Gymnanthemum coloratum: Review of its Medicinal uses, Phytochemistry and Pharmacological Properties

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Abstract: *Gymnanthemum coloratum* is a shrub or a small tree widely used as traditional medicine throughout its distributional range in tropical Africa. The current study is aimed at reviewing the phytochemistry, pharmacological properties and medicinal uses of *G. coloratum*. Literature on pharmacological properties, phytochemistry and medicinal uses of *G. coloratum* was obtained from numerous internet sources such as Scopus, Elsevier, SciFinder, Google Scholar, Pubmed, ScienceDirect, BMC and Web of Science. Other sources of information included pre-electronic sources such as journal articles, theses, book chapters, books and other scientific publications obtained from the university library. The articles published between 1964 and 2020 were used in this study. The current study showed that *G. coloratum* is used as an anthelmintic, and traditional medicine for reproductive problems, schistosomiasis, liver diseases, sexually transmitted infections, diabetes, sores and wounds, respiratory problems, malaria, skin diseases, fever and gastro-intestinal problems. Ethnopharmacological research identified glaucolides, lactones, amino acids, essential oils, alkaloids, anthocyanins, cardenolids, coumarins, flavonoids, glycosides, leucoanthocyanins, phenols, quinones, reducing sugars, saponins, steroids, tannins, terpenoids and triterpenes from the aerial parts, leaves, roots and stems of *G. coloratum*. The aerial parts, leaves, roots and whole plant parts of *G. coloratum* and compounds isolated from the species exhibited anthelmintic, antimicrobial, anti-Blastocystis, anti-inflammatory, anti-sickling, insecticidal and larvicidal, antiplasmodial, antimalarial, antioxidant, antiproliferative, anti-Toxoplasma, hypoglycaemic and antidiabetic and cytotoxicity activities. *Gymnanthemum coloratum* should be subjected to detailed phytochemical, pharmacological and toxicological evaluations aimed at correlating its medicinal uses with its phytochemistry and pharmacological activities.

Keywords: Asteraceae, Compositae, *Gymnanthemum coloratum*, indigenous knowledge, traditional medicine, *Vernonia colorata.*

INTRODUCTION

Gymnanthemum coloratum (Willd.) H. Rob. & B. Kahn is a shrub or a small tree belonging to the Asteraceae or Compositae family. The genus *Gymnanthemum* Cass. did not gain general acceptance and all species belonging to this genus were included in a broadly circumscribed genus *Vernonia* Schreb. [1], a genus that is now known to be restricted to North America [2,3]. Therefore, *G. coloratum* was later transferred to the genus *Gymnanthemum*, a genus characterized by a shrubby habit, epaleate receptacle with more or less obtuse involucral bracts, white to violet flowers and pinnately-veined leaves [1]. The genus name *Gymnanthemum* is derived from two Greek words, "*gymnos*" which means "naked" and "*anthos*" which means "flower" in reference to the lack of palease on the receptacle of *Gymnanthemum* species. The epithet "*coloratum*" is derived from the Latin word "*colorata*", which means "colourful" in reference to whitish flowers [4]. The English common names of *G. coloratum* include "lowveld tree vernonia", "lowveld bitter-tea", "star-flowered bitter-tea", "star-flowered vernonia" and "starry bitter tea". The synonyms associated with the name *G. coloratum* include *Baccharis senegalensis* Pers., *Decaneurum grande* DC., *D. senegalense* (Pers.) DC., *Eupatorium coloratum* Willd., *Gymnanthemum cupulare* Cass., *G. grande* (DC.) Sch. Bip. ex Walp., *G. quercifolium* Steetz, *G. senegalense* (Pers.) Sch. Bip. ex Walp., *Vernonia aldabrensis* Hemsl., *V. cirrifera* S. Moore, *V. colorata* (Willd.) Drake, *V. grandis* (DC.) Humb., *V. longipetiolata* Muschl., *V. oxyura* O. Hoffm., *V. polyura* O. Hoffm. and *V. senegalensis* (Pers.) Less. [1,3,5].

