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Review

Some common West African spices with antidiabetic potential: A review

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A B S T R A C T

Diabetes is a chronic metabolic disorder of glucose metabolism, which is associated with an elevated level of glucose (hyperglycemia) in the blood. The unhealthy eating habit of people, obesity, inactivity and irregular use of diabetes prescribed medications are one of the factors that have increased the prevalence of diabetes worldwide. However, the high cost of managing diabetes and adverse effects associated with the use of synthetic drugs have impelled the quest to search for cost-effective and safer alternative antidiabetic agents. Conversely, spices are added to food to improve their taste, color, flavor, and shelf-life; they also possess some therapeutic values including antidiabetic activity due to the presence of bioactive components. As a result, the present review focuses on some commonly used spices in Africa that have demonstrated antidiabetic activity in both *in vitro* and *in vivo* studies, thereafter, we highlighted some bioactive compounds in these spices and their possible mechanism of action.

Contents

1. Introduction

Diabetes mellitus is a metabolic disorder characterized by derangement of glucose, protein, and lipid metabolism, which consequently leads to an elevated level of glucose (hyperglycemia) in the blood (American Diabetes Association, 2009). Besides hyperglycemia, other conditions such as polyurea, weight loss, muscle weakness, polydipsia, polyphagia, and hyperlipidemia are also associated with diabetes. Insulin inhibits the activity of hormones stimulating lipase in the adipose tissue. In the absence of

Abbreviations: K^+-ATP, Potassium-Adenosine triphosphate; LD_{50}, Median lethal dose; HDL, High density lipoprotein; LDL, Low density lipoprotein; WHO, World Health Organization.

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insulin or during insulin resistance by receptors, the rate of lipolysis increases, thereby releasing free fatty acids into the bloodstream, this also increases β-oxidation of fatty acids and cholesterol production. Insulin also mediates the removal of cholesterol; hence, its absence leads to the manifestation of hyperlipidemia and hypercholesterolemia in diabetes (Sheikh et al., 2013). World Health Organization (WHO) statistics show that 400 million people worldwide have diabetes with about 1.5 million deaths and there is a projection of this rate doubling by 2035 due to the affluent lifestyle of people (Mohammed et al., 2015; Okoduwa et al., 2017). People with fasting blood sugar greater than 126 mg/dL or 7.0 mmol/L or random blood sugar greater than 200 mg/dL (11.1 mmol/L) are said to be diabetic.

Diabetes can be a result of a deficiency of insulin as in type I (childhood-onset) diabetes which is mainly caused by an autoimmune disease that depletes beta cells in the pancreas which produce insulin. This accounts for 10% of the type of diabetic population (Papitha et al., 2018), while type II which is a more prevalent form of diabetes is a result of the insensitivity of the receptors to insulin, it is common in middle-aged adult with obesity (Pereira et al., 2019). Some pregnant women usually in their third trimester can experience the disorder in glucose metabolism, this is often referred to as gestational diabetes, and this condition may get better or disappear after they deliver their babies. Diabetes can be due to hereditary, immune response, age, lifestyle, and stress (Bihari et al., 2011).

If the blood sugar level is not regulated it can have a serious impact on several organs and consequent lead to diseases such as hypertension, kidney disease, blindness. The cost of treating diabetes is expensive; it also comes with deleterious side effects such as weight gain, gastro disorder. Besides, people find it difficult to adjust to lifestyle modifications such as eating food that is not rich in sugar. Hence, it is important to look for alternative means of regulating blood sugar Figs. 1 and 2.

Spices are usually added to food to improve their taste, color flavor, and shelf life, they often have medicinal values too due to the presence of bioactive components in them (Dzoyem et al., 2014; Tamokou et al., 2017). Unlike synthetic antidiabetic drugs that are not mostly convenient to be taken orally by many people, spices do not require a strict regimen as they can be taken as a food supplement, tea, or oil and are easily available and cheap with little or no side effects. Flavonoids, alkaloids, terpenoids, coumarins, sulphur compounds, peptides, amines, steroids, and sometimes complex carbohydrates have been reported to possess antidiabetic potentials (Ogbonnia and Anyakora, 2009). The various mechanisms by which plant drugs demonstrated antidiabetic activities include; glycosidase (glucosidase) inhibitor, α-amylase inhibition, inhibition of hepatic glucose metabolizing enzyme, stimulation of insulin production or acting as insulin mimic, glycogenesis stimulation, reducing the release of glucagon and other hormones that counterbalance the action of insulin, antioxidant mechanism, prevention of glycosylation of haemoglobin, and regulation of glucose absorption from the gut (Ogbonnia and Anyakora, 2009).

