial layer is orange, smooth in younger stems, rough, with prominent vertical cracks in mature stem resembles a mosaic appearance, while the inner bark is yellowish red, relatively smooth, saturated with many small dots (exudates) that are dark reddish in color (Figs. **1** and **2**) [5-7].

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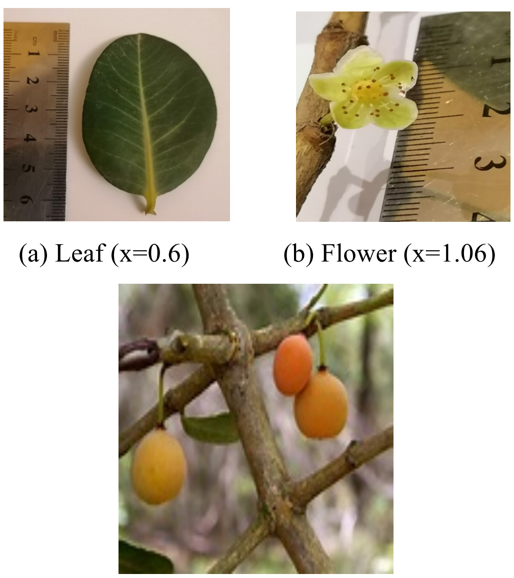
Fig. (1). Tree of *G. livingstonei* cultivated in Egypt. (*A higher resolution / colour version of this figure is available in the electronic copy of the article*).



(a) Leaf (x=0.6) (b) Flower (x=1.06)

(c) Fruit

Fig. (2). Different parts of *G. livingstonei.* (*A higher resolution / colour version of this figure is available in the electronic copy of the article*).

2.1. *Garcinia livingstonei* T. Andersson Synonyms

G. angolensis Vesque, *G. ferrandii* var. affiis Chiov., *G. ferrandii* Chiov., *G. pendula* Engl., G. *pallidinervia* Engl. [10].

2.2. Common English Names

African Mangosteen, Wild Mangosteen, Imbe, Inbe, Gupenja, Lowveld Mangosteen, Mwausungulu, Pama, Veld Mangosteen, Wild Plum, Livingstone's garcinia [6, 10].

2.3. Habitat and Distribution

African mangosteen originates in Sunda Island and the Moluccas or Spice Islands in Indonesia. *G. livingstonei* was spreading from Malaysia to the Philippines and India. It was introduced in England in 1789, Sri Lanka in 1800 and Australia in 1854. The tree is widespread in many countries, including Egypt, the warmer parts of Africa, extending from the north of Durban to Somalia and Guinea. In Southern Africa, *G. livingstonei* spreads in Limpopo and Zambezi Valleys [5, 17, 18]. In South Africa, It spreads in different regions as scrub, open woodland and in the forest; while in Zimbabwe, the plant is found along the rivers in the Lowveld and in Riparian zone. In Zambia, it is in termite mounds, Munga areas and Mopane woodland. The plant is found on rocky soil and in open coastal forest (Fig. **3**) [19].

2.4. Traditional Uses

The seeds, pulp, leaves and bark of *G. livingstonei* had been implicated traditionally in the treatment of diarrhea and digestive problems [7, 20, 21]. The dried roots were used to treat abdominal pains during pregnancy and aid in childbirth [10, 11]. While the stem bark was used as skin lightening agent [4]. Moreover, the fruits and stems were used in the treatment of cough, fever and parasitic diseases [9]. Bark was used to treat internal parasites [7]. In addition, root infusion was used as an aphrodisiac and for the treatment of impotency, while the decoction for the treatment of toothache. Also, when the stem was boiled and eyes were exposed to the vapors effective relief was achieved [8].

2.5. Nutritive Value and Proximate Analysis

G. livingstonei was reported to have high nutritional value. The fruits and seeds contain carbohydrates with content ranges (37.67 ± 0.02 - 95.02 ± 0.01%), crude fiber (2.93 ± 0.01 - 21.13 ± 0.02%), crude protein (0.65 ± 0.02 - 31.76 ± 0.21) and crude fat (1.23 ± 0.04 - 19.55 ± 0.02%). Minerals were also detected, such as nitrogen (6800 - 12940 mg/kg), calcium (4200 - 7600 mg/kg), potassium (2753 - 10830 mg/kg), magnesium (1440 - 2900 mg/kg), phosphorus (391.72 - 577.79 mg/kg), iron (156.6 - 354.6 mg/kg), manganese (7.7 - 246.8 mg/kg), sulphur (4.48 - 21.64 mg/kg), zinc (14.2 - 40.6 mg/kg) and copper (9.7 - 354.6 mg/kg) [5]. This emphasizes the importance of edible fruits for healthy human growth [22, 23].

2.6. Seed Oil

G. livingstonei seed oil is brown in color and semisolid at room temperature. Its specific gravity was 0.90 ± 0.1, while viscosity was 45.71 ± 00 $Nm^{-2}s$. The free fatty acid content was approximately 1.88% calculated as oleic acid, major unsaturated fatty acid was oleic acid (54.55%) followed by linoleic acid (5.67%) which was reported to have anti-inflammatory effects, play role in immune system and decrease the risk of coronary heart disease**.** On the other hand, the main saturated fatty acid was recognized as palmitic acid (32.64%) [5, 24, 25].

2.7. Phytochemical Studies

Phytochemical screening of *G. livingstonei* revealed the presence of phenolics and steroids in roots, stems and fruits [26], while the bark contains alkaloids, terpenoids, saponins and phenolics including flavonoids, anthraquinones and tan-