Gymnanthemum coloratum is an erect shrub or small tree up to 9 m in height [5,6]. The bark of *G. coloratum* is pale grey-brown in colour, rather rough when old and smaller branches are covered with velvety hairs. The leaves are leathery, elliptic to ovate in shape, dark green in colour and rather harshly hairy above, paler green with long dense woolly hairs below. The leaves have visible net-veins, tapering apex with tapering to slightly rounded base, markedly waxed, entire to very finely toothed margins. The flower heads occur in terminal dense heads, forming a wide branched panicle, which is white to off-white in colour and sweetly scented. The fruit is a slender nutlet, hairless, plumed with rough bristles. *Gymnanthemum coloratum* grows in open woodland, bushveld and

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grassland, at the base of koppies, along streams, in riverine fringes, termite mounds, edges of vleis and pans. *Gymnanthemum coloratum* has been recorded in Angola, Benin, Botswana, Burkina Faso, Cameroon, Central African Republic, Comoros, Côte d'Ivoire, the Democratic Republic of Congo (DRC), Eswatini, Gabon, Gambia, Ghana, Guinea, Guinea-Bissau, Kenya, Mali, Mozambique, Nigeria, Senegal, Sierra Leone, Tanzania, Togo, Zambia and Zimbabwe at an altitude ranging from 20 m to 1540 m above sea level. *Gymnanthemum coloratum* is widely used as traditional medicine throughout its distributional range in tropical Africa with the roots sold as herbal medicines in informal herbal medicine markets for the treatment and management of parasitic diseases in humans in Mozambique [7]. *Gymnanthemum coloratum* is also collected from the wild as an edible leafy vegetable in Ghana and Nigeria [8,9]. It is, therefore, within this background that the current study was undertaken aimed at documenting the phytochemistry, pharmacological properties and medicinal uses of *G. coloratum*.

Medicinal uses

The bark, leaves, roots and whole plant parts of *G. coloratum* are widely used as an anthelmintic, and traditional medicine for reproductive problems, schistosomiasis, liver diseases, sexually transmitted infections, diabetes, sores and wounds, respiratory problems, malaria, skin diseases, fever and gastro-intestinal problems (Table **1**; Figure **1**). Other minor medicinal applications of the species that are recorded in two countries and supported by at least two literature sources include the use of the species as an emetic [10,11], poison antidote [10-12] and herbal medicine for anaemia [11,12], epilepsy [8,10-12], heart failure [11,12], jaundice [11,12], pregnancy and labour [13,14], rheumatism [11,15-18] and tonsillitis [10-12].

Phytochemistry

Patel and Rawson [50] identified the compound vernonin and cardiac glycoside from the leaves, roots and stems of *G. coloratum*. Zdero *et al.* [51] isolated 19-hydroxyglaucolide A, 19-hydroxyvernodalin, vernodalin, isobutyrate, germacrene D, caryophyllene and lupeylacetate from the aerial parts of *G. coloratum*. Reid *et al.* [16] and Adu *et al*. [35] identified the compound vernodalin from the leaves of *G. coloratum*. Rabe *et al.* [29] identified sesquiterpene lactones such as vernolide, 11β,13-dihydrovernolide and vernodalin from the leaves of *G. coloratum*. Cioffi *et al.* [52] identified androst-8-en glycosides, stigmastane-type glycosides and stigmastane-type steroids from *G. coloratum* leaves. The major essential oils identified from *G. coloratum* leaves include 1-ethyl-2-methyl benzene (5.4%), 2,3-dihydroxypropyl ester (5.6%), p-xylene (8.2%), tetradecan-2-one (8.3%), hexadecan-2-one (8.6%), n-hexadecanoic acid (9.7%), hexahydrofarnesyl acetone (12.2%), 9-octadecenoic acid (12.9%), 13-docosenoic acid (13.9%), hexadecanoic acid (14.8%), 3,11-tetradecadien-1-ol (19.9%), 4-methyl-1-decene (24.1%) and cis-13-eicosenoic acid (36.6%) [9,53,54]. Other phytochemical compounds identified from the leaves of *G. coloratum* include alanine, alkaloids, anthocyanins, aspartic acid, cardenolids, coumarins, flavonoids, glutamic acid, glycine, glycosides, leucine, leucoanthocyanins, phenols, phenyl alanine, proline, phlobatannins, quinones, reducing sugars, resins, saponins, serine, steroids, tannins, terpenoids, threonine, triterpenes, tyrosine and valine [35,38,42,54-59]. Some of these phytochemical compounds identified from the species may be responsible for the biological activities of the species.

