



Antidiabetic Activity of 40 Plants of the Senegalese Flora, an Important Therapeutic Diversity for Populations

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Authors' contributions

This work was carried out in collaboration among all authors. Authors OF and OK carried out the bibliographic research. Author OF wrote the first draft of the manuscript. Author CS supervised the work and corrected the manuscript. All authors read and approved the final manuscript.

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ABSTRACT

Diabetes mellitus is group of a metabolic disorder caused by hyperglycemia resulting from defects in insulin secretion, insulin action, or both. It is a major public health problem in all countries of the world. In Africa, it was predicted that the continent, will see the greatest increase, from 19 millions in 2019 to 47 million diabetics in 2045. In the absence of sufficient public health care coverage and the high cost of modern medicine, major part of the population of developing countries turns to traditional medicine. These medicine offer a new alternative for the management of diabetes from plant organs. Most of the used part of plants has not yet been scientifically approved by researchers. In this article, we have inventorised the medicinal plants of the Senegalese flora used in the management of diabetes and whose activity has been validated scientifically by researchers.

Keywords: Diabetes; medicinal plants; anti-diabetic plants Senegalese flora.

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1. INTRODUCTION

Diabetes mellitus (DM) is a group of metabolic disorders caused by hyperglycemia resulting from defects in insulin secretion, insulin action, or both [1]. There are generally three types of diabetes. Patients with type 1 diabetes mellitus (T1DM) present a state of insulin deficiency due to a severe defect in islet β -cell function. Patients with T1DM are prone to ketoacidosis and need daily administration of insulin to control the amount of glucose in their blood. The majority of T1DM occurs in children and adolescents [2]. Patients with type 2 diabetes mellitus (T2DM) show a combination of resistance to action of insulin and insufficiency in insulin secretion [3]. And the type 3 is called gestational diabetes, which is seen in pregnant women who did not have diabetes before they were pregnant. Among the above three types of diabetes, T2DM has the highest morbidity, accounting for more than 95% of the overall incidence of diabetes, with the largest hazard [4]. The characteristic symptoms of diabetes are pruritus, polydipsia, weight loss, polyphagia, wasting, blurred vision, polyuria, tachycardia and hypotension. Eventually, as a result of these, severe complications were created in both types of diabetes mellitus such as nephropathy, retinopathy, neuropathy, dyslipidemia and cardiovascular diseases [5]. Globally, diabetes mellitus is a leading cause of morbidity and mortality, with an estimated worldwide prevalence among adults in 2011 to be 346 millions (6.1%), according to World Health Organization (WHO) [6]. This number is predicted to rise to around 439 millions (7.7%) by 2030 [7]. WHO projects that deaths resulting from diabetes will increase by two thirds between 2008 and 2030. According to Gudise et al, this number will rise to 578 millions (10.2%) by 2030 and 700 millions by 2045 [8]. The International Diabetes Federation (IDF) predicted that the African continent will see the greatest increase, from 19 millions in 2019 to 47 millions diabetic in 2045 [9]. In addition, diabetes mellitus is one of the most common chronic diseases in nearly all countries, and continues to increase in number and significance due to the changing lifestyles that lead to the reduction of physical activity and increase of obesity [7]. Interestingly, the WHO also projects that diabetes will be the seventh leading cause of death in 2030 [10]. At present, different approaches are used to control DM using modern synthetic antidiabetic drugs in addition to lifestyle modification. There are several classes of oral hypoglycemic drugs that exert antidiabetic effects through different

mechanisms, namely sulfonylureas, biguanides, α -glucosidase inhibitors, thiazolidinediones, and non-sulfonylureas secretagogues [11]. However, these synthetic oral hypoglycemic agents have characteristic profiles of serious side effects, which include hypoglycemia, weight gain, gastrointestinal discomfort, nausea, liver and heart failure, and diarrhea in addition to being rather costly and not affordable by the majority of African populations [12]. These limitations coupled with an exponential increase in the prevalence of DM motivate researchers to scientifically validate the folkloric use of a number of antidiabetic African medicinal plants as possible alternative therapies. Indeed, according to WHO, 80% of the population in many African countries depend almost entirely on traditional medicines, herbal medicines in particular, for their primary health care needs [13]. In Senegal, it is clearly recognized that, in the absence of sufficient health coverage for medicine, at least 76% of households use medicinal plants close to their homes (50%) or sold on urban markets (25%) [14]. According to Van et al [15], African continent counts for about 25% of the total number of higher plants in the world where more than 5400 medicinal plants were reported to have over 16300 medicinal uses. Lastly, ethnobotanical studies report that at least 800 plants may possess antidiabetic potential [16]. Due to its Sudano-Guinean climate, Senegal has a rich plant diversity. Thus, 3750 plant species have been identified in Senegal, of which 250 are fungi [17]. The Senegalese populations, particularly the rural one, because of their social and economic situation, mostly use these plants to treat many of the pathologies from which they suffer. The objective of this manuscript is to identify the plant species of Senegalese flora for which experimental studies of their hypoglycemic or antidiabetic effects *in vitro* or/and *in vivo* have been carried out.

2. METHODOLOGY

The search was done in electronic databases of PubMed, Scopus, ScienDirect, Web of Science and Google Scholar using English and French keywords. The search terms used were: Ethnobotanical survey, Senegalese medicinal plants, diabetes, medicinal plants, diabetes in Senegal, anti-diabetic potential, anti-glycemic potential and plant extracts. All plant species were taxonomically validated; the Latin scientific name and family were confirmed using The Plant List site (<http://www.>

theplantlist.org/). The research was done from September 11 to October 19, 2020. The text was written using Mendeley bibliography insertion system.

