Review of Botany, Nutritional, Medicinal, Pharmacological Properties and Phytochemical Constituents of *Bruguiera gymnorhiza* (L.) Lam, (Rhizophoraceae)

Collen Musara[1,*], Elizabeth Bosede Aladejana[1] and Silas M. Mudyiwa[2]

[1]*Medicinal Plants and Economic Development (MPED) Research Centre, Department of Botany, University of Fort Hare, Private Bag X1314, Alice 5700, South Africa*

[2]*Department of Livestock and Pasture Science, University of Fort Hare, Private Bag X1314, Alice 5700, South Africa*

Abstract: *Bruguiera gymnorhiza* (L.) Lam, popularly known as black Mangroves, is an economical and valuable medicinal plant that is commonly found in relatively distinct zones, which are controlled by factors such as salinity, tidal regime, soil type and seed predators.This study is aimed at reviewing the botany, nutritional and medicinal uses, phytochemistry and pharmacological properties of *B. gymnorhiza*. A comprehensive literature search was done using electronic databases including journal articles, books, theses, scientific reports and internet sources.The most widespread direct use of *B. gymnorhiza* is for wood and other uses include food, medicines, dyes and environmental services. Different compounds such as β-sitosterol, α-amyrin, β-amyrin, ursolic acid, stigmasterol, lupeol, taraxerol, bruguierol, oleanolic acid, gymnorhizol, bruguiesulfurol, isobrugierol and ellagic acid have been isolated from *B. gymnorhiza*. The leaves, dried roots,stem and barks of *B. gymnorhiza* have shown the presence of flavonoids, phenols, hydroquinones, tannins, saponins, terpenoids, gums, reducing sugars,phenolic compounds, alkaloids, steroids, terpenoids and glycosides.These compounds are sterols and have shown high anti-inflammatory activity, antidiabetic, antioxidant and angiogenic effects, inducing apoptosis, hypocholesterolemic activity, anthelminthic and antimutagenic activities. *B. gymnorhiza* plant extract contains chemical constituents of pharmacological importance, which can play a significant role in the production of pharmaceutical products for future use.

Keywords: Botany, nutritional, medicinal, phytochemistry, pharmacology, Rhizophoraceae.

1. INTRODUCTION

The mangrove genus has been described with six species throughout the world [1-4] and is well known for its Rhizophoraceous foliage of bright, shiny green leaves, trunks with robust basal buttresses, and thick, knobbly knee roots [4]. The species are characterised by the presence of spines and bristles on petals, number of flower buds in inflorescences, bud size, ribbing on calyces, numbers of calyx lobes, and shape of petal lobes [4]. *Bruguiera* taxa are primarily divided into three morphologically distinct groupings, which are a group with smaller leaves and multiple-flowered inflorescences of relatively small flowers, comprising *Bruguiera parviflora* (Roxb.) Wight & Arn.exGriff. and *Bruguiera cylindrical* (L.) Blume; a group of larger leafed entities, with larger flowers in single-flowered inflorescences, being *Bruguiera gymnorhiza* (L.) Lam, *Bruguiera sexangula* (Lour.) Poir. and *Bruguiera exaristata* Ding Hou; and, a sixth species, *Bruguiera hainesii* C.G.Rogers, that cannot be readily attributed to either group since it has an intermediate combination of character states which are notably, larger flowers in multiple-flowered inflorescences [2,4]. The focus of this study is for a group of larger leafed entities, with larger flowers in single-flowered inflorescence *B. gymnorhiza* (L.). The name 'Gymno-rhiza' means 'naked root' (in Greek), and it refers to the conspicuous exposed knee roots of this species. There has been confusion regarding the spelling of 'gymnorhiza' and an epithet was published by Linnaeus with one 'r' and quoted by Savigny in Lamarck and Poiret [5] with one 'r' as well [4].