Pharmacological Properties of *Gymnanthemum coloratum*

The following biological activities have been reported from the aerial parts, leaves, roots and whole plant parts of *G. coloratum* and compounds isolated from the species: anthelmintic, antimicrobial, anti-Blastocystis, anti-inflammatory, antisickling, insecticidal and larvicidal, antiplasmodial, antimalarial, antioxidant, antiproliferative, anti-Toxoplasma, hypoglycaemic and antidiabetic and cytotoxicity activities.

Anthelmintic Activities

Morah *et al.* [9] evaluated the anthelmintic activities of 100 μgml, 50 μg/ml and 25 μg/ml essential oil isolated from *G. coloratum* leaves against *Lumbricus terrestris*. The mortality of worms after sixteen hours of exposure ranged from 26.7% to 100% at the evaluated concentrations [9].

Antimicrobial Activities

Kelmanson *et al.* [45] evaluated the antibacterial activities of methanol, ethyl acetate and water extracts of *G. coloratum* leaves, roots and stems against *Bacillus subtilis, Escherichia coli, Kleibsiella pneumoniae, Micrococcus luteus, Pseudomonas aeruginosa, Staphylococcus aureus* and *Staphylococcus epidermidis* using the disc-diffusion assay and twofold serial dilution with neomycin (2.0 μg)

Table 1: Medicinal uses of *Gymnanthemum coloratum*

Medicinal use	Parts used	Country	References
Anaemia	Leaves and roots	DRC and Tanzania	[11,12]
Anthelmintic	Leaves and roots	DRC, Kenya, Mozambique, Senegal and Tanzania	[7,11,12,18-20]
Chewing sticks	Twigs	Ghana	[21]
Colic	Leaves and roots	South Africa	[11,17]
Diabetes	Leaves and roots	Côte d'Ivoire, Senegal, South Africa and Togo	[8,11,17,18,20-26]
Dizziness	Leaves	Senegal	[20]
Earache	Roots	Tanzania	[10]
Emetic	Bark, leaves and roots	DRC and Tanzania	[10,11]
Epilepsy	Leaves and roots	DRC and Tanzania	[8,10-12]
Fever	Bark, leaves, roots, root bark and stem bark	Burkina Faso, Cameroon, Côte d'Ivoire, DRC, Ghana, South Africa, Tanzania and Zimbabwe	[8,10-2,15,16,18,20,27-30]
General weakness	Leaves and roots	Mozambique	[13]
Gastro-intestinal problems (abdominal pains, constipation, diarrhoea, digestive disorders, dysentery and stomach ache)	Bark, leaves, roots, root bark, stem bark, twigs and whole plant	Benin, Burkina Faso, Comoros, Côte d'Ivoire, DRC, Ghana, Kenya, Mali, Mozambique, Nigeria, Senegal, South Africa and Tanzania	[10-21,27,29-36]
Heart failure	Leaves and roots	DRC and Tanzania	[11,12]
Hypertension	Leaves	Côte d'Ivoire	[8,25]
Jaundice	Leaves and roots	DRC and Tanzania	[11,12]
Liver diseases	Leaves	Burkina Faso, Côte d'Ivoire, Ghana and Mali	[11,20,33,35]
Malaria	Bark and leaves	Burkina Faso, Côte d'Ivoire, Ghana, Guinea, Mali, Senegal and South Africa	[11,20,25,28,33,35,37-41]
Nausea	Twigs	Ghana	[21]
Oedema	Roots	Zimbabwe	[15,16]
Poison antidote	Bark, leaves and roots	DRC and Tanzania	[10-12]
Pregnancy and labour (ease child birth and postpartum pains)	Leaves and roots	Côte d'Ivoire and Mozambique	[13,14]
Reproductive problems (infertility, impotence, frigidity and painful uterus)	Bark, leaves and roots	DRC, Tanzania and Zimbabwe	[10-12,15,18]
Respiratory problems (cough, pneumonia and tuberculosis)	Bark, leaves and roots	Botswana, DRC, Kenya, Mozambique, South Africa and Tanzania	[10-12,16,19,27,29,42-44]
Rheumatism	Leaves and roots	South Africa and Zimbabwe	[11,15-18]
Schistosomiasis	Bark, leaves and roots	DRC, Tanzania and Zimbabwe	[8,10-12,15,16]
Sexually transmitted infections (gonorrhoea and venereal diseases)	Bark, leaves and roots	Botswana, DRC, Mozambique and Tanzania	[10-12,13,18,27,42]
Skin diseases (boils eczema, scabies	Bark, leaves and roots	Burkina Faso, Côte d'Ivoire, DRC, Ghana, Guinea, South Africa and Tanzania	[8,10-12,16,25,27,29,30,33,35,45,46]
Sores and wounds	Leaves and roots	Côte d'Ivoire, DRC, Ghana, Mali and Tanzania	[11,12,18,34,37,38,47-49]
Tonic	Roots	South Africa	[11,16,27,29,30,45]
Tonsillitis	Bark, leaves and roots	DRC and Tanzania	[10-12]
Ulcerative colitis	Leaves and roots	South Africa	[11,17]
Vertigo	Leaves and roots	Mozambique	[13]

