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Antidiabetic properties of *Moringa oleifera*: A review of the literature

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The incidence of diabetes has been growing over the years with serious and costly consequences, both in terms of human and economic capital, particularly in low- and middle-income countries. Medicinal plants could be usefully included in the treatment of diabetes in an optimized strategy for better cost-effectiveness, given the high cost of pharmaceuticals and their side effects on patients. A total of 36 studies (articles, thesis and final dissertations) were included in the review, including 67% of ethnobotanical studies and 33% of biological and clinical trials. In ethnobotanical studies, the different parts of the plant (leaves, seeds, fruits or pods, flowers, bark and roots) were cited in all series. In contrast, in the bioassays, only leaves, seeds and roots were used in the experiments. However, leaves remain the most widely used organ, with an efficacy that has been demonstrated in bioassays confirming ethnobotanical surveys. In view of the results collected, in-depth studies on the use of *M. oleifera* in the management of diabetes particularly in Sahelian countries would be relevant in the fight against the double burden of malnutrition.

Key words: *Moringa oleifera*, diabete, antidiabetic properties.

INTRODUCTION

Several plant species are used by humans for their nutritional and/or medicinal qualities. According to the World Health Organization (2002), 80% of the world's populations use traditional medicine and medicinal plants for health care in various forms. Africa has a significant diversity of medicinal plants. Some of these plants are used in the treatment of diabetes.

Diabetes is a metabolic disease characterized by chronic hyperglycemia resulting from abnormalities in insulin secretion, insulin action or both, with serious consequences. According to estimates by the International

Diabetes Federation, there were 425 million people with diabetes worldwide in 2017, including 16 million in Africa (International Diabetes Federation 2017). Based on country profile data for diabetes (World Health Organization 2016), diabetes prevalence was estimated at 5% in Mali, 4.1% in Niger, 4.2% in Burkina Faso and 5.1% in Senegal.

Moringa oleifera is a plant of the West African pharmacopoeia (West African Health Organization (WAHO), 2013), belonging to the Moringaceae family. It has been used for a millennium (Khawaja et al., 2010)

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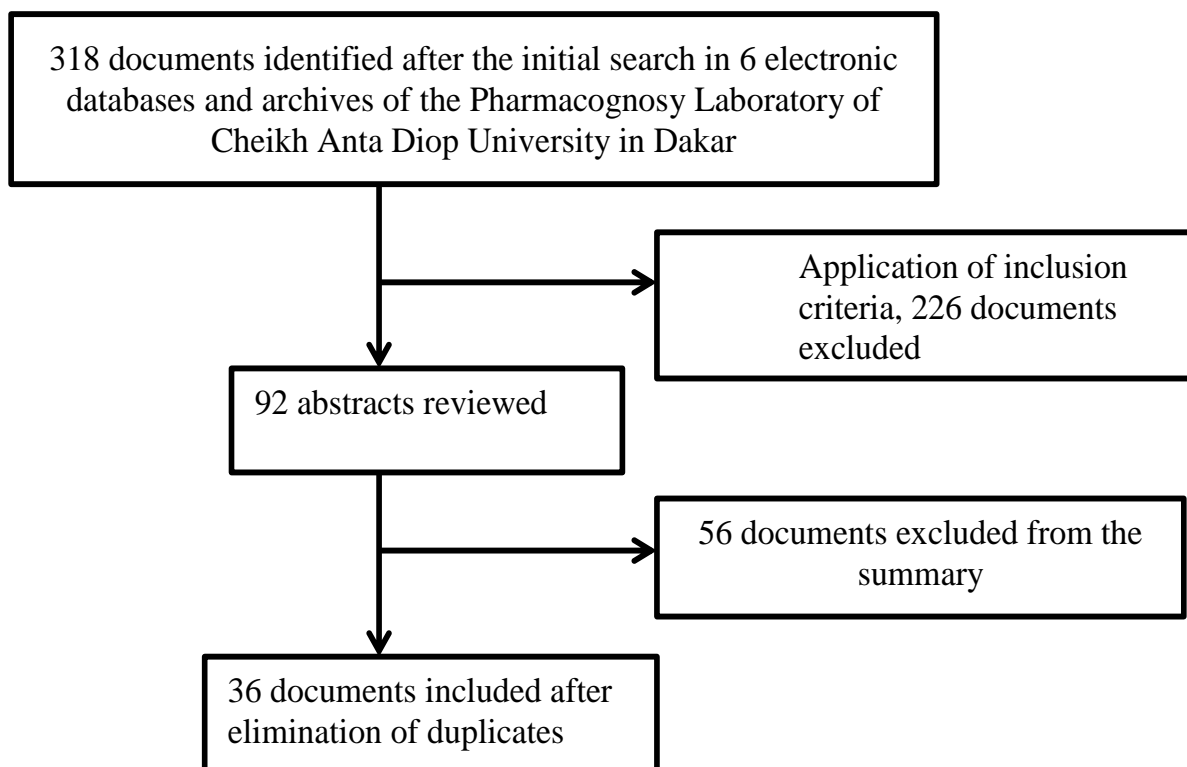