Antidiabetic potentials of several spices have been reported in the developed countries and as a result, this study aimed to evaluate the antidiabetic potentials of common spices used in African countries. Alloxan and streptozotocin are the common drugs used for inducing diabetes in animal models. They damage/destroy β-cell of the pancreas due to their cytotoxic nature thereby decreasing insulin production leading to type 1 diabetes and consequently decrease the usage of glucose by tissues, thereby leading to its elevated level in the blood (Sheikh et al., 2013). They can also be used to induce type 2 diabetes if calculated doses are used to cause partial destruction (deformation) of the pancreatic β–cells (Oguanobi et al., 2012). Some examples of drugs and the structure of compounds found in the drugs used in managing diabetes are enlisted in Table 1.

2. Spices with antidiabetic potentials

2.1. Alligator pepper

Alligator pepper or Mbongo spice or Hepper pepper or Guinea pepper or Grain of paradise is scientifically known as *Aframomum melegueta*. In Nigeria, it is called Atare in Yoruba, Chitta in Hausa, Ose-oji in Igbo (Onoja et al., 2014). In Ghana, it is called Efom wisa, it belongs to the ginger family, Zingiberaceae; it is an herbaceous perennial plant that is widely distributed in swampy areas of western and central Africa (Lawal et al., 2015; Osuntokun, 2020). The fruit contains several tiny indehiscent seeds with a strongly aromatic and pungent smell. The seed is commonly used in preparing pepper soup (as fondly called in West Africa) due to its spicy nature; it is also used as a spice for meats, sauces, and soups (Kokou et al., 2013; Osuntokun, 2020). Its various medicinal values such

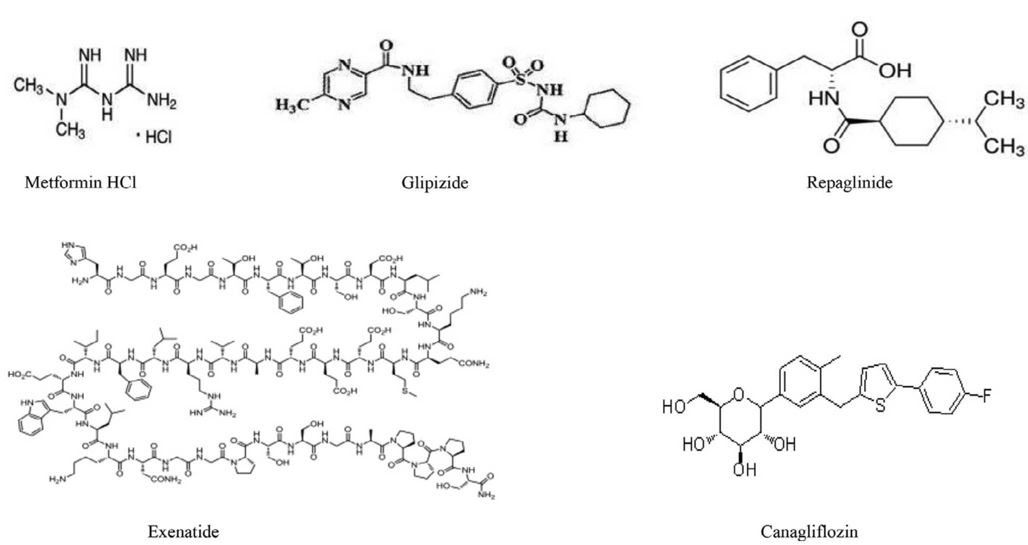

Fig. 1. Chemical structure of some drugs used for managing diabetes.

Fig. 2. Some African food spices with antidiabetic activity.

as anti-inflammatory, aphrodisiac, hepatoprotective, antitumour, antidiabetic, antiulcer, anti-venom, antimicrobial, weight loss, erythropoietic potential, and many other medicinal uses have been reported in the literature (Adesokan et al., 2010; Mojekwu et al., 2011; Onoja et al., 2014; Lawal et al., 2015; Amadi et al., 2016). Phytochemical screening of alligator pepper has revealed the presence of secondary metabolites such as flavonoids, phenolic compounds, alkaloids, tannins, terpenoids, saponins, and cardiac glycosides in the seeds (Onoja et al., 2014; Amadi et al., 2016). Aqueous extract of the seed has been documented to be rich in phenolic compounds, gingerols, acarbose, shogaols, eugenol, oleanolic acid, paradols, acarbose buplerol, (-)-arctigenin, 5-hydroxy-7-methoxyflavone and apigenin (Mohammed et al., 2015; Amadi et al., 2016). Adefegha et al. (2017) highlighted that oil of *A. melegueta* seed contained limonene, eugenol, eucalyptol, α-pinene, β-pinene, β-cadinene, β-caryophyllene, α-terpineol, germacrene. Adesokan et al. (2010) reported the antidiabetic potential of aqueous extract of *A. melegueta* in alloxan-induced diabetic rats. They reported that the 200 mg/kg of aqueous extract *A. melegueta* was able to restore blood sugar in diabetic rats within 6 days as against the 100 mg/kg metformin (reference drug) that took 14 days to demonstrate the same level of antidiabetic effect. Mohammed et al. (2015) found that 300 mg/kg of ethyl acetate fraction of *A. melegueta* restore elevated glucose concentration to normal and ameliorate diabetes-related parameter in streptozotocin-induced diabetic in the rats. Morakinyo et al. (2019) reported the efficacy of 200 mg/kg and 400 mg/kg of methanolic extract of *A. melegueta* in normalizing alloxan-induced hyperglycemia in albino rats. The extract competed better than 5 mg/kg glibenclamide, the reference drug used. The extract also exhibited little or no side effects within the four weeks of oral administration (Ilic et al., 2010). Adefegha et al. (2017) reported the antiglycemic potential of essential oil from *A. melegueta* seed. The oil exhibited *in vitro* inhibition of α-amylase and α-glucosidase, which are responsible for the breakdown of carbohydrates into glucose. They proposed that the synergistic effect of eugenol, limonene, α-pinene, and β-pinene in this oil was responsible for the antiglycemic effect.

