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# A Review of the Antidiabetic Activities of Ginger

*Gloria Aderonke Otunola and Anthony Jide Afolayan*

## Abstract

Diabetes mellitus, a chronic metabolic disorder with major health care burden worldwide, is increasing, with 173 million adults being diabetic and over 8 million deaths recorded annually. Undesirable pathological conditions and high rates of secondary failure limit the use of current antidiabetic agents, thus, the need for more effective antidiabetic agents. Medicinal plants such as spices, rich in bioactive components that promote prevention and treatment of chronic conditions such as heart disease, cancer and Type-2 diabetes, are inexpensive with no side effects. The Zingiberaceae family, of which ginger is a member, consists of many species frequently cited for their antidiabetic and hypoglycemic properties. All important scientific literatures from 2000 to 2018 on the antidiabetic potentials of *Zingiber officinale* were evaluated. According to these studies, ginger exerts its antidiabetic effects through restorative effects on pancreatic  $\beta$ -cells, increasing insulin sensitivity, action and peripheral utilization of glucose. Other mechanisms include increased synthesis of hepatic glycogen through the enhancement of glycogen regulatory enzyme expression in the liver, inhibition of carbohydrate metabolizing enzymes, stimulation of pancreatic insulin release and inhibition of hepatic glucose production. Further studies, especially in humans are needed, more so, since ginger is one of the spices generally regarded as safe.

**Keywords:** spices, diabetes, ginger, pharmacology, mechanism of action

## 1. Introduction

Diabetes mellitus (DM) is the most common endocrine disorder that affects more than 100 million people worldwide. It is a heterogeneous group of diseases, all of which ultimately lead to an elevation of glucose in the blood (hyperglycemia) and loss of glucose in the urine as hyperglycemia increases. It is characterized by increased urine production (polyurea) excessive thirst (polydipsia) and excessive eating (polyphagia).

Diabetes mellitus is a chronic metabolic disorder of the endocrine system that is characterized by defects in impaired metabolism of glucose, lipid and protein as well as insulin secretion or insufficiency. Diabetes continues to be a major health care problem worldwide and its prevalence is expected to rise from the current 382–471 million individuals by 2035 [1, 2]. There are three main types of diabetes- Type 1 diabetes (T1D), which is an autoimmune disorder leading to the destruction of pancreatic beta-cells; Type 2 diabetes (T2D), which is much more common and primarily caused by impaired glucose regulation due to a combination of dysfunctional pancreatic beta cells and insulin resistance and gestational diabetes mellitus (GDM).

Different treatments, such as insulin, pharmacotherapy and diet therapies, which exert antidiabetic effects through different mechanisms, are currently used for the management of diabetes. Such mechanisms include stimulation of insulin secretion by sulfonylurea and meglitinides drugs, increase of peripheral absorption of glucose by biguanides and thiazolidinediones, delay in the absorption of carbohydrates from the intestine by alpha-glucosidase and reduction of hepatic gluconeogenesis by biguanides [3–5].

In spite of the appreciable progress that has been made in the management of diabetes through the use of conventional drugs and management strategies, diabetes and its complications continue to be a major medical problem and rising burden of disease. Most synthetic oral hypoglycemic agents available for the treatment of the disease have some disadvantages, including drug resistance, serious side effects, cannot be used during pregnancy, are toxic and also costly [6, 7].

Spices and herbs have played important roles in civilization and history of many nations of the world. Their flavor and pungency makes them indispensable in the preparation of palatable dishes; but beyond adding flavor, spices are reputed to possess several medicinal and pharmacological properties and hence find use in the preparation of a number of medicines. Spices can be the dried leaf (e.g., bay leaf), buds (cloves), bark (cinnamon), rhizome/root (ginger), berries (grains of pepper), seeds (cumin), or even the stigma of the flower (saffron) [8].

The Zingiberaceae plant family consists of many species used as culinary herbs and spices, frequently cited for their antidiabetic and hypoglycemic properties. Ginger (*Zingiber officinale*) belongs to this family, and has a long and wide history of usage both as a culinary spice and in traditional/alternative medicine. This study attempts to update the available scientific information on the antidiabetic and hypoglycemic potentials of ginger.