3. ANTIDIABETIC EFFECT OF SENEGALESE FOLKLORE MEDICINAL PLANTS

3.1 *Acacia nilotica* (Linn)

Acacia nilotica is a versatile nitrogen fixing tree of the Leguminosae-Mimosoideae family. It is widespread in Africa and Asia. It is a complex species with nine subspecies, six of which are native to the African tropics and three more are native to the Indian subcontinent [18]. It is able to provide nutrients and therapeutic ingredients (tannins, polyphenols) to prevent, mitigate or treat many diseases. However, the tender pods and leaves are considered very beneficial in traditional medicine to treat diabetes mellitus [19]. Its use in traditional medicine for the management of complications of diabetes mellitus is known and has directed research into its therapeutic potential.

The study of Piero and al., 2015, on the antidiabetic potential of aqueous extracts of leaves in diabetic mice induced by alloxan, show satisfactory results. On the one hand, administration of 300 mg/kg intraperitoneally results in a maximum reduction in blood sugar levels of 70%, compared to insulin which reduces the blood sugar to 78%. The other hand, oral administration of aqueous extracts of *Acacia nilotica* leaves with the same dose also lowered blood sugar levels by 24%. While the conventional oral drug, glibenclamide lowered to 34% [20]. This anti-diabetic activity of extracts from the aerial part (leaves) of the *Acacia nilotica* plant is confirmed by the work of several authors: Tanko and al., in 2014 [21], Muhammad and al., in 2011 [22].

3.2 *Acacia senegal* (L.) Willd

Acacia senegal (L.) of the family Fabaceae a tree commonly known as Gum Arabic, is found in drought or arid regions. This plant is a small deciduous tree having smooth bark, pale greenish grey in colour that peels off in flakes in older twigs. Its bark, seed, leaves, fruit, and gum contain polyphenols, flavonoids, tannins, saponins, and alkaloids. It was also reported that *A. senegal* bark contains antioxidants and is

used to treat bedsores and wounds, antimicrobial, anti-Fasciola activity, and also antidiabetic property.

According to the work of Shikha et al., the stem bark extracts of this plant has a satisfactory antidiabetic activities. In the study, the administration of maximum dose (400 mg/kg body weight) of ethyl acetate extract reduces the blood glucose level at 38.76% from experimental animals on day 15. The same dose of this extract also decreased the serum cholesterol, serum triglycerides, serum Low Density Lipoprotein (LDL) cholesterol, serum urea and creatinine levels by 25.97%, 31.36%, 45.96%, 73.69% and 58.73% respectively [23]. Antidiabetic activities of *A. senegal* plant is confirmed by other studies. Indeed, Jangid and Purohit in 2019, with a dose of 500 mg/kg body weight of ethanolic extract of *A. senegal* bark in induced hypothyroid albino rats [23]. Shikha and al., 2012, on the hypoglycemic activity of stems barks extracts using the glucose uptake by isolated rat hemidiaphragm *in vitro* [24].

3.3 *Adansonia digitata* (L.)

Adansonia digitata is a species of the Bombacaceae family, an african plant known as baobab tree. Leaves, bark and fruits of this plant are traditionally employed in several african regions as food stuffs and for medicinal purposes, and for that reason baobab is also named "the small pharmacy or chemist tree". The native African population commonly used, baobab fruit in the preparation of food, decoctions, sauces and natural refreshing drink due to its nutritional properties. The pulp is therapeutically used as analgesic anti-diarrhea and for treatment of smallpox and measles.

Recently, evaluation of hypoglycemic activity of methanolic extract of the stem bark of *Adansonia digitata* in diabetic Wistar rat was studied. In the studied concentration, 100 mg / kg body weight, has the highest activity with a reduction percentage of glycemic levels of 51% after 7 hours administration of the extract [25].

3.4 *Allium cepa* (L.)

The onion (*Allium cepa*) is a biennial plant of the Alliaceae family which was officially introduced by Carl Linnaeus in his book of the plants species(1753) [26]. Onion is made from the

oldest herbs which have a wide range of therapeutic effects. According to research, red onion may be effective in treating gastrointestinal complaints and intestinal spasms [27]. Onion is a rich source of flavonoids mainly derived from quercetin and therefore has high antioxidant properties [28]. Quercetin in onion juice has been shown to dramatically decrease blood sugar levels in diabetic mice [29].

The effect of methanolic extracts of *Allium Cepa* in diabetic neuropathy in mice, induced by oral administration of Streptozotocin, shows its antidiabetic potential. Indeed, the administration of 200 mg/kg body weight of extracts of external scales of allium cepa leads to a significant decrease in plasma glycemia [30]. This work on the anti-diabetic activity of extracts from the *Allium cepa* plant confirms that of K. Kumari and al., in 2002 [31].

3.5 *Allium sativum* (Linn)

Allium sativum (Garlic) native to Central Asia, is a herbaceous plant of the Liliaceae family. It is a species of perennial, monocotyledonous vegetable plant whose bulbs and head are made up of several cloves of garlic. It is one of the most popular herbs used around the world to reduce various risk factors associated with several diseases [32]. In fact, garlic contains a variety of effective compounds that exhibit anticoagulant (anti thrombotic), antioxidant, antibiotic, hypocholesterolemic and hypoglycemic activities as well as hypotensive [33]. Most studies have shown that garlic can lower blood sugar levels in diabetic mice, rats and rabbits [32],[33]. The hypoglycemic properties of the ethanolic extract of the *Allium sativum* bulbs were evaluated in normoglycemic rats in order to scientifically validate its traditional therapeutic use. Maximum hypoglycemic activity is observed at a dose of 500 mg/kg, which reduces significantly blood sugar after 7 and 14 days administration [34]. This study is in line with those of Mahesar and al., 2010, on the aqueous extract of *Allium Sativa*. They observed a significant lowered blood sugar levels, 38.88% and serum cholesterol level, 57%, after one month of treatment [33].

3.6 *Annona muricata* (Linn)

Annona muricata (Linn) is belonging of Annonaceae family, commonly called "Soursop". It is a small, upright evergreen tree growing up to 5 to 6 meters in height. It has a long history of

use in herbal medicine in the tropics of southern and North America, including the Amazon and in West Africa [35].