Figure 1. Diagram showing the procedure for selecting the documentation for this review.

and originated from Arabia and India. It is particularly resistant to many climatic conditions (Fortin et al., 2009). It is used in human food (Sarr et al., 2012; Mawoumaand Mbofung, 2014), as fodder for livestock (Altom et al., 2018; Belhiet al., 2018), aquaculture (Hêdji et al., 2014), in phytotherapy for the treatment of many diseases in several countries, particularly in sub-Saharan Africa, in water purification (Bundiand Njeru, 2018), as biodiesel (Mirhashemi et al, 2018), and bio-pesticide. It can be found in several West African countries where it is associated with market gardening (Rabo et al., 2015).

In Senegal, nebeday leaves are used as a condiment in the cereal-based couscous dish "Mbum", and also in phytotherapy, because it is within the reach of most houses (Ndong et al., 2003; Kerharo, 1969). *M. oleifera* is rich in vitamins and minerals (Toury et al., 1963); the leaves contain 4 times more Vitamin A than carrot; 7 times more Vitamin C than orange; 2 times more potassium than banana, more iron than spinach, more calcium than milk and more protein than eggs (Sy et al., 2018). It has antioxidant (Ndiaye et al, 2002), anti-inflammatory (Isingoma et al., 2018), antibiotic (Fall, 2009), analgesic (Tiloke et al., 2018), anticancerous (Sy et al., 2018), diuretic, antispasmodic (Cáceres et al, 1992), anti-ulcer (Gopalakrishnan et al., 2016), anti-epileptic (Joy et al., 2013), and antianemic properties (Menasria et al., 2018). The objective of this work is to

review the literature on the anti-diabetic properties of *M. oleifera*.

METHODOLOGY

Collection sources

Our sources are mainly composed of articles, final dissertations, and thesis.

Methods

We collected data through the archives of the Pharmacognosy and Botany Laboratory of the Faculty of Medicine, Pharmacy and Odontology and the Central Library of Cheikh Anta Diop University in Dakar. But also we searched online databases: Google Scholar, Hinari, Science direct, Pubmed, Binum-UCAD (digital library of Cheikh Anta Diop University in Dakar) and African Journals Online (AJOL).

For internet searches with databases, we used the following keywords and associations, in French and English: "diabetes mellitus", "*Moringa oleifera*", "*Moringa oleifera*" AND "diabetes mellitus", "medicinal plants" AND "diabetes mellitus". We also created an alert on Google Scholar with the same keywords. We have included in our review only studies less than or equal to 10 years (January 2009-July 2019). We identified 318 documents (Figure 1). After application of inclusion criteria, 92 abstracts were reviewed. After eliminating those deemed irrelevant for the theme and duplicate, we obtained 36 publications. The data analysis was

carried out using a spreadsheet to highlight the raw data, the percentages of use of each part of the plant, the dosages used in bioassays.

RESULTS AND DISCUSSION

We classified the results into two categories: ethnobotanical studies (67%); biological and clinical trials (33%). For ethnobotanical studies, details on the year of publication, the reference of the source, the country where the survey was carried out, the parts of the plant mentioned in the studies, the methods and the results are represented in Table 1. In these studies, leaves were the most used with 41%, followed by seeds, 19% and roots, 19% (Figure 2). For biological and clinical trials, details on the year of publication and the reference of the source, the country where the survey was carried out, the parts of the plant mentioned in the studies, the methods and the results are represented in Table 2. The parts of the plant studied were leaves in 82% of cases, seeds in 9% and roots in 9% (Figure 3). The dosages used during the studies ranged from 100 to 800 mg (Figure 4).

Therapeutic virtues of the organs of *M. oleifera*

M.oleifera possesses many therapeutic values. It has analgesic, anti-inflammatory, antipyretic, anticancer, antioxidant, nootropic, hepatoprotective, gastroprotective, anti-ulcer, cardiovascular, anti-obesity, anti-epileptic, anti-urolithiatic, diuretic, local anesthetic, anti-allergic, antihelminthic, wound healing, antimicrobial, immunomodulatory and antidiarrheal properties (Bhattacharya et al., 2018).

The juice of the leaves was considered as detergent and antiscorbutic; they relieve children of convulsions, headaches and treated conjunctivitis (West African Health Organisation (WAHO), 2013). Fresh leaves crushed and placed, in poultice, on abscesses could cause them to mature and promote the expulsion of foreign bodies. The poultice application of heated leaves has been indicated for the treatment of syphilitic ulcers (Fortin et al., 2009). Leaf decoction has been used in the treatment of high blood pressure and erectile dysfunction (Diop, 2014), and also as antipyretic (Sèye, 2014).