## 2. Methodology

Online published articles from Google Scholar, ScienceDirect, Scopus, ResearchGate, PubMed and SciELO were explored for data collection. For literature search, key words such as spices, diabetes, Zingiberaceae, ginger, in vivo, in vitro, pharmacological, medicinal, hypoglycemic and antidiabetic were used. The study reviewed all important literature from 2000 to 2018.

## 3. Results

The following sections describe various studies reporting the hypoglycemic and antidiabetic properties of ginger, phytochemical constituents responsible for these properties and its mechanisms of action.

### 3.1 Ginger (*Zingiber officinale* Roscoe)

The ginger (Zingiberaceae) family consists of 53 genera and over 1200 medicinal plants, typically tropical annuals or perennials, often with large rhizomes. This plant family is well-known for its medicinal values and is distributed widely throughout the tropics, particularly in Southeast Asia.

Ginger (**Figure 1**) has been used for thousands of years for the treatment of numerous ailments, such as colds, nausea, arthritis, migraines and hypertension. Several authors have reviewed the medicinal, chemical, and pharmacological properties of ginger [9–13]. Ginger is recognized by the U.S. Food and Drug



and 6-paradol reduced blood glucose in HFD-fed mice. Al-Qudah et al. [32] reported that aqueous extract of ginger was effective in lowering serum glucose, restoration of hematological indices to normal and repair damaged pancreas in alloxan-induced diabetic rats.

In another study, Oludoyin and Adegoke [33] investigated the effect of ginger extracts on blood glucose in normal and streptozotocin-induced diabetic rats. The authors reported that the fasting blood glucose in diabetic rats was reduced to normal by both raw and cooked ginger extracts in a manner comparable to glibenclamide. Evaluation of the nutritional and antidiabetic activity of ginger powder, its aqueous and methanolic extract, as well as the essential oil in streptozotocin-induced diabetic rats [34] revealed reduction in levels of alanine and aspartate aminotransferase (ALT and AST), alkaline phosphatase (ALP), liver total lipid and cholesterol of diabetic rats; and increased levels of liver glycogen and triglyceride compared to positive control group. In the study, ginger oil showed the best anti-diabetic activity, followed by ginger extracts. Again, another study reported that ginger extract administered at 200 mg/kg/day/kg body weight for 10 weeks to male Sprague-Dawley diabetic rats, exhibited protective activity against insulin resistance [34].

Al-Noory et al. [35] showed that fresh ginger extracts led to decrease in the levels of total cholesterol (TC) and low density lipoprotein (LDL) in the serum of alloxan-induced diabetic rats, compared with the control groups; and previous extracts caused reduction in LDL to levels comparable to normal group and equal to the effect of atorvastatin given at a dosage of 10 mg/day. Similarly, oral administration of aqueous ginger extract to streptozotocin (STZ)-induced diabetic rats for a period of 30 days was reported to give a dose-dependent antihyperglycemic effect, 68% decrease in plasma glucose level at a daily dose of 500 mg/kg body weight, indicating that ginger is a potential phytomedicine for the treatment of diabetes [36]. Iranloye et al. [37] also showed that ginger effectively reduced fasting blood glucose, malondialdehyde levels and enhanced insulin sensitivity in alloxan-induced and insulin-resistant diabetic rats compared to control rats.

Treatment of streptozotocin-induced Type I diabetic rats with *Z. officinale* juice (4 mL kg<sup>-1</sup>, p.o. daily for 6 weeks) was reported to produce a significant increase in insulin levels, decrease in fasting glucose levels, as well as significant decrease in the area under the curve of glucose in an oral glucose tolerance test [38]. According to Nammi et al. [23], treatment with an ethanolic extract of ginger at doses of 100, 200, and 400 mg/kg for 6 weeks, significantly reduced the marked increase in body weight, serum glucose, insulin, total cholesterol, LDL cholesterol, triglycerides, free fatty acid and phospholipids induced by high-fat diet.

The study conducted by Al-Amin et al. [39] on the antidiabetic and hypolipidemic properties of ginger (*Zingiber officinale*) in streptozotocin-induced diabetic rats revealed that raw ginger at a dose of 500 mg/kg, was significantly effective in lowering serum glucose, cholesterol and triacylglycerol as well as reduction in urine protein (reversal of diabetic proteinuria) levels, of diabetic rats. Ethanolic extracts of *Zingiber officinale* (200 mg/kg) given orally for 20 days was reported to produce significant antihyperglycemic effect ( $P < 0.01$ ) in diabetic rats, while also lowering serum total cholesterol and triglycerides, coupled with increased HDL-cholesterol levels when compared with pathogenic diabetic rats [40].