Table 1
Example of drugs used for managing type 2 diabetes.

Drugs	Mechanism	Side effect
Metformin (Glucophage)	Inhibits glucose production by the liver thereby making the body to be sensitive to insulin	Causes nausea and diarrhea
Sulfonylureas (glyburide, glipizide glimepiride)	Stimulates the pancreas to produce more insulin	Cause hypoglycemia and unnecessary weight gain
Meglitinides (prandin and starlix)	Stimulating the body to produce more insulin, faster effect	Cause hypoglycemia and weight gain
GLP-1 receptor agonists (exenatide, liraglutide and semaglutide)	Injectable drugs that lower blood glucose by slowing down digestion	Joint pain and high risk of pancratitis
SGLT2 inhibitor (canagliflozin, dapagliflozin and empagliflozin)	Blood glucose by preventing reabsorbtion of glucose by the kidney	Low blood pressure, urinary tract infection.
Insulin	Hormone that converts glucose to glycogen (storage form of glucose)	Can often lead to hypoglycemia (low blood sugar)

2.2. West African black pepper

West African black pepper or Ashanti pepper or Guinea pepper is scientifically known as *Piper guineense* (Schum & Thonn), it belongs to the Piperaceae family, it is an herbaceous plant with elliptically shaped leaves and is distributed throughout the West Africa regions, it is also common in Guinea and Uganda (Okpala and Ekechi, 2014). In Nigeria, it is called Iyere in Yoruba, Uziza in Igbo, and Poivrie in French. The fruit (berry) of *P. guineense*is used as a spice to add aroma, flavor, and hotness to soup (Owolabi et al., 2013). Various parts of the plants such as the roots, seeds, stem bark, and leaves are used in folk medicine. It is usually consumed by women in the southeastern part of Nigeria after childbirth to expel remains in the womb through uterine contraction and to enhance the flow of breast milk (Udoh et al., 1996). It is used as an aphrodisiac (Kpomah et al., 2012), hepatoprotective (Oyinloye et al., 2017), antioxidant, bronchitis, cough, stomachache (Owolabi et al., 2013), anticonvulsant, anticancer, antidiabetic (Khaliq et al., 2015), haematopoietic, antiulcer, rheumatism (Uhegbu et al., 2015), insecticidal (Ihemanma et al., 2014), antimicrobial (Mgbeahuruike et al., 2019). Alkaloids, flavonoids, amides, tannins, triterpenoids, polyphenols, cardiac glycosides, and saponins are the secondary metabolites found in *P. guineense* (Uhegbu et al., 2015; Ekoh et al., 2014). Essential oils of *P. guineense* fruit contains the following linalool, asaricin, β-caryophyllene, piperine, α-pinene, myrcene, 1,8-cineole, β-Ocimene, β-elemen, cedrene, elemol, elemicin, β-caryophyllene oxide, benzoic acid, sesquiterpene β-caryophyllene, bicyclogermacrene, humulene, monoterpenes β-pinene (Juliani et al., 2013; Owolabi et al., 2013). The constituent compounds obtained in *P. guineense* are dependent on the geographical location of where it is obtained. Ekoh et al. (2014) acknowledged the antihyperglycemic activity of 500 mg/kg of aqueous extract of *P. guineense* in alloxan-induced diabetic rats. Wodu et al. (2017) also reported antihyperglycaemic activity of methanolic extract of 100 mg/kg *P. guineense* in alloxan-induced diabetic female albino Wistar rats in a 14-day study. Their findings revealed that 50 and 100 mg/kg *P. guineense* normalize hyperglycemia in the rats better than 10 mg/kg of glibenclamide, which was the reference drug. Atal et al. (2012) isolated piperine, a major alkaloid found in the Piper genus; they reported that 20 mg/kg piperine restore normal blood glucose in alloxan-induced diabetic mice. Alkaloids have been reported to inhibit α-glucosidase and the transport of glucose to the epithelial cells in the intestine (Khaliq et al., 2015). Reports on toxicology and haematological evaluation by Uhegbu et al. (2015) in albino rats revealed that the plant has no toxic effects on the liver of the animals. They reported that it increased the haemoglobin content in the animal model; they proposed that the vitamins, minerals, and phytochemicals present in the plant were responsible for this haematopoeitic activity.

