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RESEARCH ARTICLE

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Antidiabetic Activity of Ethanolic extract of seeds of *Aframomum melegueta* in Streptozotocin-induced Type-I Diabetes in Rats

Izunya AM[1], Oaikhena AG[1], Akpamu U[2], Eseine AEC[3] and Ujaddughe MO[4]*

[1]Anatomy Department, Ambrose Alli University, Ekpoma, Nigeria

[2]Physiology Department, Federal University, Oye-Ekiti, Nigeria

[3]Medical Biochemistry Department, Ambrose Alli University, Ekpoma, Nigeria

[4]School of Anatomical Sciences, Faculty of Health Sciences, University of the Witwatersrand, Johannesburg, South Africa

ABSTRACT

Background: There is a rising burden of Diabetes mellitus globally, and it has thus become a disease of concern. People, especially in poor communities, have, over the years, used medicinal plants to treat diabetes and its complications. *Aframomum melegueta* (AM), commonly known as grains of paradise, is a medicinal plant celebrated for its rich phytochemical content and therapeutic properties. Much work has been done to find scientific evidence to support the use of medicinal plants, thus AM has been investigated for its hypoglycemic effects in Streptozotocin (STZ)-induced diabetes in Wistar albino rats.

Objective: To evaluate the antidiabetic activity of the ethanolic extract of the seeds of *Aframomum melegueta* in STZ-induced type-I diabetes in rats.

Materials and Methods: STZ-induced type-I diabetic rats (n = 5) were administered ethanolic seed extract (250 and 500 mg/kg, p.o.) of AM or vehicle (normal saline) or standard drug glimepiride (0.1 mg/kg) for 21 days. Blood samples were collected from the tail veins and were analyzed for serum glucose on days 0 and 21 by using glucose oxidase-peroxidase reactive strips and a glucometer. For the oral glucose tolerance test, glucose (2 g/kg, p.o.) was administered to nondiabetic control rats and the rats treated with glimepiride (0.1 mg/kg, p.o.) and ethanolic seed extract of AM (250 and 500 mg/kg). The serum glucose levels were analyzed at 0, 30, 60, and 120 min after drug administration. The effect of the extract on the body weight of the diabetic rats was also observed.

Results: The ethanolic seed extract of AM (250 and 500 mg/kg, p.o.) induced a significant reduction ($p < 0.05$) of fasting blood glucose levels in STZ-induced type-I diabetic rats on day 21. In the oral glucose tolerance test, the extract increased the glucose tolerance and caused an increase in the body weight of the diabetic rats.

Conclusion: There is sufficient evidence that *Aframomum melegueta* has significant antidiabetic activity as it lowers the fasting blood sugar level and increases body weight in diabetic rats, as well as increases the glucose tolerance in glucose-loaded normal rats.

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Introduction

Diabetes is a metabolic disorder characterized by hyperglycaemia caused by the destruction of the β-cells of the pancreas or cellular resistance to the action of insulin. It is usually associated with absolute or relative deficiencies in insulin secretion or insulin action [1]. Diabetes is a life threatening, common and very prevalent disease affecting citizens of both developed and developing countries. It is therefore a global health problem and there is an increasing need to combat the disease.

The global prevalence of diabetes is estimated to increase from 4% in 1995 to 5.4 % by the year 2025 [2,3]. WHO has predicted that the major burden will occur in developing countries of Africa and Asia contribute a significant fraction of this figure [4]. There is also a rising burden from the complications of DM alongside the ever-increasing prevalence of the disease [5]. It is projected that the prevalence of diabetes mellitus would have increased by 5.4% in 2025 [6].

In Nigeria, the current prevalence of DM among adults aged 20-69 years is reported to be 1.7% [4,7]. It is widely perceived

Contact Oriasotie Moses Ujaddughe, Faculty of Health Sciences, University of the Witwatersrand, Johannesburg, South Africa.

that prevalence figures reported by the IDF grossly under-report the true burden of DM in Nigeria, given that they are derived through the extrapolation of data from other countries, meanwhile, different researchers have reported prevalences ranging from 2% to 12% across the country in recent years [8-11].

