

## Review

### PHYTOCHEMICAL CONSTITUENTS AND HERBARIUM SPECIMENS OF COMMONLY USED ANTIDIABETIC MEDICINAL PLANTS FOUND IN JOS NORTH, PLATEAU STATE – A CRITICAL REVIEW

EGHAREVBA, Henry Omoregie<sup>1</sup>; \*IBRAHIM, Jemilat Aliyu<sup>1</sup>; ABRAHAM, Chika Harriet<sup>2</sup>; KUNLE, Oluyemisi Folashade<sup>1</sup>

<sup>1</sup>Department of Medicinal Plant Research and Traditional Medicine, National Institute for Pharmaceutical Research and Development (NIPRD), PMB 21, Abuja, Nigeria

<sup>2</sup>Department of Pharmacognosy, Faculty of Pharmaceutical Sciences, University of Jos, Jos, Plateau State, Nigeria

## ABSTRACT

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\*Corresponding Author's Email:  
sadiqoyene@yahoo.com

Ten medicinal plants commonly used for the management of *Diabetes mellitus* in Jos North, Plateau State was identified through a preliminary survey and herbarium specimens prepared for reference and to provide information that may be useful for inclusion in the West African and Nigerian Pharmacopoeia. Most of the plants used by the herbal medicine practitioners were readily available and the herbal medicines were prepared mostly by decoction and administered orally. Reviews of related literatures revealed that some of these plants have been reported to contain antidiabetic molecules like quercetin and related flavonoids, tannin, triterpenoid, sterols, alkaloids, glycosides and saponins which might be responsible for their antidiabetic properties. These plants may be good sources of new antidiabetic drugs.

Key words: Diabetes mellitus, medicinal plants, phytochemicals, flavonoids, quercetin, Nigeria

## INTRODUCTION

### Medicinal plants and healing

The practice of healing with medicinal plants is as old as mankind itself and man's search for drugs from nature dates back thousands of years. There is ample evidence from various sources - written documents, preserved monuments and even original plant

medicines. A turning point in the knowledge and use of medicinal plants was reached in the early 19<sup>th</sup> century with the discovery and isolation of alkaloids from poppy (1806), ipecacuanha (1817), strychnos (1817), pomegranate (1878) and other plants and then the isolation of glycosides. This marked the beginning of scientific pharmacy. Chemical methods were improved upon whereby other active substances from medicinal plants were also discovered (Jancic, 2002).

A threat of elimination of medicinal plants from therapy was experienced in the late 19<sup>th</sup> and early 20<sup>th</sup> centuries. Many authors wrote that drugs obtained from medicinal plants had many short-comings due to the destructive action of enzymes, which caused fundamental changes during the process of drying suggesting that medicinal plants healing action depended on the mode of drying. In the 19<sup>th</sup> century, therapeutic alkaloids and glycosides isolated in pure form were increasingly supplanting the plant from which they had been isolated. Nevertheless, it was soon ascertained that although the action of pure alkaloids was faster, the action of alkaloid containing drugs was fuller and longer lasting. In early 20<sup>th</sup> century, stabilization methods for fresh medicinal plants were proposed, especially the ones with labile medicinal components. Moreover, much effort was invested in the study of the conditions of manufacturing and cultivation of medicinal plants (Dervendzi *et al.*, 1992).

Today a higher number of unofficial herbal drugs are being used. Their use is grounded on the experiences of traditional medicine or on the new scientific research and experimental results (Blumental *et al.*, 1998).

### Safety and Efficacy of Medicinal Plants

Recent approach to the official approval of the public use of medicinal plants requires that they should be safe. Although plants used for up to 30 years without reported case of adversity are usually termed safe, regulatory requirements still ensures that the minimum safety test are done before approval for public use. The fact that these plants have been used for generations shows that most of them could be considered safe, however, since the safety limits or dosage were almost never determined by traditional healers, it is important that safety tests are conducted on all medicinal plants in use (Sofowora, 2008).