2.3. Ethiopian pepper

Ethiopian pepper is scientifically known as *Xylopia aethiopica* (Dunal), it belongs to the Annonaceae, and the species name aethiopica derived its name from Ethiopia, which is the origin of the tree, though it is now widely distributed in almost all parts of Western and Central Africa (Orwa et al., 2009). It is called Uda in Igbo and is commonly used in the southeastern part of Nigeria by women that are just put to bed to control bleeding (Johnkennedy et al., 2011). The fruit is popularly used as a spice in soup due to its aromatic pungent smell (Mohammed and Islam, 2017). It has been reported to possess antihelminthic (Ekeanyanwu and Etienajirhevwe, 2012), anti-rheumatism, anti-arthritis (Mohammed et al., 2015), antiproliferative, antioxidant (Adaramoye et al., 2017), hypolipidemic, antihypertensive, hepatoprotective (Adefegha et al., 2018), female fertility enhancement, antihemorrhoids (Yin et al., 2019), haematopoeitc (Johnkennedy et al., 2011), antimicrobial activities (Ogbonna et al., 2013). Various parts of the plants such as fresh and dried fruit, leaf, stem bark, root, and essential have been reported for their medicinal values (Ogbonna et al., 2013). Phytochemical analysis revealed the presence of alkaloids, flavonoids, glycosides, terpenoids, fats, and oil in *X. aethiopica* (Victor et al., 2013). Tegang et al. (2018) reported that the main compounds in the essential oil of *X. aethiopica* were β-pinene-pinene, α-phellandrene, Z-c-bisabolene and α-pinene, α-thujene, *cis*-β-ocimene, c-terpinene, oleanolic acid, kaurenoic, and xylopic acids. Papitha et al. (2018) reported the ability of ethanolic extract of *X. aethiopica* to normalize glucose concentration in streptozotocin-induced Sprague-Dawley male rats. They reported *X. aethiopica* competed favourably with metformin, the reference drug. Okpashi et al. (2014) reported the antidiabetic potential of 250 mg/kg of chloroform extract of *X. aethiopica* fruit. This study revealed that extracts did not only regulated blood glucose when compared to glibenclamide (control/standard drug) but also prevented hyperlipidemia, which is a complication that is characteristics of diabetes. They also reported that the extract was not toxic based on biochemical parameters investigated and that it displayed greater glucose regulating activity when combined with *Psidium guajava* leave extract. Ogbonnia et al. (2008) reported the hypoglycemic potential of *X. aethiopica* fruits and *Astonia congensis* mixture. They reported the safety of the acute administration of the mixture based on the biochemical parameters evaluated, however, their findings revealed that long-term use of the mixture could lead to kidney problems. Mohammed and Islam (2017) reported the ability of acetone fraction of *X. aethiopica* fruit in ameliorating oxidative stress in type 2 diabetic rats due to the high content of antioxidants in it. Ofusori et al. (2016) in their histological and immunohistochemical investigations reported that aqueous leaf extract of *X. aethiopica* aids recovery of β-cells of the pancreas and normalized glucose concentration in streptozotocin-induced diabetic rats. Gometi et al. (2014) reported the non-toxic effect of chloroform extract of *X. aethiopica* based on liver marker enzymes investigated. Mohammed et al. (2019) found that oleanolic acid, an active antidiabetic compound isolated from *X. aethiopica* fruit inhibited α-glycosidase and α-amylase, molecular docking was also carried out on this compound and enzymes to confirm its antidiabetic potential. Famuyiwa et al. (2018) isolated kaurenoic and xylopic acids from *X. aethiopica*, they reported that 10 mg/kg kaurenoic and 20 mg/kg xylopic acids exhibited hypoglycemic effect; their investigation revealed that 20 mg/kg kaurenoic was safe and exhibited better glucose-lowering activity than to 5 mg/kg glibenclamide (the reference drug).