The study of hypoglycemic activity of aqueous leaves extracts of *A. muricata* in rat models with diabetes mellitus by streptozotocin induction, indicates satisfactory activity at the maximum extract dose of 100 mg/kg body weight. In fact, the morphology of the pancreas of treated rat with *A. muricata* extracts showed viable cellularity with a distinct mass of β cells [36].

3.7 *Annona senegalensis* (Pers.)

Annona senegalensis (Pers.) of the Annonaceae family is a shrub or small tree of about 2-6 m height, mostly found in the savanna and parts of tropical rain forest regions. It is found in Senegal, Nigeria, Cape Verde Island, Sudan and South Africa [37]. *A. senegalensis* is used in ethnomedicine for the treatment of different ailments [38]. Diabetic animals treated for 91 days with *A. senegalensis* leaves extracts, showed a loss of weight by 20.14% in the diabetic control and by 11.31% in those treated, compared to the negative control. In addition, the blood glucose levels of the treated rats were significantly lower than those of the untreated diabetic control [39].

3.8 *Anogeissus leiocarpus* (DC.)

Anogeissus leiocarpus (African birch) of the Combretaceae Family is a tropical plant with large ecological distribution across Africa. The plant parts (leaf, stem, bark and root) are used in traditional medicine for treatment of lot of ailments such as microbial infections, hepatic disease and oxydative stress.

The study of hypoglycemic activity *in vitro* of leaves extracts of this, indicates an inhibition activities of the α -amylase enzyme and α -glycosidase in a range of concentrations 0-0.8 mg/ml. The results show that the extracts inhibit the activity of the enzyme amylase with a $IC_{50\%}$ of 242.17 μ g/ml compared to that of Acarbose which is 11.77 μ g/ml used as control [40].

3.9 *Arachis hypogaea* (L.)

Arachis hypogaea L. known as peanut belongs to the Fabaceae family, has been valued for its high nutritional content throughout the world [41].

Some therapeutic effects of this plant peanut seed extracts have been reported, such as antioxidative, antidiabetic, antibacterial and anti-inflammatory activities [42]. The *in vitro* studies carried out by Andrew et al. show a significant inhibitory activities of A hypogea seed extracts against the amylase and glycosidase enzymes [43].

3.10 *Blighia sapida* (K.D.Koenig)

Blighia sapida belongs is the Sapindaceae family, also known as the Akee apple. It's native to tropical West Africa : Benin, Burkina Faso, Cote d'Ivoire, Ghana, Guinea, Guinea Bissau, Mali, Nigeria, Senegal, Sierra Leone and Togo as well as Gabon, Cameroon, Sao Tome and Principe. It is an evergreen tree that grows to about 10 metres high, with a short trunk and a dense crown.

Aqueous extract of *Blighia sapida* leaves was investigated for anti-diabetic activity in alloxan-induced diabetic albino rats. The results revealed that the levels of blood glucose, serum cholesterol, albumin, creatinine, urea, triacylglyceride and malondialdehyde increased significantly in the diabetic animals whereas the liver glycogen, Hb, PCV, liver, kidney- and pancreas-body weight ratios decreased significantly.

Contrary to ethno-medicinal claim, this study has revealed that the aqueous extract of *Blighia sapida* leaves at the doses of 25, 50, 100mg/kg body weight did not have anti-hyperglycemic activity and is not suitable for managing complications associated with diabetes [44].

3.11 *Calotropis procera* (Aiton)

Calotropis procera, from the Apocynaceae family, is a plant commonly known in Senegal as "foftan" in Wolof [45]. It is a shrub native to Africa, with milky juice, common on depleted soils, overgrazed land, and around villages and frequent in town in gardens and on flower beds [46]. This species has remarkable medicinal potential due to its richness in bioactive substances. In traditional medicine, it is noted in the treatment of diabetes.

The results of therapeutic study on diabetes of the dried extract of *C. procera* leaves at 300 and 600mg/kg, show the presence of hypoglycemic and antidiabetic secondary metabolic agents activities. In fact, these extracts cause, in part,

a maximum reduction in blood sugar levels of 43.7% for the first dose, for 150min and 43.9% for the other after 30min of the injection. And on the other hand, the effect of extracts on the biochemical parameters of the treated rats with the doses of 300 and 600 mg/kg showed statistically significant reductions in the levels of uric acid, aspartate aminotransferase (AST) and alanine aminotransferase (ALT) versus diabetic control and significant increases in creatinine, total cholesterol and triacylglycerides [47].

3.12 *Carica papaya* (L.)

Carica papaya is a plant belonging to the Caricaceae family it is also called as pawpaw with potential medicinal values and has been cultivated in most of the tropical countries. *C. papaya* leaves, fruits, seeds, flowers and parts of roots have been documented for their nutritional and medicinal benefits [48].

A study on the inhibitory effects *in vitro* of *C. papaya* seeds extracts on α -amylase and α -glycosidase, reveal a satisfactory hypoglycaemic activity. Indeed, the results revealed that all fractions inhibited α -amylase activity in a dose-dependent ranging (20–100 mg/ml). While the standard inhibitory test was 74.64 mg/ml [49]. This activity has been confirmed by several other works: Juárez-Rojop and al, 2012 [50], Ezekwe and al, 2017 [51].

3.13 *Cassia abbreviata* (Oliv.)

Cassia abbreviata, is a plant belonging to the Caesalpiniaceae family and is widely distributed across Africa [52]. The roots, stem bark and fruit pulp of *C. abbreviata* extracts are traditionally used for treatment of inflammatory, fever, joint pains, malaria, diarrhea, leprosy, bilharzias, stomach pains, diabetes mellitus and its complications and other illnesses [53].

The antidiabetic effect of ethanolic extract of *C. abbreviata* stem bark and the possible mechanism of its action have recently been studied in diabetic rats. The results reveal that only two doses (150 and 300 mg / kg body weight) have significantly fasting blood sugar levels reduction in diabetic rats.