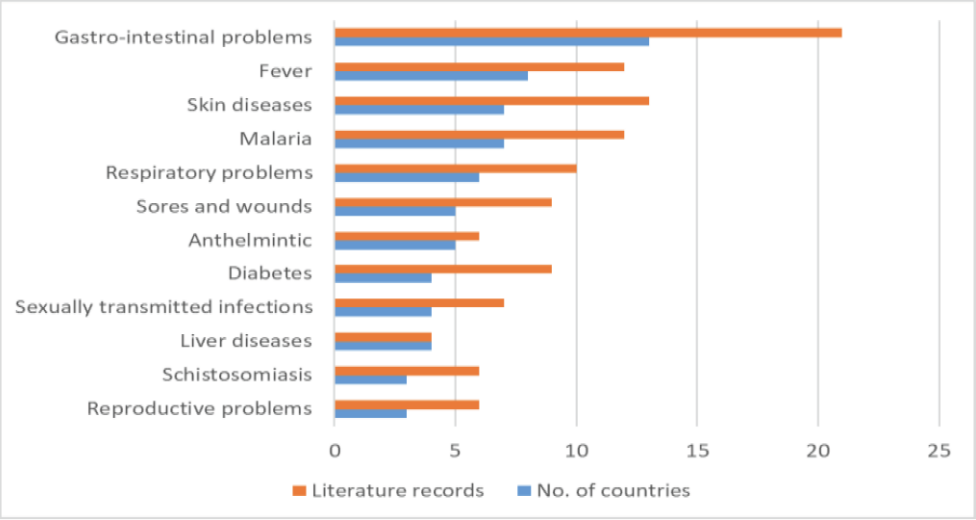

Figure 1: Medicinal applications of *Gymnanthemum coloratum* derived from literature records.