2.4. African chili

Red pepper or African chili or Bird chili is scientifically known as *Capsicum frutescens*, it belongs to the Solanaceae family. Its fruit is smaller but more spicy/pungent than *Capsicum annum* and it is widely cultivated in Africa and all over the world (Anthony et al., 2013). The unripe fruit is green, but it is red or orange when ripe, while the seeds are yellow in colour. It is used as a spice for adding hotness or heat to the soup. The fruit can be consumed fresh, or it can be dried and processed into powder, paste, and chopped pepper (Liu et al., 2020). Phytochemical screening of *C. frutescens* indicated that it contained flavonoids, alkaloids, terpenoids, tannins, and saponins (Izah et al., 2019; Maya et al., 2019). The fruit contains the following compounds δ-elemene, α-humelene, γ-himachalene, β–bisabolene, homocapsaicin, capsaicin, dihydrocapsaicin, vanillyl-nonanamide. The oil contains capsaicin and vitamin E. Al-Samydai et al. (2019) reported the presence of capsaicin, dihydrocapsaicin, tridecanoic acid, phytol, kauran-16-ol, eugenol and 1, 2-benzenedicarboxylic acid, mono (2-ethylhexyl) ester in acetone fraction of ethanolic extract of *C. annuum* fruit. Capsaicin is colourless, odourless, hydrophobic, and crystalline compound (Al-Samydai et al., 2019). The degree of hotness of the fruit/seed is dependent on the concentration of capsaicinoids in it. *C. frutescens* have been reported to possess anti-inflammatory, anticancer (Al-Samydai et al., 2019), antimicrobial (Doğan et al., 2018), hypertension (Anthony et al., 2013), antioxidant, antidiabetic, antianalgesic (Izah et al., 2019), hypolipidemia and cardioprotective activity (Lim, 2012).

Watcharachaisoponsiri et al. (2016) reported that 5 mg/mL ethanolic extract of *C. frutescens* inhibited α-glucosidase and α-amylase, which are key enzymes that hydrolyse polysaccharide to glucose, consequently preventing overload of glucose in the blood. Anthony et al. (2013) reported that the potential of *C. frutescens* supplemented diet to normalize fasting glucose concentration, body weight, lipid profile, and other biochemical parameters in alloxan-induced diabetic rats. Dougnon and Gbeassor (Dougnon and Gbeassor, 2016) reported the hypoglycemic effect of powder *C. frutescens* in rabbits. Islam and Choi (Islam and Choi, 2008) found that 2% of *C. frutescens* increased insulin concentration in streptozotocin-induced Sprague Dawley diabetic rats with no toxic effect at high dosage. Kim et al. (2018) reported that the extract of *C. annum* seed decreases gluconeogenesis in the liver, while it increased the usage of glucose by muscles *in vitro*. Magied et al. (2014) reported hypoglycemic activity of *C. annum* in alloxan-induced diabetic rats, which were also subjected to a high-fat diet. Their investigation revealed that capsaicin was responsible for this activity.

2.5. African nutmeg

African nutmeg or Calabash nutmeg is scientifically known as *Monodora myristica*, it is a flowering plant that belongs to the Annonaceae family and grows in the wild in many African countries (Okonji et al., 2014). It is called Ariwo or Abo Lakoshe in Yoruba, Uhuru in Igbo (Ukachukwu et al., 2012). The seed is used as a spice due to its aromatic flavor. Phytochemical screening of *M. myristica* extracts revealed that they contain alkaloids, tannins, saponins, flavonoids, flavonol, steroids, terpenoids, phenol, and glycosides (Dougnon and Ito, 2020). Dongmo et al. (2019) reported that the essential oil of *M. myristica* contains α-phellandrene (61.5 ± 5.1%), germacradienol (7.9 ± 0.6%), and δ-cadinene (4.2 ± 1.1%). Other medicinal uses such as antibacterial, antioxidant, anti-inflammatory, antidiabetic (Ukachukwu et al., 2012), antihypertensive (Dougnon and Ito, 2020), antiprotozoal, hyperlipidemia, cytotoxic, antiarthritis (Nwankwo, 2018) have established in the literature. Okonji et al. (2014) reported the antidiabetic potential of ethanolic extract of *M. myristica* seed based on its ability to inhibit pancreatic α-amylase, which is a key enzyme, involved in converting starch and glycogen to glucose. The inhibition of this enzyme delays the digestion of carbohydrates thereby decreasing the release and absorption of glucose subsequently offering a good strategy for the regulation of blood glucose. They reported 96.58% inhibition of pancreatic α-amylase at 1000 μg/mL (IC_{50} value 408.17 ± 2.945 μg/mL); the study further revealed that this inhibition is dose-dependent. In addition, they proposed that this inhibition might be due to the presence of flavonoids in this plant. Ademosun and Oboh (2015) also reported the inhibitory activity of aqueous *M. myristica* seed on α-amylase and α-glucosidase.