2. METHODOLOGY AND JUSTIFICATION OF THE STUDY

The literature search was performed from January 2020 to June 2020. A mixed-method review approach, which involved combining quantitative and qualitative research, was used to compile the review. The literature on nutritional composition, medicinal uses, phytochemical and pharmacological properties of *B. gymnorhiza* was collected from textbooks, theses and online research articles from databases such as Elsevier, Google Scholar, Scopus, Science Direct, SciFinder, PubMed, BMC, and Web of Science. These data sources were chosen based on the topic covered and the main search key terms included "taxonomy,

*Address correspondence to this author at the Medicinal Plants and Economic Development (MPED) Research Centre, Department of Botany, University of Fort Hare, Private Bag X1314, Alice 5700, South Africa;
E-mail: collinmusara@gmail.com

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botany, distribution, nutritional composition, medicinal uses, biological and chemical properties" in relation to *B. gymnorhiza*. Search terms were set to be in the title, keywords and abstract. To avoid too much filtering of literature, the terms were searched individually. The aim of this study was to review and to provide a detailed appraisal of the existing knowledge and literature on the botany, nutritional composition, medicinal uses, phytochemistry and pharmacological properties *of B. gymnorhiza* for future pharmacological and phytochemical research.

3. BOTANICAL DESCRIPTION

Bruguiera gymnorhiza (L.) Lam, (syn.: *Bruguiera conjugata* Auct) is a member of the Rhizophoraceae family, whose common names are black mangrove (Eng.); swartwortelboom (Afr.); isiKhangazi, isiHlobane (isiZulu); isiKhangathi (isiXhosa) [6]. It is a salt-tolerant, buttressed, and small to large evergreen true mangrove tree, 8-25 m with occasional stems reaching 35 m [6-8]. The tree crown is conical at first stages but later becomes more irregular [8]. *B. gymnorhiza*'s trunk is straight, about 40-90 cm diameter, with numerous root knees emanating from long horizontal roots [7]. In permanently waterlogged conditions, short aerial roots that do not reach to the soil are often present on the stems [3]. *B. gymnorhiza* has smooth to roughly fissured, thick, black to reddish brown bark [6,8]. The leaves are crowded at the ends of branches and are apple green when they are young, becoming yellow with age [8]. They are thick, opposite each other, elliptic-oblong, 9-20 cm long, 5-7 cm wide, acute at both ends, entire, without visible veins,leathery and glabrous [6,7] with plain leaf margins [8]. The tree has solitary creamy white or red to yellowish flowers that are 3- 4 cm long [7, 8] with red to pink-red, bell-shaped hypanthium. Its petals are 8-18, 13-15 mm hidden at base of each sepal [7], petals are creamy white, falling with the stamens; sepals are green in shade but pink in direct sunlight [8]. Petioles are 2–4.5 cm long; the calyx has 10-14 very narrow, leathery lobes;pistil with inferior 3-4-celled ovary, each cell with 2 ovules, style slender; stigma with 3-4 short forks [7]. The fruit is a fleshy berry up to 25 mm long, germinating on the tree to form a ribbed, brown hypocotyl (incipient root) [8]. The viviparous propagule (fruit) is cigar shaped 15-25 cm in length [9] and 1.5 -2 cm in diameter [3,10].

According to Duke and Ge, [4], *B. gymnorhiza* is notably distinguished from other *Bruguiera* by a number of characteristics such as open flowers showing petals with 3 longish bristles at lobe tips, large, single-flowered inflorescences with petals having a spine roughly the same length as the paired lobes, as distinct from much longer spines of *B. cylindrica*, *B. hainesii* and *B. parviflora*; and, its acute petal lobes with 3-4 bristles, being distinct from the more rounded petal lobes and fewer bristles of *B. sexangula*, *B. rhynchopetala* and *B. exaristata.* The calyces of *B. gymnorhiza* are often also distinctly bright red, almost scarlet in colour, but not always (Figure **1**).

3.1. Habitat and Distribution

B. gymnorhiza is most commonly found in relatively distinct zones, which are controlled by factors such as salinity, tidal regime, soil type, and seed predators [12]. *B. gymnorhiza* is widely distributed in the tropical and subtropical coastlines or regions of the world [13] ranging from the southern tropical Indian Ocean to tropical Australia [6] including the tropical south and east Africa, just north of East London (Eastern Cape) to

Figure 1: (A) Whole plant (B) Fruits (C) Flower (D) Root of *Brugeria gymnorhiza.*
Source: Alchetron, [11].

Somalia, Madagascar, southeastern Asia, Australia [7,14] Sri Lanka, Hawaii, Seychelles, Ryukyu; throughout Malaysia to Philippines, Micronesia, and Polynesia [7].

4. USES AND CULTURAL ASPECTS

The most widespread direct use of *B. gymnorhiza* is for wood and other uses include food, medicines, dyes and environmental services.