Hypoglycemic effect of ginger (4 and 8 g/kg), administered intraperitoneally to rats after 30 min of diabetes induction, with the effect being more pronounced after 2 h has been reported. In another study, Otunola and Afolayan [41], showed that aqueous extract of a spice mixture containing ginger at 500 mg/kg body weight extract significantly ( $p < 0.05$ ) lowered the elevated fasting blood glucose, lipid and hematological indices of alloxan-induced diabetic rats at equipotent level with glibenclamide.

Several *in vitro* hypoglycemic potentials of ginger and its bioactive constituents especially 6-shogaol have been reported (**Table 1**).

The capacity of ginger for hypoglycemic, antidiabetic, insulogenic, better glucose tolerance, increased serum insulin levels, reduction in elevated lipid levels, and prevention of weight loss associated with diabetes in human diabetic patients have also been reported (**Table 2**).

### 3.3 Phytochemical components of *Zingiber officinale*

GC-MS profiling of diethyl extracts as reported by Koch et al. [46] showed the presence of monoterpenes such as ( $\alpha$ -pinene, camphene, myrcene, and  $\alpha$ -phellandrene), oxygenated monoterpenes (geranial, citronellal, neral, linalool, borneol, and  $\alpha$ -terpineol), and sesquiterpenes ( $\alpha$ - and  $\beta$ -farnesene, ar-curcumene, zingiberene, zingiberenol, copaene, or cadinene). The most abundant substances in the extracts were  $\alpha$ -zingiberene (37.9%),  $\beta$ -sesquiphellandrene (11.4%), (E,E)- $\alpha$ -farnesene (9.6%), geranial (8.2%), ar-curcumene (6.3%), and  $\gamma$ -terpinene (5.1%).

Similarly, Sharma et al. [47] reported that the essential oil of fresh ginger rhizome was characterized by high percentage of sesquiterpenes (66.66%), monoterpenes (17.28%) and aliphatic compounds (13.58%). The predominant sesquiterpene was zingiberene (46.71%) followed by valencene (7.61%),  $\beta$ -funebrene (3.09%) and selina-4(14),7(11)-diene (1.03%).

### 3.4 Mechanism of action

Various mechanisms have been proposed for the antidiabetic and hypoglycemic activities of medicinal plants. These include peripheral utilization of glucose, increased synthesis of hepatic glycogen by enhancement of glycogen regulatory enzyme expression in the liver, inhibition of carbohydrate metabolizing enzymes, stimulation of pancreatic insulin release, insulomimetic actions and inhibition of hepatic glucose production [55, 56].

According to Dearlove et al. [57], spices such as cinnamon, cloves, oregano, and allspice possess bioactive compounds that have (1) antiglycation properties which inhibit the formation of AGEs; (2) antioxidant activities that neutralize the

In vitro study	Result/outcome	References
[6]-Gingerol on 3 T3-L1 cells	Enhanced differentiation of 3T3-L1 preadipocytes and insulin-sensitive glucose uptake	Sekiya et al. [42]
[6]-Shogaol or [6]-gingerol on 3 T3-L1 cells	Significant inhibition of TNF- $\alpha$ -mediated adiponectin expression in 3T3-L1 adipocytes. [6]-Shogaol acted as a peroxisome proliferator-activated receptor (PPAR) $\gamma$ agonist, while [6]-gingerol acted by suppressing TNF- $\alpha$ -induced JNKs signaling	Isa et al. [43]
Ethyl acetate extract of ginger on L6 myotube cell surface	Stimulated glucose uptake and GLUT4 expression in L6 myotube cell surface, reduced lipid content in 3T3 adipocyte, and inhibited protein glycation. Inhibited $\alpha$ -amylase (IC <sub>50</sub> = 980.2 $\mu$ g/mL) and $\alpha$ -glucosidase (IC <sub>50</sub> = 180.1 $\mu$ g/mL)	Rani et al., [44]
Aqueous extract of ginger at 5, 10, 20, 40 g/L incubated with (PBS), glucose + BSA for 5 weeks	Dose-dependent, antidiabetic activity through inhibition of glucose diffusion and reduced glycation	Sattar et al., [45]