Advances in research have established the fact that the ethnomedicinal use of some plants has some scientific backing. Scientists have been able to relate observed bioactivities of these plants to the presence of known primary and secondary metabolites in such plants. Some of these metabolites functions independently or in synergy to exert the pharmacological effect (Evans, 2002). For instance *Zanthoxylum tingoassuiba* and *Z. hyemale* essential oils have also been reported for their antimicrobial activity (Detoni *et al.*, 2009; Simionatto *et al.*, 2005) and *Z. lepreurii* and *Z. xanthoxyloides* for

their antioxidant activity (Dongmo *et al.*, 2008). The antimalarial, artemisinin, was isolated from *Artemisia annua*, and the anticancer alkaloid drugs, vinblastine and vincristine, were isolated from *Catharanthus roseus* (Evans, 2002). Most drug discovery researches are now based on structures of molecules found in plants and other natural sources. There are hundreds of medicinal plants that can be used for management of different diseases. *Thymus vulgaris* has been reported to slow down ageing, *Salvia officinalis* has been reported as an excellent antiseptic for treating mouth ulcers and sore throats, while *Matricaria recutita* has been reported as a safe treatment for stomach upsets in children (Abdul, 1990). *Myristica fragans* and its oils are used as stimulants, carminative, flavouring agents, and also used externally in chronic rheumatism (Abdul, 1990).

### Medicinal plants and diabetes mellitus

Diabetes mellitus is a diseases condition characterized by high levels of glucose in the blood that result from defects in insulin secretion, or action, or both. Under normal condition blood glucose levels are properly regulated by insulin, a hormone produced by the pancreas. When the blood glucose elevates after a meal, insulin is released from the pancreas to normalize the glucose level. A patient with diabetes will have hyperglycemia due to the absence or insufficient production of insulin. There both Type 1 (insulin dependent) and Type 2 (non-insulin dependent). Diabetes may present an acute or a chronic medical condition which though can be controlled but last a lifetime and medications are usually very costly (Gupta and De, 2012).

Currently many countries face large increase in the number of people suffering from diabetes. The World Health Organization estimated that about 30 million people suffered from diabetes in 1985 and the number increased to more than 171 million in 2000. It is estimated that the number will increase to over 366 million by 2030 and this large increase will occur in developing countries especially among people aged between 45 and 64 years (Wild *et al.*, 2004). Based on this statistics, there is need for more work to be done on plants used in the management of *Diabetes mellitus* to supplement orthodox drugs.

There are advantages in the use of medicinal plants. They are often cheaper than orthodox medicines and easily accessible. They can be bought without a prescription, acceptable, natural, etc., hence their

development for treatment of *Diabetes mellitus* should be encouraged as many cannot afford orthodox drugs. Some of these antidiabetic plants and in fact a whole lots of others are endangered due to their uncontrolled harvesting and other anthropogenic activities of man. The time-dependent transformation of the genetic and chemical constituents and the variation due to geographic location of their natural habitat are also of major concern. Hence there is a great need to preserves parts of these plants in herbariums.

There are many plants and plant extracts which possess marked hypoglycemic activity. From ancient times such materials have been used for the treatment of *Diabetes mellitus* and still find extensive use in traditional medicine world-wide (Evans, 2002; Gupta and De, 2012). The traditional use of various *Dioscorea* species in oriental medicine appears justified by the demonstration of the hypoglycemic activity of their polysaccharides in animal tests. In Mexican traditional medicine, one of the most important antidiabetic remedies is a root decoction of *Psacalium decompositum*, Compositae. Plant mucilages with similar pharmacological properties include those from some members of the Malvaceae (*Abelmoschus* spp., *Althae* spp.) and Plantago (Plantaginaceae) (Evans, 2002). This work was aimed at documenting and reviewing some medicinal plants commonly used by traditional medicine practitioners (TMPs) in Jos, Plateau State, Nigeria for the management of diabetes mellitus, and developing a herbarium specimen for easy of their identification and reference.

## MATERIALS/METHODS

The materials include newspapers, cardboard papers, cotton wool, cello tape, herbarium press with strap, digital camera, polythene bags, secateurs and methylated spirit. These materials were used for the preparation of the herbarium voucher specimen. Review was based on data from online internet search and other library materials.

### Plant Collection and voucher specimen preparation

A preliminary survey was conducted by visiting some herbal medicine practitioners within Jos North Local Government Area of Plateau State and collecting information on herbal preparations used for the management of *Diabetes mellitus*. Information on the plants, plant parts, methods of preparation, dosage and

duration of use, as well as possible areas where the plants could be collected were also documented.

Herbarium specimen of the plants containing leaves, seeds, fruits, flowers and stem or branched wherever applicable were collected between the months of May-July 2013 from Jos North Local Government Area of Plateau State and stored in polythene bags. The collected specimens were later arranged in the folder between few layers of newspaper. Plant identification, authentication and voucher number allocation were done by at the School of Forestry, Jos. Then the herbarium specimen was prepared and kept in the herbarium section of the Department of Pharmacognosy, University of Jos.