4.1. Nutritional and Chemical Properties of *B. gymnorhiza*

The results of proximate composition of both species of *B. gymnorhiza* (leaves and propagules) are shown in Table **1**. The ash content, which is the index of mineral contents, for *B. gymnorhiza* propagules has the value of 9.17% and it has been reported that protein-calories malnutrition deficiencies is a major factor responsible in nutritional pathology [15]. The highest crude proteins observed in the leaves of *B. gymnorhiza* was (9.62%) and the fat content observed was much less in leaves as well as propagules of *B. gymnorhiza* (0.72% and 0.81%) respectively [16]. *B. gymnorhiza* leaves showed rich source of crude fibre while the estimated carbohydrate contents in propagules were standing to be higher than the leaves [16]. An intake of dietary fibres can lower the serum cholesterol level, risk of coronary heart disease, hypertension, diabetes and breast cancer [17]. The total energy content was estimated to be 272.88 (Kcal/100 g) and 300.29 (Kcal/100 g) for the leaves and propagules of *B. gymnorhiza,* respectively, which is an indication that it could be an important source of dietary calorie [16].

B. gymnorhiza is one of the numerous types of mangrove commonly used as a food source for humans because of its high nutrition content [18]. The seedlingsof *B. gymnorhiza* are sliced, soaked to leach out the tannins, and then grounded into a paste to make a sweetmeat [19]. The fruits, leaves and peeled seedlings are soaked, boiled, and eaten during periods of severe food shortages [7]. Leaves and peeled propagules are eaten as fallback food in Papua New Guinea after soaking and boiling while propagules have been used as a food source in India, Bangladesh, and other parts of south eastern Asia [8]. In Melanesia and Nauru, the fruit (propagule) is eaten cooked, after it is scraped or grated, washed, and dried (to remove tannins) then cooked and served as a meal, occasionally mixed with coconut [8]. In Solomon Islands, the fruit is sold as a vegetable [20]. A study by Amin *et al.*, [14] revealed that the fruit has 4.82 % protein, 14.23 % amylose content, 0.24 % fat, 7.46 % crude fibre. Oftenly, in Java, the fruit is chewed as mordant in the betel quid when there is no other option available, whilst the Chinese use the fruit to make sweet meat [7]. The bark is used to flavour raw fish by Dutch Indians [7] while the flowers are used as vegetable in Thailand [21]. Study by Pendury [18] showed that lindur starch hypocotyl has 10.85 % sucrose, 3.31 % protein, 4.65-5.65 % ash, 0.89 % fat, 1.40 % crude fiber, 57.2 1 % - 73.19 % high starch and 31.45 % amylose content.

4.2. Fodder and Feed

Although few animals use *B. gymnorhiza* as a major source of food; birds feed and depend on the floral nectaries subsequently dispersing pollen to neighbouring trees [8]. *Bruguiera* species also provide bee forage though they have limited nectar (largely consumed by birds), but they do have copious pollen that may be gathered by bees [8]. *B. gymnorhiza* is also a largely unknown source of native animal foods but however, a variety of insets, crabs, and molluscs have been observed grazing on green leaves in the forest canopy [8].

4.3. Environmental services and Other Uses

B. gymnorhiza are dicotyledonous woody shrubs or trees, often form unique ecological environments, which provide an appropriate habitat for a rich assemblage of species [8,22]. Also, they support communities of phytoplankton, zooplankton, and fish and play a unique role as hatchery and nursery habitat for juveniles of fish whose adults occupy other habitats such as coral reefs and seagrass beds [8,23].

Table 1: Proximate analysis of leaves and propagules of *B. gymnorhiza* species by Patil *et al.* [16]

Sample	Moisture (%)	Ash (%)	Crude Protein (%)	Fat (%)	Crude Fibre (%)	Carbohydrates (%)	Total Energy (Kcal/100g)
Leaves	8.49	8.47	9.62	0.72	15.72	56.98	272.88
Propagules	6.68	9.17	4.37	0.81	10.09	68.88	300.29

Generally, mangroves play a pivotal role in protecting and supporting marine food chains [8,24] through organic matter, which serves as nutrient supply in coastal regions. While the foliage of *B. gymnorhiza* is of relatively poor quality [25], its generally high productivity tends to create highly organic soil environments, which are exported to nearby marine environments [8].