**Table 1.**  
*In vitro* hypoglycemic potentials of ginger and its bioactive constituents.

<b>Human trials/dosage</b>	<b>Results</b>	<b>References</b>
Type 2 diabetic men (40–60 years) given 3 g/day of dry ginger powder in divided doses for 30 days. Number-8 T2D, 8 placebo	Significant reduction of blood glucose, triglyceride, total cholesterol, LDL and VLDL cholesterol	Andallu et al. [48]
Randomized double-blind placebo-controlled trial, patients with Type 2 diabetes, given 2 g/day of ginger extract supplementation. Number-28 T2D, 30 Placebo	Significantly lowered levels of insulin, LDL-C, TG, HOMA index and increased the QUICKI index; no significant changes in FPG, TC, HDL-C and HbA1c; improved insulin sensitivity	Mahluji et al. [49]
Randomized controlled trial of Type 2 diabetic men between 30 and 70 years given 1.6 g/day of ginger or wheat flour capsule. Number-33 T2D, 30 Placebo	Decreased fasting blood glucose, glycosylated hemoglobin, fasting insulin, homeostasis model assessment-insulin resistance index, total cholesterol and triglyceride. No change in BMI, LDL-C, HDL-C and HDL-C	Arablou et al. [50]
Randomized controlled trial of Type 2 diabetic patients (30–70 years) given either 3 g/day ginger or cellulose microcrystalline capsules for 8 weeks. Number-40 T2D, 41Placebo	Significant reduction in fasting blood glucose and glycosylated hemoglobin; no change in BMI, fasting insulin and homeostasis model assessment-insulin resistance index	Mozaffari-Khosravi et al. [51]
Randomized, double-blind, placebo-controlled, clinical trial where Type 2 diabetic patients received 2 g/day of ginger powder supplement or lactose as placebo for 12 weeks. Number-22 T2D, 19 placebo	Significant reduction of fasting blood sugar, hemoglobin A1c, apolipoprotein B, apolipoprotein B/apolipoprotein A-I and malondialdehyde in ginger group compared to baseline and control group, while increasing apolipoprotein A-I in Type 2 diabetic patients	Khandouzi et al. [52]
Randomized controlled trial of Type 2 diabetic patients (20–60 y) T2DM given 3 g ginger or lactose capsule/day for 3 months. Number-22 T2D, 23 Placebo	Reduced fasting blood glucose, glycosylated hemoglobin, fasting insulin, homeostasis model assessment-insulin resistance index	Shidfar et al. [53]
Double-blind placebo-controlled trials of Type 2 diabetic patients were randomly allocated to 2000 mg/day of ginger or placebo for 10 weeks. Number-25 T2D, 25 placebo	Reduced serum levels of fasting blood glucose, hemoglobin A1C compared to placebo group, reduced ratio of LDL-C/HDL-C; but no significant change in serum concentrations of triglycerides, total cholesterol, LDL-C, and HDL-C	Arzatii et al. [54]

**Table 2.** *Clinical (human) trials of the antidiabetic potentials of ginger.*

effects of ROS; and (3) anti-inflammatory potentials. Some studies associate the antidiabetic action of ginger to its bioactive principles such as gingerol and shogaol which have the capacity to enhance glucose uptake in rat’s skeletal muscle cells, and promote increased expression and translocation of GLUT-4 glucose transporter to the plasma membrane of the cells thus clearing excess glucose from the serum [34].

Another mechanism proposed was the inhibition of key enzymes of carbohydrate metabolism— $\alpha$ -glucosidase and  $\alpha$ -amylase by phenolic compounds (gingerols and shogaols) present in ginger [23, 45]; while other authors showed that ginger increases muscle and liver glycogen stores by enhancing peripheral utilization of glucose, thus limiting gluconeogenesis in the liver and kidney in a manner similar to insulin [37].

Son et al. [58], posits that-gingerol exerts its antidiabetic effects through multiple mechanisms that include—(1) increased glucose uptake in the absence

of insulin, (2) induction of 5' adenosine monophosphate-activated protein kinase phosphorylation, (3) promotion of glucose transporter 4 (GLUT4) translocation to plasma membrane, (4) suppression of advanced glycation end product-induced rise of ROS levels in pancreatic  $\beta$ -cells, (5) reduction of fasting blood glucose levels and improved glucose intolerance, (6) regulation of hepatic gene expression of enzymes involved in glucose metabolism toward decreased gluconeogenesis and glycogenolysis, while increasing glycogenesis, thereby reducing blood glucose concentrations.