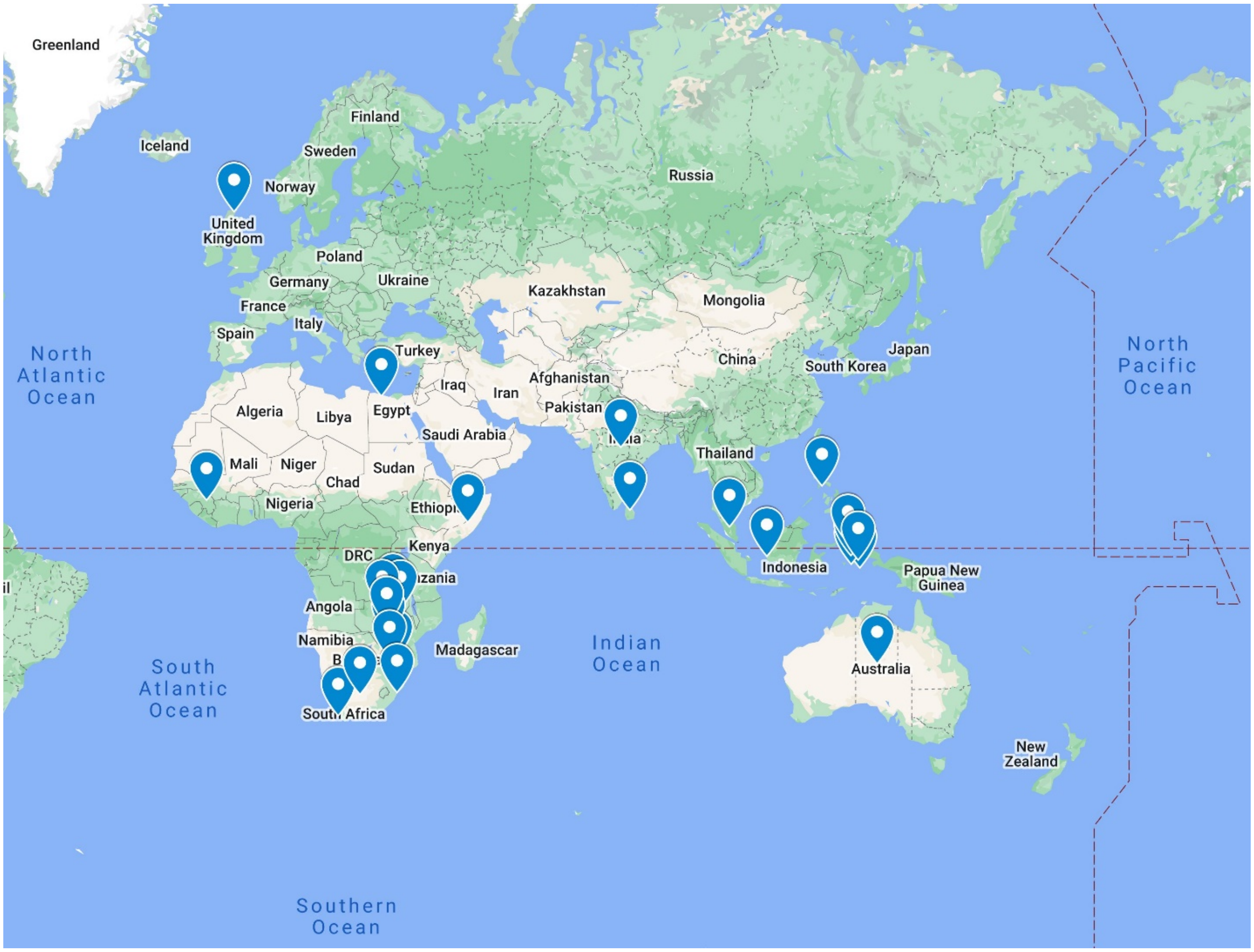


Fig. (3). Distribution of *G. livingstonei*. (*A higher resolution / colour version of this figure is available in the electronic copy of the article*).

Table 1. Reported total phenolics of different parts of *Garcinia livingstonei* T. Anderson.

Plant Parts	Phenols (mg GAE/g)	Flavonoids (µg QE/g)	Tannin (µg/g)	References
Fruit	115.5 ± 34.1	-	-	[15]
Epicarp	174.02 ± 0.17	49.85 ± 0.06	7.96 ± 0.02	[5]
Mesocarp	83.35 ± 0.08	55.32 ± 0.11	4.24 ± 0.01	
Seed coat	10.72 ± 0.00	19.25 ± 1.15	0.96 ± 0.00	
Seed	106.41 ± 0.15	99.98 ± 0.23	1.57 ± 0.00	

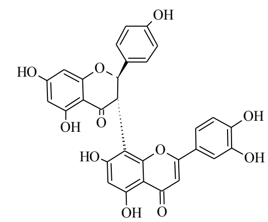
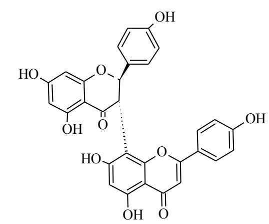
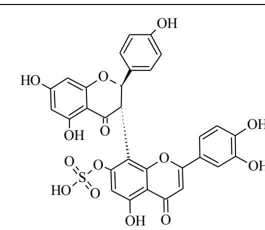
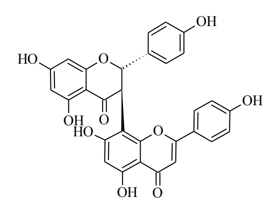
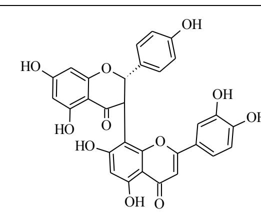
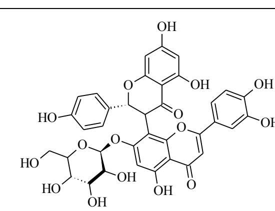
nins [21, 27]. Estimation of phenolic content of different parts of *G. livingstonei* is demonstrated in Table **1** [5, 15]. The total phenolic content of fruits was 115.5 ± 34.1 mg GAE/g of dry fruit; while the epicarp of fruit contains the highest phenolic and tannin contents (174.02 ± 0.17 mg GAE/g and 7.96 ± 0.02 µg/g, respectively); the highest flavonoids were reported in the seeds with values 99.98 ± 0.23 µg QE/g [15]. Moreover, the oxalate content in the fruit epicarp was (0.03 ± 0.01 µg/g), while the highest amount was found in the seed (0.30 ± 0.19 µg/g). On the other hand, mesocarp and seed coat contains nearly the same amount (0.04 µg/g) [5].

Different classes of constituents reported in *G. livingstonei* as biflavonoids, benzophenones, xanthones and triterpenes, are represented in Tables **2-6**.