as a positive control. The methanol and ethyl acetate extracts of the leaves exhibited activities against *Bacillus subtilis, Micrococcus luteus, Pseudomonas aeruginosa* and *Staphylococcus aureus* with minimum inhibitory concentration (MIC) values ranging from 0.5 mg/ml to 4.0 mg/ml [45]. Reid *et al.* [16] evaluated the antibacterial activities of hexane, ethyl acetate, water and ethanol extracts of *G. coloratum* leaves and the compound vernodalin isolated from the species against *Escherichia coli, Klebsiella pneumoniae, Pseudomonas aeruginosa, Bacillus subtilis, Micrococcus luteus, Staphylococcus aureus* and *Staphylococcus epidermidis* using the disc diffusion assay with neomycin as a positive control. *Micrococcus luteus, Klebsiella pneumoniae* and *Staphylococcus aureus* were inhibited by ethyl acetate extract while the MIC of vernodalin against *Staphylococcus aureus* was 100 µg/ml [16]. Rabe *et al.* [29] evaluated the antibacterial activities of the compounds vernolide, 11β,13-dihydrovernolide and vernodalin isolated from the leaves of *G. coloratum* against *Staphylococcus aureus, Bacillus subtilis, Escherichia coli* and *Klebsiella pneumoniae* using the micro-dilution technique with neomycin as a positive control. The compounds exhibited activities with the MIC values ranging from 0.1 mg/ml to >8.0 mg/ml [29]. Stafford *et al.* [60] evaluated the antibacterial activities of ethanol extracts of *G. coloratum* leaves against *Bacillus subtilis, Staphylococcus aureus, Escherichia coli* and *Klebsiella pneumoniae* using the micro plate method. The extract exhibited activities with the MIC values ranging from 0.8 mg/ml to 1.6 mg/ml [60]. Adebayo *et al.* [56] evaluated the antibacterial activities of aqueous and ethanol extracts from the leaves of *G. coloratum* against *Escherichia coli, Klebsiella pneumoniae, Pseudomonas aeruginosa* and *Staphylococcus aureus* using agar diffusion and the dilution methods with chloramphenicol as a positive control. The extracts exhibited activities with zone of inhibition ranging from 5.0 mm to 24.0 mm and the MIC values ranging from 4.0 mg/ml to 6.0 mg/ml [56]. Guenne *et al.* [57] evaluated the antibacterial activities of dichloromethane, ethyl acetate and butanol extracts of *G. coloratum* leaves against *Escherichia coli, Vibrio cholerae, Salmonella typhimirium, Bacillus cereus, Escherichia coli, Proteus mirabilis, Shigella dysenteriae* and *Staphylococcus aureus* using agar diffusion method and serial dilution technique. The extracts exhibited activities with the zone of inhibition ranging from 6.0 mm to 34.0 mm and the MIC values ranging from 2.5 mg/mL to >20.0 mg/mL [57]. Julien *et al.* [58] evaluated the antibacterial activities of ethyl acetate extract of *G. coloratum* leaves against *Staphylococcus aureus* and *Pseudomonas aeruginosa* using agar diffusion method and serial dilution technique. The extract exhibited activities against *Staphylococcus aureus* and *Pseudomonas aeruginosa* with the zone of inhibition of 13.0 mm and 11.0 mm and the MIC values of 3.1 mg/mL and 3.1 mg/mL, respectively [58]. Adebayo *et al.* [8] evaluated the antibacterial activities of crude, aqueous, petroleum ether, chloroform and diethyl ether leaf extracts of *G. coloratum* against *Staphylococcus aureus, Pseudonomas aeruginosa, Escherichia coli, Klebsiella pneumoniae* and *Salmonella typhi* using the agar-well diffusion methods. The aqueous and crude extracts exhibited activities against *Staphylococcus aureus* with MIC values ranging from 5.0 mg/ml to 7.5 mg/ml [8]. Bongo *et al.* [59] evaluated the antibacterial activities of petroleum ether, ethyl acetate and methanol extracts of the leaves of *G. coloratum* against *Escherichia coli* and *Staphylococcus aureus* using the microdilution method.

Only *Staphylococcus aureus* was sensitive to the extract exhibiting MIC value of ≤ 250.0 µg/mL [59]. Adu *et al.* [35] evaluated the antibacterial activities of the compound vernolide isolated from the leaves of *G. coloratum* against *Escherichia coli, Staphylococcus aureus* and *Enterococcus faecalis* using the micro broth dilution assay. The compound showed activities against *Escherichia coli, Staphylococcus aureus* and *Enterococcus faecalis* with MIC values ranging from 0.3 mg/ml to 0.4 mg/ml [35]. Morah *et al.* [9] evaluated the antimicrobial activities of essential oil isolated from *G. coloratum* leaves against *Candida albicans, Rhizopus nigricans, Streptococcus faecalis, Staphylococcus aureus, Pseudonomas aeruginosa* and *Salmonella typhi* using the agar disc diffusion and the dilution methods. The essential oil exhibited activities with zones of inhibition ranging from 8.0 mm to 20.0 mm while MIC values ranging from 0.8 µg/ml to 3.1 µg/ml [9].

Anti-Blastocystis Activities

Christensen *et al.* [71] evaluated the anti-*Blastocystis* activities of ethanol extracts of folium, flos and radix of *G. coloratum* against *Blastocystis* spp. (subtype 4) using an anti-Blastocystis activity assay with metronidazole as a positive control. The extracts exhibited activities with half maximal inhibitory concentration (IC_{50}) value of 117.9 µg/mL [71].

Anti-Inflammatory Activities

Stafford *et al.* [70] evaluated the anti-inflammatory activities of aqueous and ethanol extracts of *G. coloratum* leaves using the cyclooxygenase (COX-1) inhibition assay. The COX-1 inhibition exhibited by aqueous and ethanol extract was 38.0% and 100.0%, respectively [70]. Cioffi *et al.* [52] evaluated the anti-inflammatory activities of the chloroform: methanol (9:1) extract of the *G. coloratum* leaves which exhibited activities using a carrageenan-induced rat paw assay. Cioffi *et al.* [52] also evaluated the anti-inflammatory activities of the compounds androst-8-en glycosides, stigmastane-type glycosides and stigmastane-type steroids from *G. coloratum* leaves using the carrageenan-induced rat paw assay, and the compounds were either inactive or exhibited weak activities [52].