## RESULT AND DISCUSSION

A total of ten plants were collected from their various natural habitats (Table 1). The plant parts collected were mostly leaves, although some had fruits and flowers while some had none. These plants were preserved in form of herbarium specimens and allocated voucher numbers. Table 2 shows the plant parts used, the method of preparation and the duration of use.

## DISCUSSION

### *Bridelia ferruginea*

The antidiabetic activity of *B. ferruginea* has been documented by several researchers. The presence of some well-known bioactive molecules in some *Bridelia* species, for example, galocatechin-(4'-O-7)-epigallocatechin, quercetin, myricetin glycosides, bridelone, bridelonine, isoflavone which may be responsible for the observed activity may justify the uses of these species as remedy for many disease conditions such as antiamebic, antianemic, antibacterial, anticonvulsant, antidiarrhoeal, antihelmintic, anti-inflammatory, antimalarial, antinociceptive, antiviral, anti-diabetic, etc., in African and Asian traditional medicines (Ngueyem *et al.*, 2009). The Hypoglycemic effects of the water and methanol extracts of the *Bridelia ferruginea* leaf have been reported in alloxan-induced diabetic rats (Addae-Mensah and Achenbach, 1985; Onunkwo *et al.*, 1996).

**Table 1: Plant Specimens and Their Voucher Numbers**

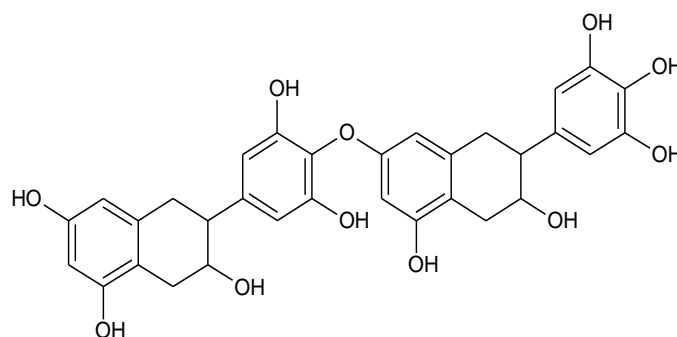
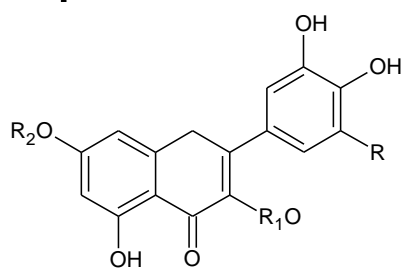
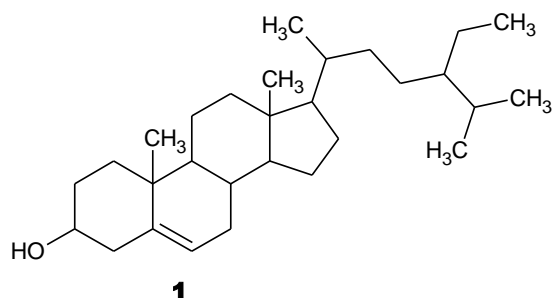
Scientific names	Family	Voucher numbers
<i>Bridelia ferruginea</i>	Phyllanthaceae	FHJ023
<i>Khaya senegalensis</i>	Meliaceae	FHJ024
<i>Loranthus bengwensis</i>	Loranthaceae	FHJ028
<i>Momordica charantia</i>	Cucurbitaceae	FHJ025
<i>Moringa oleifera</i>	Moringaceae	FHJ030
<i>Nauclea latifolia</i>	Rubiaceae	FHJ029
<i>Ocimum gratissimum</i>	Lamiaceae	FHJ026
<i>Psidium guajava</i>	Myrtaceae	FHJ031
<i>Terminalia catappa</i>	Combretaceae	FHJ027
<i>Vernonia amygdalina</i>	Asteraceae	FHJ032