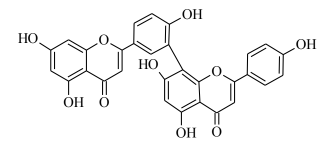
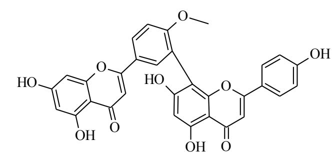
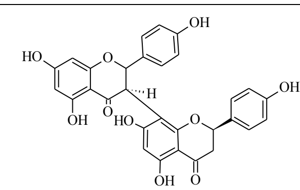
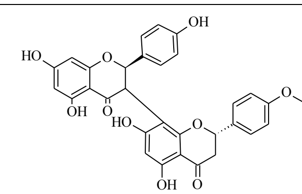
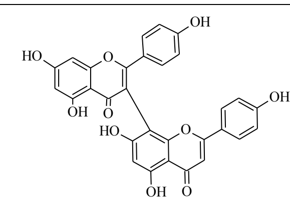
2.8. Biflavonoids

Bifalvonoids are flavonoid dimers resulting from the connection of two units of flavone, flavanone, flavanonol, flavonol or aurones or mixtures of these, in addition to less common chalcone and isoflavone dimers [28]. Several biological activities were reported for biflavonoids, including

Table 2. Reported biflavonoids from *Garcinia livingstonei* T. Anderson.

Biflavonoids					
Compound Name	**Plant Part**	**Extracts/Fractions**	**Geographical Distribution**	**References**	**Chemical Structures**
Morelloflavone Type					
Morelloflavone	Heartwood, bark and leaves	Acetone extract	India	[32]	
	Stem bark	Ethyl acetate/methanol extract	South Africa	[4]	
	Stem wood	Ethyl acetate and acetone extracts	Kasane	[33]	
	Fruits	Ethyl acetate fraction	Florida	[14]	
	Root bark	Ethyl acetate soluble extract	Tanzania	[13]	
BGH-111 (4′,4″,5,5″,7,7″-hexahydroxy-3 (8″-) flavonyl flavanone	Heartwood, bark and leaves	Acetone extract	India	[32]	
Morelloflavone-7″-sulphate	Stem bark	Ethyl acetate/ methanol extract	South Africa	[4]	
Volkensiflavone	Fruits	Methanol extract	Florida	[15]	
		Ethyl acetate frac-tion		[14]	
	Stem wood	Ethyl acetate and acetone extracts	Kasane	[33]	
	Root bark	Ethyl acetate soluble extract	Tanzania	[13]	
Fukugetin	Fruits	Methanol extract	Florida	[15]	
Fukugiside	Fruits	Ethyl acetate frac-tion	Florida	[15]	
		Methanol extract		[14]	

(Table 2) Contd….

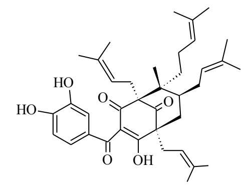
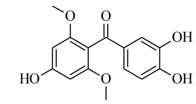
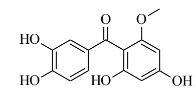
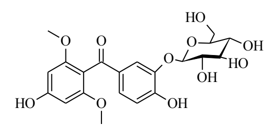
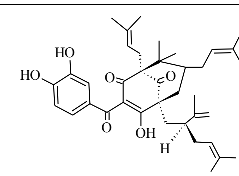
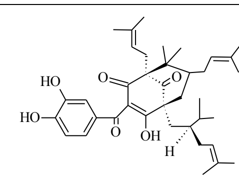
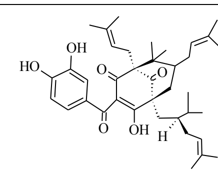
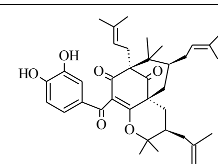
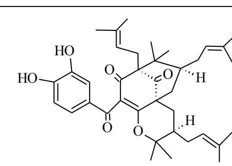
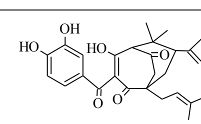
Biflavonoids					
Compound Name	**Plant Part**	**Extracts/Fractions**	**Geographical Distribution**	**References**	**Chemical Structures**
Amentoflavone Type					
Amentoflavone	Heartwood, bark and leaves	Acetone extract	India	[32]	
	Fruits	Methanol extract	Florida	[15]	
		Ethyl acetate fraction		[14]	
	Leaves	Ethyl acetate fraction	South Africa	[9, 48, 51]	
4′-monomethoxyamentoflavone(Podocarpusflavone A)	Twigs	Ethyl acetate extract	Kasane	[33]	
	leaves	Ethyl acetate fraction	South Africa	[9, 48, 51]	
	Heartwood, bark and leaves	Acetone extract	India	[32]	
GB-1a Type					
GB-1a	Stem wood	Ethyl acetate and acetone extracts	Kasane	[33]	
Ent-naringeninyl-(I-3*α*,II-8)-4’-*O*-methylnaringenin	Root bark	Ethyl acetate soluble extract	Tanzania	[13]	
IC3′-IIC8″ Type					
3,8″-biapigenin	Fruits	Ethyl acetate fraction	Florida	[14]	

antioxidant, antimicrobial, antiallergenic, anti-inflammatory, hepatoprotective and antiviral activities [29]. There are many types of biflavonoids depending on position and type of linkage between the two flavonoids [30, 31]. Reported biflavonoids in *G. livingstonei* are shown in Table **2**. Morelloflavone type biflavonoids; namely morelloflavone was isolated from the heartwood and bark in India [32], fukugetin and fukugiside were isolated from the fruits in Florida [14, 15]. Amentoflavone type namely, amentoflavone and podocarpusflavone A were isolated from the leaf extract in India [32]. GB-1a type was isolated from the twigs and stem wood in Kasane [33], in addition, ent-naringeninyl-(I-3α,II-8)-4’-O-methylnaringenin was extracted from the root bark in Tanzania [13] and 3,8″-biapigenin that belongs to IC3′-IIC8″ type was isolated from the fruits in Florida [14].

2.9. Benzophenones

Most of the isolated benzophenones belong to polyisoprenylated benzophenones that have 13-carbon skeleton forming two rings connected by a carbonyl group. Benzophenones reported in family Clusiaceae are characterized by the presence of two to five isoprene units [34]. Benzophenones have several pharmacological activities as HIV inhibitory activity [35] and were used as skin lightening agents [4]. Benzophenones reported in *G. livingstonei* are demonstrated in Table **3**. Guttiferone A was isolated from the fruit in Tanzania as the principal active constituent through bioassay guided fractionation of the HIV inhibitory activity [35] and Guttiferone A and E were also isolated from the fruits in Florida [14]. Moreover, 4,3′,4′-trihydroxy-2,6-dimethoxy-benzophenone and its glycoside; 3′-*β*-D-glucosyloxy-4,4′-dihydroxy-2,6-dimethoxy-benzophenone were isolated

Table 3. Reported benzophenones from *Garcinia livingstonei* T. Anderson.

