Antihyperglycemic Properties of Mangrove Plants

(*Rhizophora mucronata* and *Avicennia marina*): An Overview

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**Abstract:** The increased occurrences of diabetes have led to the utilization of the curative plants in search of the best remedies. The usage of medicinal plants has been embraced worldwide since it is a critical part of the public healthcare. *Rhizophora mucronata* and *Avicennia marina* are vulnerable plants that require protection for their continued significance in the cure of diabetes. The two plants have proved to be antiviral and antibacterial in nature. Traditionally, the *Rhizophora mucronata* and *Avicennia marina* were utilized to cure diabetes. Although there is tremendous progress in the diabetes cure through the oral hypoglycemic compounds, there is a consistent search for the newer medicines. Mostly these mangrove trees have antidiabetic activity despite the fact that they have not been accepted. However, the traditional medicine system has used such plants with success. This review showed some of the previous data on the *Rhizophora mucronata* and *Avicennia marina* that were tested on the rats in medical laboratories.

**Key words:** *Rhizophora mucronata* · *Avicennia marina* · Diabetes · Bioactive compounds.

**INTRODUCTION**

The diabetes complications involve the retinal, renal and the cardiovascular complications. To date, diabetes remains a severe metabolic disorder where medicinal plants have the potential to help treat the condition effectively. The allopathic medicines cannot cure diabetes since they do not restore the standard glucose homeostasis. However, the traditional and the modern practitioners across the world need to incorporate the ideas of the medicinal plants and the synthetic drugs together to ensure the development of strong antidiabetic medicines [1].

Medicinal plants have continued to offer valuable therapeutic elements in the contemporary medicine and in the traditional structures [2-6]. *Rhizophora mucronata* and *Avicennia marina* are mangrove plants that exist at the interface of the earth and the waters in both the humid and subtropical latitudes. The plants survive in the environments of elevated salinity, severe tides, anaerobic soils and lofty temperatures, muddy and anaerobic soils. Accordingly, *Rhizophora mucronata* have gained morphological and physiological adaptations to the severe environmental circumstances. Therefore, it is likely that the species have bioactive compounds potential for long-term treatment of diabetes and other significant disorders. The two plants are not directly consumed as food since they contain high amounts of tannins and other distasteful agents.

However, the *Avicennia marina* is consumed after the processing of its hypocotyls [7]. Such plants have been scientifically proven to be effective against the human, plant, animal pathogens and have significant bioactivities. The benefits of these mangrove species fall into two categories where it can be utilized as a mangrove ecosystem as a whole or converted to other functions. On the other hand, their products could be used. People exploit both *Rhizophora mucronata* and *Avicennia marina* to the advantage of the local community, but with the increased population, the resources have been abused significantly.

Notably, extensive screening of the *Rhizophora mucronata* and *Avicennia marina* has been reported in several ethnomedical systems. Nevertheless, the uses of the plants have not been in great details in all the countries present. Thus, these herbal remedies are critical objects for the future research. It must be scientifically proven that the herbal medicines offer safe, efficient and
reliable alternative therapy for diabetes. Conversely, this means that all the plants with the antidiabetic potential need to be identified, that would involve an ethnobotanical analysis in various regions to document and assess the plants that could be utilized for a diabetes cure. According to various researchers, the medicinal plants do not have adverse effects and most of the modern medicines are derived from such plants. Therefore, the purpose of this review was to give an extensive and systematic overview of both Rhizophora apiculata and Avicennia marina that are used to treat diabetes.

**Rhizophora mucronata**

**Description:** Rhizophora mucronata belongs to family Rhizophoraceae and commonly known as red mangrove. It is an evergreen tree that is small to medium size of about 20-25m growing on the river banks [8]. The tallest trees are near the water whereas the shorter ones are located further inland. It possesses many aerial stilt roots around the trunk. Its leaves are elliptical with a 12cm length and 6cm width. They maintain elongated tips though they easily break off. The pale underside of the leaves has corky warts while the flowers grow in axillary clusters on the branches. Every flower has cream-coloured calyx that has four sepals and white hairy petal. Its seeds are viviparous that begin to grow while still held to the tree. The root starts to elongate and can extend to at least a meter. The propagule then gets detached from the twig once adequately developed to the source underneath the mud.