3.14 *Cassia occidentalis* (Linn)

Cassia occidentalis is a weed of the Caesalpiniaceae family. The plant is annual and

widespread throughout India and tropical Africa. This plant is used in many African traditional medicines to treat various illnesses. It is known to have antibacterial, antifungal, antidiabetic, anti-inflammatory, antimutagen and hepatoprotective activity. Antidiabetic study of *C. occidentalis* ethanolic root extracts showed a significant activity when a dose of 500 mg/kg of was administered to streptozotocin-induced diabetic mice. A significant decrease in the level of serum creatinine, serum cholesterol was observed [54].

3.15 *Combretum micranthum* (G.Don)

Combretum micranthum is a species of the Combretaceae family, known as kinkéliba in French and "sékhev" in Wolof in Senegal [55]. The plant is a small tree, which can reach 5 to 6m in height. It is a widely known ethnomedicinal plant used in West Africa to treat several ailments such as diabetes [56].

In vivo study of *C. micranthum* leaf extracts on diabetic rats shows an important hypoglycemic and antidiabetic activities. Indeed, the results of this study reveal that the dose of 100mg/kg caused a maximum reduction of 24.6% in blood sugar levels compared to glibenclamide which reduced it to 31.6% [56].

3.16 *Detarium microcarpum* (Guill)

Detarium microcarpum of the Fabaceae family is an African leguminous medicinal plant found in the tropical forests [57]. In view of the recognized antidiabetic potential of *D. microcarpum*, the plant's blood sugar lowering activity was studied in normal and diabetic rats. The results show that at a maximum dose of 2000 mg/kg of extracts, the methanolic fraction of the extract from the roots of *D. microcarpum* is able to reduce 67.3% of blood sugar compared to glibenclamide 57.5% at the 32nd hour of treatment on diabetic rats [57].

3.17 *Eucalyptus citrinoides* (Benth).

Eucalyptus citrinoides, native to Australia is a species of the Myrtaceae family. *E. citrinoides* is recognized in the management of several pathologies due to its pharmacological properties: Antiseptic of the respiratory and urinary tracts, antibacterial, antipyretic and hypoglycaemic [58]. In a glucose tolerance test, the extract significantly reduced the increase in

blood glucose levels. The single-dose treatment causes the reduction in blood sugar at 19.5 and 22.9% at a dose of 250 and 500mg/kg of body weight respectively. While another subacute study found a reduction in blood sugar at 49.9 and 56.8% respectively for 250 and 500mg/kg, after 21 days of treatment. These values are comparable to those of the standard drug Glibenclamide, for which the reduction in blood sugar was 66.6% [59].

3.18 *Eugenia jambolana* (Lam)

The *Eugenia jambolana* tree belongs to the Myrtaceae family and consists of about 90 genera and 2800 species. The barks, leaves, and seeds of this plant have been used in the treatment of diabetes [60]. Several scientific studies on the hypoglycemic activity of *E. jambolana* pulp and seed extracts have been well documented [60,61].

Recently, Prasad et al. Have conducted a study on the alcoholic extract of *E. Jambolana* seeds in diabetic rats by streptozotocin induction. The results of daily administration of the plant's seed extract for 28 days showed a significant reductions in blood sugar levels of 54.5% and glycosylated hemoglobin levels of 7.1%.

Also, a significant increase in High-Density Lipoprotein cholesterol levels with concomitant decreases in total cholesterol, triglycerides, Low Density Lipoprotein cholesterol, Very Low Density Lipoprotein cholesterol were observed [62].

3.19 *Garcinia kola* (Heckel)

Garcinia kola, commonly called bitter kola is widely known for the medicinal properties of its seeds, root, stem bark, fruit and leaves. The leaves of *G. kola* have been reported to possess medicinal properties [63]. The use of *G. kola* seeds extracts is common in traditional medicine in West Africa and by African immigrants in Saudi Arabia [64].

G. kola, is a plant characterized by its hypoglycemic and anti-diabetic properties. Recent studies have reported activity in diabetic rats of methanolic extracts from the leaves of *G. kola*. These studies reveal that oral administration for 14 consecutive days of 100 and 200 mg/kg of soft leaves extract and 0.5 mg/kg for glibenclamide (reference), a significant decrease of glycemic level [63].

Table 1. Resume of the listed plants and the references

Family	Species	Parts Used	Models used in the Study	References
MIMOSOIDEAE	<i>Acacia Nilotica</i> (Linn.)	Leaves	Alloxan- induced diabetic mices	[20]
MIMOSACEAE	<i>Acacia senegal</i> (L.)	Stem Barks	Alloxan- induced diabetic rats	[23], [24]
BOMBACACEAE	<i>Adansonia Digitata</i> (L.)	Stem Barks	Streptozotocin -induced diabetic rats	[25]
ALLIACEAE	<i>Allium Cepa</i> (L.)	Bulbs	Streptozotocin-induced diabetic mices	[30], [31]
LILIACEAE	<i>Allium sativum</i> (Linn.)	Bulbs	Streptozotocin - induced diabetic rats and rabbits	[34],[33]
ANNONACEAE	<i>Annona Muricata</i> (Linn.)	Leaves	Streptozotocin – induced diabetic rats	[36]
	<i>Annona Senegalensis</i> Pers.	Leaves	Alloxan – induced diabetic rats	[39]
COMBRETACEAE	<i>Anogeissus leiocarpus</i> (DC.)	Leaves	α -amylase and α - glucosidase inhibition enzyme	[40]
COMBRETACEAE	<i>Arachis Hypogaea</i> (L.)	Seeds	Alloxan – induced diabetic rats and α -glucosidase inhibition enzyme	[42], [43]
SAPINDACEAE	<i>Blighia sapida</i> (K.D.Koenig)	Leaves	Alloxan – induced diabetic rats	[44]
APOCYNACEAE	<i>Calotropis Procera</i> (Aiton)	Leaves	Streptozotocin- induced diabetic rats	[47]
		Seeds	α -amylase and α -glucosidase inhibition enzyme	[49]
CARICACEAE	<i>Carica papaya</i> (L.)	Leaves, Roots	Streptozotocin , Alloxan- induced diabetic rats	[50], [51]
CAESALPINIACEAE	<i>Cassia abbreviata</i> (Oliv.)	Stem Barks	Glucose-induced diabetic rats, Alloxan- induced diabetic rats	[52], [53]
CAESALPINIACEAE	<i>Cassia occidentalis</i> (Linn.)	Roots	Streptozotocin-induced diabetic mices	[54]
COMBRETACEAE	<i>Combretum micranthum</i> (G.Don)	Leaves	Alloxan-induced diabetic rats	[56]
FABACEAE	<i>Detarium microcarpum</i> Guill.	Roots	Alloxan-induced diabetic rats	[57]
MYRTACEAE	<i>Eucalyptus citrinoides</i> (Benth.)	Leaves	Alloxan-induced diabetic rats	[59]
MYRTACEAE	<i>Eugenia jambolana</i> (Lam.)	Seeds	Streptozotocin- induced diabetic rats	[62]
CLUSIACEAE	<i>Garcinia kola</i> Heckel	Leaves	Streptozotocin- induced diabetic rats	[63]
		Seeds	Streptozotocin- induced diabetic rats	[64]
LAMIACEAE	<i>Hyptis Suaveolens</i> (L.)	Leaves	Streptozotocin- induced diabetic rats	[65]
ICACINACEAE	<i>Icacina senegalensis</i> (Juss.)	Roots	Alloxan-induced diabetic rats	[66]
EUPHORBIACEAE	<i>Jatropha curcas</i> (L.)	Leaves	Alloxan-induced diabetic rats	[67]
MELIACEAE	<i>Khaya senegalensis</i> Desv.	Stem Barks	Glucose-induced hyperglycemic rats, Alloxan-induced diabetic rats	[68], [70]