The decoction of flowers had therapeutic effects to fight against infertility and sexual dysfunction in men and women (Fortin et al., 2009). Fruits were used in the treatment of inflammation disorders, asthma, rhinitis (Gueye, 2011). The seed powder was used against hypertension (Diop, 2014). The seeds were also used in the treatment of splenomegaly; wound healing. They also help to treat hyperthyroidism, rheumatism. Processed *M. oleifera* seed meal could be used to treat malnutrition problems (West African Health Organisation (WAHO), 2013). The bark of *Moringa* contains two alkaloids, called

Moringin and Moringinin (Kerharo, 1969). It is used for the treatment of heart problems, yellow fever, and toothache. Massages, based on crushed roots, have a beneficial effect on rheumatism and joint pain. The roots, in powder form by the nasal route, can be used for fever, headaches and neuralgia (Gueye, 2011).

Antidiabetic effects of *M. oleifera*

The anti-diabetic activity of *Moringa oleifera* has been reported in several studies in sub-Saharan Africa and in other parts of the world. Leaves of *M.oleifera* are suitable source of green leafy vegetables to reduce diabetic complications in diabetic patients (Giridhari et al., 2011). Aqueous extract inhibits the activity of α amylase and α glucosidase; it improves antioxidant capacity, glucose tolerance and rate of glucose uptake in yeast cell. The aqueous extract can be used as phytopharmaceuticals for the management of diabetes when used as adjuvant or alone (Khan et al, 2017).

The results of ethnobotanical studies have made it possible to make an inventory of the wealth of anti-diabetic medicinal plants in sub-Saharan Africa and the interest of these remedies by communities. In Senegal, the study done among the Fulani shepherds of Widou Thiengoly, municipality of Tèssékéré, Iferlo, Department of Nioro du Rip and Tivaouane, showed that the populations and traditional practitioners use greatly *Moringa oleifera* for treating diabetes mellitus (Delattre et al., 2001; Guèye, 2016; Diop, 2014; Sèye, 2014).

In addition, other ethnobotanical studies carried out in Africa show the presence of medicinal plants in the daily management of diabetes mellitus at the community level, as is the case in Mali (Koné, 2017; Razingué, 2010) and Chad (Etuk and Mohammed, 2009) where the use of species varies according to ethnic groups. *M.oleifera* has been cited in all its surveys as a reference among other anti-diabetic medicinal plants due to its effectiveness. The results of ethnobotanical surveys on the use of medicinal plants as an alternative means of treating diabetes identified 112 plant species belonging to 51 families in Togo (Ayeni et al., 2016); 168 traditional herbal medicines in Tanzania (Lunyera et al., 2016); and a total of 24 plant species belonging to 20 families in South Africa (Semenya et al., 2012).

The methods of preparation in traditional medicine are in the form of decoction, maceration, infusion or supplementation of leaf or seed powder in food. In a study conducted in Tanzania, the prevalence of traditional medicine used among individuals with diabetes was 77.1% (Lunyera et al., 2016). The use of the plant was related to its accessibility (cost), its effectiveness in lowering blood sugar, reducing or eliminating classic signs of disease; but others also said the opposite. Access to medical care, particularly for chronic diseases, remains a major issue in rural areas, where medicinal

Table 1. Summary of ethnobotanical studies.

Country (References)	Part of plant	Methods	Results
Senegal (Diop et al., 2019)	Leaves Barks	A sample of 120 people (60 men and 60 women) divided into 6 strata was interviewed about medicinal plants: identification of pathologies treated by the plants and their methods of preparation.	<i>Moringa oleifera</i> has been cited for the treatment of metabolic disorders such as diabetes, dermatological, cardiovascular diseases. Decoction and infusion are the two most common methods of preparation.
Chad (Dongock et al., 2018)	Roots, Seeds	A sample of 200 people was surveyed across 4 ethnic groups (Ngambaye, Laka, Kaba and Arabs) using questionnaires about medicinal plants used in the treatment of diabetes and high blood pressure in 216 households targeting farmers and traditional therapists.	Results by ethnic group revealed that <i>Moringa</i> was cited among plants that treat diabetes and high blood pressure.
Mali (Jazy et al., 2017)	Leaves	Survey of traditional practitioners of the Bwa ethnic.	Traditional therapists, including <i>Moringa oleifera</i> have mentioned 11 species of anti-diabetic plants.
Niger (Koné, 2017)	Leaves, seeds, fruits, roots, barks	Survey of 168 traditional practitioners (Niamey and Tillabéri) using a questionnaire.	12 recipes based on <i>Moringa oleifera</i> have been identified for the treatment of diabetes, high blood pressure, sickle cell crises, and hemorrhoids.
Senegal (Cissé et al., 2016)	Leaves; Roots; Barks	Study among Fulani shepherds WidouThiengoly with ferlo, the data were collected using an interview guide.	<i>Moringa oleifera</i> has been mentioned among 74 species distributed in 32 botanical families in the treatment of diabetes, infections and bad breath.
Senegal (Guèye, 2016)	Leaves; Flowers; Roots	Inventory of medicinal species sold in the markets of Touba (Diourbel Region) and their therapeutic indications using a questionnaire, with 53 herbalists in 12 sites.	181 species, 151 genera belonging to 70 botanical families were collected from the different sites. <i>Moringa oleifera</i> was indicated against diabetes, but also cardiac disorders, infection, bad breath, epilepsy and leprosy.
Tanzania (Kouakou et al., 2016)	Leaves, Seeds Flowers, Roots	Survey on Practices and Frequency of Traditional Medicine Use Among Members of the Diabetes Community in Northern Tanzania. Data collection was carried out through focus groups and in-depth interviews with a sample of 481 adults.	The prevalence of traditional medicine used among individuals with diabetes was 77.1%. Several traditional herbal medicines (168) used to treat diabetes, the most common of which were: <i>Moringa oleifera</i> , <i>Cymbopogon citrullus</i> , <i>Hagenia abyssinica</i> , <i>Aloe vera</i> , <i>Clauseria anisata</i> , <i>Cajanus cajan</i> , <i>Artemisia</i> and <i>Afra Persea americana</i> .
Ivory Coast (Vandi et al., 2016)	Leaves	Survey on medicinal plants used in the treatment of diabetes and obesity in five municipalities of Abidjan.	The plant species listed were 26, 18 of which were anti-diabetic (69.23%), divided into 23 genera and 18 families. <i>Moringa oleifera</i> was mentioned as effective against diabetes mellitus and obesity.