**Distribution and Habitat:** Rhizophora mucronata is located on the river banks of the Indo-Pacific areas and the sea edges [9]. It is the individual mangrove species that one can find in the East Africa. It is native to African nations like Egypt; eastern Ethiopia; eastern Tanzania; Somalia; the Seychelles; southeastern Sudan; Mauritius; eastern Kenya; Mozambique; Madagascar eastern South Africa down the Nahoon in the southern. It is also present in South Pacific (Vanuatu and Solomon Islands), Asia (Burma; Indonesia; Taiwan; Papua New Guinea; Iran; Malaysia; Pakistan; Sri Lanka; Vietnam; Thailand; India; Burma; Cambodia; the Ryukyu Islands of Japan & the Philippines and Australia (Queensland and Northern Territory). In all these regions, the Rhizophora mucronata inhabits the estuaries, tidal creeks and the flat coastal areas that are prone to tidal flooding. It has higher tolerance compared to other mangrove species and mostly creates an evergreen fringe to mangrove regions.

However, it appears as a pure stand at some times or could develop along with the Rhizophora apiculata. Rhizophora mucronata regenerates quickly from seed though the seed is destroyed by crabs. Poecilusfallax attacks the tree.

**Uses:** Importantly, Rhizophora mucronata has several uses. The plant's timber is a source of firewood and helps construct buildings like poles and pilings. It also contributes to making fish traps. The young shoots can be used as a vegetable. It curbs coastal erosion and restores the mangrove habitats [10, 11]. The roots provide the breeding place for fish and prawns, as well as the shelter for the juveniles. [12]. It also act as protection barrier against storms, hurricanes and tsunamis [10, 13].

**Avicennia marina**

**Description [14]:** Avicennia marina, belongs to the family Avicenniaceae and commonly known as grey mangrove. Avicennia marina grows like the shrub to about 10 meters height in the tropical areas. They have gnarled arrangements of several branches with thick leaves. It has aerial roots that develop to about 20cm with a diameter of approximately 1centimeter. This ensures sufficient oxygen absorption since its deficient in its habitats. The roots provide firm support to the plant during the regular tidal waves. It has white to golden yellow flower color that is in a bunch of three to five. Its fruit has huge cotyledons which surround the new seedling stem. It is prone to stunted growth under extreme saline situations. They dwell well where the waters are both salty and fresh. Nevertheless, in extreme salinity, the species can excrete the salts via the leaves.

**Distribution and Habitat:** It is found on the East Coast of Africa, South Asia and Australia. Some are found in the New Zealand, Arabian Peninsula coast, Egypt, Eritrea, Somalia, Qatar, Yemen, United Arab Emirates, Oman, Saudi Arabia and the red sea. They can create hatcheries for fish and shellfish and sometimes offer recreational fisheries [15].

**Diabetes Concern and the Use of Plants for its Treatment:** Diabetes is a global challenging health condition which has tremendously affected the human being. It is a disease condition resulting from the body system metabolic disorder due to hyperglycemia. However, the increasing number of diabetic issues has raised concern in the medical system and the society. This review, therefore, gave an expounded investigation
of the *Rhizophora mucronata* and *Avicennia marina* plants utilized to lower the glucose levels and boost insulin production [16]. Mostly, diabetes is linked to interruptions in the fat, carbohydrate and protein metabolism that cause a deficiency in insulin actions and production when the pancreas cannot produce sufficient insulin. Additionally the condition could result from the body failure to respond to the readily produced insulin [17]. Due to increased cases of diabetes, people have been advice to adopt healthy lifestyles and ensure regular health care for the affected individuals.

Researchers have revealed that the natural remedies are highly viable compared to the use of synthetic drugs and the oral medications that could lead to adverse body side effects [18]. Hence, this has resulted in several plants being recognized and confirmed highly successful for managing diabetes mellitus. Notably, such herbal drugs can be utilized alongside with other synthetic medicines like insulin. There are active components in the medicinal plants that are critical for the healing of diabetes and its related problems. Plant-based drugs have been utilized to fight against the diabetes conditions for a long time now.