There are different types of DM which include type-1, type-2, maturity onset diabetes of the young (MODY) and gestational diabetes [12]. Type-1 DM is an autoimmune syndrome characterized by insulin insufficiency, and it presents itself early in childhood and adolescence [13]. Type 2 diabetes has a prevalence of 7079 cases per 100,000; it is characterized by insulin resistance and insulin deficiency caused by pancreatic β-cell damage [14,15]. Maturity-Onset Diabetes of the Young (MODY) is a monogenic form of diabetes caused by a single-gene mutation leading to impaired insulin secretion, typically presenting in children, adolescents, or young adults [12]. Gestational diabetes is characterized by hyperglycemia that happens during pregnancy [16]. Classical symptoms of diabetes include polyuria, polydipsia, polyphagia and weight loss. It is a major cause of severe health complications and premature deaths in many developing countries [17].

Several conventional drugs are useful in the treatment of diabetes mellitus, and they treat diabetes by lowering glucose levels in the blood. However, some of these medications produce diverse functional and morphological alterations, some of which lead to severe complications of the eye, kidney and heart [18]. Most of these synthetic agents are also relatively expensive for people in the developing countries [19]. Therefore, there is the need to search for more agents that can either compliment or serve as better alternatives to the existing anti-diabetics. The use of herbal medicine is gaining popularity both in developing and developed countries because of their natural origin and less side effects [20]. The importance of anti-diabetic plants in the development of economic and effective treatment for diabetes has been recognized by the World Health Organization [21]. The use of herbal remedies for the treatment of diabetes has also been authenticated by World Health Organization [22].

There are numerous traditional medicinal plants reported to have hypoglycemic properties, such as Allium sativum (garlic), Azadirachta indica (neem), Vinca rosea (nayantara), Trigonalla foenum (fenugreek), Momordica charantia (bitter ground), and Ocimum santum (tulsi), and many of them proved to be not very effective in lowering glucose levels in severe diabetes [23]. In this regard, is a polyphenolic flavonoid -rich herb, *Aframomum melegueta* (AM), whose role in promoting health has been demonstrated previously [24-26].

Aframomum melegueta (AM) (grains of paradise) is an herbaceous perennial plant species belonging to the family Zingiberaceae (Ginger family). It is native to the swampy habitats along West African Coast. Depending on the country, it is called several names including Melegueta pepper, Alligator pepper and Guinea pepper. In Nigeria, it is called Atare (Yoruba), Ose oji (Ibo) and Citta (Hausa). It is one of such plants having both medicinal and nutritive values and popularly used as herbal remedy against a wide range of ailments both in Nigeria and several other countries of the world [27].

Various parts of AM have been claimed to possess medicinal properties [28]. The seeds are used for treatment of diarrhoea [29,30], stomachache [30,31], as a carminative and for inflammatory conditions [31-34]; it has been established to be a potent antifungal agent [35]. It is used for treatment of snake bites [36]. Its various medicinal values such as anti-inflammatory, antioxidant, aphrodisiac, hepatoprotective, antitumour, antidiabetic, antiulcer, anti-venom, antimicrobial, weight loss, erythropoietic potential, and many other medicinal uses have been reported in the literature [25,26,37-41]. Traditionally, an herbal mixture of Alligator pepper seed (*Aframomum melegueta*) and water leaf (*Talinum triangulare*) has been acclaimed to be effective in the treatment of diabetes in human in some areas of Oyo State, Nigeria [42].

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 that have been known to have anti-hyperglycemic activity [26,40,43-45].

Considering the necessity of revitalizing folk medicine and identifying the antidiabetic effects of medicinal herbs in nature that have valuable therapeutic effects, the present study aimed to determine the scientific basis for the use of this plant in the management of diabetes using glucose loaded-normal and streptozotocin- induced type-I diabetic rats.