#### **4. Conclusion**

This study presented an update on the antidiabetic potentials of ginger from the Zingiberaceae family. Although several *in vivo* and *in vitro* reports were available, there were relatively few clinical (human) trials. The doses and outcomes also varied; as well as the mechanism of action through which antidiabetic effects were mediated. Although these reports are indicative of the anti-diabetic or hypoglycemic potentials of ginger, the doses and outcomes also varied; most importantly, the mechanisms of action through which anti-diabetic effects are mediated were highlighted. Ginger, according to these studies, exerts its anti-diabetic effects through restorative effects on pancreatic  $\beta$ -cells, increasing insulin sensitivity, insulin-like action and peripheral utilization of glucose. Other mechanisms include increased synthesis of hepatic glycogen through the enhancement of glycogen regulatory enzyme expression in the liver, inhibition of carbohydrate metabolizing enzymes, stimulation of pancreatic insulin release, and inhibition of hepatic glucose production. However, further studies, especially in humans are therefore needed and the oral safety of the various extracts under prolonged usage must be confirmed, more so, since ginger is one of the spices generally regarded as safe.

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#### **Conflict of interest**

The authors declare no conflict of interest.

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## References

- [1] Ogurtsova K, da Rocha Fernandes JD, Huang Y, Linnenkamp U, Guariguata L, Cho NH, et al. Global estimates for the prevalence of diabetes for 2015 and 2040. *IDF Diabetes Atlas*;2017(128):40-50
- [2] Bi X, Lim J, Henry CJ. Spices in the management of diabetes mellitus. *Food Chemistry*. 2017;217:281-293
- [3] Hui, Hongxiang, Xiaoning Zhao, and Riccardo Perfetti. Structure and function studies of glucagon-like peptide-1 (GLP-1): The designing of a novel pharmacological agent for the treatment of diabetes. *Diabetes/ Metabolism Research and Reviews*. 2005;21(4):313-331
- [4] Bathaie SZ, Mokarizade N, Shirali S. An overview of the mechanisms of plant ingredients in the treatment of diabetes mellitus. *Journal of Medicinal Plants*. 2012;4(44):1-24
- [5] Kooti W, Farokhipour M, Asadzadeh Z, Ashtary-Larky D, Asadi-Samani M. The role of medicinal plants in the treatment of diabetes: A systematic review. *Electronic Physician*. 2016;8(1):1832
- [6] Kumari KD, Suresh KP, Samarasinghe K, Handunnetti SM, Samaranayake TSP. Evaluation of a traditional Sri Lankan herbal beverage (water extract of dried flowers of *Aegle marmelos*, Bael fruit) in type II diabetic patients. *Journal of Diabetes and Metabolism*. 2013;4(6)
- [7] Haque N, Salma U, Nurunnabi TR, Uddin MMJ, Jahangir FK, Islam SMZ, et al. Management of type 2 diabetes mellitus by lifestyle, diet and medicinal plants. *Pakistan Journal of Biological Sciences*. 2011;14:13-24
- [8] Viuda-Martos M, Ruiz-Navajas Y, Fernández-López J, Pérez-Álvarez JA. Spices as functional foods. *Critical Reviews in Food Science and Nutrition*. 2010;51(1):13-28
- [9] Afzal M, Al-Hadidi D, Menon M, Pesek J, Dhahi MSG. An ethnomedicinal, chemical and pharmacological review. *Drug Metabolism and Drug Interactions*. 2001;18:159-190
- [10] Bode AM, Dong Z. The amazing and mighty ginger. In: Benzie IFF, Wachtel-Galor S, editors. *Herbal Medicine: Biomolecular and Clinical Aspects*. 2nd ed. Boca Raton, FL: CRC Press/Taylor & Francis; 2011. Available from: <https://www.ncbi.nlm.nih.gov/books/NBK92775/>
- [11] Grzanna R, Lindmark L, Frondoza CG. Ginger—An herbal medicinal product with broad anti-inflammatory actions. *Journal of Medicinal Food*. 2005;8(2):125-132
- [12] Ali BH, Blunden G, Tanira MO, Nemmar A. Some phytochemical, pharmacological and toxicological properties of ginger (*Zingiber officinale* Roscoe): A review of recent research. *Food and Chemical Toxicology*. 2008;46(2):409-420
- [13] Ghayur MN, Gilani AH. Pharmacological basis for the medicinal use of ginger in gastrointestinal disorders. *Digestive Diseases and Sciences*. 2005;50:1889-1897. DOI: 10.1007/s10620-005-2957-2
- [14] Nicoll R, Henein MY. Ginger (*Zingiber officinale* Roscoe): A hot remedy for cardiovascular disease? *International Journal of Cardiology*. 2009;131:408-409
- [15] Wu KL, Rayner CK, Chuah SK. Effects of ginger on gastric emptying and motility in healthy humans. *European Journal of Gastroenterology & Hepatology*. 2008;20(5):436-440