Family	Species	Parts Used	Models used in the Study	References
COMPOSITAE	<i>Lactuca sativa</i> (Linn)	Leaves	α -amylase and α -glucosidase inhibition enzyme	[72],[73],[74]
ANACARDIACEAE	<i>Mangifera indica</i> (L.)	Leaves	Alloxan-induced diabetic rats	[76]
RUBIACEAE	<i>Mitragyna inremis</i> (Willd.)	Stem Barks	Alloxan-induced diabetic rats	[75]
CUCURBITACEAE	<i>Momordica charantia</i> (Linn)	Stem Barks	Alloxan-induced diabetic rats	[77]
MORINGACEAE	<i>Moringa Oleifera</i> Lam.	Fruits	Streptozotocin-induced diabetic rats	[78]
MORINGACEAE	<i>Sclerocarya Birrea</i>	Fruits	Streptozotocin-induced diabetic rats	[80]
ANACARDIACEAE		Leaves	Alloxan-induced diabetic rats	[81]
MYRTACEAE	<i>Syzygium Aromaticum</i> (L.)	Stem Barks	Streptozotocin-induced diabetic rats	[82]
FABACEAE	<i>Tamarindus indica</i> (L.)	Buds	Streptozotocin-induced diabetic rats	[83]
FABACEAE		Seeds	Glucose adsorption capacity, in vitro diffusion, amylolysis kinetics and glucose transport across	[86]
MENISPERMACEAE	<i>Tinospora bakis</i> (A.Rich)	Stem Barks	Alloxan-induced diabetic rats	[85]
FABACEAE	<i>Trigonella foenum-graecum</i> (Linn)	Seeds	Streptozotocin-induced diabetic rats	[78]
ASTERACEAE	<i>Vernonia amygdalina</i> (Del.)	Seeds	High-fat die- induced hyperglycemic mice	[89]
COMPOSEAE	<i>Vernonia Colorata</i> (Willd)	Leaves	Clinical trial in diabetic patients	[91]
SAPOTACEAE	<i>Vitellaria paradoxa</i> (subsp.)	Leaves	Glucose-induced hyperglycemic rats	[92]
ZINGIBERACEAE	<i>Zingiber officinale</i> Roscoe	Stem Barks	Rabbits normoglycemic state and Glucose-induced hyperglycemic rabbits	[93]
ZINGIBERACEAE		Leaves	α -amylase and inhibition enzyme and Glucose-induced hyperglycemic rats	[94]
RHAMNACEAE	<i>Ziziphus mauritiana</i> (Lam.)	Roots	Streptozotocin-induced diabetic rats	[95]
RHAMNACEAE	<i>Ziziphus mucronata</i> (Willd)	Leaves	Glucose-induced hyperglycemic rabbits	[97]
RHAMNACEAE		Roots barks	rabbits	[98]
RHAMNACEAE		Roots	Glucose-induced hyperglycemic rabbits	[99]

These results are consistent with those obtained recently in 2020 by Ahmed and al., on the evaluation of the metabolic, antioxidant and anti-inflammatory effects of seeds of *G. Kola* on diabetic rats [64].

3.20 *Hyptis suaveolens* (L.)

Hyptis suaveolens has been considered as a disagreeable weed, distributed in the tropics and subtropics area. It is a medicinal plant of ethnobotanical importance. Almost all parts of this plant are used in folk medicine to treat various diseases. A study of the ethanolic extract of *H. suaveolens*, on animals whose diabetes is induced by streptozotocin, at doses of 250 and 500mg/kg body weight, indicates significant activity. The results show, after 21 days of treatment, a maximum reduction in blood sugar from 237.00 to 98.83mg/dl at a dose of 500 mg/kg of extracts. While in the case of glibenclamide, it goes from 232.33 to 94.50mg/dL. In addition The levels of triglycerides, total cholesterol, very low density lipoproteins were reduced in the treated animals, compared to their control values in diabetic animals [65].

3.21 *Icacina senegalensis* (Juss)

Icacina senegalensis is a savannah suffrutex with glabrous or pubescent leafy shoots of about 2-3 feet high and a large fleshy tuber with creeping roots. The plant is indigenous to west and central Africa. It grows wild on light sandy soils in the savannah areas of Senegal, Gambia, Ghana, Nigeria, Guinea, Central African Republic, Congo and parts of Sudan. Different parts of the plant, especially the leaves, root and stem are widely used in traditional medicine. Scientific studies on the hypoglycemic and antidiabetic activity of *I. senegalensis* extracts have been well documented.