Table 1. Continue

Cameroon (Lunyera et al., 2016)	Leaves, Barks, Fruits	Census of medicinal and food plants used in 3 districts and 2 major markets (Yaoundé and Douala) through semi-structured surveys with a sample of 240 people.	<i>Moringa oleifera</i> was used for the treatment of diabetes and other diseases, as well as for food supplements.
Nigeria Ayeni et al., 2016	Leaves	Study in the Oja-Oba and Hausa markets of Nigeria on vegetables used and having medicinal properties, using a semi-structured questionnaire with a sample of 100 people in equal proportions.	Tribes used <i>Moringa oleifera</i> for the treatment of diabetes, gastric ulcer and for its nutritional value use.
Togo (Holaly et al, 2018)	Seeds; Roots	Study of plants used in the treatment of diabetes among 164 traditional healers in the Maritime region of Togo, conducted through interviews with a semi-structured questionnaire.	The authors identified 112 plant species belonging to 51 families, including <i>Moringa oleifera</i> , which was used orally in the form of decoction, maceration and powder.
Benin (Lalèye et al., 2015)	Leaves, Seeds, Roots, Barks	Assessment of the diversity, knowledge and use of diabetic plants by traditional healers, plant traders and farmers from different parts of Benin.	The leaves of <i>Moringa oleifera</i> were used for the treatment of diabetes as powder, decoction, maceration, infusion, ...
Senegal (Diop, 2014)	Leaves; Seeds	Traditional pharmacopoeia in Nirodu Rip Department for the treatment of six diseases: diabetes, hypertension, wound, erectile dysfunction, pain, fever.	The population survey identified 22 plants for antidiabetic phytotherapy and among these plants, <i>Moringa oleifera</i> was the most widely used.
Senegal (Sèye, 2014)	Leaves, Flowers	Ethnobotanical survey on the use of <i>Moringa oleifera</i> leaves in phytotherapy in the department of Tivaouane.	<i>Moringa oleifera</i> was identified as antidiabetic plants.
Togo (Atakpama et al., 2014)	Leaves	Descriptive and prospective study (semi-structured ethnobotanical survey) in the form of an individual interview, with a sample of 113 people.	A total of 46 medicinal indications have been reported for <i>Moringa oleifera</i> , the most common of them were diabetes and high blood pressure.
Benin (Agoyi et al., 2013)	Leaves	Endogenous knowledge on the use of <i>Moringa oleifera</i> in Benin among 439 people.	<i>Moringa oleifera</i> has been used in the treatment of 34 diseases, including diabetes (in powder form or leaf infusion).
Nigeria (Popoola et al., 2013)	Leaves Seeds Barks Roots	Study of the sustainability of local knowledge, used and geographical distribution of <i>Moringa oleifera</i> in Nigeria among 665 people.	Different parts of the plants were used by communities for treatment of diabetes, high blood pressure, malaria, typhoid fever, colds, coughs, sterility. The Fulani ethnic groups used <i>Moringa oleifera</i> as food but also as fodder the plant.

Table 1. Continue.