Anti-Sickling Activities

Bongo *et al.* [59] evaluated the anti-sickling activities of petroleum ether, ethyl acetate and methanol extracts of the leaves of *G. coloratum* using the Emmel test. The extracts showed anti-sickling activities with a normalization rate of between 10.0% and 50.0% [59].

Insecticidal and Larvicidal Activities

Morah *et al.* [9] evaluated the insecticidal and larvicidal activities of essential oil isolated from *G. coloratum* leaves against adult and larvae of *Anopheles mosquitoes*. The essential oil exhibited activities with the median lethal concentration (LC_{50}) values of 75.0 µg/ml and 50.0 µg/ml after sixteen hours of exposure for the larvae and adult mosquitoes, respectively [9].

Antiplasmodial Activities

Benoit *et al.* [62] and Benoit-Vical *et al.* [63] evaluated the antiplasmodial activities of the aqueous extract of leaves and stems of *G. coloratum* against two strains of *Plasmodium falciparum*, FcB 1-Colombia (chloroquine-resistant) and F32-Tanzania (chloroquine-sensitive) using the parasite ^{3}H-hypoxanthine incorporation assay with chloroquine as a positive control. The extract exhibited activities with the IC_{50} values ranging from 2.4 mg/L to 7.8 mg/L [62,63]. Kraft *et al.* [64] evaluated the antiplasmodial activities of petrol ether: ethyl acetate (1:1) extracts of the aerial parts of *G. coloratum* and the compounds 11β,13-dihydrovernodalin, vernodalol, 11β,13-dihydrovernolide and 11β,13,17,18-tetrahydrovernolide isolated from the aerial parts of the species using the [^{3}H] hypoxanthine incorporation assay against the chloroquine sensitive and chloroquine-resistant strains of *Plasmodium falciparum*. The extracts and compounds exhibited activities with the IC_{50} values ranging from 1.1 µg/mL to 4.8 µg/mL [64]. Clarkson *et al.* [65] evaluated antiplasmodial activities of aqueous, dichloromethane, and dichloromethane: methanol (1:1) extracts of leaves and twigs of *G. coloratum* against *Plasmodium falciparum* using the parasite lactate dehydrogenase (pLDH) assay. Both the dichloromethane: methanol (1:1) extracts of the leaves and twigs showed activities with the IC_{50} values of 4.7 µg/ml and 14.1 µg/ml, respectively [65]. Ménan *et al.* [66] evaluated the antiplasmodial activities of water, ethanol and pentane extracts of the leaves of *G. coloratum* against two strains of *Plasmodium falciparum*, FcM29-Cameroon (chloroquine-resistant) and a Nigerian chloroquine-sensitive strain, with chloroquine as a positive control. The extracts exhibited activities with the IC_{50} values ranging from 10.0 µg/ml to 102.0 µg/ml in comparison to IC_{50} values of 0.03 µg/ml to 0.04 µg/ml exhibited by the positive control [66]. Chukwujekwu *et al.* [67] evaluated the antiplasmodial activities of the compounds vernolide and vernodalin isolated from the

leaves of *G. coloratum* against a chloroquine-sensitive strain of *Plasmodium falciparum* (D10), using the parasite lactate dehydrogenase (pLDH) with chloroquine as a positive control. The compounds vernolide and vernodalin exhibited activities with the IC_{50} values of 1.9 µg/ml and 0.5 µg/ml, respectively, against the IC_{50} value of 7.6 ng/ml exhibited by the positive control [67]. Idris *et al.* [54] evaluated antiplasmodial activities of methanol extracts of the leaves of *G. coloratum* against *Plasmodium bergei* at 200, 400 and 600 mg/kg body weight with chloroquine as a positive control. The extract exhibited dose-dependent activities, reducing parasitemia by 81.8%, 80.9% and 83.2% for 200, 400 and 600 mg/kg body weight groups, respectively, compared to 100% inhibition exhibited by the positive control [54].

Antimalarial Activities

Kaou *et al.* [31] evaluated the antimalarial activities of dichloromethane, methanol and methanol: water (1:1) extracts of *G. coloratum* aerial parts and roots using culture-adapted reference strain of *Plasmodium falciparum* type W2 resistant to chloroquine, pyrimethamin and proguanil. The dichloromethane extracts of roots and aerial parts were the most active with the IC_{50} values of 3.0 µg/ml and 6.0 µg/ml, respectively [31].