Benzophenones					
Compound Name	**Plant Part**	**Extracts/Fractions**	**Geographical Distribution**	**References**	**Chemical Structures**
Guttiferone A	Fruits	Dichloromethane/ methanol extract	Tanzania	[35]	
	Fruit peel	Ethyl acetate extract	South Africa	[4]	
	Fruits	Ethyl acetate fraction	Florida	[14]	
	Fruits	Methanol extract		[15]	
4,3′,4′-trihydroxy-2,6-dimethoxybenzophenone	Twigs	Methanol extract	Kasane	[33]	
3′,4,4′,6-tetrahydroxy-2-methoxybenzophenone					
3′-*β*-D-glucosyloxy-4,4′-dihydroxy-2,6-dimethoxy-benzophenone	Stem wood	Ethyl acetate and acetone extracts			
Guttiferone E	Fruits	Methanol extract	Florida	[15]	
Guttiferone K		Ethyl acetate fraction		[14]	
Xanthochymol		-			
Cycloxanthochymol					
Isoxanthochymol					
Gambogenone					

together with 4,6,3′,4′-tetrahydroxy-2-methoxybenzophenone [33]. Other benzophenones were also isolated, namely; guttiferone E and K, xanthochymol, cycloxanthochymol, isoxanthochymol and gambogenone [14].

2.10. Xanthones

The xanthone skeleton is a conjugated ring system composed of two aromatic rings B fused through a carbonyl group and an oxygen atom; the word "xanthone" is derived from the Greek word xanthos, meaning yellow. Xanthones have diverse pharmacological properties, including antibacterial, antiviral, antioxidant, anti-inflammatory, anti-coagulant and cytotoxic activity against lung cancer [13, 36]. As shown in Table **4**, xanthones reported in *G. livingstonei* extracted by dichloromethane from the root bark of South Africa afforded 1,4,5-Trihydroxy-3-(3-methylbut-2-enyl)-9H-xanthen-9-one, 6,11-Dihydroxy-2,2-dimethyl-pyrano[3,2-c] xanthen-7(2H)-One, 4-(3′,7′-dimethylocta-2′, 6′-dienyl)-1,3,5-hydroxy-9H-xanthen-9-One, 6,l1-Dihydroxy-3-methyl-3-(4-methylpent-3-enyL)-3H,7H-pyrano[2,3-c]xanthen-7-one and 12b-hydroxy-des-Dgarcigerrin A [37]. While garcilivin A, B and C were isolated from the root bark [38]. Alloathyriol and 6-deoxyisojacareubin, norathyriol and montixanthone were also reported in the twigs and stem wood [14, 33]. In addition, garcilivin A and C, dihydroxy-3-methyl-3-(4-methylpent-3-enyl)pyrano[2,3-*c*]xanthen-7(3*H*)-one, 4[(*E*)-3,7-dimethylocta-2,6-dienyl]-1,3,5-trihydroxy-9*H*-xanthen-9-one, and 1,4,5-trihydroxy-3-(3-methylbut-2-enyl)-9*H*-xanthen-9-one were isolated from the root bark [13].

2.11. Flavonoid

Flavonoid was represented by only eriodictyol obtained from the seeds of *G. livingstonei* [39]. Eriodictyol possesses anti-oxidant, anti-diabetic and anti-inflammatory activities [40]. This encourage further studies to reveal other related compounds in Table **5**.

2.12. Triterpenes

Betulin, betulin aldehyde and other triterpenes were isolated from the stem of *G. livingstonei*, in addition to sargaol, which was isolated from the hexane fraction of the fruit kernels (Table **6**) [4, 33].

2.13. The Pharmacological Activities

Reviewing the available literature, *G. livingstonei* reported benefits from almost all plant parts in addition to its isolated compounds (Tables **7**-**11**). The plant showed wide antimicrobial activity against several micro-organisms such as bacteria, virus and fungi, in addition to anti-oxidant and cytotoxic activities [15, 26, 27, 41].

2.14. Anti-microbial Activity

Diseases caused by bacteria have a great effect on human health [42]. Nowadays, there is great interest in the usage of natural antibacterial remedies extracted from plants [43]. Other *Garcinia* species showed good activity as antibacterial against a broad spectrum of bacteria, for example, the twigs of *G. hombroniana* and the acetone extract and fractions of *G. goudotiana* leaves and their isolated compounds exhibited potent antibacterial activity against Gram-positive bacteria [44, 45]; also, *G. kola* seed and some volatile constituents of *G. atroviridis* fruits were effective against Gram-positive and Gram-negative bacteria [46, 47]. Concerning *G. livingstonei*, published data revealed that the acetone extract of leaves showed good antibacterial activity against *Staphylococcus aureus*, *Enterococcus faecalis*, *Escherichia coli* and *Pseudomonas aeruginosa* with MIC (0.07, 0.04, 0.06 and 0.63 mg/ml, respectively). The fractions were also evaluated against the four bacteria and results showed that the most effective fraction against *E. coli* was chloroform fraction with MIC = 0.095 mg/ml; concerning *S. aureus*, the ethyl acetate extract (MIC = 0.195 mg/ml) was the best. The most effective fraction of *E. faecalis* and *P. aeruginosa* was Carbon tetrachloride fraction (MIC = 0.115 mg/ml) [48-50]. MIC values for the isolated 4′-methoxyamentoflavone were 8, 40, 60 and 8 µg/ml against *E. coli*, *S. aureus*, *P. aeruginosa* and *E. faecalis*, respectively. While, for amentoflavone the MIC values were 40, 40, 100 and 60 µg/ml, respectively [9]. MIC for amentoflavone and 4′-monomethoxyamentoflavone against *Mycobacterium smegmatis* were 0.60 ± 0.70 and 1.40 ± 1.56 mg/ml, respectively [51]. Aqueous extract of *G. livingstonei* bark showed MIC of 1.56 mg/mL on all the tested bacteria except for *E. coli*, and *Shigella sonnei* MIC was 0.78 mg/mL, while MIC of the methanol extract was 0.39 mg/mL for all tested bacteria with the exception of *E. coli*, and *S. sonnei* (MIC = 0.78 mg/mL); while MBC of the water and methanol extracts was 12.5 mg/mL for all the tested bacteria except for *S. aureus* MBC of methanol extract was 6.25 mg/mL [21]. The antimicrobial activity of the dichloromethane:methanol (1:1) extract of the bark was evaluated against twelve pathogens and the extract displayed an average broad-spectrum MIC value of 270 µg/mL [27]. Also, the methanol and dichloromethane extracts of the bark were screened against ten different bacteria and the lowest MIC were against *Bacillus cereus* which is equal 0.06 and 0.12 mg/mL, respectively [7].