B. gymnorhiza mangroves contribute to coastal stability and protection [8,24,26] through trapping sediment and keeping sea storms and winds at bay thereby minimising soil erosion and damage to properties. In South Africa, the tree has been planted to stabilize dunes and in freshwater swamps [7,8]. In the Philipines, *B. gymnorhiza* mangroves has been planted to protect coastal homes from wind and wave action and those mangroves that naturally occur adjacent to agricultural areas serve as protection for crops from sea spray or storms [8]. *B. gymnorhiza* has been found to have great phytoremediation potential [24,26] and also the highest efficiency on water treatment [27]. *B. gymnorhiza* mangroves are also important for carbon sequestration and storage [26], as fish breeding grounds [26,28], and landscaping, for instance, the sprouting hypocotyls are packaged and sold in Japanese tourist shops as ornamental plants [25].

The *B. gymnorhiza* tree is utilised in the production of dyes ranging from red-brown to black and the bark has high tannin content but tends to colour leather excessively unless the bark is collected at the end of each growing season [8]. The phlobaphene colouring matter is used in China and Malaya for making black dye [29]. On the other hand, the knee roots *B. gymnorhiza* are used for making perfumes and the flowers are used in body ornamentation/garlands, for example in Hawaii, they are used to produce a type of lei called the kukuna o ka la (“rays of the sun”) [33].

B. gymnorhiza wood is well known for being waterproof, resistant to borers, tough and effectively indestructible hence making it valuable timber [7,8,31]. Though the wood is hard to work on, its durability makes it widely used for structural components, for example poles, beams, and rafters of traditional homes and other structures [7,31]. The wood is also used to make the paddles and oars to propel boats and canoes on some islands [31]. In the Marshall Islands, it has been used for keel-pieces (maal), outrigger (kie), and outrigger struts (kein-eon erre) [8]. The timber is also used for furniture, fishing stakes, spears, transmission and telephone poles in some regions (the Andaman Islands), and is likely durable in direct contact with the ground [8]. The wood is also used to make other items including beehives, digging sticks, handcart handles,

Table 2: Medicinal uses of *B. gymnorhiza*

Plant parts	Uses	References
Fruits, bark and leaves	Treatment of diarrhoea and fever	[6,13,34,35]
	Treatment of diabetes, pain, burns, intestinal worms, and liver disorders	[13,35]
Roots and barks	Treatment of diabetes	[6,36-38]
Fruits and roots	Treatment of diarrhoea in Central China	[21,39]
Stems	Treatment of viral fever	[37,38]
Leaves	Treatment of burns, cuts, wounds, intestinal worms, liver disorders and tumour inhibitors	[6,8,33,40-43]
Bark, roots and leaves	Treatment of diarrhoea, malaria and burns	[9,37]
Fruit	Has antiviral properties; used for diarrhoea treatment and also play a role in the treatment of shingles and eye diseases	[9,37,39]
Root and leaves	Treatment of burns	[9,21,44]
Bark	Treatment of diarrhoea and fever in Indonesia	[45]
	Treatment of malaria and diarrhoea in the Solomon Islands	[37,38]
	As an abortifacient and for treating burns in the Solomon Islands.	[8]
	Cambodians use the astringent (and mildly toxic) bark to treat malaria	[31]

axe handles, pounding poles and drums [31]. The wood has a high calorific value and is used and for charcoal fuelwood [8,10,31] and also as a source of chips for pulp production and rayon manufacture [32].

5. MEDICINAL USES

The World Health Organization has reported that more than 80% of world population rely on the use of plant as an alternative medicine and *B. gymnorhiza* has been widely used for this purpose. From the ethomedicinal survery, the medicinal uses of *B. gymnorhiza* have been recorded in various countries such as China, Indonesia, Solomon Islands, Bangladesh, Thailand and Indian Sundarbans. Medicinally, *B. gymnorhiza* has been reported to be used in the treatment of various ailments/complaints such as diabetes, diarrhoea, viral fever, malaria pain and burns among others [13] (Table **2**), however, further clinical investigation is required inorder to aunthenticate this information.

5.1. Pharmacological Activities of *B. gymnorrhiza*

There are a few reports on the pharmacological activities of *B. gymnorhiza* in the literature. Till date, only a few studies have been conducted on the antimicrobial, hepatoprotective, hypoglycemic effect, antioxidant, antinociceptive, antiinflammatory and toxicity of the plant.