South Africa (Semenya et al., 2012)	Leaves Seeds	Ethnobotanical survey on medicinal plants used by Bapedi healers to treat diabetes mellitus in Limpopo province, SouthAfrica.	24 plant species belonging to 20 families have been identified. The leaves or seeds of <i>Moringa oleifera</i> were used raw or cooked for 5-10 min.
Burkina Faso (Nadembega et al., 2011)	Leaves	Study of use of medicinal plants by traditional healers through semi-structured and openinterviews with 41 healers as well as focus groups in households.	<i>Moringa oleifera</i> leaf powder has been reported to be effective against diabetes.
Senegal (Mballo, 2010)	Leaves Seeds Roots	Taxonomic inventory and medicinal importance of plants in sectors 13 and 16 of the Michel Adanson Botanical Conservatory, among herbalists and traditional practitioners in Mbour.	The analysis of the data revealed 52 plants, including <i>Moringa oleifera</i> as therapeutic indication: diabetes, cardiovascular, gastric, neurologicaldiseases.
Uganda (Kasalo et al., 2010)	Leaves	Data collection using surveys of heads of households aged 18 and above in four rural districts of Uganda.	This study established that <i>Moringa oleifera</i> is used for the treatment of diabetes.
Mali (Razingue, 2010)	Leaves, Seeds	Survey on the complementary use of medicinalplants among 206 patients with type 2 diabetes at the Bamako Diabetes Centre.	Diabetic patients cited 48 plant species, including <i>Moringa oleifera</i> .
Nigeria (Soladoye et al., 2012)	Leaves	Survey of medicinal plants in the treatment of diabetes in southwest Nigeria.	The survey revealed a high use of medicinal plants with about 132 speciesbelonging to 56 families for the treatment of diabetes, including <i>Moringa oleifera</i> .
Senegal (Cissé, 2009)	Leaves, Fruits, Roots	Survey on medicinal plants sold in the 39 markets in Dakar and its suburbs, with a sample of 103 sellers.	About fifty plants were cited as the most popular in the cities and suburban markets. <i>Moringa oleifera</i> has been mentioned in the treatment of diabetes, infections, and breath disorders.

plants play an important role in the community health system. However, the World Health Organisation (WHO) encouraged research on traditional medicine for the treatment of these chronic non-communicable diseases (Organisation Mondiale de la Santé, 2013). Most preparations of these remedies do not have specific dosages, which could be dangerous with cases of toxicity in some plants.

In bioassays, doses ranging from 100 to 800 mg were tested in animals. Extracts (aqueous, methanolic and ethyl acetate) of 200 mg/kg were most commonly used in the work (Figure 4). The inclusion criteria for animals in bioassays were dependent on blood glucose levels after diabetes induction. Streptozotocin and

alloxane at various doses have been used as experimental models to induce diabetes in laboratory animals in studies. They cause the insulin-producing cells of the pancreas to be destroyed by inducing necrosis. Most of the trials use metformin or tolbutamid as the reference drug. Studies have shown that aqueous extract of *M. oleifera* leaves had dose-dependent hypoglycemic activity in alloxan-induced diabetic rats and was almost as effective as standard drugs (tolbutamid, metformin).

Aqueous extract at doses of 100 and 200 mg/kg of *M.oleifera* leaves improved fasting glucose levels, with an increase in HDL cholesterol levels and a decrease in LDL cholesterol and triglycerides in diabetic rats induced by either Streptozotocin or alloxan. Methanolic extract from

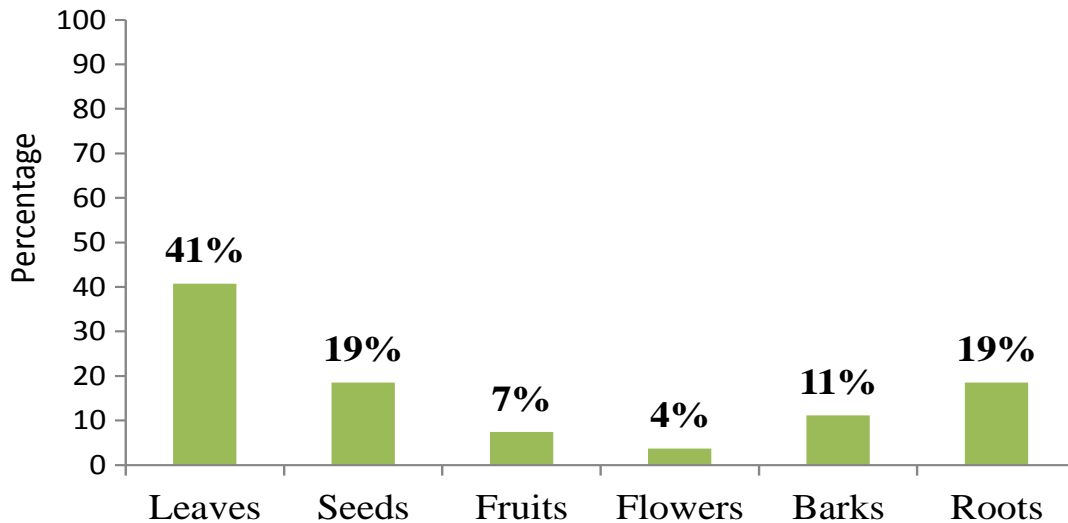


Figure 2. Plant parts in ethnobotanical studies.