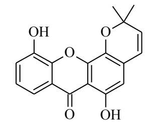
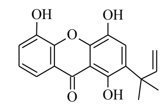
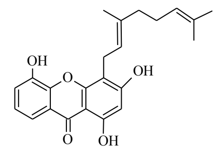
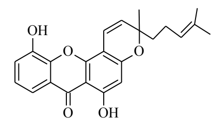
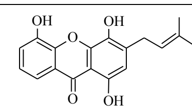
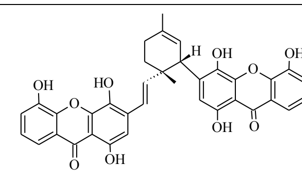
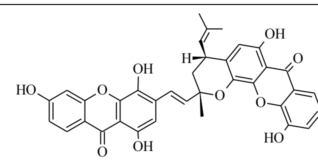
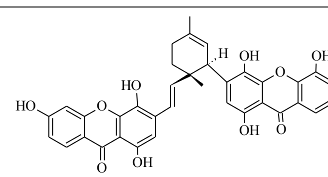
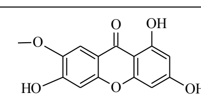
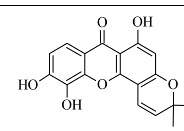
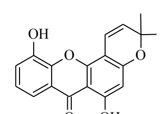
2.15. Therapeutic Index

Therapeutic index (TI) which is the ratio of cytotoxicity to MIC; for the water extract of the bark recorded the highest therapeutic index against *E. coli* and *S. sonnei* with value of 0.98; while for *S. aureus*, *K. oxytoca* and *S. enterica*; it was 0.49. Therapeutic index for methanolic bark extract could not be determined as the value of its cytotoxicity was > 400 µg/ml [21].

2.16. Antioxidant Activity

Antioxidants are our first line of defense against free radical damage that when present at low concentration compared with that of an oxidizable substrate significantly delay or inhibit oxidation of that substrate. The need for antioxidants becomes even more critical with increased exposure to free radicals, pollution, drugs and stress [52, 53]. The approved antioxidant activity of *Garcinia* species was reported, for example, the methanolic extract of *G. penducalata*, the twigs of *Garcinia merguensis*, the isolated biflavonoids from the epicarp of *Garcinia brasiliensis* and chloroform fraction of the methanol extract of *Garcinia morella* fruit, and different

Table 4. Reported xanthones from *Garcinia livingstonei* T. Anderson.

Xanthones					
Compound Name	**Plant Part**	**Extracts/Fractions**	**Geographical Distribution**	**References**	**Chemical Structures**
6,11-Dihydroxy-2,2-dimethyl-pyrano[3,2-c] xanthen-7(2H)-one	Root bark	Dichloromethane extract	South Africa	[37]	
12b-Hydroxy-des-dgarcigerrin A					
4[(*E*)-3′,7′-Dimethylocta-2′,6′-dienyl]-1,3,5-trihydroxy-9*H*-xanthen-9-one	Root bark	Dichloromethane and chloroform extracts	South Africa and Tanzania	[13, 37]	
6,11-Dihydroxy-3-methyl-3-(4-methylpent-3-enyl)-3H,7H-pyrano[2,3-*c*]xanthen-7-one		-			
1,4,5-Trihydroxy-3-(3-methylbut-2-enyl)-9H-xanthen-9-one	Root bark	Dichloromethane and chloroform extracts	South Africa and Tanzania	[13, 37, 38]	
Garcilivin A				[13, 38]	
Garcilivin B		Dichloromethane extract	South Africa	[38]	
Garcilivin C		Dichloromethane and ethyl acetate soluble extracts	South Africa and Tanzania	[13, 38]	
Alloathyriol	Fruits	Ethyl acetate fraction	Florida	[14]	
Isojacareubin	Fruit kernels	Dichloromethane extract	South Africa	[4]	
6-deoxyisojacareubin					
	Stem wood	Chloroform extract	Kasane	[33]	

(Table 4) Contd….

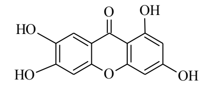
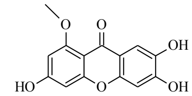
Xanthones					
Compound Name	**Plant Part**	**Extracts/Fractions**	**Geographical Distribution**	**References**	**Chemical Structures**
Norathyriol	Twigs	Methanol extract	-	-	
Montixanthone	Stem wood	Ethyl acetate and acetone extracts			

Table 5. Reported flavonoid from *Garcinia livingstonei* T. Anderson.

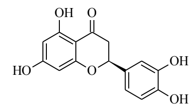
Compound Name	Plant Part	References	Chemical Structures
Eriodictyol	Seeds	[39]	

Table 6. Reported triterpenes from *Garcinia livingstonei* T. Anderson.

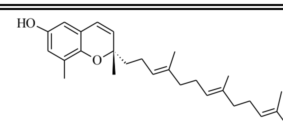
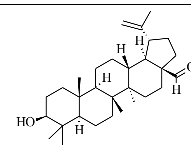
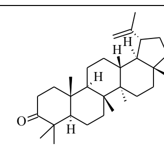
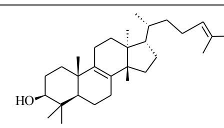
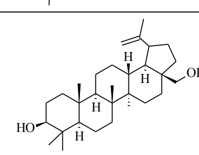
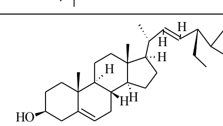
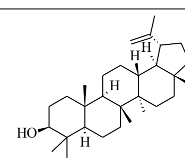
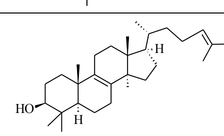
Compound Name	Plant Part	Extracts/Fractions	Geographical Distribution	References	Chemical Structures
Sargaol	Fruit kernels	Hexane fraction	South Africa	[4]	
Betulin aldehyde	Stem bark	Dichloromethane extract			
Lupenone					
Euphol		-			
Betulin					
	Stem wood	Ethyl acetate and acetone extracts	Kasane	[33]	
Stigmasterol		Chloroform extract			
	Stem bark	Dichloromethane extract	South Africa	[4]	
Lupeol					
	Twigs	Ethyl acetate extract	Kasane	[33]	
Lanosta-8,24-diene-3b-ol	Stem wood	Chloroform extract			

Table 7. Reported anti-microbial activity of leaves acetone extracts and its fractions of *Garcinia livingstonei* T. Anderson.