**Table 2: Plant Parts, Method of Preparation and Duration of Use**

Name of plant	Parts used	Method of preparation	Duration of use
<i>Bridelia ferruginea</i>	Leaves	The leaves are pounded and boiled with water or the leaves are boiled, filtered and then the extract is used.	The extract is taken orally, three times a day (morning, afternoon and evening) for one week.
<i>Khaya senegalensis</i>	Leaves and wood	The leaves are pounded and boiled with red potash and alum after which the preparation is filtered. The wood is boiled with water and the extract is taken.	The extract is taken orally, three times a day (morning, afternoon and evening) for six days.
<i>Loranthus bengwensis</i>	Leaves	The leaves are dried under shade and powdered. The powder is used as tea whenever the need arises.	The tea is taken orally, three times a day (morning, afternoon and evening) for three months.
<i>Momordica charantia</i>	Leaves and Stems.	The leaves and stem are pounded, boiled and filtered.	The extract is taken orally, three times a day (morning, afternoon and evening) for three days.
<i>Moringa oleifera</i>	Leaves	The leaves are boiled with <i>Cassia occidentale</i> leaves, filtered and then the extract is used.	The extract is taken orally three times a day for three days.
<i>Nauclea latifolia</i>	Leaves, ripe fruit and roots.	The roots, leaves and ripe fruit are pounded, boiled and filtered. The extract is used.	The extract is taken orally three times a day (morning, afternoon and evening) for three days.
<i>Ocimum gratissimum</i>	Leaves	The leaves are boiled, filtered and the extract is used.	The extract is taken three times a day for three days.
<i>Psidium guajava</i>	Leaves	The leaves are dried under shade and then powdered.	The powder is used as tea (cold water or hot water can be used for the tea preparation) in the morning and evening daily for three days.

<i>Terminalia catappa</i>	Leaves, stem	The leaves and stem are pounded, boiled and filtered.	The extract is taken three times a day for three days.
<i>Vernonia amygdalina</i>	Leaves	The leaves are boiled with <i>Carica papaya</i> leaves and the preparation is filtered.	The extract is taken orally, three times a day (morning, afternoon and evening) for one week.

The Hypoglycemic effects of the water and methanol extracts of the *Bridelia ferruginea* leaf have been reported in alloxan-induced diabetic rats (Addae-Mensah and Achenbach, 1985; Onunkwo *et al.*, 1996). Addae-Mensah and Achenbach (1985) demonstrated the hypoglycemic activity of  $\beta$ -sitosterol (**1**), quercetin (**2**), quercetin-3-glycoside (**3**) and epigallocatechin (**4**) (Figure 11) isolated from the plant. Onunkwo *et al.* (1996) also showed that the quercetin in the plant was partly responsible for the hypoglycemic activity. Sokeng *et al.* (2005) proposed an action mechanism similar to glibenclamide or sulfonylurea drugs which stimulate the production of insulin from the Islet cells for the blood glucose level lowering activity of the plant extract in type 2 diabetic rats. Other compounds that have been reported from the plant include 3',4',4,5,7-pentahydroxyflavon (luteoforol), galocatechin-(4'-O-7)-epigallocatechin, quercetin-3-neohesperidoside, myricetin-3-glucoside, myricetin-3-rhamnoside, 5'-demethoxy- $\beta$ -peltatin-5-O- $\beta$ -D-glucopyranoside and  $\beta$ -peltatin-5-O- $\beta$ -D-glucopyranoside (Ngueyem *et al.*, 2009). In addition to quercetin, the other flavonoids may play synergistic roles in the antidiabetic property.



### *Khaya senegalensis*

The plant extracts of *K. senegalensis* have been reported to exhibit anti-diabetic effects (Etuk and Mohammed, 2009) as well as anti-bacterial (Koné *et al.*, 2004), anti-tumor, antioxidant (Androulakis *et al.*, 2006), and anti-plasmodial activities (El-Tahir *et al.*, 1998). Extract from the stem bark of *Khaya senegalensis* has been reported to contain alkaloids, saponins, flavonoids, tannins and limonoids (Khalid, 2012). The stem bark extract of containing cardiac glycosides, alkaloids, saponins, flavonoids and tannins had been shown to exhibit significant ( $P < 0.05$ )  $\alpha$ -glucosidase inhibitory effect in a concentration dependent manner (Andrew *et al.*, 2013). The observed pharmacological effect was related to the presence of some of these secondary metabolites. For instance, tannin is known to inhibit  $\alpha$ -glucosidase and insulin degradation as well as improve glucose utilization (Peungvicha *et al.*, 1998; Mohamadin *et al.*, 2003). This is in addition to the fact that it has antioxidative activity minimizing oxidative stress which is one of the key factors in tissue damage in diabetes mellitus. Thus antioxidants like tannins may protect beta cells and increase insulin secretion (Feillet-Coudray *et al.*, 1999). Some plant saponins have been reported to exhibit glucagon decreasing effect and also stimulate the release of insulin from pancreas which may enhance

blood glucose utilization, while flavonoids like quercetin has been established to possess antidiabetic activity (Norberg *et al.*, 2004). Compounds reported from the plants include a tetranortriterpenoids of the mexicanolide group, 2,6-dihydroxyfissinolide, fissinolide and methyl 3 $\beta$ -acetoxy-6-hydroxy-1-oxomeliac-14-enoate. These compounds were reported to have antiplasmodium activity (Khalid, 2012), and some antimalarial indoloquinoline alkaloids have been reported to exhibit antidiabetic properties (Addae-Mensah and Osei-Safo, 2012).