Materials and Methods

Materials, Chemicals and Reagents

Streptozotocin (use to induced diabetes), Sodium citrate, and Citric acid (used to dissolved streptozotocin), were purchased from a chemical company in United State. Glimepiride (a sulfonylurea drug for treatment of type II diabetes) was use as the standard drug and was purchased from a pharmacy store in Edo State, Nigeria. Ethanol (99%; used for the *Aframomum melegueta* seed extraction) was purchased from a chemical store in Ibadan, Nigeria. All other chemicals and reagents used in the present study were of analytical grade.

Plant and Plant Extract Preparation

Dry pods of *Aframomum melegueta* were purchased from the local market in Ekpoma (6.7430° N, 6.1421° E), Edo State. Nigeria. Identification and authentication of the fruits were carried out at the Forestry Research Institute of Nigeria, Ibadan, Oyo State. The pods were peeled to collect the seeds, which were then sorted out to remove the extraneous materials and then air-dried for 3 days. The dried seeds were then pulverized and packaged in polyethene air-tight- bags. After 3 days, the package pulverized seeds were extracted with ethanol using the method of Arokiyaraj et al. [46] and Jeyaseelan et al. [47].

Experimental Animals

Twenty-five adults male Wistar rats of comparable weights (100 ± 20g) were used for this study. The rats were obtained from the

animal house of the College of Medicine, Ambrose Alli University, Ekpoma and transferred to the Department of Anatomy animal holding facility in the same institution. They were housed in plastic cage with a wire screen top. The animals were fed *ad libitum* with clean tap water and pelleted rat chow for 14 days' acclimatisation. They were maintained at room temperature on a 12-hour dark-light cycle and under standard care of laboratory animals as stated in the guidelines and regulations for the use of animals in scientific experiments.

Induction of Diabetes

Diabetes was induced by intra-peritoneal injection of 50mg/kg, body weight of freshly prepared streptozotocin dissolved in 0.10M citrate buffer (pH 4.5) in 20 rats after 24 hours' food fasting. This is following the methods by Mythili et al. and Szkudelski [48,49]. To stave off the hypoglycemia during the first day after the streptozotocin injection, diabetic rats were given 5% glucose solution orally as reported by Orhan et al. [50]. Rats with blood glucose levels higher than 250mg/dl after three days (72 hrs.) of streptozotocin injection were considered diabetic as previously documented by El Khateeb et al. [51].

Experimental Design

Oral Glucose Tolerance Test (OGTT)

The oral glucose tolerance test was performed on overnight (18-hour) fasted 20 normal rats. Rats divided into four groups (n = 5) were administered either drinking water or AMEE, 250 and 500 mg/kg, respectively. 20% glucose (5mL/kg oral) was fed 30 min after the administration of the extract. GP (0.1 mg/kg) was used as the standard drug. Blood was withdrawn from the tail vein at 30, 60, and 120 min of glucose administration and glucose levels were estimated using glucose oxidase-peroxidase reactive strips and a glucometer (Accu-Chek, Roche Diagnostics, USA). The mean increment of glyceamia in each group was calculated as the sum of increases in blood glucose divided by the number of animals after each period according to the method of Madar [52].

Experimental Design for Antidiabetic Study

Overnight fasted diabetic rats were divided for the antidiabetic study in the following manner: Group I: normal control rats administered 1 ml normal saline for 21 days; Group II: diabetic control rats administered 1 ml normal saline daily for 21 days; Group III: diabetic rats administered AMEE (250 mg/kg); Group IV: diabetic rats administered AMEE (500 mg/kg); Group V: diabetic rats administered the standard drug Glimepiride (GP) (0.1 mg/kg) for 21 days.

Body weight and fasting blood glucose of all rats were determined before the start and end of the experiment. After 21 days of treatment, blood was collected from tip of the tail vein and fasting blood glucose levels were measured using a complete blood glucose monitoring system (One-Touch Ultra Easy Glucose Meter, Lifescan Inc. Milpitas, USA). The initial body weight was subtracted from the final body weight to obtain the body weight gain (BWG).