Bacteria	MIC of Leaves (mg/mL)							Reference
-	Acetone Extract	Hexane	Ethyl Acetate	Cloroform	Carbon Tetra Chloride	Butanol	10% Water/Methanol	[48-50]
Escherichia coli	0.06	0.23	0.175	0.095	0.115	0.78	1.875	
Staphylococcu aureus	0.07	0.23	0.195	0.31	0.355	1.25	1.875	
Pseudomonas aeru-ginosa	0.63	2.5	1.405	0.095	0.115	0.78	1.875	
Enterococcus faecalis	0.04	Not Detected	0.99	0.195	0.115	Not Detected	Not Detected	

Table 8. Reported anti-microbial activity of bark extracts of *Garcinia livingstonei* T. Anderson.

Bacteria	MIC and MBC (mg/mL) of Bark Extracts				
-	**Methanol**	**Dichloromethane**	**Dichloromethane: Methanol (1:1)**	**Water**	**References**
Escherichia coli	0.41	2.00	-	0.78	[7]
	0.78 (MBC=12.5)	-	-	0.78 (MBC=12.5)	[21]
Shigella sonnei	0.83	0.50	-	0.78	[7]
	0.78 (MBC=12.5)	-	-	0.78 (MBC=12.5)	[21]
Enterococcus faecalis	0.18	0.75	-	-	[7]
Bacillus cereus	0.06	0.12	-	-	
Salmonella typhimurium	0.25	2.00	-	-	
Klebsiella oxytoca	0.39 (MBC=12.5)	-	-	1.56 (MBC=12.5)	[21]
Salmonella enterica	0.39 (MBC=>12.5)	-	-	1.56 (MBC=12.5)	
Staphylococcu aureus	0.39 (MBC=6.25)	-	-	1.56 (MBC=12.5)	
Brevibacterium agri	-	-	0.02	0.75	[27]
Brevibacterium linens	-	-	0.06	8	
Gentamycin-methicillin re-sistant *S. aureus*	-	-	0.5	2	
Methicillin-resistant *S. aureus*	-	-	0.25	1.5	
Staphylococcus epidermidis	-	-	0.00006	0.004	
Propionibacterium acnes	-	-	0.25	>8	
Pseudomonas aeruginosa	-	-	0.5	>8	
Candida albicans	-	-	0.25	4	
Microsporum canis	-	-	0.13	0.5	
Trichophyton mentagrophytes	-	-	0.13	6	

Table 9. Reported anti-microbial activity of isolated compounds from leaves of *Garcinia livingstonei* T. Anderson.

Bacteria	MIC of Isolated Compounds (µg/mL)		References
-	Amentoflavone	4′_ Monomethoxyamentoflavone	-
Mycobacterium smegmatis	0.60 ± 0.70	1.40 ± 1.56	[51]
Escherichia coli	40	8	[9, 48]
Staphylococcu aureus	40	40	
Pseudomonas aeruginosa	100	60	
Enterococcus faecalis	60	8	

Table 10. Pharmacological activities of extracts of *Garcinia livingstonei* T. Anderson.

Pharmacological Activities	Plant Parts	Extracts	Values	Geographical Distribution	References
Antioxidant activity	Stem wood	Combined ethyl acetate and acetone extracts	IC_{50} = 30.3 ± 4.2 µg/ml	Kasane	[33]
		Methanol extract	IC_{50} = 53.6 ± 7.4 µg/ml		
	Twigs	Ethyl acetate extract	IC_{50} = 100.1 ± 5.9 µg/ml		
	Fruit	Methanol extract	IC_{50} = 108.4 ± 12.9 µg/ml	Florida	[15]
	Bark	Aqueous extract	IC_{50} = 0.35 ± 0.06 µg/ml	South Africa	[21]
		Methanol extract	IC_{50} = 0.39 ± 0.04 µg/ml		
Anti-HIV-1	Fruit	Ethanol extract	EC_{50}= 2.25 ± 0.51 µg/ml	Tanzania	[26]
Anti-HIV-1 protease activity	Root		IC_{50} = 37.2 µg/ml	-	[16]
	Stem		IC_{50} = 32.2 µg/ml		
Anti *Cryptococcal meningitis*, *Herpes zoster*, *Herpes simplex*, skin rashes and tuberculosis chronic diarrhea	Fruit	Not mentioned	-	Zambia	[61]
Fungicidal activity	Root bark	Dichloromethane extract	Against *C. Cucumerinurn*	South Africa	[41]
Cytotoxic activity			Col15 (ED_{50} = 10), SW480 cell lines (ED_{50} = 10)		
			LC_{50} = 17(0.3-43) µg/ml (Brine shrimp toxicity)		
	Fruit	Ethanol extract	A549 (CC50 = 8 µg/ml), DU145 (CC_{50} = 8.2 µg/ml), KB (CC_{50} = 5.7 µg/ml), and Kbivin human cell lines (CC_{50} = 12 µg/ml).	Tanzania	[26]
	Bark	Aqueous extract	(HEK) 293 cells (EC_{50} = 769.9 µg/ml ± 36.33) R2 = 0.35	South Africa	[21]
		Methanol extract	(HEK) 293 cells (EC_{50} = > 400 µg/ml for methanol) R2 = 0.89		
			LC_{50} = 19.12 after 24 hrs. and 46.85 after 48 hrs		[7]

Table 11. Pharmacological activities of isolated compound of *Garcinia livingstonei* T. Anderson.