2.6. Pepper elder

Pepper elder is also known as a "Shiny bush" or "Silver bush" is scientifically known as *Peperomia pellucida*,it is an angiosperm plant that belongs to the Piperaceae family. The leaves and stem are succulent and are used as a spice for preparing food due to their aromatic nature and their ability to stimulate appetite and aid digestion. The plant is a weed with a tiny seed that grows in the wild in almost all parts of the world. It is called Rinrin or Renren among the Yorubas, Southwest of Nigeria (Alves et al., 2019). Flavonoids, alkaloids, saponin, sterols, tannins, reducing sugars, carotenoids and triterpenes are the major secondary metabolites reported to be present in *P. pellucida* (Sheikh et al., 2013; Sultana et al., 2016; Waty et al., 2017). Its essential oil contains predominantly monoterpenoid alcohols, sesquiterpenes, aromatic and aliphatic aldehydes (Okoh et al., 2017). Dillapiole, dill-apiol, pellucidatin, peperochromen-A, peperomin A, phenylpropanoids, myristicin, germacrene, carotol, pygmaein, piole, *trans*-3-pinanone, methylethylidenepropane dinitrile, linalool, limonene, apiole, phytol, β-caryophyllene, and linalyl acetate (Alves et al., 2019; Okoh et al., 2017). Antihemorrhagic wound dressing, antibacterial (Sheikh et al., 2013), anti-inflammatory, antioxidant (Hamzah et al., 2012), cytotoxic, antisickling, antihypertensive, immunostimulatory (Minh, 2019). Sheikh et al. (2013) reported the hypoglycemic effect of ethanolic extract of *P. pellucida* in alloxan-induced diabetic mice. Their investigation revealed that 250 mg/kg and 500 mg/kg significantly lowered glucose levels in diabetic mice in a dose-dependent manner when compared to metformin (the reference drug). The study revealed that the extract regenerated β-cell of the pancreas, thereby restoring insulin secretion and subsequently control of diabetics due to the presence of alkaloid, saponin, and flavonoid in the extract. They also found that the extract normalizes elevated lipid concentration in the blood. Sultana et al. (2016) also reported similar observations where the antidiabetic and antihyperlipidemic potential of various solvent partition extract of *P. pellucida* in alloxan-induced diabetic mice. They reported that chloroform extract gave the highest antidiabetic activity among the various solvents investigated. Furthermore, the safety of the extract at higher doses (500 mg/kg) was also documented. In another study carried out by Hamzah et al. (2012), the antidiabetic potential of *P. pellucida* supplemented diet in alloxan-induced diabetic rats was also reported. They revealed that 10% and 20% w/w supplement showed higher activity than the standard drug (glibenclamide 600 μg/kg). They proposed that the *P. pellucida* might have insulin-mimetic activity by closing Na^{+}/K^{+}-ATP channels and depolarizing membrane, consequently stimulating the influx of Ca^{2+}. They also reported that the supplement ameliorated diabetes-induced oxidative stress and dyslipidemia. Waty et al. (2017) reported the safety of the methanolic extract of *P. pellucida* following acute administration in rats even at 4000 mg/kg (LD_{50} value is greater than 4000 mg/kg). Biochemical and histopathology investigations revealed that there was no significant difference between the liver and kidney of the control and that of the male and female mice given 4000 mg/kg of the extract.

2.7. African basil

African basil or scent leaf is scientifically known as *Ocimum gratissimum*, it belongs to the Labiaceae family. It is an herbaceous plant that is widely distributed in the savanna and tropical rainforest of West Africa (Oguanobi et al., 2012). In Nigeria, it is called "Efinrin" in Yoruba, "Nchanwu or Nehonwu" in Igbo, and "Daidoya or ai daya ta guda" in Hausa. It is commonly used as a spice for cooking due to it has a minty aromatic flavour (Okoduwa et al., 2017). Phytochemical screening revealed that *O. gratissimum* leaf contained alkaloids, glycosides, flavonoids, steroid glucosides, polyphenols, saponin, steroids, tannins, and terpenoids (Bihari et al., 2011). L-chicoric acid, eugenyl-β-d-glucopyranoside, linolenic acid, l-caftaric acid and vicenin-2 are the compounds responsible for the antidiabetic potential of *O. gratissimum* (Casanova et al., 2014). It has been reported to possess antimicrobial, antidiabetic, hypolipidemic, hepatoprotective, antidiarrhoeal, antiinflammatory, antihypertensive, antioxidant, and immunostimulatory potential (Makinwa et al., 2013). Oguanobi et al. (2012) reported the antidiabetic potential of aqueous extract of *O. gratissimum* in streptozotocin-induced type 2 diabetic in neonatal Wistar rats in a dose-dependent manner. Okoduwa et al. (2017) reported the antidiabetic potential of *O. gratissimum* leaf extract in rats using fortified diet-fed streptozotocin-model of inducing type 2 diabetes. They used n-hexane, chloroform, ethyl acetate, n-butanol, and water to fractionate the extract, their studies revealed that the n-butanol fraction had the highest antidiabetic activity. This study revealed that 250 mg/kg of n-butanol fraction *O. gratissimum* exhibited a higher hypoglycemic effect than 500 mg/kg metformin (the reference drug). Their acute toxicity study revealed that the extract is safe at 250 mg/kg, which was the minimum effective dosage; mortality and signs of toxicity were not experienced even at an extremely high dosage of 5000 mg/kg mortality. Their findings also revealed the hypolipidemia effect and ability of the plant extract to regenerate pancreatic β-cells. Mohammed et al. (2007) also reported the higher antidiabetic potential of 500 mg/kg aqueous leaves extract of *O. gratissimum* on blood glucose levels of streptozocin-induced diabetic Wistar rats than insulin (reference drug/hormone). Bihari et al. (2011) also reported the antidiabetic activity of *O. gratissimum* and other species in an alloxan-induced diabetic animal model. Their study showed that 250 mg/kg methanolic extract of *O. gratissimum* exhibited hypoglycemic effect that is comparable to glibenclamide (the standard drug). Casanova et al. (2014) reported that 3 mg/kg of chicoric acid, a compound isolated from *O. gratissimum* reduced hyperglycemia in diabetic mice by 50% in just 2 h of treatment by increasing insulin secretion by the β-cells of the pancreas by inhibiting protein tyrosine phosphatase 1B, an enzyme that negatively regulates insulin sensitivity.