Antimicrobial Activity

The methanol, ethanol and chloroform extracts of *B. gymnorhiza* showed antimicrobial activity with the ethanol extract exhibiting more inhibitory effect against the common bacterial pathogens used in the study [37]. Also, the aqueous extract of *B. gymnorhiza* inhibited the growth of *S. aureus* and *B. cereus* at zone of inhibition greater that 17 mm and 15 mm respectively, thus, the plant showed activity against the organisms [46]. The study of Seepana *et al*. [47] revealed that the ethanol and aqueous extract showed activity against *Salmonella typhii* at the inhibition zone of 18 mm and 11 mm, respectively, while no activity was recorded for *E. coli*, *Shigella flexneri* and *Klebsiella pneumonia*. The pericarp, exocarp, endocarp of fruit and leaves of *B. gymnorhiza* plant exhibited antibacterial activity against common bacterial pathogens (both Gram-positive and Gram-negative bacteria) in a disc diffusion assay [9]. The study further showed that the n-hexane extract of the different parts of this plant showed more antibacterial activity than water extract [9].

Hepatoprotective Properties

The hepatoprotective activity of hydro-methanolic leaf extract of *B. gymnorhiza* was examined in D-galactosamine (GalN) and it induced (200 mg/kg, i.p) hepatitis in Wistar rats. The extract was administered orally at the dosage of 125 mg/kg and 250 mg/kg, p.o to the rats for 7 days. The *in vivo* study showed that the leaves of *B. gymnorhiza* produced dose-dependent protection against GalN induced hepatitis in rats. The extract decreased the GalN induced elevation of alanine transaminase, aspartate aminotransferase and alkaline phosphatase in serum and resist oxidative stress marked by lipid peroxides, glutathione and catalase in hepatic parenchyma [6]. Thus, it could be deduced that the leaves of *B. gymnorhiza* possess the potential to treat hepatic injuries coupled with the ability to produce an antioxidant effect [6].

Hypoglycemic and Antihyperlipidemic Effects

The ethanol extract of the bark of *B. gymnorhiza* was evaluated for its anti-hyperglycemic effect in streptozotocin- (STZ-) induced diabetic rats. Ethanolic extract (400 mg/ kg body weight) was administed orally for 21 consecutive days. The rats treated with the extracts for 21 days showed significant reduction in blood glucose level in the STZ-induced diabetic rats, which was comparable with the standard drug glibenclamide (0.5 mg/kg). Thus, the extracts normalized the levels of blood glucose in the rats [36]. Furthermore, in the diabetic rats, there was a significant reduction in the level of total cholesterol, triglycerides, very-low-density lipoprotein, and low-density lipoprotein along with increased high-density lipoprotein level [36]. The results suggested that the potent anti-diabetic and anti-hyperlipidemic effects of the plant extract were due to the presence of various potent antidiabetic active compounds, which produced an antihyperglycemic effect in diabetic rats [48]. Thus, further study is required to isolate the active ingredients in the plant and optimize them to gain potency. Likewise, cooked and raw *B. gymnorhiza* has been reported to show activity against type 2 diabetes with the latter exhibiting strong insulin-mimetic effect against the disease [49].

Antinociceptive Activity

The methanol root extract of *B. gymnorhiza* was tested for antinociceptive activity using the model of acetic acid-induced writhing in Young Swiss-albino mice. While the extract was administed orally at the concentration of 250 mg/kg and 500 mg/kg body

weight, the standard drug diclofenac sodium, at the dose of 25 mg/kg of body weight, was administed to the rats.The findings depicted that the extract produced significant inhibition of writhing at the oral dose of 250 mg/kg and 500 mg/kg body weight (34.13% and 47.96% inhibition in the test animals, respectively) ($P < 0.001$) and were comparable to the control, which exhibited about 60% writhing inhibition ($P< 0.001$) [21]. Based on this result, it could be deduced that the methanolic root extract of *B. gymnorhiza* might possesses antinociceptive activity.