Statistical Analysis

The results were presented as mean ± SEM. The data were analysed by using one way analysis of variance (ANOVA) followed by Student's t-test. The significance level for all tests was taken as P value < 0.05.

Results

Effect of AMEE on Oral Glucose Tolerance Test in Normal Rats following Glucose Loading

In OGTT, the AMEE induced significant reduction in plasma glucose levels from 60 min onwards (Fig 1). The greatest effect was seen in the AMEE (500mg/kg) and glimepiride (0.1mg/kg) treated groups after 120 minutes of glucose loading (Figure 1).

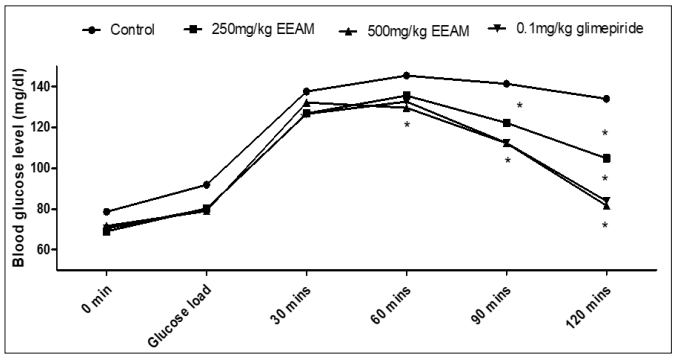


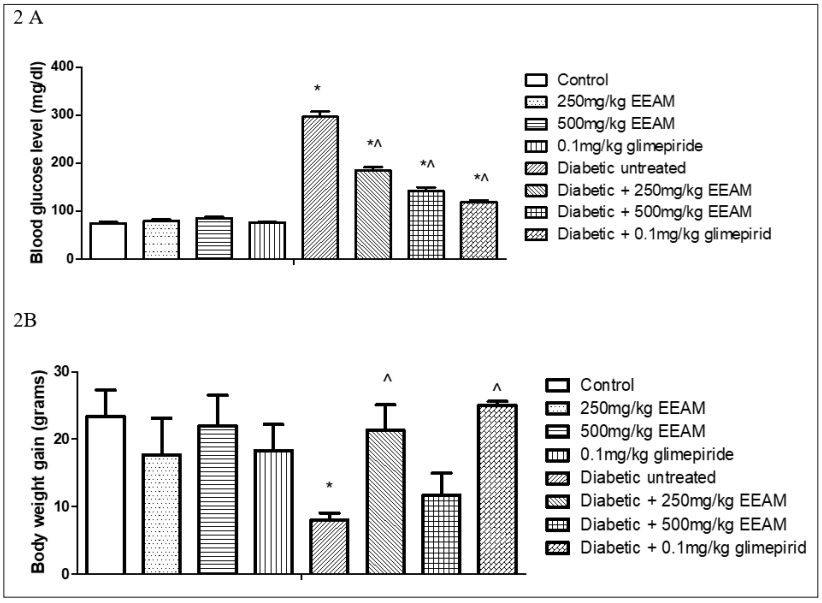
Figure 1: Effect AMEE in glucose-loaded normal rats

Values are means ± SEM, n = 5, * indicate statistically significant compared with control.

Key: AMEE = *Aframomum melegueta* ethanolic extract

Effect of AMEE on fasting blood sugar and Body Weight Gain of control and STZ-Induced Diabetes in Adult Male Wistar Rats after 21 days Oral Administration

In STZ diabetic rats there was a significant increase ($p < 0.05$) in fasting blood glucose (FBG) and a significant decrease ($p < 0.05$) in body weight gain (BWG) compared to normal control rats. However, a significant decrease in FBG was observed in diabetic rats treated with AMEE (250 and 500 mg/kg) and glimepiride (0.1 mg/kg) and a significant increase in BWG was observed in diabetic rats treated with AMEE (250 mg/kg) and glimepiride (0.1 mg/kg) compared to diabetic control rats (Figures 2 A &B).