2.8. African locust beans

African locust beans are scientifically known as *Parkia biglobosa* and it is a legume, which is a member of the Mimosaceae family (Odetola et al., 2006). In Nigeria, it is commonly known as "iru" in Yoruba, "ogiri" in Igbo, and "dadawa" in Hausa. Its fermented seed is usually used as a local condiment/seasoning commonly added to different kinds of soups to improve their taste (Sule et al., 2015). *P. biglobosa* is widely distributed in several African countries, especially in the savanna where it is being cultivated as food/source of nutrients, medicine, shade/shelter, a high source of income, and for improving soil fertility (Teklehaimanot, 2004). Its pulp is sweet and edible, while the seed (beans) is commonly processed as a seasoning. It is rich in protein, carbohydrates, lipids, fiber, and essential minerals (Sule et al., 2015). Traditionally, it is used for improving eyesight, healing wound, treating leprosy (Odetola et al., 2006), antidiabetes (Fred-Jaiyesimi and Abo, 2009), antihypertensive, antidiarrhoea (Ajaiyeoba, 2002), anti-snake venom (Asuzu and Harvey, 2003), analgesic (Kokou et al., 2013). Interestingly, their pharmacological uses such as antimicrobial (Ajaiyeoba, 2002), antihypertensive, antidiabetes, and antihyperlipidemia (Odetola et al., 2006) have been documented in the literature. The phytochemical screening of extracts of *P. biglobosa* revealed that it contains tannins, cardiac glycosides, flavonoids, polyphenols, saponin, steroids, and alkaloids (Ajaiyeoba 2002; Fred-Jaiyesimi and Abo 2009; Sunmonu and Lewu, 2019). Cis-ferulates, lupeol, gallocatechin, epi-catechin, and 3-O-gallat are the major compounds isolated from *P. biglobosa* tree bark (Tringali et al., 2000). Sule et al. (2015) reported the hypoglycemic potential of *P. biglobosa* seed supplemented diet in rats. Their investigation revealed that 40% locust bean seed significantly lowers ($p < 0.05$) blood glucose level within 7 days than the control group, while it took 20% locust bean seed supplemented diet between 14 and 21 days to exert the same effect in rats. Odetola et al. (2006) reported that 6 g/kg of aqueous and methanolic extract of *P. biglobosa* ameliorated alloxan-induced diabetes in rats. Their investigation revealed *P. biglobosa* competed favourably with the standard drug (glibenclamide) in normalizing blood sugar. They also reported that aqueous extract of *P. biglobosa* performed better than the methanolic extract and the standard drug in restoring weight loss in the diabetic rat. Their investigation revealed that the weight loss restoration and the lipid profile (high HDL and low LDL) of the rats treated with aqueous extract of *P. biglobosa* were like those of the normal control. Fred-Jaiyesimi and Abo (2009) reported the hypoglycemic potential of chloroform and hexane fractions of methanolic extract of *P. biglobosa* seed in glucose-loaded and alloxan-induced diabetic rats. Their investigation revealed that the chloroform fraction (1 g/kg) demonstrated significant antidiabetic potential than 5 mg/kg of glibenclamide (the standard drug). Ogunyinka et al. (2017) reported that *P. biglobosa* seed protein isolates ameliorated hepatic damage and oxidative stress in streptozotocin-diabetic male rats. Table 2 and Fig. 3 show some of the compounds isolated from spices with antidiabetic potentials.

Table 2
Major compounds isolated from spices with antidiabetic activity.