Recently, the work of Akuodor and al., 2014, has showed an antidiabetic and hypolipidemic activity of the aqueous extract of the root of *I. senegalensis* in diabetic rats induced by alloxan. After 14 days of treatment these extracts indicate a maximum decrease in blood sugar from 282.50 to 108.00 mg/dl at the maximum dose of 400 mg/kg comparable to that of the standard drug, glibenclamide. But also a decrease in the weight of treated rats from 162.20g to 160.33g at the maximum dose was observed, while that of untreated rats increased to 190.67g [66].

3.22 *Jatropha curcas* (L.)

Jatropha curcas is a drought resistant shrub or tree belonging to the Euphorbiaceae family which is cultivated in central and south America, South-East Asia, India and Africa. Different parts of the *J. curcas* plant are used in Indian traditional medicine for the treatment of several disorders. Its therapeutic potential in the traditional treatment of diabetes has focused on scientific studies. The study of Vitayakuma et al, 2010, showed a potential antihyperglycemic activity in diabetic rats induced by alloxan. After oral administration of extracts from the leaves of *J. curcas*. The maximum reduction is carried out at 500mg/kg where the blood sugar drops from 237.0 to 98.83 mg/dl and the cholesterol from 152.86 to 72.52 mg/dl. While the profile of the standard drug (Glibenclamide) was (232.33 to 94.5 mg/dl) [67].

3.23 *Khaya Senegalensis* (Desv)

Khaya senegalensis commonly known as caillcedrat or <Khay> in wolof is a tree that belongs to the Meliaceae family. It can reach 35 m in height and its bark is very thick, scaly. This tree is widespread in the central and western regions of the country. The anti-diabetic effect *K. senegalensis* stem bark was performed by Laléyé and al., 2015, [68]. Many studies on the stem bark extracts of *K. senegalensis* show an important antihyperglycemic activity, thus preventing the rise in blood sugar levels. *In vivo* study on the aqueous extract of the bark of the tree with an administration of doses of 500 mg/kg of body weight, has a significant decrease of glycemic level [68]. Other authors have also shown in their studies, anti-diabetic effects of *k. senegalensis*: Arnould and al., 2015, [69], Muhammed and al., 2016, [70].

3.24 *Lactuca sativa* (Linn)

Lactuca sativa (Lettuce) is a well known plant worldwide due to its use in the preparation of salad, soup and vegetable curries. Also, this plant exhibit excellent medicinal properties. The latex sap of *L. sativa* possess antifungal properties. Stem of *L. sativa* has shown depressant effects [71]. *L. sativa* is also proved to have hypoglycaemic effect. Several scientific studies on the hypoglycemic and anti-diabetic activity of *L. sativa* extracts have been well documented: those by Ramos and al, 1995 and Yingyan group, 2018 [72],73]. Recently Geetha et al., 2015, showed by an *in vitro* study that *L.*

sativa extracts possess a powerful inhibitory activity of the α -amylase and α -glucosidase enzymes. Indeed, the results show that at a concentration of 200 μ g/ml, the extracts inhibit 25% of the α -amylase activity and 80% of α -glucosidase activity [74].

3.25 *Mangifera indica* (L.)

Mangifera indica «Mango» in Wolof is a juicy fruit belongs to the *Anacardiaceae* family and is grown in many parts of the world, particularly in tropical countries and is also considered to be the national fruit of India and Philippines and the national tree of Bangladesh. Stems, bark, leaves and seeds of mango are found to have important role for the treatment of diabetes. Almost all parts of this plant are used in traditional medicine to treat various diseases, including diabetes. Many scientific studies have been on the organs (bark of stems and leaves) of *M indica* [75]. Luka and Mohammed, give date conducted study which aqueous *Magifera* leaves extract was administered orally at a dose of 400 mg/kg body weight to normal and alloxan-induced diabetic rats for 21 days. The results showed a significant level decrease of glucose, cholesterol, triglycerides and enzymatic activities [76].

3.26 *Mitragyna inermis* (Willd)

Mitragyna inermis (family: Rubiaceae) is known as Xoos in "Wolof". The plant is a low branching 10-15m tall tree, with white flower turning yellow, and white flower heads [55]. *M. inermis* is well known for its ornamental and medicinal purposes. It is used for the treatment of diabetes, ulcers, body hair, dysentery and bone pain [77].

Recently, the effect of aqueous extracts from the fruits of the *M. inermis* plant at a dose of 400 mg / kg / day on the fasting blood sugar of STZ-induced diabetic rats was investigated. The results showed that the extracts of *M. inermis* did not modify the glycemia of the diabetic rats at the different times (0, 60, 120 and 180 min). But after 2 weeks of treatment of the diabetic rats with the aqueous extracts of *M. inermis*, a significantly reduction in blood sugar of 42% was noted. As well as a significant 44% decrease in total cholesterol in diabetic rats was also noted [78].

3.27 *Momordica charantia* (Linn)

M. charantia is a seasonal plant widely distributed in Senegal. Depending on the region of the country, it presents culinary and

therapeutic properties [79]. This cucurbitaceae is a climbing plant that can reach 3 to 4 m with leaves that can reach 4 to 12 cm [69]. It is used in the Ayurvedic system of medicine for treating various diseases including diabetes mellitus.

The anti-diabetic effect of *M. charantia* has been widely reported. Experiments on streptozotocin-induced diabetic male rats wistar have shown that *M. charantia* fruit juice has high potential for the prevention and treatment of diabetes mellitus. In the study of Mona and al., 2017, treatment with *Momordica charantia* extracts shows a significant reduction of serum glucose (135.99 ± 6.27 and 149.79 ± 1.90 vs. 253.40 ± 8.18) for prophylaxis and treatment respectively. The insulin resistance index, total cholesterol and triglyceride level were also decreased [80].