Figures 2A & B: Effect of AMEE on (A) FBG and (B) BWG of control and STZ-induced diabetes in adult male wistar rats after 21 days oral administration

Values are means ± SEM, n = 5, * statistically significant at p≤0.05 compared with control, ^ statistically significant at p≤0.05 compared with diabetic untreated.

Key: AMEE = *Aframomum melegueta* ethanolic extract

Discussion

Management of diabetes with the agents devoid of any side effects is still a challenge to the medical system [53]. This has led to an increase in the demand for natural products with antihyperglycemic activity and fewer side effects. Plants may act on blood glucose through different mechanisms, some of them may have insulin-like substances and some may inhibit insulinase activity [54,55]. Stimulation of beta-cells to produce more insulin and others may increase beta -cells in the pancreas by activating regeneration of pancreatic cells [56,57].

The present work has detected the antidiabetic effect of the ethanolic seeds extract of AM in streptozotocin- induced type-1 diabetic rats. Streptozotocin injection caused diabetes mellitus, probably due to destruction of the β-cells of the islets of Langerhans of the pancreas [58]. Over-production of glucose and decreased utilization by the tissues form the fundamental basis of hyperglycemia in diabetes mellitus [59].

When AMEE was administered to glucose-loaded normal rats, hypoglycemia was observed after 60 min, with the maximum effect being seen at 120 min. Our investigations also indicate the efficacy of the AMEE in the maintenance of blood glucose levels in normal and streptozotocin induced diabetic rats. Induction of diabetes with STZ is associated with a characteristic loss of body weight, which is due to increased muscle wasting [60] and loss of tissue proteins [61]. Diabetic rats treated with the AMEE showed an increase in body weight as compared to the diabetic control, which may be due to its effect in controlling muscle wasting, i.e., by reversal of antagonizing [62]

Summary and Conclusion

Many workers have shown *A. melegueta* to be effective in diabetes mellitus; both type 1 and type 2 in various animal models. In the present study, ethanolic extract of AM seeds was used to evaluate the hypoglycemic effect on glucose-loaded normal and STZ induced diabetic rats. The parameters considered in the study were fasting blood glucose and body weight. For the above purpose, the extract was administered by oral route. The results of the study indicate that AMEE has potential to improve the glucose tolerance within a short period of time as suggested by oral glucose tolerance test and to reduce the fasting blood glucose levels after a treatment period of 3 weeks. In conclusion our study suggests that AM may have beneficial effect in diabetes mellitus and may improve glucose tolerance also. Thus, this holds the scope of a new generation of antidiabetic drug. However, there is need for further studies on experimental animals and human beings, using various active principles, to establish their usefulness, exact mode of action and toxicity data.

Ethical Consideration

The ethical approval for this research was approved by the Heath Research Ethics Committee of Ambrose Alli University, Ekpoma. The study was carried out in line with local, national and international ethical codes and guidelines governing the use of animals in research.

Conflict of Interest

The authors declare no conflict of interest. All authors approved the manuscript for publication.

References

[1] Bhupesh CS, Jjitendra G, Sonia S, Yogesh K, Mahendra G. Antihyperglycaemic activity of root of Berberis aristata DC in alloxan-induced diabetic rats. Int J Green Pharm. 2009; 3: 259-262.

[2] King H, Aubert RE, Herman WH. Global burden of diabetes, 1995-2025: prevalence, numerical estimates, and projections. Diabetes Care. 1998; 21: 1414-1431.

[3] Lin X, Xu Y, Pan X, Xu J, Ding Y, et al. Global, regional, and national burden and trend of diabetes in 195 countries and territories: an analysis from 1990 to 2025. Sci Rep. 2020; 10: 14790.

[4] International Diabetes Federation. Diabetes atlas. Int Diabetes Fed. 2017; 8: 1-150.