Table 2. Summary of biological and clinical trials.

Country (References)	Part of plant	Methods	Results
Nigeria (Umar et al., 2018)	Roots	Study of the hypoglycemic and antioxidant activity of powder and methanol extracts of <i>Moringa oleifera</i> root on alloxan-induced diabetic rats for 28 days.	The effects of the extracts were evaluated by measuring changes in blood glucose levels, biochemical parameters, oxidative stress biomarkers and pancreatic tissue. This study showed that the root of <i>Moringa oleifera</i> had a hypoglycemic effect.
Nigeria (Onyagbodor et al., 2017)	Leaves	Study on the protective and ameliorative potential of ethanol extract of <i>Moringa oleifera</i> leaf (500-200 mg/kg) on alloxan-induced diabetes in Wistar rats	Extract treatment caused hypoglycemia after fourteen days of treatment in normal rats. <i>Moringa</i> leaf possesses protective and ameliorative antidiabetical potential in rats.
South Africa (Omodanisi et al., 2017)	Leaves	Diabetes was induced by a single dose of streptozotocin (55 mg/kg) in 48 adult male Wistar strain rats. <i>Moringa oleifera</i> methanolic extract (250 mg/kg) has been given for six weeks.	Treatment of rats with <i>Moringa oleifera</i> showed a significant decrease in blood glucose compared to the control batch.
Nigeria (Olayaki et al., 2015)	Leaves	Diabetes induced by an intraperitoneal injection of alloxane (120 mg/kg). Normal and diabetic control rats received saline solution. Rats in the other groups have received 300 or 600 mg/kg of <i>Moringa oleifera</i> methanolic extract or metformin (100 mg / kg) for 6 weeks.	These results showed that the hypoglycemic effects of <i>Moringa oleifera</i> could be by stimulating insulin release, resulting in increased glucose absorption and glycogen synthesis.
Nigeria (Altom et al., 2018)	Seeds	This study examines the effect of aqueous seed extract of <i>Moringa oleifera</i> (400 mg/kg) in 36 healthy adult female Wistar albino rats weighing between 200g and 225 g. Diabetes was induced by an injection of alloxan (150 mg/kg).	<i>Moringa oleifera</i> seed extract showed a hypoglycemic effect with 69.7% and 89.6% decrease in blood glucose levels in hyperglycemic rats.

Table 2. Continue

Nigeria (Edoga et al., 2013)	Leaves	Study of the effects of the aqueous extract (100, 200, 300 mg/kg) of <i>Moringa oleifera</i> on alloxan-induced blood glucose levels in diabetic albino rats (120 mg/kg).	The results showed a 33.29%, 40.69% and 44.06% reduction in blood glucose concentration within 6 h of administration, respectively.
Nigeria (Adeeyo et al., 2013)	Leaves	Comparative study of the antidiabetic effect of the aqueous extract of mistletoe leaves and <i>Moringa oleifera</i> .	The results showed that after one week of treatment, 77.78% and 88.9% of animals in diabetic groups treated with Mistletoe and <i>Moringa</i> became normoglycemic, respectively.
Nigeria (Aja et al., 2013)	Leaves	Evaluation of the antidiabetic activity of aqueous extracts of <i>Moringa oleifera</i> and <i>Bridelia ferruginea</i> (200, 400 and 800 mg/kg) in 24 alloxane-induced diabetic male albino rats (100 mg/kg).	After seven days of treatment, the antidiabetic activity of the two extracts was determined from glucose and transaminase activities in rat blood.
Nigeria (Oyedepo et al., 2013)	Leaves	Evaluation of the anti-hyperlipidemic effect of the aqueous extract of <i>Moringa oleifera</i> leaves (400mg/kg) in diabetic rats induced by alloxane monohydrate (100mg/kg).	After 28 days of treatment with <i>Moringa oleifera</i> , a reduction in plasma lipid imbalances associated with diabetes mellitus was observed in the experimental animals.
Nigeria (Kofia et al., 2017)	Roots	Comparative study of the hypoglycemic effects of aqueous extract (150 mg/kg) of <i>Moringa oleifera</i> leaves and three other plants on alloxane-induced diabetic rats (150 mg/kg).	The results showed that the leaves of <i>Vernonia amygdalina</i> had more hypoglycemic effects followed by <i>Moringa oleifera</i> .
Cameroon (Etuk et al., 2009)	No part of the plant was mentioned	Analytical study on 54 diabetics. Four anti-diabetic plants were identified among users, beneficial effects on blood sugar levels and renal risks analyzed.	The results showed that <i>Moringa oleifera</i> and <i>Leptadenia hastata</i> were better anti-diabetic plants and may have a protective effect on nephron in diabetics.
Nigeria (Tsabang et al., 2015)	Leaves	Evaluation of the hypoglycemic activity of ten plants cited as antidiabetic by an upstream ethnobotanical study.	Bioassays showed that the aqueous extract of <i>Moringa oleifera</i> leaves resulted in a significant reduction in fasting blood glucose levels.
Cameroon (Luka et al., 2013)	Leaves	Clinical follow-up of 182 people (116 diabetics and 66 hypertensive) for 10 days with different varieties of medicinal plants prepared as decoction, maceration and infusion, and administered orally two or three times a day.	At the end of the follow-up, herbal remedies reduced hyperglycemia in 69.4% of type 1 diabetics and 80% of type 2 diabetes patients, with a significant reduction in high blood pressure in hypertensive patients. For both diseases, 64.17% of blood glucose and blood pressure values were regulated.