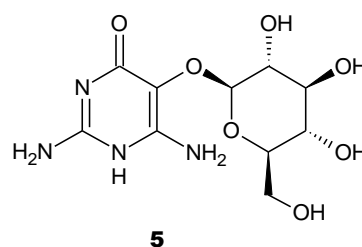
### *Loranthus bengwensis*

Aqueous extract of the leaf has been reported to exhibit hypoglycemic activity in normal rabbit (Osadolor and Ojewe, 2014). *Loranthus bengwensis* has been found to contain quercetin, a flavonoid that can stimulate increased secretion of insulin from the beta cells of pancreas in animal model and in clonal pancreatic beta cells in culture (Bayazit, 2004). Lectins, polypeptides, polysaccharides, saponins tannins, triterpenes, viscotoxin and a number of phenolic compounds (e.g. digallic acid, o-coumaric acid) found in their free states or as glycosides are among compounds reported from the plant (Duong *et al.*, 2003). Lectins are carbohydrate-binding protein which are highly specific for sugar moiety and has been found to possess insulin-like activity due to its affinity to the insulin receptors. This compound lowers blood glucose concentrations by acting on peripheral tissues and suppressing appetite (Khan and Singh, 1996; Ahmad *et al.*, 2012)

### *Momordica charantia*

A study reported by McWhorter (2001), attributed the hypoglycemic activity of *M. charantia* to vicine (5), a pyrimidine nucleoside polypeptide-p and charantin (a 1:1 mixture of  $\beta$ -sitosteryl glucoside and 5,25-stigmasteryl glucoside that influence glucose uptake, glycogen synthesis in muscle and liver and suppresses glucose synthesis). The plant has also been reported to contain lectin which has been reported to mimic insulin (Ahmad *et al.*, 2012). Polypeptide-K and oil isolated from the seed were found to inhibit  $\alpha$ -glucosidase and  $\alpha$ -amylase invitro (Ahmad *et al.*, 2012). Polypeptide-p was previously isolated by Kanna *et al.* (1981) from the seeds by acid ethanol extraction, and had been found to decrease blood glucose in Streptozotocin-induced diabetic rats and increased glycolytic enzyme activity. Polypeptide-p was also shown to have hypoglycemic

effects in juvenile and maturity-onset diabetic patients (Kanna *et al.*, 1981; Virdi *et al.*, 2003; Kanna, 2004). However, polypeptide-K was said to have better glucose lowering activity than polypeptide-p (Ahmad *et al.*, 2012). Other compounds reported from the plant include momordicin I & momordicin II, cucurbitacin B, Glycosides (momordin, charantin, charantosides, goyaglycosides), terpenoid compounds (momordicinin, momordicilin, momordol), cytotoxic (ribosome inactivating) protein such as momorcharin. 3 $\beta$ ,25-dihydroxy-7 $\beta$ -methoxycucurbita-5,23(*E*)-diene; 3 $\beta$ -hydroxy-7 $\beta$ ,25-dimethoxycucurbita-5,23(*E*)-diene; 3-*O*- $\beta$ -D-allopyranosyl-7 $\beta$ ,25-dihydroxycucurbita-5,23(*E*)-dien-19-al; 5 $\beta$ ,19-epoxy-19-methoxycucurbita-6,23-diene-3 $\beta$ ,25-diol and 5 $\beta$ ,19-epoxy-19,25-dimethoxycucurbita-6,23-diene-3 $\beta$ -ol; 3 $\beta$ ,7 $\beta$ ,25-trihydroxycucurbita-5,23(*E*)-dien,19-al; 5 $\beta$ ,19-epoxycucurbita-6,23(*E*)-diene-3 $\beta$ ,19,25-triol; 5 $\beta$ ,19-epoxy-19-methoxycucurbita-6,23(*E*)-diene-3 $\beta$ ,25-diol; momordicoside L and *p*-methoxybenzoic acid have also been isolated. Sitosterol and stigmastadienol, which are the aglycones of charantin have also been reported (Harinantenaina *et al.*, 2006). Tan *et al.* (2008), isolated a number of related triterpenoids among which were 3-*O*- $\beta$ -D-allopyranosyl-5 $\beta$ ,19-epoxycucurbita-6-ene-23(*R*),24(*S*),25-triol (karaviloside XI); 3-*O*- $\beta$ -D-glucopyranosyl-5 $\beta$ ,19-epoxycucurbita-6-ene-23(*R*),24(*S*),25-triol (Momordicoside Q), etc., while Tabata *et al.* (2012) reported kuguaglycoside C. Some isolated cucurbitane triterpenoids had exhibited antidiabetic properties (Harinantenaina *et al.*, 2006; Gupta and De, 2012).