3.28 *Moringa oleifera* (Lam)

M. oleifera is one of the 14 species in the Moringaceae family, it is a shrub or small tree, with very fast initial growth, which can reach 7 to 12 meters in height. In Senegal this tree grows in all regions with an important resurrection capacity. It is very popular in certain ethnic groups of the population for its culinary properties [79]. The aqueous extract of *Moringa* leaves has potent hypoglycemic activity. Studies show a reduction of 33.29; 40.69 and 44.06% of the blood sugar of diabetic albino rats induced by alloxan at doses of 100, 200 and 300 mg / kg, respectively, after 6 hours of administration of the extracts orally [81].

3.29 *Sclerocarya Birrea* (A. Rich ; Hochst.)

Sclerocarya birrea of the family Anacardiaceae is a species widely used in Africa against various diseases, including diabetes. In 2008 in a cross-sectional survey conducted in Dakar, 43% of patients attending consultancy at the hospital declared using *S. birrea* [82]. This shows the wide use of the plant for the treatment of various diseases. Although research on biological effects is lacking, apart from diabetes which has been the subject of recent studies. Aqueous extracts of Stem Bark of *S. birrea* have been shown to exert hypoglycemic effects in animal models. In rats with streptozotocin-induced diabetes, the acute administration of 5 mg/ml of extract reveals on the one hand a reduction in blood sugar levels and re-establishes plasma insulin levels after 2 weeks of treatment. And on the other hand its

mechanism of action was linked to glucose metabolism, as ATP generation and glucose oxidation were improved after the 24-hour treatment. These data show a direct action of *S. birrea* on insulin-secreting cells and promote further delineation for the use of the plant in the management of diabetes [82].

3.30 *Syzygium aromaticum* (L.)

S. aromaticum belonging to the "Myrtaceae" family is a spice well known for its medicinal properties. This plant is an evergreen tree that reaches 8 to 12 m, having large square leaves and 25 blood flowers in many groups of terminal clusters. The dried flower buds of *S. aromaticum* (clove) have long traditionally been used in the treatment of diabetes mellitus in the South Asia countries.

The effect of ethanolic extracts of the bud of *S. aromaticum* on diabetic rats has recently been studied. Three dose levels of *S. aromaticum* (100, 300 and 500 mg/kg) were used in the study. After 15 days of treatment, all doses of ethanolic extract of *S. aromaticum* bud showed an antidiabetic effect. But the maximum dose of 500 mg/kg showed a more significant antidiabetic effect compared to other doses. Because at this dose the blood sugar is reduced from 311.17 to 109.17mg/dl [83].

3.31 *Tamarindus indica* (L.)

T. indica (Family: Fabaceae) is also one of the popular drugs in Ayurvedic system of medicine. The fruits of *T. indica* is used as a digestive, carminative, laxative, expectorant and blood tonic. Other parts of the plant possess antioxidant, antihepatotoxic, anti-inflammatory, antimutagenic, antidiabetic and antihyperglycaemic activities [84,85].

The results, from an *in vitro* study on aqueous extracts of *T. indica* seeds, showed significant inhibitory effects on the movement of glucose in external solution through the dialysis membrane compared to the control [86].

T. indica extracts have also been observed to promote glucose uptake by yeast cells. Yerima and al.,2014, reported a similar activity of the *T. indica* bark extracts and the stems extract, from an *in vivo study* in diabetic wistar rats [84].

3.32 *Terminalia avicennioides* (Guill)

Terminalia belongs to Combretaceae family consisting of about 514 species of which only 54 are accepted and recognized. This plant is a yellowish brown, hard and durable wood, commonly found in the savannah region of West Africa. It is reported to have been used traditionally to treat varieties of diseases in both animals and humans, such as tuberculosis, cough and diabetes mellitus.

Yahaya et al.,2019, recently demonstrated the antidiabetic potential of extracts from the stem bark of *T. avicennioides* in diabetic rats induced by alloxan. In this study, the extracts significantly decreased blood glucose, total serum cholesterol, serum triglyceride and serum low density lipoprotein levels in diabetic rats compared to negative controls. However, the serum high density lipoproteins (HDL) level was significantly increased in rats treated with hexane, Ethyl acetate and crude methanolic extracts [87].

3.33 *Tinospora bakis* (A.Rich)

T. bakis is a species of the Menispermaceae Family. This species is a shrub with lianoid stems which cling to large neighboring plants [55]. The effect of aqueous extracts of *T. bakis* seeds at a dose of 400 mg / kg / day on the fasting glycemia of diabetic rats induced by Streptozotocin has been demonstrated. The aqueous extracts of *T. bakis* significantly reduced blood glucose level at 60 min and remained low over the next 120 min compared to the diabetic control rats. At the same time, a significant decrease (42%) of total cholesterol was observed in diabetic rats [78].

3.34 *Trigonella foenum-graecum* (Linn)

Trigonella foenum graecum (TFG) is an annual herbaceous plant of the Fabaceae family. It is used worldwide as a culinary spice and as a medicinal herb. In addition to its dietary uses, it has been known for centuries for its therapeutic effects in traditional medicine [88].

The seeds and leaves are also known for their anti-diabetic properties. The hypoglycemic properties of TFG plant have been demonstrated in diabetic rats induced by alloxan or streptozotocin. According to recent research, extracts from the seeds of TFG have a preventive and curative effect in type 2.

An other study conducted on mice with established diabetes, TFG reduced fasting blood sugar, plasma insulin and insulin resistance [89].

3.35 *Vernonia amygdalina* (Del)

Bitter leaf scientifically known as *V. amygdalina* is one of the most famous plants found in Africa and Asia. It is the most cultivated species of the *Vernonia* genus that is about 1,000 species of shrub. *V. amygdalina* has been the most prominent species in the family of Asteraceae that had been studied in Africa. This plant has been known as food and medicinal plants used in Asia and Africa (West Africa) due to its pharmacological effects (antioxidant, anti-diabetes, antiinflammatory, anticancer, anti-malaria, and among others) [90].