- [16] Qian QH, Yue W, Wang YX, Yang ZH, Liu ZT, Chen WH. Gingerol inhibits cisplatin-induced vomiting by down-regulating 5-hydroxytryptamine, dopamine and substance P expression in mice. *Archives of Pharmacological Research*. 2009;**32**(4):565-573
- [17] Ojewole JAO. Analgesic, anti-inflammatory and hypoglycaemic effects of ethanol extract of *Zingiber officinale* (Roscoe) rhizomes (Zingiberaceae) in mice and rats. *Phytotherapy Research*. 2006;**20**(9):764-772
- [18] Elkhishin IA, Ibrahim AA. A study of the cardiovascular toxic effects of *Zingiber officinale* (ginger) in adult male albino rats and its possible mechanisms of action. *Mansoura Journal of Forensic Medicine and Clinical Toxicology*. 2009;**17**(2):109-127
- [19] Singh A, Sanjiv D, Jaswinder S, Shankar K. Experimental advances in pharmacology of gingerol and analogues. *Pharmacy Global: International Journal of Comprehensive Pharmacy*. 2010;**2**(4)
- [20] Salim KS. Hypoglycemic property of ginger and green tea and their possible mechanisms in diabetes mellitus. *Open Conference Proceedings Journal*. 2014;**5**:13-19
- [21] Yiming L, Van HT, Colin CD, Basil DR. Preventive and protective properties of *Zingiber officinale* (ginger) in diabetes mellitus, diabetic complications, and associated lipid and other metabolic disorders: A brief review. *Evidence-based Complementary and Alternative Medicine*. 2012:10. Article ID 516870
- [22] Kalejaiye OF, Iwalewa EO, Omobuwajo OR, Oyedapo OO. Hypoglycaemic effects of Nigerian *Zingiber officinale* rhizome on experimental diabetic rats. *Nigerian Journal of Natural Products and Medicine*. 2002;**6**(1):33-35
- [23] Nammi S, Satyanarayana S, Basil DR. Protective effects of ethanolic extract of *Zingiber officinale* rhizome on the development of metabolic syndrome in high-fat diet-fed rats. *Basic & Clinical Pharmacology & Toxicology*. 2009;**104**(5):366-373
- [24] Abdulrazaq NB, Maung MC, Ni NW, Rahela Z, Mohammad TR. Beneficial effects of ginger (*Zingiber officinale*) on carbohydrate metabolism in streptozotocin-induced diabetic rats. *British Journal of Nutrition*. 2012;**108**(7):1194-1201
- [25] Jafri SA, Sohail A, Muhammad Q. Hypoglycemic effect of ginger (*Zingiber officinale*) in alloxan-induced diabetic rats (*Rattus norvegicus*). *Pakistan Veterinary Journal*. 2011;**31**(2):160-162
- [26] Morakinyo AO, Akindele AJ, Ahmed Z. Modulation of antioxidant enzymes and inflammatory cytokines: Possible mechanism of anti-diabetic effect of ginger extracts. *African Journal of Biomedical Research*. 2011;**14**(3):195-202
- [27] Lindstedt I. Ginger and diabetes: A mini-review. *Archives of General Internal Medicine*. 2018;**2**(2):29-33
- [28] [www.amazon.com/Culinary-Ginger-Zingiber-Officinalecooking/dp/B01NAJQ6C6](http://www.amazon.com/Culinary-Ginger-Zingiber-Officinalecooking/dp/B01NAJQ6C6) [Accessed: 18 July 2018]
- [29] Lamuchi-Deli N, Mohammad A, Hossein B-R, Ghorban M. Effects of the hydroalcoholic extract of *Zingiber officinale* on arginase I activity and expression in the retina of streptozotocin-induced diabetic rats. *International Journal of Endocrinology and Metabolism*. 2017;**15**(2)
- [30] de La Heras N, Munoz VM, Fernandez MB, Ballesteros S, Farre LA, Roso RB, et al. Molecular factors involved in the hypolipidemic- and insulin-sensitizing effects of a ginger (*Zingiber officinale* Roscoe) extract