M. oleifera leaves at doses of 300 and 600 mg/kg has hypoglycemic effects in alloxan-induced diabetic rats, improved glucose tolerance, glycogen synthesis, and lipid metabolism (Olayaki et al., 2015). Treatment with aqueous extract of leaves (7 days) and seeds (28 days) of *M. oleifera* at a dose of 400 mg/kg in alloxane-induced diabetic rats had hypoglycemic activity (Adeeyo et al., 2013; Oyedepo et al., 2013).

Administration of aqueous extracts of *M. oleifera* leaves at doses of 250 and 800 mg/kg in alloxane-induced diabetic rats showed satisfactory hypoglycemic activity, as well as an improvement in pancreatic function in rats (Omodanisi et al., 2017; Aja et al., 2013). Oral administration of leaf extract reduced plasma lipid imbalances associated with diabetes, the mechanisms of which might increase blood glucose utilization by

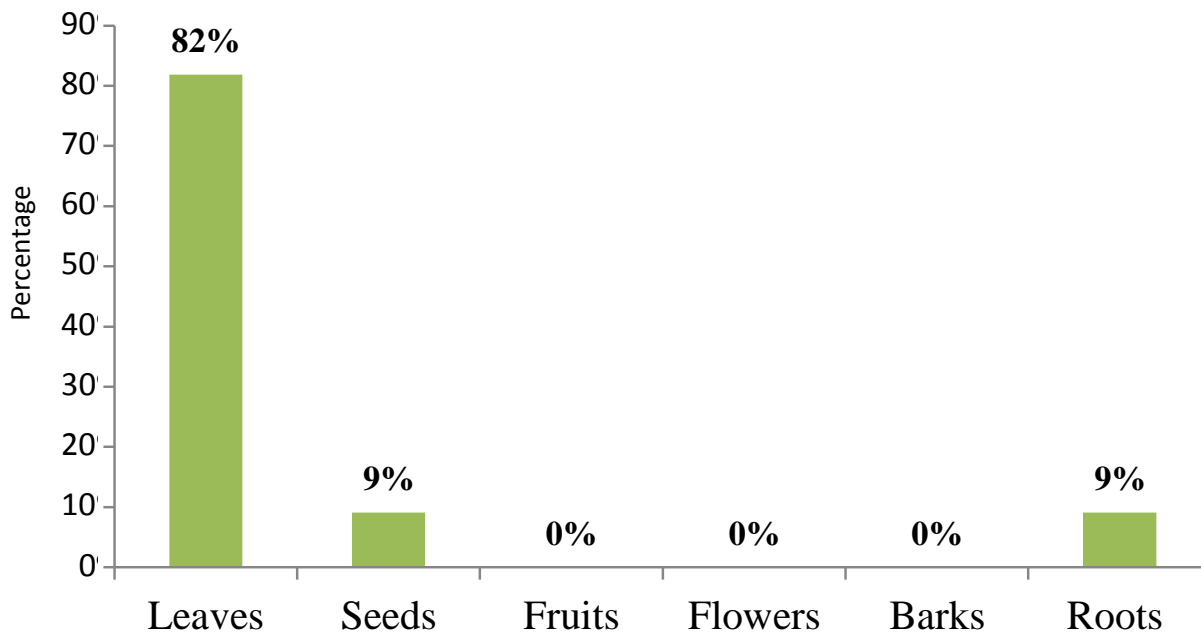


Figure 3. Plant parts used in biological and clinical trials.