[5] Uloko AE, Ofoegbu EN, Chinenye S, Fasanmade OA, Fasanmade AA, et al. Profile of Nigerians with diabetes mellitus—Diabcare Nigeria study group (2008): results of a multicenter study. Indian J Endocrinol Metab. 2012; 16: 558-564.

[6] Moller DE, Flier JS. Insulin resistance - mechanism, syndromes and implications. N Engl J Med. 1991; 325: 938-948.

[7] Uloko AE, Musa BM, Ramalan MA, Gezawa ID, Puepet FH, et al. Prevalence and risk factors for diabetes mellitus in Nigeria: a systematic review and meta-analysis. Diabetes Ther. 2018; 9: 1307-1316.

[8] Nyenwe EA, Odia OJ, Ihekwaba AE, Ojule A, Babatunde S. Type 2 diabetes in adult Nigerians: prevalence and risk factors in Port Harcourt, Nigeria. Diabetes Res Clin Pract. 2003; 62: 177-185.

[9] Puepet FH, Ohwovoriole AE. Prevalence of risk factors for diabetes mellitus in a non-diabetic population in Jos, Nigeria. Niger J Med. 2008; 17: 71-74.

[10] Sabir AA, Isezuo SA, Ohwovoriole AE. Dysglycaemia and its risk factors in an urban Fulani population of northern Nigeria. West Afr J Med. 2011; 30: 325-330.

[11] Gezawa ID, Puepet FH, Mubi BM, Uloko AE, Bakki B, et al. Socio-demographic and anthropometric risk factors for type 2 diabetes in Maiduguri, North-Eastern Nigeria. Sahel Med J. 2015; 18: 1-7.

[12] American Diabetes Association. Diagnosis and classification of diabetes mellitus. Diabetes Care. 2013; 36: S67-S74.

[13] Mayer-Davis EJ, Lawrence JM, Dabelea D, Divers J, Isom S, et al. Incidence trends of type 1 and type 2 diabetes among youths, 2002-2012. N Engl J Med. 2017; 376: 1419-1429.

[14] American Diabetes Association. Standards of medical care in diabetes—2009. Diabetes Care. 2009; 32: S13-S61.

[15] Khan MAB, Hashim MJ, King JK, Govender RD, Mustafa H, et al. Epidemiology of type 2 diabetes - global burden of disease and forecasted trends. J Epidemiol Glob Health. 2020; 10: 107-111.

[16] Msollo SS, Martin HD, Mwanri AW, Petrucka P. Awareness and screening practices for gestational diabetes mellitus among pregnant women. Tanz J Agric Sci. 2021; 20: 1-11.

[17] Cooke DW, Plotnick L. Type 1 diabetes mellitus in pediatrics. Pediatr Rev. 2008; 29: 374-385.

[18] MacGilliury MH, Voorhes ML, Putnam TI. Hormone and metabolism profiles in children and adolescents with type 1 diabetes mellitus. Diabetes Care. 1982; 5: 38-47.

[19] Rubin RJ, Altman WM, Mendelson DN. Health care expenditures for people with diabetes mellitus. J Clin Endocrinol Metab. 1992; 78: 809A-809F.

[20] Modak M, Dixit P, Londhe J, Ghaskadbi J, Paul T, et al. Indian herbs and herbal drugs used for the treatment of diabetes. J Clin Biochem Nutr. 2007; 40: 163-173.

[21] World Health Organisation. Diabetes mellitus: report of a WHO study group. WHO Tech Rep Ser. 1985; 727: 1-113.

[22] Bailey CJ, Day C. Traditional plant medicines as treatment for diabetes. Diabetes Care. 1989; 12: 553-564.

[23] Grover JK, Yadav S, Vats V. Medicinal plants of India with anti-diabetic potential. J Ethnopharmacol. 2002; 81: 81-100.

[24] Toh YS, Lim CL, Ling APK, Chye SM, Koh RY. Overview of the pharmacological activities of Aframomum melegueta. Pertanika J Trop Agric Sci. 2019; 42: 1-15.