Pharmacological Activities	Part Used	Isolated Compound	Values	Geographical Distribution	References
Antioxidant activity	Twigs and stem wood	4,3′,4′- trihydroxy-2,6-dimethoxybenzophenone	IC_{50} = 50.0 µm	Kasane	[33]
		3′-*β*-D-glucosy-loxy-4,40-dihydroxy-2,6-dimethoxy-benzophenone	IC_{50} = 353.0 µm		
		3′,4,4′,6-tetrahydroxy-2-methoxyben-zophenone	IC_{50} = 27.2 5 µm		
		Montixanthone	IC_{50} = 59.1 6 µm		
		6- deoxyisojacareubin	IC_{50} = 1010 µm		
		Botulin	IC_{50} = 743.0 µm		
		Morelloflavone	IC_{50} = 37.0 µm		
		podocarpusflavone	IC_{50} = 498.0 µm		
		Volkensiflavone	IC_{50} = 402.3 µm		
		GB-1a	IC_{50} = 425 µm		
	Leaves	Amentoflavone	TEAC = 0.9	South Africa	[48]
		4′-Monomethoxyamentoflavone	TEAC = 2.2		
HIV inhibitory	Fruit	Guttiferone A	EC = 1-10 µg/ml	Tanzania	[35]
Skin lightening activity	Stem bark	Morelloflavone, morelloflavone-7″-sulphate, guttiferone A and sargaol	MeWo cells (MC = < 0.25 at 25 µM/ml)	South Africa	[4]
Antiparasitic activities	Root bark	6,11-Dihydroxy-3-methyl-3-(4-methylpent-3-enyl)-3H,7H-pyrano[2,3-*c*]xanthen-7-one	*T. brucei* (IC_{50} = 5 ± 3 µm) *T. cruzi* (IC_{50} = 8 ± 3 µm) *P. falciparum* (IC_{50} = 52 ± 17 µm).	Tanzania	[13]
		4[(*E*)-3,7-dimethylocta-2,6-dienyl]-1,3,5-trihydroxy-9*H*-xanthen-9-one	*T. brucei* (IC_{50} = 2 ± 0.1µm) *T. cruzi* (IC_{50} = 5.7 ± 6.4 µm) *P. falciparum* (IC_{50} = 6 µm)		
		1,4,5-trihydroxy-3-(3-methylbut-2-enyl)-9*H*xanthen-9-one (27, 10 and 0.78 µm)	*L. infantum* (IC_{50} = 27 µm) *P. falciparum* (IC_{50} = 10 ± 0.1 µm) *T. brucei* (IC_{50} = 0.87 ± 0.23 µm) *T. cruzi* (IC_{50} = 7 ± 0.1 µm)		
		Garcilivin A	*P. falciparum* (IC_{50} = 6.7 ± 1.5 µm) *L. infantum* (IC_{50} = 32 µm) *T. brucei* (IC_{50} = 0.4 ± 0.1 µm) *T. cruzi* (IC_{50} = 4 ± 2.8 µm)		
		Garcilivin C	*T. brucei* (IC_{50} = 7.7 ± 1.1 µm) *T. cruzi* (IC_{50} = 39.2 ± 23.2 µm)		

(Table 11) Contd….

Pharmacological Activities	Part Used	Isolated Compound	Values	Geographical Distribution	References
-	-	*Ent*-naringeninyl-(I-3α,II-8)-4'-*O*-methylnaringenin	*P. falciparum* (IC_{50} = 6 µm) *T. brucei* (IC_{50} = 28.3 ± 2.9 µm) *T. cruzi* (IC_{50} = 34.7 ± 4.6 µm) *P. falciparum* (IC_{50} = 6 ± 1.7 µm)	-	-
-	-	Volkensiflavone	*T. brucei* (IC_{50} = 37 ± 1.0 µm) *T. cruzi* (IC_{50} = 56 ± 13.9 µm) *P. falciparum* (IC_{50} = 48 ± 14.2 µm)	-	-
Cytotoxicity	Leaves	Amentoflavone	Vero monkey kidney cells (CC_{50} = 381 µg/mL) (A) and > 600 µg/mL (B)	South Africa	[9, 48]
		4′-Monomethoxyamentoflavone	Vero monkey kidney cells (CC_{50} = 600 µg/mL)		
	Root bark	Garcilivin A	MRC-5 cells (IC_{50} = 2 ± 0.1 µm)	Tanzania	[13]
		Garcilivin C	MRC-5 cells (IC_{50} = 52.3 ± 5.5 µm)		
		Ent-naringeninyl-(I-3α,II-8)-4'-*O*-methylnaringenin	MRC-5 cells (IC_{50} = 38.0 ± 2.6 µm)		
		Volkensiflavone	MRC-5 cells (IC_{50} = 40 ± 4.4 µm)		
Acetyl cholinesterase inhibition activity	Root bark	6,11-Dihydroxy-3-methyl-3-(4-methylpent-3-enyl)-3H,7H-pyrano[2,3-*c*]xanthen-7-one	K_i= 1.9 ± 1.4 µM	South Africa	[70]
		4[(*E*)-3′,7′-Dimethylocta-2′,6′-dienyl]-1,3,5-trihydroxy-9*H*-xanthen-9-one	K_i= 26.8 ± 5.4 µM		
Mono amine oxidase inhibition activity		4[(*E*)-3′,7′-Dimethylocta-2′,6′-dienyl]-1,3,5-trihydroxy-9*H*-xanthen-9-one	MAO-A (IC_{50} = 37.4 µM)		
			MAO-B (IC_{50} = 65.5 µM)		

Abbreviations: Col15 = (Colon carcinoma), SW480 = (Colon carcinoma), A549 = (Lung adenocarcinoma), DU145 = (Prostate carcinoma), KB = (Nasopharyngeal carcinoma), Kbivin = (Vincristine-resistant nasopharyngeal), HEK 293 cells = Human Embryonic Kidney, MRC-5 = Human diploid embryonic lung cell line, MeWo = human melanoma cells.

parts of other species all exhibited an interested anti-oxidant activity [54-57]. For *G. livingstonei,* the potent antioxidant activity of 4,3′,4-trihydroxy-2,6-dimethoxybenzophenone, 3′,4,4′,6-tetrahydroxy-2-methoxybenzophenone, montixanthone and morelloflavone were reported with IC_{50} values of 50.0, 27.2, 59.1 and 37.0 µM, respectively, using the DPPH assay isolated from the twigs and stem wood compared to vitamin C (IC_{50} = 82.4 µM) [33]. The methanolic extract of the fruit also was reported to exhibit antioxidant activity using the DPPH scavenging assay (IC_{50} = 108.4 ± 12.9 µg/mL) [15]. In addition 4′-monomethoxyamentoflavone had a good antioxidant activity than amentoflavone [48]. Water and methanol extracts of *G. livingstonei* bark showed antioxidant activities with IC_{50} values 0.35 ± 0.06 and 0.39 ± 0.04 µg/mL, respectively [21].

2.17. Anti-HIV Activity

According to WHO, HIV is considered a major public health problem. In 2020, 1.5 million people were affected by HIV [58]. *Garcinia* exhibited a marked effect against HIV which is evidenced by that the isolated compounds from the fruits of *G. speciosa* and *G. nuntasaenii* for example showed significant inhibitory activities against HIV [59, 60]. The isolated guttiferone A exhibited HIV inhibitory activity [35]. The ethanolic fruit extract from Tanzania showed significant anti-HIV-1 activity with EC_{50} value of 2.25 ± 0.51 µg/ml. The cytotoxicity on the T-cells was CC_{50} = 6.1 µg/ml [26]; while the roots and the stems showed anti-HIV-1 protease activity with IC_{50} values of 37.2 and 32.2 µg/ml, respectively [16]. The activity of *G. livingstonei* fruits from Zambia against *Cryptococcal meningitis*, chronic diarrhea, skin rashes, *Herpes simplex*, *Herpes zoster* and tuberculosis was also reported [61].