Even in the ancient time, diabetes was known and the people relied on the herbs for a cure [19]. Diabetes mellitus is described as the condition where an individual has inappropriate hyperglycemia resulting from a relative or total deficiency of insulin. Importantly, it could occur due to insulin resistance at the cellular level. However, diabetes can be treated using the general medicines. The pathogenesis of the insulin-dependent diabetes is via the environmental causes which activate the autoimmune actions on the genetically vulnerable people. In turn, it causes progressive loss of insulin. However, the non-insulin dependent diabetes is linked to impaired insulin production, age and obesity. The diabetes mellitus is a collection of disorders that have different etiology and pathogenesis. Its characteristics are elevated fasting and postprandial glucose absorption, deficiency in insulin, abnormalities in glucose, protein and lipid metabolism [20].

Most of the medicinal plants add to the dietary and assist in the treatment of several diseases like the diabetes. Notably, very few medicinal trees have gained scientific and medical evaluations. Remedies must be put in place since most of the medicinal plants still have toxic substances that are harmful to the body. Currently, screening of various medicinal plants for biological actions is significant. Such plants have been confirmed unique with the capacity to produce several novel natural products. They contain anti-inflammatory, antidiabetic and antimicrobial elements [21]. With this paper, one has adequate knowledge on the use pattern of medicinal plants to tackle diabetic oriented issues. Therefore, significant care is necessary for the development of drugs from such extracts to make sure that the protocol is ecologically safe and economically viable [22].

 Determination of the likelihood of obesity occurrence is significant for the medical practitioners since it can assist in the mitigation of the development of diabetes in the young persons. Additionally, the diabetic condition has the potential to cause vision loss, renal failure, peripheral neuropathy that risks suffering from the foot ulcers, charcot joints, amputations and autonomic neuropathy, that could result in cardiovascular difficulties and sexual dysfunction [23].

The relationship between the bioactive reagents in the *Avicennia marina* and the *Rhizophora mucronata* and diabetes: Diabetes results mainly from the oxidative stress and an elevation in the reactive oxygen species which possess significant impacts. The disorder of the metabolism of the fats, proteins and carbohydrates poses a serious threat to the functioning of the body [24]. Notably, the patients encounter raised blood sugar after each meal due to a deficiency in insulin. The present statistic shows that approximately 2.8% of the global population has the disease and prospects indicate that by 2025, the percentage will have raised to 5.4% [25].

However, several plants have various natural antioxidants especially, the flavonoids, tannins and vitamin C and E. These reagents have the potential to sustain β-cells activity and reduce the blood glucose levels. According to different published results, the medicinal plants are exceedingly affordable with reduced side impacts in comparison with the counterfeit medicines. Additionally, they have proven to be highly active in the diabetes cure [26, 27]. Nevertheless, it is recommended that one undergoes an early diagnosis, management and ensure effective change in the lifestyles. Meaningfully, diabetes increased prevalence, variable pathogenesis, advanced process and several complications justify the urgent need for possible treatments. However, currently, the various treatments include pharmacotherapy, insulin and diet therapy controls diabetes [28].

Now, the health sector has ensured the development of numerous glucose reducing drugs which exert antidiabetic implication via the diverse mechanism. To start with, the insulin secretion can be stimulated by sulfonylurea and meglitinides drugs. Additionally, biguanides and thiazolidinediones are utilized to increase
the peripheral glucose absorption. The alpha-glucosidase causes delayed carbohydrates absorption from the intestines while biguanides reduce the hepatic gluconeogenesis [29]. However, despite the use of such advanced measures in the management of diabetes, the outcomes in patients remain far from perfect. Notably, the synthetic treatments have some limitations like drug resistance, toxicity and adverse effects. For instance, the sulfonylurea becomes ineffective after six years of treatment. Also, the glucose reducing medicines cannot control hyperlipidemia [30]. Therefore, the implications of such drugs and their interactions in the body are an alarming concern.

Currently, most of the treatment utilizing the medicinal herbs is highly recognized. The components of the plants mainly have anti-diabetic actions. The anti-hyperglycemic effects arising from the treatment with plants are as a result of the capacity to improve the pancreatic tissue performance. Indeed, this is done through elevating the insulin secretions or lowering the intestinal glucose absorption.