[25] Mohammed A, Kumar D, Rizvi SI. Antidiabetic potential of some less commonly used plants in traditional medicinal systems of India and Nigeria. J Intercult Ethnopharmacol. 2015; 4: 78.

[26] Onoja SO, Omeh YN, Ezeja MI, Chukwu MN. Evaluation of the in vitro and in vivo antioxidant potentials of Aframomum melegueta ethanolic seed extract. J Trop Med. 2014; 2014: 1-7.

[27] Agoha RC. Medicinal plant of Nigeria. Offsetdikker. 1974; 22: 158.

[28] Ma Y, Xu H, Sun Y, Fan H, Li Y, et al. Botanical, phytochemistry, pharmacology and applications of genus Aframomum: a review. Rec Nat Prod. 2025; 19: 1-15.

[29] Toh YS, Lim CL, Ling APK, Chye SM, Koh RY. Overview of the pharmacological activities of Aframomum melegueta. Pertanika J Trop Agric Sci. 2019; 42: 1-15.

[30] Osuntokun OT. Aframomum melegueta (grains of paradise). Ann Microbiol Infect Dis. 2020; 3: 1-6.

[31] Umukoro S, Aladeokin AC. Therapeutic effects of grains of paradise (Aframomum melegueta) seeds. Nuts Seeds Health Dis Prev. 2011; 1: 535-543.

[32] Kokwaro JO. Medicinal plants of East Africa. Gen Printers Ltd. 1976; 1: 244.

[33] Houghton PJ, Osibogun IM. Flowering plants used against snakebite. J Ethnopharmacol. 1993; 39: 235-236.

[34] Rafatullah S, Galal AM, Al-Yahya MA, Al-Said MS. Gastric and duodenal anti-ulcer and cytoprotective effects of Aframomum melegueta in rats. Int J Pharmacogn. 1995; 33: 311-316.

[35] Okigbo RN, Ogbonnaya UO. Antifungal effects of tropical plant leaf extracts on post-harvest yam rot. Afr J Biotechnol. 2006; 5: 727-731.

[36] Nebojsa L, Barbara M, Alexander P, Ilya R. Toxicological evaluation of grains of paradise (Aframomum melegueta). J Ethnopharmacol. 2010; 127: 352-356.

[37] Adesokan AA, Akanji MA, Adewara GS. Hypoglycaemic efficacy of aqueous seed extract of Aframomum melegueta in alloxan-induced diabetic rats. Sierra Leone J Biomed Res. 2010; 2: 1-8.

[38] Lawal OA, Kasali AA, Opoku AR, Ojekale AB, Oladimeji OS, et al. Chemical composition and antibacterial activity of essential oil from Aframomum melegueta leaves. Essent Oil-Bear Plants. 2015; 18: 222-229.

[39] Mojekwu TO, Yama OE, Ojokuku SA, Oyebadejo SA. Hypoglycaemic effects of aqueous extract of Aframomum melegueta leaf in diabetic rats. Pac J Med Sci. 2011; 8: 28-36.

[40] Amadi SW, Zhang Y, Wu G. Research progress in phytochemistry and biology of Aframomum species. Pharm Biol. 2016; 54: 2761-2770.

[41] Chan KC, Choo NR, Abdullahi A, Ismail Z. Antiplasmodial studies of Eurycoma longifolia using lactate dehydrogenase assay. J Ethnopharmacol. 2004; 92: 223-227.

[42] Olaitan HM, Nwinyi FC, Akumka DD, Mohammed A. Veterinary and biomedical studies. Abuja J Vet Biomed Sci. 2018; 1: 11-18.

[43] Middleton EJ, Kandaswami C, Theoharis CT. Effects of plant flavonoids on mammalian cells. Pharmacol Rev. 2000; 52: 673-751.

[44] Nwaehujor CO, Eban LK, Ode JO, Ejiofor CE, Igile GO. Hepatotoxicity of Aframomum melegueta seed extract in rats. Am J Biomed Res. 2014; 2: 61-66.