Antioxidant Activities

Guenne *et al.* [55] evaluated the antioxidant activities of methanol extracts of *G. coloratum* leaves using 2, 2'-diphenyl-1 picrylhydrazyl (DPPH) free radical scavenging, 2,2'-azinobis (3 ethylbenzothiazoline-6-sulphonate (ABTS) and ferric reducing antioxidant power (FRAP) assays with quercetin as a positive control. The extract exhibited activities with the IC_{50} value of 14.0 µg/ mL in DPPH, 54.4 µmol/g in ABTS and ferric ion reduction of 0.6 mmol AAE/g [55].

Antiproliferative Activities

Kaou *et al.* [31] evaluated the antiproliferative activities of dichloromethane, methanol and methanol: water (1:1) extracts of *G. coloratum* aerial parts on human monocytic THP1 cells in an *in vitro* toxicity assay. The dichloromethane extract was the most active with the IC_{50} value of 10.0 µg/ml [31].

Anti-Toxoplasma Activities

Benoit-Vical *et al.* [63] evaluated the anti-Toxoplasma activities of the aqueous extract of leaves and stems of *G. coloratum* on Toxoplasma gondii in an *in vitro* assay assessed on MRC5 tissue cultures and quantified by enzyme-linked immunoassay. The extract exhibited activities with IC_{50} values ranging from 17.0 mg/L to 18.0 mg/L [63].

Hypoglycaemic and Antidiabetic Activities

Sy *et al.* [68] evaluated the hypoglycaemic and antidiabetic activities of the aqueous extract of the leaves of *G. coloratum* in normoglycaemic and alloxan-induced diabetic rats in comparison to glibenclamide antidiabetic activities. The extract at 300 mg/kg, per os induced hypoglycaemic effect in normoglycaemic rats. In alloxan-induced diabetic rats, the extract at 300 mg/kg, per os decreased the blood glucose level. Therefore, the extract exhibited hypoglycaemic and antidiabetic activities in normoglycaemic and alloxan-induced diabetic rats [68]. Sy *et al.* [22] evaluated the hypoglycaemic and antidiabetic activities of acetonic and hexanic extracts of the leaves of *G. coloratum* in normoglycaemic and alloxan-induced diabetic rats. The acetonic extract at 100 mg/kg, per os induced a reduction of blood glucose in normoglycaemic rats while the hexanic extract increased the glycaemia in normoglycaemic rats. Therefore, the acetonic extract possesses both hypoglycaemic and antidiabetic activities in normoglycaemic and alloxan-induced diabetic rats [22].

Cytotoxicity Activities

Ménan *et al.* [66] evaluated the cytotoxicity activities of water, ethanol and pentane extracts of the leaves of *G. coloratum* against melanoma cells (A375) by estimating the cell growth using the [^{3}H]-hypoxanthine incorporation assay after 24 hours and 72 hours of incubation. The extracts exhibited activities with the IC_{50} values ranging from 30.0 µg/ml to 150.0 µg/ml [66]. Chukwujekwu *et al.* [67] evaluated the cytotoxicity activities of the compounds vernolide and vernodalin isolated from the leaves of *G. coloratum* using the 3-(4,5-dimethylthiazol-2-yl)-2–5-diphenyltetrazolium bromide (MTT) colorimetric assay with emetine as a positive control. The compounds vernolide and vernodalin exhibited activities with the IC_{50} values of 1.8 µg/ml and 1.5 µg/ml, respectively, against the IC_{50} value of 0.08 µg/ml exhibited by the positive control [67].

CONCLUSION

The present review summarizes the medicinal uses, phytochemistry and pharmacological properties of *G.*

coloratum. Although *G. coloratum* has been the subject of phytochemical and pharmacological research during the past 50 years, there is not yet enough data correlating the ethnomedicinal uses of the species with its phytochemical and pharmacological properties. Detailed studies on the pharmacokinetics, *in vivo* and clinical research involving both extracts and compounds isolated from the species, are required. Therefore, future research should focus on the molecular modes or mechanisms of action, pharmacokinetics and physiological pathways for specific extracts of the species including identification of the bioactive compounds of the species and their associated pharmacological activities.

CONFLICT OF INTEREST

The author declares no conflict of interest.

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