The present review is based on the research of how Avicennia marina and Rhizophora mucronata are important for the cure of diabetes. The methanolic extract from the leaves of these plants have the anti-diabetic agents [31]. However, this is proved through the use of alloxan stimulated diabetic rats. They were then orally administered an extract of Rhizophora mucronata. The impact of the Rhizophora mucronata illustrated anti-diabetic characteristics which were taken for advanced assessment in medical research and the remedy development. The results showed that hydro alcoholic fruit extracts of Avicenna marina reduce the serum glucose level in the test rats. It was found that the extracts considerably reduced the blood glucose levels.

Rhizophora mucronata bark has significant amount of bioactive compounds like the glycosides, anthroquinone, phenolics compounds, catechin, triterpenes, sugar, protein and tannins that assist in the management of diabetes. The tannin substance binds rapidly and occurs in two forms; the condensed and the hydrolysable tannin. The condensed form results in the flavonoids while the hydrolysable form comprises of the monosaccharide that has catechin derivative associated with it. The phenolic properties demonstrate its enzyme inhibitory and the metabolic activity. These metabolic substances contribute to their medicinal purposes. The bark proves to have the major constituents for the treatments. Rhizophora mucronata has thermostable compounds that contain higher thermo labile components [31]. The biological tests did help to determine the elements’ concentrations and their effects on the diabetic subjects.

Avicennia marina contains the ecological and the economic benefits [32]. Various parts of the plant have been proven to have ethno medicine uses in treating of various diseases like diabetes. Notably, the pharmacological investigations on the Avicennia marina reveal antioxidant, anti-inflammatory, antiviral, antimicrobial and antidiabetic activities on the species [33, 34]. It has unique bioactive compounds like the alkaloids, flavonoids, phenols, saponins, tannins, glycosides and terpenoids [35]. Hence, this has ensured the traditional medicine practitioners utilize its products to develop drugs from the biological active phytochemical.

The science research and development perspectives must utilize the available medicinal plants to improve the diabetes treatment. Besides, this would advance the profiles of the plants with important compounds that are potent for pharmaceutical applications. The review shows baseline information of the healing ability of these species. Further studies on the species would be crucial to bridging the gap that exists in the application of the ethno medicine and the modern scientific findings of these plants. Avicennia marina is very useful since it is found all around the globe by use for the treatment of many diseases by most of the local communities. This is because they possess highly bioactive elements from the roots, stems, seeds, bark, leaf and the fruits.

Strategies to discover drugs from these natural products must incorporate practical scientific experiments to avoid detrimental impacts on the plants. In this way, the plant's therapeutic importance will be realized. Avicennia marina has different metabolites for various chemicals that make it necessary for pharmacological uses. The phytochemical components of the species have been performed using various solvent extracts like benzene, hexane, methanol, ethanol, acetone and chloroform. This helps to trace the phytochemicals present in the different plant parts.

The pharmacological actions reported in the Avicennia species have been validated on its importance in the medicinal uses via exploration of the bioactivity of the plants either in vitro or in vivo. However, such studies entailing the elucidation of the active compounds will result in medicinal science aiming to treat diabetes effectively [36]. Indeed, the therapeutic usefulness of the species in diabetes treatment calls for conservation of these medicinal plants for the development of essential drugs in future. These plants prove to be competent...
reservoirs for the isolation of biomolecules such as the lipids. Importantly, this is attributed to their high content in polyphenolics and metabolites that are implanted in the sticky polysaccharides.

Notably, the lipids generated from the ethnomedicinal plant's tissues readily undergo extensive enzyme degradation once their extraction is via chloroform-methanol combination. The phenolic compounds and the polysaccharides components show retardation in the isolation of total lipids from the Rhizophora mucronata leaves. The primary fat in the Rhizophora mucronata is the tri-terpenoids whose concentration has antidiabetic actions. The species also provide food supplements that aid in the reduction of the diabetes complications. Some of the components like the gums and glues have also gained interest in the present industry of medicine. In fact, the properties of the proteins, amino acids and the carbohydrates are crucial for maintained life processes [37]. The others components include carbon, sulfur molecules which would have great pharmacological and toxicological significance. Such pharmacological activities make them useful in the diabetes cure. The phenolic compounds include the lignin that contributes to the flavor and taste of the foods. Importantly, the different classes of flavonoids are significant for the physiological procedure and display antioxidant activity and have antihistamines both that are critical in the management of diabetes [38].