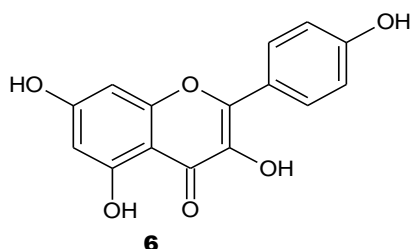


### *Moringa oleifera*

Phytochemical investigations of *M. oleifera* have revealed the presence of 4-(4'-*O*-acetyl- $\alpha$ -L-rhamnopyranosyloxy) benzyl isothiocyanate, 4-( $\alpha$ -L-rhamnopyranosyloxy) benzyl isothiocyanate, niazimicin, pterygospermin, benzyl isothiocyanate, and 4-( $\alpha$ -L-rhamnopyranosyloxy) benzyl glucosinolates (Fahey, 2005). Gupta *et al.* (2012) isolated two

phytoconstituents, quercetin and kaempferol (**6**), from the methanol extract of dried pods of *Moringa oleifera*. The two flavonoids were found to induce a significant reduction in serum glucose and increased serum insulin and protein levels (Gupta *et al.*, 2012). Tende *et al.*, (2011) also reported the presence of flavonoids, tannin, anthraquinone, cardiac glycosides alkaloids, triterpenoids, saponins and reducing sugars in the leaf of *M. oleifera*. Some terpenoids, phytosterols, glycosides, flavonoids and tannins have been reported to exhibit antidiabetic properties (Tende *et al.*, 2011; Ahmad *et al.*, 2012).

Phytochemical analyses have shown that its leaves are particularly rich in potassium, calcium, phosphorous, iron, vitamins A and D, essential amino acids, as well as such known antioxidants such as  $\beta$ -carotene, vitamin C, and flavonoids (Mbikay, 2012). Some other compounds reported from the plants include niazirin, niazirinin, anthocyanins, proanthocyanidin, kaempferol-3-O-(6'-malonyl-glucoside), 4-hydroxymellein,  $\beta$ -sitosterone, octacosanic acid,  $\beta$ -sitosterol, 3-caffeoylquinic and 5-caffeoylquinic acid etc. (Surbhi *et al.*, 2014).



### *Nauclea latifolia*

The use of the plant as antidiabetic agent in ethnomedicine and the antidiabetic activity of the plant extract have been reported severally (Gidado *et al.*, 2005; Antia and Okokon, 2014). The plant is known to contain alkaloids, flavonoids, tannins, steroids, glycosides, saponins, and vitamins A, C, and E, (Karou *et al.*, 2011; Egbung *et al.*, 2013). Alkaloids such as naucleafoline, nauclechine, naufoline, nauclefine, naucedidinal, epinaucedinal, augustine, cardambine, naucleidal and epinaucleidal have been reported from the plant. Five monoterpene indole-alkaloids, naucleamides A to E, have been isolated and characterized (Karou *et al.*, 2011). The indole alkaloid strictosamine and strictosamide, and twelve other compound 24-en-cycloartenone, ursolic aldehyde, quinovic acid, rotundic acid,  $3\beta,19\alpha,23,24$ -tetrahydroxyurs-12-en-28-oic acid, pyrocincholic acid

$3\beta$ -O- $\beta$ -D-fucopyranoside, quinovic acid  $3\beta$ -O- $\beta$ -D-glucopyranoside,  $\beta$ -sitosterol, stigmastan-3,6-dione, stigmast-4-en-6 $\beta$ -ol-3-one and daucosterol have been reported from the root of the plant (Wang *et al.*, 2011; Antia and Okokon, 2014). Other compounds like naucleamides A, naucleamide F, quinovic acid-3-O-beta-rhamnosylpyranoside, and quinovic acid 3-O- $\beta$ -fucosylpyranoside have also been reported from the plant (Ata *et al.*, 2009). Although it is not known how the aqueous extract of the leaves of *N. latifolia* exert the observed hypoglycemic effect, it has been suggested that some of the terpene indole-alkaloids, tannins and flavonoids may be playing some roles (Gidado *et al.*, 2005; Antia and Okokon, 2014).