Antidiarrheal Effects and Gastro Intestinal (GI) Motility

When tested for its antidiarrheal effects on castor oil-induced diarrhoea in mice, the methanolic roots extract increased mean latent period and decreased the frequency of defecation significantly at the dose of 500 mg/kg body weight ($P< 0.01$), thereby inhibiting diarrheal by 65.28% in the mice. However, the standard antidiarrheal agent Loperamide exhibited an inhibition of 72.22%. Hence, the study revealed that the extract of *B. gymnorhiza* posses antidiarrheal activity. The extract also decreased the charcoal induced Gastro Intestinal (GI) motility in mice and reduced the movement of GI tract (8.20 mm) in comparison to the control animals (14.75 mm) [21]. Furthermore, the leaves and stem extracts (250, 500 mg/kg, body weight) of *B. gymnorhiza* produced significant anti-diarrheal effects on castor oil-induced diarrhoeal mice by delaying the onset of diarrhoeal and reducing the frequency of defecation [13].

Anticancer Activity

The extracts (petroleum ether, $CHCl_3$, Et_2OAC and MeOH) of *B. gymnorhiza* coupled with *bruguiesulfurol, bruguierol* and *isobrugierol* isolated from the flowers of the plant showed activity in the NF-*k*B luciferase assay [50]. There is limited information on the anticancer property of this plant, however, based on this result, it could be deduced that *B. gymnorhiza* possessed cancer chemo-preventative activity [50], hence, further study is required on the anticancer properties of the plant.

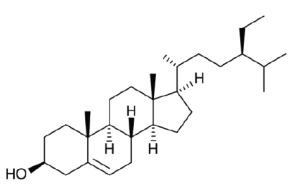
In Vitro Antioxidant Activity

The methanolic extracts of both leaves and roots of *B. gymnorhiza* have displayed antioxidant effects in different antioxidant assays namely; 2, 2-diphenyl-1-picrylhydrazyl (DPPH), reducing power and ferric reducing antioxidant power [51]. The DPPH radical scavenging activity was IC_{50} 30 and 21 µg/mL; antioxidant content of 88.21±1.38 and 26.88±0.76 mg AEAC/g; reducing power of 3.34±0.12 and 0.43±0.19 mg AEAC/g and ferric reducing antioxidant power of 3.23±0.05 and 3.88±0.04 mg AEAC/g in both the leaves and roots of *B. gymnorhiza,* respectively [51]. In addition, in a DPPH antioxidant assay, the methanolic leaf extract showed percentage inhibition of 68% and 59% at 2 and 1 mg/mL, respectively [52]. Likewise, the methanolic leaf and bark extracts of *B. gymnorhiza* had 50% inhibitory concentration (IC_{50}) value of 0.038±0.003 and 0.025±0.003 µg/mL, respectively [37]. Both the leaves and stem extracts of *B. gymnorhiza* showed significant DPPH radical scavenging, nitric oxide, hydrogen peroxide scavenging and also concentration dependent reducing power activities [13]. The hydro-methanolic leaves extract of *B. gymnorhiza* exhibited strong reducing power and DPPH radical scavenging, nitric oxide radical inhibitions, hydroxyl radical scavenging action, superoxide radical inhibitions and ABTS cation diminutions at IC_{50} values of 17.93 µg/mL, 0.355 µg/mL, 0.305 µg/mL, 0.311 µg/mL, 0.356 µg/mL and 0.056 µg/mL, respectively, thus has strong antioxidant properties [6]. According to Lee *et al*. [53], *B. gymnorhiza* contains large amount of antioxidant, thus, it is recommended for future drug development.

Toxicity

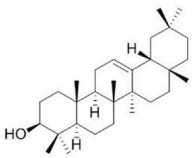
The *in vivo* toxicological assay of the ethanolic root extract of *B. gymnorhiza* was examined on male Wister rats of body weight 180-200 g. Oral administration of the extract at 100, 200, and 400 mg/kg body weight doses were admistered for 14 days. The result showed that the extract did not produce any significant changes in the behavioural and neurological responses of the rats even at the dosage of 400 mg/kg body weight. Also, the acute toxicity result, LD_{50} (data not shown), depicted the non toxic nature of the extract.Thus, the author concluded that the extract of *B. gymnorhiza* was safe to be used in animals, however, further studies are required inorder to validate the safe consumption of the plant [36]. In addition, the stem and leaves extracts of *B. gymnorhiza* showed no mortality and observable signs of acute toxicity in oral acute toxicity evaluation,even at the doses ranging from 100-1000 mg/kg body weight [13]. However, in the *in vitro* brine shrimp lethality bioassay, the leaves and stem extracts showed LD_{50} value of 201.31 µg/ml and 232.09 µg/ml, respectively. From the above results, it can be deduced that the extracts *B. gymnorhiza* do not have significant cytotoxic activity [13].