Administration of *V. amygdalina* leaf extracts did not significantly modify the peak of blood glucose under carbohydrate load, nor significantly reduced the blood glucose levels at the different points of the curves [91].

3.36 *Vernonia colorata* (Willd)

V. colorata is a plant of the Composeae family, used in Senegal, in traditional settings, in the treatment of diabetes. It is widespread in Africa, particularly in Benin, Cameroon, Côte d'Ivoire, Senegal and Togo. In Senegal, it grows in the cool soils of lower Casamance but also near the Niayes area around Dakar region. In traditional settings, the leaves are used in the treatment of bilharzia, amoebic dysentery, skin rashes and diabetes [92]. Previous work has shown that the acetone extract of *V. colorata* leaves induces hypoglycemic effect in normoglycemic and antihyperglycemic rats on a glucose tolerance test and in type 2 diabetic rats.

Recently, the effect of total acetone extract from *V. colorata* leaves was evaluated on blood glucose fractions obtained in normoglycemic rats and in a glucose tolerance test. The results show that, in normoglycemic rats, 30 mg / kg the total acetone extract causes significant hypoglycemia activities [92].

3.37 *Vitellaria paradoxa* (subsp)

V. paradoxa or native species of the family of Sapotaceae, is a slow growing semi-domesticated fruit tree. This tree grows naturally in the wild of the dry savannah belt of West Africa, from Senegal in the West to Sudan in the

East and on to the foot hills of the Ethiopian mountains.

Different parts of the plant including leaves, roots, seeds, fruit and stem bark have been used in the treatment of enteric infections such as diarrhea, dysentery, helminthes and other gastrointestinal tract infections, skin diseases and wound infections.

Recently, a study on hypoglycemic and antihyperglycemic activity was made on the barks of the stems of the *V. paradoxa* plant. Results show that extract with doses of 80, 400 and 800 mg / kg of body weight to rabbits have an important hypoglycemic activity of -15.91% after 2 hours of treatment. But also an antihyperglycemic activity, after reduction of blood sugar from 60.87% to 3.26% to stabilize it at normal blood sugar with a concentration of 800 mg/kg body weight of the rabbits [93]. Abubakar et al., Confirm this hypoglycemic activity of the plant of *V. paradoxa* with an IC₅₀ of 224.95 ± 0.14 µg/ml on the activity of the α-amylase enzyme [94].

3.38 *Zingiber officinale* (Roscoe)

Zingiber officinale (Ginger) of the the family Zingiberaceae is one of the most popular spices over the world. Southeast Asia is its origin and then ginger spread to Europe, it was used as a medicine herbal for several years to treat a variety of symptoms like pain, vomiting. It was also reported that ginger possess anticlotting, anti-cancer, anti-inflammatory, analgesic and antidiabetic activities.

Administration of ginger to type 2 diabetic rats induced by intraperitoneal injection of streptozotocin (STZ) at different doses for 2 months, indicate a significantly increase in serum insulin and high density lipoprotein (HDL) concentrations. Body weight, fasting blood sugar, cholesterol total, low density lipoprotein (LDL) and HbA1 levels were significantly lower in the non-diabetic control group and in diabetics treated with a high dose of ginger compared to the control diabetic group[95].

3.39 *Zizyphus mauritiana* (Lam)

Zizyphus mauritiana from the Rhamnaceae family, is a shrub or small tree, known in arid and semi-arid tropics. In Africa, its area of extension stretches from the west of the continent to the eastern and southeastern borders [96].

The antihyperglycaemic activity of aqueous extracts of *Z. mauritiana* leaves was evaluated in hyperglycaemia caused by oral administration of glucose in rabbits. Aqueous maceration of the leaves at a dose of 150 mg/kg caused inhibition of blood glucose by 56.02%, 35.46% and 38.49%, respectively 30, 90 and 120 min after administration of glucose [97]. Denou and al., 2016, also demonstrated this hypoglycaemic activity of *Z. mauritiana* with the root bark extracts. At a dose of 8 mg/kg, they revealed reductions in blood sugar levels of 53.49% and 53.6% respectively at 90 and 180 minutes. While the Metformin or reference drug used lowers blood sugar by 31.2% after 108min of treatment [98].

3.40 *Ziziphus mucronata* (Willd)

Z. mucronata is a species of the Rhamnaceae family known under the name of “jujubier” (local French) or “sedèmi buki” (Wolof). It is a thorny tree on the trunk with alternate leaves, green flowers in bundle and axillary. The plant of *Z. mucronata* is widely used in traditional Senegalese medicine, for the treatment of several pathologies: enuresis, hematuria, oliguria, other urinary infections, hypertension and diabetes [55].

Recently, a study examined the antidiabetic effects of the butanol fraction of the root of *Z. mucronata* in rat model of type 2 diabetes. After four weeks of treatment, the results show that the extracts at a dose of 300 mg / kg of the body weight have satisfactory antidiabetic activity. The extracts indicate significantly lower glycemia (19.24 vs 28.96mmol/l), improved glucose tolerance capacity (21.26 vs 28.56mmol/l), serum insulin higher (131.37 vs 64.20pmol/l) and hepatic glycogen (2.40 vs 1.54mg/g of tissue) were observed in the group ingested at 300 mg/kg of *Z. mucronata* compared to the diabetic control group [99].

4. CONCLUSION

In this review, we have tried to list the medicinal plants of the Senegalese flora whose effects on diabetes have been scientifically approved. The non-exhaustive list of 40 plants shows the diversity of available plants in the management of diabetes disease. This potential should be better exploited-- on the one hand, by experimenting with therapeutic combinations from active extracts to possibly have synergistic

effects of the extracts; and, on the other hand, by proceeding with the purification, isolation and characterization of active compounds contained in the extracts already active on diabetic parameters in general. Work to raise awareness and share results between scientists, populations and traditional healers in the control of active plant organs and dosages would also be necessary.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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