### *Ocimum gratissimum*

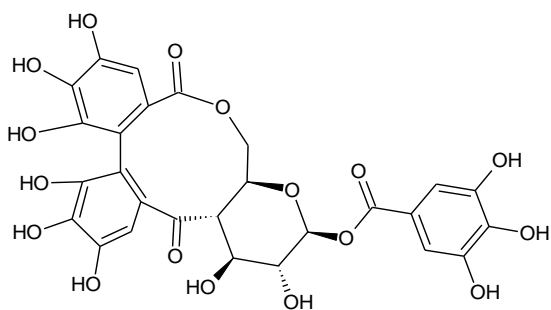
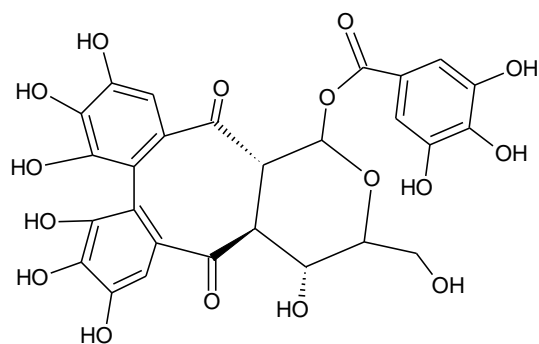
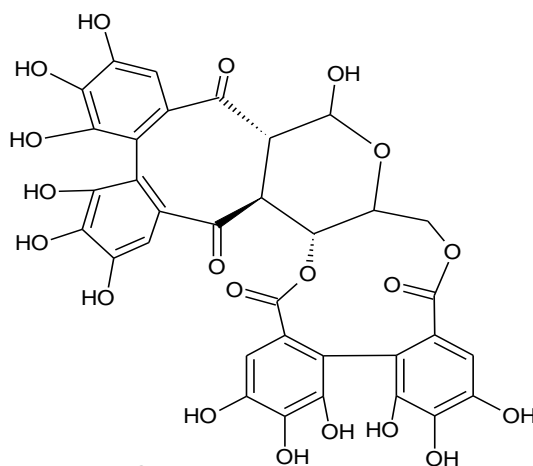
Different species of *Ocimum*, for instance *Ocimum suave*, *Ocimum gratissimum*, *Ocimum basilium* and *Ocimum camium*, have been exploited by different ethnic group in Nigeria since time immemorial for different ailments and the hypoglycemic activity of the plant species has been reported by many authors (Mohammed *et al.*, 2007; Makinwa *et al.*, 2013). *Ocimum gratissimum* contains oil rich in thymol and eugenol which has been reported to possess a number of pharmacological activities. It has also been reported to contain aromatic and volatile oil, linolenic acid, eugenol oil, oleic acid, alkaloid, flavonoid, tannins, steroids, saponins, resin, terpenoids, glycerin and cardiac glycosides (Prabhu, *et al.*, 2009). A number of terpenoids such as bornyl acetate,  $\beta$ -elemene, methyleugenol, neral,  $\beta$ -pinene, camphene,  $\alpha$ -pinene, etc., ursolic acid, campesterol, cholesterol, stigmastanol,  $\beta$ -sitosterol and methyl esters of common fatty acids have been reported (Arfa and Rashed, 2008).

The mode of action of *O. gratissimum* and the specific molecule responsible for its antihyperglycemic activities has not been identified, however, the flavonoids, tannins and alkaloid in the plant, may be acting singly or in synergies to exert the hypoglycemic activity (Ihekoronye and Ngoddy, 1985).

### *Psidium guajava*

The antidiabetic activity of the leaf has been reported by several workers (Cheng *et al.*, 1983; Ojewole, 2005). Magnesium in the fruit peel has been reported to be partly responsible for the antidiabetic activity of the fruit. The tannin (flavonoid glycosides) such as