Based on the findings available, it can be deduced that the different parts of the *B. gymnorhiza* plant



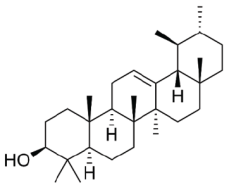
Name: Beta-sitosterol

Molecular formular: $C_{29}H_{50}O$



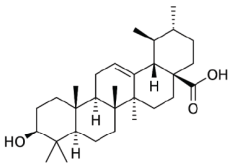
Name:Beta-amyrin

Molecular formular: $C_{30}H_{50}O$



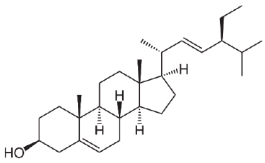
Name: Alpha-amyrin

Molecular formular: $C_{30}H_{50}O$



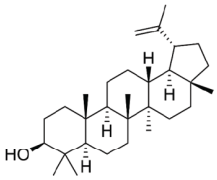
Name: Ursolic acid

Molecular formular: $C_{30}H_{48}O_3$



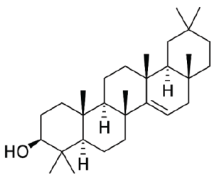
Name: Stigmasterol

Molecular formular: $C_{30}H_{48}O_3$



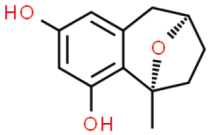
Name: Lupeol

Molecular formular: $C_{30}H_{50}O$



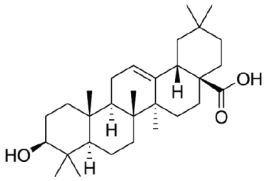
Name: Taraxerol

Molecular formular: $C_{30}H_{50}O$



Name: Bruguierol

Molecularformular: $C_{12}H_{14}O_3$



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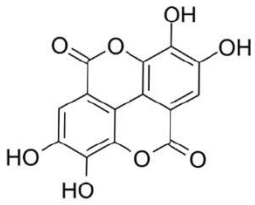
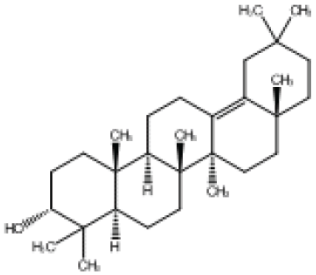
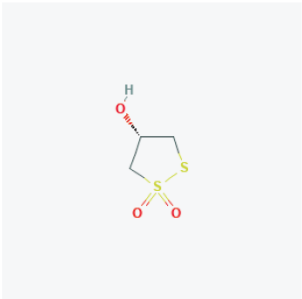


$C_{20}H_{48}O_3$





Name: Ellagic acid

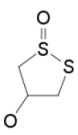
Molecular formular: $C_{14}H_6O_8$

Name: Gymnorhizol

Molecular formular: $C_{30}H_{50}O$

Name:Bruguiesulfurol

Molecular formular:$C_3H_6O_3S_2$



Name: Isobrugierol
Moleculae formular: $C_3H_6O_2S_2$

Figure 2: Chemical compounds from *B. gymnorhiza*.

extract contain chemical constituents of pharmacological importance, which can play a significant role in the production of pharmaceutical products.

5.2. Phytochemical Constituents of *B. gymnorhiza*

Mangroves are considered a rich and diverse source of bioactive metabolites such as essential oils, limonoids, flavonoids, coumarins, terpenoids, glycosides and alkaloids, which have wide applications in pharmaceutical and medicinal sectors [6,38,54,]. The amount of tannin from the bark of *B. gymnorhiza* ranges from 4 - 53.12% tannin [55,56]. The bark also contains D-glucose, rhamnose, arabinose, tannins, a mixture of bruguierol and isobruguierol [36]. According to Duke [54], the leaves of *B. gymnorhiza* may contain 18.3% H_2O, 13.5% tannin; outer cortex (small trees) 14.6 and 7.9, outer cortex (large trees) 14.2 and 10.8; twig bark 13.1 and 14.8, bole bark (small trees) 16.3 and 31.7, while the bole bark of large trees contains 12.5% H_2O, 42.3% tannin in Burma. The hydrolysis of the sterol esters of the leaves produced beta-sitosterol, cholesterol, campesterol, stigmasterol and 28-isofucosterol [36].