2.18. Inhibition of Melanoma

Hyperpigmentation is one of the problems that take interest of most population and melanoma is one of the major causes of skin cancer deaths [62, 63]. Xanthones isolated from *G. mangostana* were effective as anti-melanoma [64], also the hydroalcoholic extract of leaves of *G. gardneriana* was potent in the treatment of hyperpigmentation disorders [65]. Moreover, the aqueous extract of fruits of *G. atroviridis* showed anti tyrosinase activity and inhibited melanin content [66]. Concerning *G. livingstonei*, morelloflavone, morelloflavone-7″-sulphate and sargaol are responsible for its skin lightening activity [4].

2.19. Antiparasitic Activity

The antiparasitic activity of isolated compounds from root bark was evaluated against *Plasmodium falciparum*, *Leishmania infantum*, *Trypanosoma brucei* and *T. cruzi*. 1,4,5-trihydroxy-3-(3-methylbut-2-enyl)-9*H*xanthen-9-one showed a marginal activity against *L. infantum*, *P. falciparum* and *T. brucei* with IC_{50} = 27, 10 and 0.78 µM, respectively, on the other hand garcilivin A showed nonselective cytotoxicity (IC_{50} = 2.0 µM) against all parasites tested [13].

2.20. Antifungal Activity

The dichloromethane extract of root bark of *G. livingstonei* exhibited fungicidal activity against *Cladosporium cucumerinurn* [41]. However, no other reports were traced in the literature concerning this matter.

2.21. Cytotoxic Activity

Cancer is one of the major causes of death worldwide, which needs the use of protocols chemotherapy and radiotherapy protocols in the treatment or further need of surgical intervention [67, 68]. Recently, plant based remedies are preferred for the improvement of health [69]. The cytotoxic activity of root bark extract of *G. livingstonei* was tested against two human colon carcinoma cell lines (Col15 and SW480 cell lines) and the brine shrimp toxicity showed LC_{50} = 17(0.3-43) µg/ml; the ED_{50} values were 10 and 8 µg/ml, respectively [41]. Also the ethanolic fruits' extract from Tanzania exhibited cytotoxic activity against other cell lines, A549 (Lung adenocarcinoma), DU145 (Prostate carcinoma), KB (Nasopharyngeal carcinoma) and Kbivin (Vincristine-resistant nasopharyngeal) human cell lines with CC_{50} values of 8, 8.2, 5.7 and 12 µg/ml, respectively [26]. The mutagenic potential of amentoflavone and 4′-monomethoxyamentoflavone were assessed by the Ames test against *Salmonella* strain TA98. Amentoflavone had some genotoxic effect at the concentration of 100 µg/plate; however, 4′-monomethoxyamentoflavone was inactive [48]. The safety of the two compounds was assessed with MTT assay using Vero monkey kidney cells. The compounds had low toxicity against the cell line with cytotoxic concentrations of 50% of the cells (LD_{50}) of 386 microg/mL and > 600 microg/mL for amentoflavone and 4"-methoxy amentoflavone, respectively [9]. Moreover, the water extract of bark had the highest EC_{50} value of 769.9 ± 36.33 µg/mL, followed by the methanol extract 400 ± 36.33 µg/mL against HEK cells (Human Embryonic Kidney) [21]. In addition, the methanol extract of bark of *G. livingstonei* showed LC_{50} = 19.12 after 24 hrs and 46.85 after 48 hrs [7].

2.22. Acetylcholinesterase and Monoamine Oxidase Inhibition Activity

The isolated xanthones, namely; 12b-Hydroxy-des-dgarcigerrin A, 6,11-Dihydroxy-3-methyl-3-(4-methylpent-3-enyl)-3H,7H-pyrano[2,3-*c*]xanthen-7-one, 1,4,5-Trihydroxy-3-(3-methylbut-2-enyl)-9H-xanthen-9-one and 4[(*E*)-3′,7′-Dimethylocta-2′,6′-dienyl]-1,3,5-trihydroxy-9*H*-xanthen-9-one were evaluated for their activity as acetylcholinesterase inhibitors for the treatment of Alzheimer's disease, the most active xanthone was 6,11-Dihydroxy-3-methyl-3-(4-methylpent-3-enyl)-3H,7H-pyrano[2,3-*c*]xanthen-7-one with K_i value of 1.9 ± 1.4 µM and 4[(*E*)-3′,7′-Dimethylocta-2′,6′-dienyl]-1,3,5-trihydroxy-9*H*-xanthen-9-one with K_i value of 26.8 ± 5.4 µM. The later xanthone also showed monoamine oxidase (MAO) inhibition activity, with IC_{50} values for MAO-A and MAO-B equal 37.4 and 65.5 µM, respectively. In conclusion, 4[(*E*)-3′,7′-Dimethylocta-2′,6′-dienyl]-1,3,5-trihydroxy-9*H*-xanthen-9-one had interesting activity for Alzheimer's disease therapy [70].

CONCLUSION

Garcinia species are members of family Clusiaceae, well known for their edible fruits and bioactive constituents. Several species of *Garcinia* are distributed in different parts of the world such as Malaysia, Indonesia, India, tropical Africa and Egypt. *G. livingstonei* is an economically important fruit crop useful as raw material for plant based products in industrial sector related to food, cosmetic or neutraceuticals. *G. livingstonei* is a rich source of bioactive constituents that are beneficial in several health problems, exemplified by amentoflavone, morelloflavone and volkensiflavone which are effective as anti-oxidant, antibacterial and melanogenesis inhibitors. The presence of benzophenones *viz*, as guttiferone A with anti-HIV potential and xanthones as garcilivin C and montixanthone are active anti-parasitic and cytotoxic agents, reflecting their value as potential sources for natural drugs. Moreover, *G. livingstonei* has high nutritive contents including minerals, carbohydrates, crude fat and crude proteins. These elements promote plants as food supplements.

LIST OF ABBREVIATIONS

HIV = Anti-human Immunodeficiency Virus

TI = Therapeutic Index

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The authors declare no conflict of interest, financial or otherwise.

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