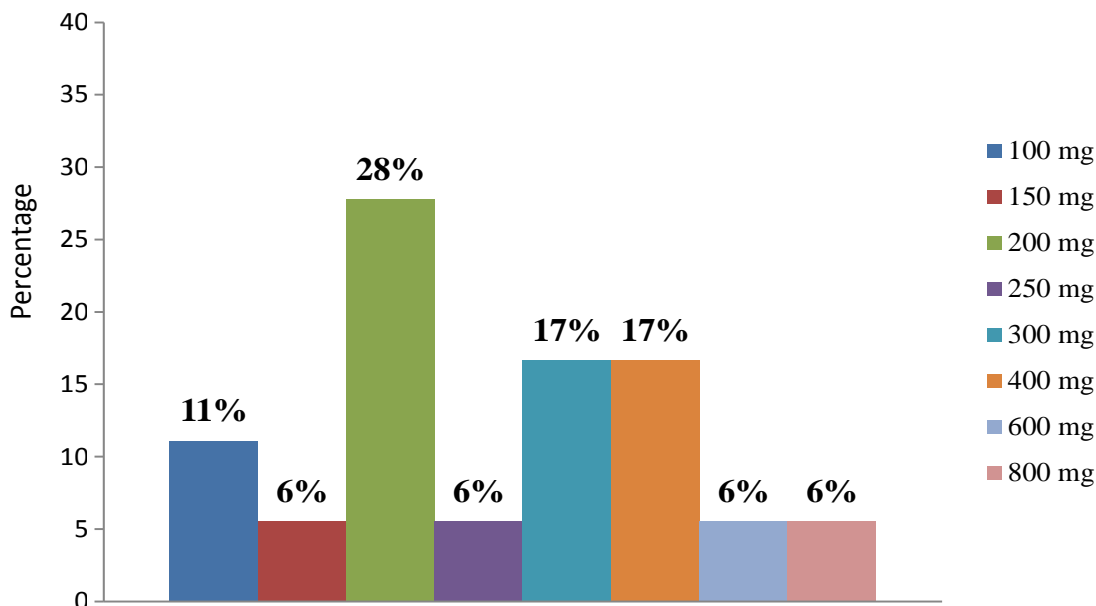


Figure 4. Doses used in bioassay.

inhibiting hepatic glycogenesis or by absorbing glucose in muscle and fat tissue (Oyedepo et al., 2013).

However, high levels of HDL and reduced LDL concentrations after administration of *M. oleifera* extracts may play a protective role against the development of atherosclerosis and cardiovascular complications of diabetes (Olayaki et al., 2015). The richness of African

flora in medicinal plants, as well as the adaptability of *M. oleifera* to the Sahelian climate and its daily use in food, should encourage decision-makers to support research on this so-called miracle plant. This can be done through funding and institutional support to conduct clinical trials in diabetics based on ethical standards.

Oxidative stress has been suspected to be the cause of

chronic non-communicable diseases, particularly in diabetes mellitus. This leads to a reduction in insulin secretion by Langerhans cells and a decrease in the action of the hypoglycemic hormone worsening the state of insulin resistance in the profile of type 2 diabetes (Delattre et al., 2001). The phytochemical constituents of *M. oleifera* offer a protective action against oxidative stress, preventing or slowing down the oxidation of other molecules. Generally, this is done by trapping free radicals and reducing the development of inflammatory cytokines due to its high phenolic content (Omodanisi et al., 2017).

Hypoglycemic activity of *M. oleifera* may be probably due to the presence of antioxidants such as flavonoids, quercetin and kaempferol, polyphenols and vitamins, in different parts of the plant (Adeeyo et al., 2013). Quercetin significantly increases the hepatic activities of glucokinase like insulin. Leaves contain terpenoids, which appear to be involved in the stimulation of the β cells and the subsequent secretion of preformed insulin (Konmy et al., 2016). Other compounds found in *Moringa oleifera* leaves like isothiocyanates seem to reduce insulin resistance and hepatic gluconeogenesis.

The organs of *Moringa oleifera* also contain flavonoids, tannins, alkaloids, saponins, terpenoids (Abdulkadir et al., 2016; Hafiz et al., 2016). Phytochemical analysis of root powder extracts with methanol revealed the presence of some secondary metabolites, namely alkaloids, tannins, flavonoids, cardiac glycosides, saponins, triterpenes and steroids (Umar et al., 2018). The healing effects of *M. oleifera* diabetic wounds could be attributed to the presence of tannins, which are polyphenolic components with tissue renewal and infection control properties (Dongock et al., 2018).

M. oleifera is also used in the treatment of many diseases such as high blood pressure and obesity that can be attributed to the presence of β -sitosterol in the leaves.

The use of underground parts could pose a threat to species if there are no mechanisms for restoration and safeguarding of biodiversity by communities.

Limitations of the study

We have collected little data on the anti-diabetic properties of *M. oleifera* in sub-Saharan Africa; this is explained by the non-publication of research works (theses and dissertations) in scientific journals and also on academic digital libraries (internet), and those that have not been indexed by the databases.

Conclusion

M. oleifera is a plant with many benefits for humans, nutritionally, medicinally and economically. Its promotion could help to combat the double burden of malnutrition,

including under-nutrition and chronic non-communicable diseases such as diabetes mellitus, especially in low- and middle-income countries, which are also facing the effects of climate change. In view of all this information gathered on the anti-diabetic properties of *M.oleifera*, it would be necessary to conduct clinical trials in the Sahel countries, given its accessibility and easy adaptation to the climatic conditions of the region.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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