The flavonoids and flavonol-lignin prevent lipid peroxidation. Practical modifications of the flavonoids compound found in the species develop substances that are marketed for the reduced symptoms of diabetes. Also, the biosynthetic component made by the intermediates of the cinnamic acids and flavonoids reveal significant antioxidant activity that is crucial to the management of diabetes. The high level of compounds like tannin and the distastefulness in the plants makes them not advisable to be consumed directly as food. Avicennia marina hypocotyls are processed and then added to the diet. Their metabolites ensure improved bioactivities. Nonetheless, the distribution of the species allows individuals to choose on how they can apply the products for the benefits of the society without abusing the resources.

Toxicity studies on the Avicennia marina indicate that there are no toxicity impacts against the normally growing cells [39]. The extracts, therefore, prove useful in the treatment of diabetes without any detrimental effect on the body. It gives the urge to strive to get the medicinal value of the plant alongside its other uses. Traditionally, the species is still used to lower the diabetes symptoms. However, despite the scientific validation of the active biochemical compounds in the Avicennia marina, there exists a large gap to enlarge the existing knowledge on the species uses as an antidiabetic.

The Protective Implications of the Hydro-alcoholic Extracts of Avicennia marina: Diabetes is described as the chronic metabolic disorder that is attributed to absolute or relative deficiencies in the secretion of insulin [40]. The insulin activity is linked to the chronic hyperglycemia and the lipid, protein and carbohydrate metabolism disorders. However, diabetes occurs in three types, type 1 diabetes that results from cell damage that causes total insulin deficiency, diabetes, types 2 and gestational diabetes. The others diabetes disorders include β-cell function genetic defect in insulin activity, exocrine pancreases disease infections, endocrinopathies and other immune-mediated diabetes. In fact, the β-cells that are located in the pancreas play a crucial role in the glycemic homeostasis. The lipotoxicity, glucotoxicity, incretin receptor expression and the inflammatory mediators modulate the operation and endurance of the β-cell. However, the oxidative stress is believed to lead to the onset and the expansion of diabetes in the body.

Diabetes has severe problems that affect the human health. Indeed, it could result in micro and macrovascular issues [41]. Uncontrolled diabetes situations are allied with chronic problems that involve blindness, renal failure and heart disease. Critical alterations in the metabolism and the lipid structure occur. The liver and the kidneys help in the absorption, metabolism and the oxidation of the free fatty acids and synthesize the phospholipids, triglycerides and cholesterol. The herbal medicine has, therefore, become a significant aspect to explore and to cure diabetes.

The traditional medicine has increasingly become popular among the consumers as an alternative to the use of synthetic drugs [42]. The medicinal plants generate different chemicals elements during their metabolic mechanisms for their survival in the ecology. Extracts from various parts of the plants show bioactive properties that are used for medicinal purposes. The herbal drugs and plants elements have very low toxicity and no side effects have been reported worldwide on the use of the herbs. In fact, most of the experiments show that the plants have hypoglycemic properties that manage diabetes [43]. The presence of such characteristic indicates the significance of the plants in the delivery of the anti-diabetic response. For instance, tannin boosts the performance of Beta-cells
and raises the secretion of insulin. Quercetin is proves to be an effective antioxidant which poses many mechanisms associated with the exclusion of the oxygen radicals thereby preventing lipid peroxidation and chelation of the metal ion [44]. However, the factors related to these plants lead to the elimination of the diabetic complication.

Type 1 and 2 diabetes conditions are linked with the significant development of the free radicals and the lowered antioxidant potential. The diabetes is a natural state in the developed and the growing nations that affect millions of individuals. The condition is believed to increase in the future due to increased changes in the lifestyles. Therefore, the management of diabetes is significantly recognized and it possesses a significant threat. These have led to the development of the counterfeit and plant medicines. However, the plant drugs are highly favored since the synthetic drugs have dangerous side implications that involve the hypoglycemia, nausea, liver and heart failure, gastrointestinal discomfort, weight gain and diarrhea [45]. Thus, a lot of people have turned into the several plants available due to their richness in the antidiabetic species. The herbal preparations lack significant side implications. Estimates show that many plants species possess secondary metabolites that manage diabetes mellitus worldwide.