[45] Morakinyo AE, Oyedapo OO, Akinpelu BA, Fajobi AO, Fasakin WO, et al. Antioxidant and anti-inflammatory constituents of Aframomum melegueta leaf extract. Int J Med Plants. 2018; 112: 888-903.

[46] Arokiyaraj S, Balamurugan R, Augustian P. Antihyperglycemic effect of Hypericum perforatum extract in diabetic rats. Asian Pac J Trop Biomed. 2011; 1: 386-390.

[47] Jeyaseelan EC, Pathmanathan MK, Jeyadevan JP. Inhibitory effect of solvent extracts on phytopathogenic bacteria. Arch Appl Sci Res. 2011; 3: 1-8.

[48] Mythili MD, Vyas R, Akila G, Gunasekaran S. Effect of streptozotocin on rat pancreatic islets. Microsc Res Tech. 2004; 63: 274-281.

[49] Szkudelski T. Mechanism of alloxan and streptozotocin action in pancreatic beta cells. Physiol Res. 2001; 50: 537-546.

[50] Orhan N, Aslan M, Deliorman Orhan D, Ergun F, Yesilada E. Antidiabetic and antioxidant activities of grapevine leaves in diabetic rats. J Ethnopharmacol. 2006; 108: 280-286.

[51] El-Khateeb AY, Eid A-KN, Mahmoud HI. Phytochemical constituents, hypoglycemic and haematological effects of methanolic Acalypha wilkesiana leaves extract on streptozotocin-induced diabetic rats. Eur J Chem. 2014; 5: 430-438.

[52] Madar Z. Effect of acarbose and miglitol on postprandial glucose levels following ingestion of various sources of starch in nondiabetic and streptozotocin-induced diabetic rats. J Nutr. 1989; 119: 2023-2029.

[53] Chaudhury A, Duvoor C, Reddy Dendi VS, Kraleti S, Chada A, et al. Clinical review of antidiabetic drugs: Implications for type 2 diabetes mellitus management. Front Endocrinol. 2017; 8: 6.

[54] Chang MW, Johnson MA. Effect of garlic on carbohydrate metabolism and lipid synthesis in rats. J Nutr. 1980; 110: 931-936.

[55] Collier E, Watkinson A, Cleland CF, Roth J. Partial purification and characterization of insulin-like material from spinach and Lemna gibba G3. J Biol Chem. 1987; 262: 6238-6247.

[56] Chakravarthy BK, Gupta S, Gambhir SS, Gode KD. Pancreatic beta cell regeneration - a novel antidiabetic mechanism of Pterocarpus marsupium. Indian J Pharmacol. 1980; 12: 123-128.

[57] Bopanna KN, Kannan J, Gadgil S, Balaraman R, Rathod SP. Antidiabetic and antihyperglycemic effects of neem seed kernel powder in alloxan diabetic rabbits. Indian J Pharmacol. 1997; 29: 162-167.

[58] Kavalali G, Tuncel H, Goksel S, Hatemi MH. Hypoglycemic activity of Urtica pilulifera in streptozotocin-diabetic rats. J Ethnopharmacol. 2002; 84: 241-245.

[59] Chattopadhyay R. Hypoglycemic effect of Ocimum sanctum leaf in normal and streptozotocin diabetic rats. Indian J Exp Biol. 1993; 31: 891-893.

[60] Swanston-Flat SK, Day C, Bailey CJ, Flatt PR. Traditional plant treatment for diabetes: Studies in normal and streptozotocin diabetic mice. Diabetologia. 1990; 33: 462-464.

[61] Chatterjea MN, Shinde R. Textbook of Medical Biochemistry. New Delhi: Jaypee Brothers Medical Publishers; 2002. Diabetes mellitus; p. 317.

[62] Whitton PD, Hems DA. Glycogen synthesis in perfused liver of streptozotocin diabetic rats. Biochem J. 1975; 150: 150-153.