Compounds	Mechanism	References
Gingerol	Enhances glucose uptake, transport and translocation	(Li et al., 2012)
	Regulates enzymes by decreasing gluconeogenesis and glycogenolysis; while increasing glycogenesis	(Son et al., 2015)
Acarbose	Inhibits α-amylase and α-glucosidase	(Kumar et al., 2016)
Shogaols	Stimulates glucose utilization	(Wei et al., 2017)
	Inhibition of advanced glycation end-product	(Nonaka et al., 2019)
Eugenol	Attenuates key enzymes of glucose metabolism	(Srinivasan et al., 2014)
	Ameliorates insulin resistance, increases insulin production	(Al-Trad et al., 2019)
	Inhibits α-glucosidase and prevents formation of advanced glycation end-product	(Singh et al., 2016)
Oleanolic acid	Improves insulin response by preserving and enhancing functionality of β-cells; activation of the transcription factor Nrf2	(Castellano et al., 2013)
	Promote insulin signal transduction and inhibit insulin resistance	(Wang et al., 2011)
	Inhibits glucose production and stimulates glucose utilization	(Zhang et al., 2014)
Linalool	Enhances glucose uptake	(More et al., 2014)
Piperine	Inhibits α-glucosidase	(Kumar et al., 2013)
	PPAR-γ receptor agonist	(Kharbanda et al., 2016)
Capsaicin	Inhibits α-glucosidase, α-amylase, and tyrosinase	(Nanok and Sansenya, 2020)
Phenylpropanoids	Stimulates insulin secretion	(Krishnan et al., 2014)
Limolene	Regulates enzymes involved in carbohydrate metabolism, stimulates insulin secretion and prevents glycation of haemoglobin	(Murali and Saravanan, 2012; Habtemariam, 2018)
Phytol	activation of nuclear receptors and heterodimerization of RXR with PPARγ	(Elmazar et al., 2013)
β-caryophyllene	insulinotropic and β cell regeneration	(Basha and Sankaranarayanan, 2016; Kumawat and Kaur, 2020)
L-chicoric acid	Enhances insulin release and glucose uptake	(Tousch et al., 2008)
Vicenin-2	Inhibitsα-glucosidase, protein tyrosine phosphatase 1B (PTP1B), aldose reductase (RLAR), and prevents advanced glycation end products (AGE)	(Islam et al., 2014)

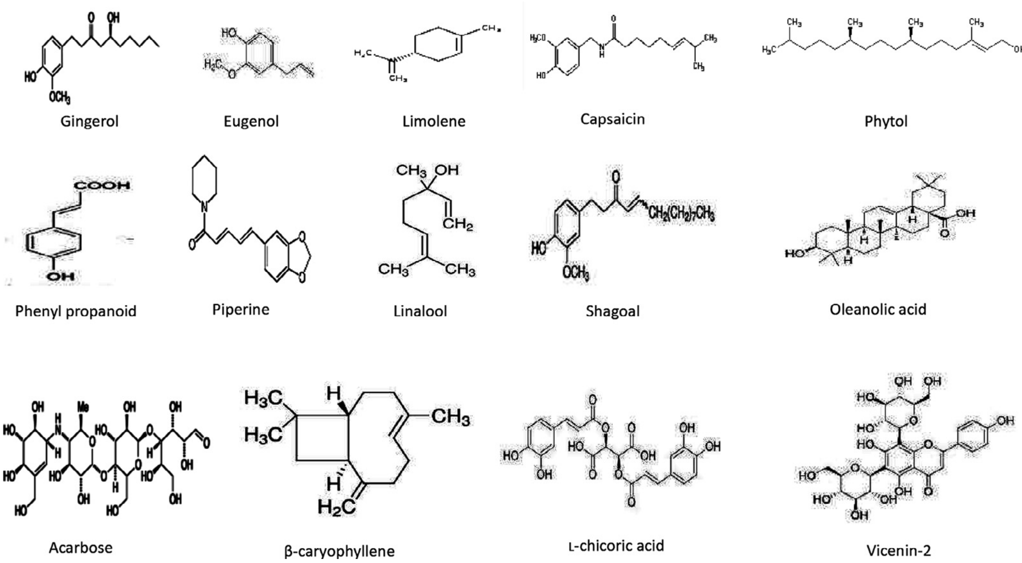

Fig. 3. Chemical structure of compounds isolated from spices with antidiabetic potential.

3. Conclusions

Health is wealth, early management of diabetes will help to arrest complications associated with it and prevent various organs and tissues from unnecessary stress and damage. This study showed that numerous spices with antidiabetic potential abound on the continent of Africa. Several studies have shown that these spices demonstrated higher antidiabetic activity than the conventionally used antidiabetic drugs such as metformin and glibenclamide. Some bioactive compounds found in these spices have been developed into drugs in advanced countries. Several advantages are associated with the use of spices as an alternative antidiabetic agent. However, most of the studies carried out on the antidiabetic activity of spices have been based on *in vitro* and animal models; hence, there is a need for a clinical trial in human subjects. Furthermore, it will be interesting to study the effect of combining two or more of these spices in a polyherbal formulation to explore them for better efficacy and safety because each spice possesses different mechanisms of regulating blood sugar.

Author contribution statement

O.O.O., K.O. and R.I.A. conceptualized the review idea; K.O. and R.I.A. wrote the first draft of the manuscript; O.O.O. and K.O. proofread the manuscript; all authors approved the manuscript for submission.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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