The present survey observed that different compounds such as β-sitosterol, α-amyrin, β-amyrin, ursolic acid, stigmasterol,lupeol, taraxerol, bruguierol, oleanolic acid, Brugunin A; Bruguierol D; Bruguierols A, B, C; Aminopyrine; 7,3′,4′,5′-tetrahydroxy-5-methoxyflavone; 3-β-(Z)-coumaroyllupeol; Menisdaurillide; Vomifoliol; Apiculol; Steviol, gymnorhizol, *bruguiesulfurol*, *isobrugierol* and ellagic acid have been isolated from *B. gymnorhiza* as shown in Figure **1** [6,13,48,50,57]. These compounds are sterols and have shown high anti-inflammatory activity, antidiabetic and antihyperlipidemicactivity, antioxidant and angiogeniceffects, inducing apoptosis, hypocholesterolemicactivity, anthelminthic and antimutagenic activities [58].

The leaves, dried roots and barks of *B. gymnorhiza* showed the presence of flavonoids, phenols, hydroquinones, tannins, saponins, terpenoids, gums and reducing sugars [6,21,37,38,50]. Other phytoconstituents such as phenolic compounds, alkaloids, steroids, terpenoids and glycosides have been reported in the n-hexane and water extracts of *B. gymnorhiza* plant as indicated in Table **3** [9].

In the phytochemical screening done by [13], the leaf and stem extracts showed the presence of anthraquinone glycosides, flavonoids, alkaloids, tannin, saponins. While terpenoid and gum were absent in the leaf, gum was present in the stem and the formal absent. The experimental results also indicated that leaf extract contained gallic acid, vanillic acid, vanillin and ellagic acid whereas stem extract contained gallic acid, (+)-catechin, vanillic acid, vanillin, ellagic acid and benzoic acid [13].

Table 3: Phytochemical constituents of *B. gymnorhiza* fruit and leaf by Roy *et al*. [9]

Phytochemicals	n-hexane extract	Water extract
Saponins	+	-
Flavonoid	+	-
Phenolic compounds	+	+
Alkaloids	-	-
Steroids	-	-
Terpenoids	+	+
Glycosides	+	+
Tannins	+	-
Reducing sugars	-	-

(-) Absent; (+) Present.

There are diverse new and known bioactive constituents which were found in *B. gymnorhiza* hypocotyls such as 3-*β*- (Z) -coumaroyllupeol and cyclohexylideneacetonitriles [6,59], dammaranetriterpenes (bruguierins) in flowers [50] while, brugunins, and bruguierols were found in stems [60]. It is hypothesised that some of the compounds present in *B. gymnorhiza* have potential inhibitory actions on hepatitis B virus and also in HepG2 cells activations [6], though no experimental evidence has come out yet.

6. CONCLUSIONS

The mangrove plant *B. gymnorhiza* are considered as the most essential bioresources among the most productive and biologically complex ecosystems on the planet as they play a critical role in the conservation and protection of the forest as well as future emergency food or famine food in coastal areas. The leaves, dried roots, stem and barks of *B. gymnorhiza* have shown the presence of flavonoids, phenols, hydroquinones, tannins, saponins, terpenoids, gums, reducing sugars, phenolic compounds, alkaloids, steroids, terpenoids and glycosides. Based on the researches carried out, the plant possesses antidiabetic, antimicrobial, antioxidant, antinociceptive, antiinflammatory, hepatoprotective and anticancer properties. Different parts of the plant such as leaves,

roots, stems fruits and barks are used for the treatment of diarrhoea, viral fever, malaria, pain, burns shingles and eyes diseases among others. It can be deduced that the different parts of the *B. gymnorhiza* plant extract contain chemical constituents of pharmacological importance, which can play a significant role in the production of pharmaceutical products. Further studies are required to isolate and characterize the active components of the extracts and to scientifically evaluate the traditional medicine and learn how to combine these therapies with modern medicine.

CONFLICT OF INTEREST STATEMENT

The authors have not declared any conflict of interest.

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