Scientists have, therefore, identified the antioxidant compounds in the *Rhizophora mucronata* and *Avicennia marina* that are used for antidiabetic treatment. Importantly, they have unique biological activities which are rich in the medicinal contents that can manage diabetes and relieve the associated oxidative stress. The species have been proven to produce reactive oxygen species as well as massive antioxidant products levels. Meaningfully, the oxidative stress leads to the development of diabetic problems which makes the plant crucial to improving diabetes and its correlated difficulties [16]. In fact, this makes it a global concern to determine the antioxidant elements which are pharmacologically effective and display reduced or lacks side effects. However, the phytochemicals and the metabolites generated from these trees are stated to display potent antioxidant compounds for both enzymatic and non-enzymatic actions [46]. The plants exhibit antidiabetic mechanisms that are linked to the specific metabolites like the flavonoids, triterpenoids, polysaccharides and the limonoids [47]. In fact, this makes the plant crucial to tackling the diabetic and its related oxidative stress associated difficulties.

It is crucial to understand the processes that get involved in the diabetes condition prior comprehension of the occurrence of the diabetes condition. The pathological process entailed consists of four critical metabolic processes that destroy the hyperglycemia-induced cell and diabetes related disorders like the rise in the polyol conduit flux; protein kinase C trigger; augmented sophisticated glycation end product (AGE) creation and raised hexosamine pathway flux [48]. Cell damage is portrayed through the destruction of the carbohydrates, lipids and proteins. On the other hand, the complications associated to diabetic consist of the nephropathy, neuropathy and the retinopathy [49].

Additionally, it is significant to understand that the oxidative stress impacted on the insulin signaling. The standard insulin signaling pathway can be impaired during the oxidative stress situation that in turn causes the beginning of the signaling pathways [50]. Conversely, this comprises of the reduction in the GLUT-4, gene transcription, activation of the stress kinases and alteration in the mitochondrial activity; and the mediated apoptosis of the free fatty acids. The study demonstrates that the oxidative stress state can trigger several stress kinases together with the stress signaling activation like the NF-κβ that has adverse impacts on the standard insulin signaling protocol. However, the trigger of other stress signaling process like the MAPK, p38 and the JNK/SAPK interferes with the insulin indication by the dephosphorylating the IRS. Indeed, this results into the deactivation of the signaling cascades that causes insulin resistance. The glucose transporters facilitate the glucose diffusion into the cell. Here, the GLUT1 and GLUT4 have a critical role in the insulin signaling.

However, the oxidative stress regulates the GLUT4 expression that further decreases [51]. Additionally, the mitochondria have a crucial role in insulin release from the β-cells to respond to the blood glucose levels. The dysfunction of the mitochondrial due to oxidative stress causes the insulin resistance and could be the causal of the diabetes expansion [52]. Besides, the free fatty acids (FFA) and the hyperglycemia increase ROS and the reactive nitrogen species creation degrees and initiate the stress signaling conduits that result in the dysfunction of the β-cell and the resistance of the insulin. This knowledge guides on the antidiabetic potential of the phytochemicals that the mangrove species may have. It involves their elements such as the steroids, aliphatic alcohols, hydrocarbons, free fatty acids, tannins, terpenes, lipids, tannins, triterpenes, pheromones, alkaloids, steroids, phenolics, etc. compounds that have recognized pharmacological bioactivity.
Compounds of the *Rhizophora mucronata* and *Avicennia marina* That Have the Antidiabetic Activity

**Alkaloids:** Alkaloids produce antihyperglycemic activity by making sure that the pancreas produces insulin from the β-cell of islets and enhances the transportation of the blood sugar to the marginal cell. The alkaloids include trigonellin, granatoin, xylogranatinin and acanthicifoline (47).

**Polysaccharides:** These have antihyperglycemic effects, the impact is due to the increased tolerance to glucose, elevated serum insulin levels and lowered blood glucose.

**Flavonoids:** They assist in the diabetic treatment through prevention of the β-cell apoptosis, promotion of the β-cell propagation and the secretion of insulin and enhance the insulin activity. *Avicennia marina* is highly rich in the flavonoids that exhibit hypoglycemic activities.

**Saponins:** Mainly steroidal glycosides and triterpenoids: Importantly these compounds have potent hypoglycemic effect that revealed the existence of the α-amyrin in the *Avicennia marina* which helps in the antidiabetic actions of this mangrove species. In fact, the ursolic acid, oleanolic acid and lupeol are pentacyclic triterpenoids located in the mangrove species like the *Avicennia marina* that have the antidiabetic activities [53].