strictinin (**7**), isostrictinin (**8**) and pedunculagin (**9**) present in *P. guajava* have been used to enhance insulin sensitivity in the clinical management of *Diabetes mellitus* (Rai *et al.*, 2007, 2009; Chauhan *et al.*, 2010; Pandian, 2013). The plant has been extensively studied and several bioactive compounds characterized. Guava contain many phytochemicals including polysaccharides, vitamins, essential oils, minerals, enzymes, proteins, sesquiterpenoid alcohols, triterpenoid acids, alkaloids, glycosides, steroids, flavanoids, tannins, saponins and also high in lutein, zeaxanthine and lycopene (Joseph and Priyar, 2011). Major compounds reported from the plant include quercetin, quercetin-3-O- $\beta$ -D-(2"-O-galloylglucoside)-4'-O-vinylpropionate, guajavolide (2 $\alpha$ -,3 $\beta$ -,6 $\beta$ -,23-tetrahydroxyurs-12-en-28,20 $\beta$ -olide), guavenoic acid (2 $\alpha$ -,3 $\beta$ -,6 $\beta$ -,23-tetrahydroxyurs-12,20(30)-dien-28-oic acid), dihydrobenzophenanthridine, cryptonine, guaijavarin, morin-3-O- $\alpha$ -L-lyxopyranoside and morin-3-O- $\alpha$ -L-arabopyranoside, etc. (Joseph and Priyar, 2011). Its essential oil is rich in  $\beta$ -caryophyllene, limonene,  $\alpha$ -pinene,  $\beta$ -pinene and selin-7(11)-en-4 $\alpha$ -ol (Egharevba *et al.*, 2010; Joseph and Priyar, 2011; El-Ahmady *et al.*, 2013; Barad *et al.*, 2014). In addition to the reported hypoglycemic activity of some flavonoids present in the plants, there may be some synergistic actions from the tannins and alkaloid compounds present in the plant.

**7****8****9**

### *Terminalia catappa*

The antidiabetic property of the extract of this plant had been reported (Nagappa *et al.*, 2003). The antidiabetic effect of the plant had been attributed to its  $\beta$ -carotene content (Ahmed *et al.*, 2005). Alkaloid, reducing sugar, resins, steroids, tannins (punicalagin, punicalin, terflavins A and B, tergallagin, tercatatin, chebulagic acid, geranin, granatin B, corilagin), flavonoids (isovitexin, vitexin, isoorientin, rutin) saponins, anthraquinones, anthraquinone glycosides, triterpenoids (ursolic acid, 2 $\alpha$ , 3 $\beta$ , 23-trihydroxyurs-12-en-28 oic acid) and essential oil rich in phytol, squalene,  $\alpha$ -farnesene, palmitic acid and hydrocarbon have been reported from the plant (Ahmed *et al.*, 2005; Oduro *et al.*, 2009; Matos *et al.*, 2009; Muhammad and Mudi, 2011; Owolabi *et al.*, 2013). The tannins have been reported to be antidiabetic. Other compounds reported include cyanidin-3-glucoside, ellagic-acid, gallic-acid, brevifolin-carboxylic-acid, eugenic acid, asiatic acid and squalene (Mininel *et al.*, 2014 Nagappa *et al.*, 2003)

### *Vernonia amygdalina*

The hypoglycemic activity of the crude plant has been reported by several authors (Owen *et al.*, 2011; Ijeh and Ejike, 2011). Several stigmastane-type saponins (vernioside A1, A2, A3, A4, B1, B2, B3, C, D and E), sesquiterpene lactones (vernolide and vernodalol, vernolepin, vernodalin, vernomygdin, hydroxyvernolide), steroids, flavonoids (quercetin, luteolin, luteolin-7-O- $\beta$ -glucuronoside, luteolin-7-O- $\beta$ -glucoside), coumarin (caffeoylquinic acids) have been

isolated and characterized (Momoh *et al.*, 2010; Johnson *et al.*, 2011; Engwa *et al.*, 2015). The plant has been found to contain peptide (edotide), anthraquinones, xanthenes, alkaloids and tannins and the leaf essential oil was rich in alpha-muurolol, 1,8-cineole and  $\beta$ -pinene (Ijeh and Ejike, 2011). The saponins and flavonoids present in *Vernonia amygdalina* may be responsible for its hypoglycemic activity (Asawalam and Hassanali, 2006; Owen *et al.*, 2011). *V. amygdalina* also have been reported to contain large quantity of Thiamine, Pyridoxine, Ascorbic acid, Glycine, Cysteine and Casein hydrolysate significantly more than other botanicals such as *Bryophyllum pinnatum*, *Eucalyptus globules* and *Ocimum gratissimum* (Mwanauta *et al.*, 2014)

## CONCLUSION

The discovery that some of these plants used by the traditional healers actually contain compounds like quercetin and related flavonoids, tannins, saponins, sterols, alkaloids etc., with proven antidiabetic properties tend to support the scientific basis for their ethnomedicinal uses. The activities of these phenolic compounds may be a pointer that diabetes is closely related to oxidative stress. However, the mode or mechanism of action of some of these compounds and their analogues need to be investigated further. This may lead to new sources of antidiabetic drugs.

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