**Phenolic Compounds:** Importantly, this could inhibit the hypoglycemic actions through increased degrees of serum insulin that rise the tissues sensitivity to the insulin effects. In turn, this stimulates the enzymatic activities for the use of glucose and inhibits the α-amylase activity.

**Tannins** curb the diabetes disorders by decreasing the AGEs and the oxidative stress formation. Both the *Rhizophora mucronata* and *Avicennia marina* are rich of the tannins [54].

**Progress of Antidiabetic Research in Rhizophora mucronata and Avicennia marina:** Mangrove plants have been documented to inhabit the hostile ecological situations that have high salinity and temperatures, water logging and reduced light and oxygen levels [55]. Research shows that they have abundant antioxidant elements discussed in this context. However, this is the case for all the other mangrove trees that are associated with increased antidiabetic activity. The research done have reported that there are several ways that the plants can show their antidiabetic potential: reduction of the intestinal glucose absorption, insulin mimetic motion, lowering of the AGEs and exerting antioxidative effects.

The evidence that *Avicennia marina* has the antihyperglycemic activity was done through its ethanolic leaf extracts in alloxan stimulated diabetic rats. After they were treated for 15 days, the blood glucose reduced considerably while the total hemoglobin (Hb), serum insulin degrees and the total proteins increased. Notably, the leaf extracts from the *Avicennia marina* can decrease the serum urea which is evidence that it can protect the significance tissues such as the pancreas, liver and the kidney. The likely mechanism associated with the antihyperglycemic activity of the *Avicennia marina* is due to be the capacity to stimulate the surviving β-cells that in turn releases enormous amounts of insulin. Additionally, the methanolic extracts of the *Avicennia marina* pneumatophores or the aerial roots indicate the antihyperglycemic effect that could be attributed to the AGEs inhibition. The recent studies showed that the triterpenoids like the stigmasterol-3-O-β-D-glucopyranoside reveal hypoglycemic constituents in the tree species and responsible for its antiglycation actions.

*Rhizophora annamalayana, Rhizophora apiculata* and *Rhizophora mucronata* have shown the antidiabetic activity [56]. The ethanolic root extracts from these species indicated the potentiality for antidiabetic effects. Notably, the chloroform and the ethanolic aqueous sub fractions extracts from their roots show richness in phytochemicals that have antihyperglycemic activity. The purification of the extracts results in the isolation of lupeol, β-sitosterol-β-D-glucoside, β-sitosterol, inositol, oleanolic acid, palmitic acid and pinitol. Therefore, the antidiabetic characters lead into the drastic scavenging and the safeguarding of β-cell. The administration of the aqueous extract modulated the blood sugar, body weight, FFA, plasma, triglycerides, cholesterol, glycylated hemoglobin and phospholipids to standard intensity in the alloxan-induced rats.

The antidiabetic action of *Rhizophora mucronata* could result in the improved levels of the insulin secretion and its mechanism. *Rhizophora mucronata* can restrain carbohydrate digestion and absorption. Additionally, the aqueous bark extracts of *Rhizophora mucronata* have significant hypoglycemic and antihyperglycemic reactions. Additionally, the *Rhizophora mucronata* hydro-alcoholic bark extracts show anti-hyperglycemic activity that is associated with its α-glycosidase inhibition potential [57].

**CONCLUSIONS**

Plants are natural antioxidants and useful herbal remedies mostly due to their anti-diabetic compounds, like the phenolics, tannin, flavonoids and alkaloids which boost the pancreatic tissues performances via elevation...
of the insulin secretion and lowering the absorption of glucose by the intestines. However, further research is significant to separate the active biochemical compounds of the plants and to identify their molecular interactions that are vital for the assessment of their curative elements. Additionally, these traditional therapeutic plants are widely recognized in the world to cure diabetes. While, the existing information about most of the plants needs to undergo regular studies to determine the anti-diabetic mechanism of the prospective plants.

However, studies on the **Rhizophora mucronata** and **Avicennia marina** have shown that they contain the anti-diabetic characteristics as described in this context. Moreover, there should be clinical intervention to offer evidence for secure and efficient utilization of the identified trees in diabetes treatment.

**REFERENCES**