in rats fed a high-fat diet. *Applied Physiology, Nutrition, and Metabolism*. 2017;**42**:209-215

[31] Wei CK, Tsai YH, Korinek M, Hung PH, El-Shazly M, Cheng YB, et al. 6-Paradol and 6-shogaol, the pungent compounds of ginger, promote glucose utilization in adipocytes and myotubes, and 6-paradol reduces blood glucose in high-fat diet-fed mice. *International Journal of Molecular Sciences*. 2017;**18**:168

[32] Al-Qudah MMA, Moawiya AH, El-Qudah JMF. The effects of aqueous ginger extract on pancreas histology and on blood glucose in normal and alloxan monohydrate-induced diabetic rats. *Biomedical Research*. 2016;**27**(2)

[33] Oludoyin AP, Adegoke SR. Effect of ginger (*Zingiber officinale*) extracts on blood glucose in normal and streptozotocin-induced diabetic rats. *International Journal of Clinical Nutrition*. 2014;**2**:32-35

[34] Anfenan MLK. Evaluation of nutritional and antidiabetic activity of different forms of ginger in rats. *Middle-East Journal of Scientific Research*. 2014;**21**:56-62

[35] Al-Noory AS, Amreen AN, Hymoor S. Antihyperlipidemic effects of ginger extracts in alloxan-induced diabetes and propylthiouracil-induced hypothyroidism in (rats). *Pharmacognosy Resarch*. 2013;**5**:157-161

[36] Abdulrazaq N, Cho M, Win N, Zaman R, Rahman M. Beneficial effects of ginger (*Zingiber officinale*) on carbohydrate metabolism in streptozotocin-induced diabetic rats. *British Journal of Nutrition*. 2012;**108**(7):1194-1201. DOI: 10.1017/S0007114511006635

[37] Iranloye BO, Arikawe AP, Rotimi G, Sogbade AO. Anti-diabetic and anti-oxidant effects of *Zingiber officinale* on

alloxan-induced and insulin-resistant diabetic male rats. *Nigerian Journal of Physiological Sciences*. 2011;**26**(1)

[38] Akhani SP, Vishwakarma SL, Goyal RK. Anti-diabetic activity of *Zingiber officinale* in streptozotocin-induced type I diabetic rats. *The Journal of Pharmacy and Pharmacology*. 2004;**56**:101-105

[39] Al-Amin ZM, Thomson M, Al-Qattan KK, Peltonen-Shalaby R, Ali M. Anti-diabetic and hypolipidaemic properties of ginger (*Zingiber officinale*) in streptozotocin-induced diabetic rats. *British Journal of Nutrition*. 2006;**96**(4):660-666

[40] Bhandari U, Kanojia R, Pillai K. Effect of ethanolic extract of *Zingiber officinale* on dyslipidaemia in diabetic rats. *Journal of Ethnopharmacology*. 2005;**97**:227-230. DOI: 10.1016/j.jep.2004.11.011

[41] Otunola GA, Afolayan AJ. Antidiabetic effect of combined spices of *Allium sativum*, *Zingiber officinale* and *Capsicum frutescens* in alloxan-induced diabetic rats. *Frontiers in Life Science*. 2015;**8**(4):314-323

[42] Sekiya K, Ohtani A, Kusano S. Enhancement of insulin sensitivity in adipocytes by ginger. *Bio Factors*. 2004;**22**(1-4):153-156

[43] Isa Y, Miyakawa Y, Yanagisawa M, et al. [6]-Shogaol and [6]-gingerol, the pungent of ginger, inhibit TNF-alpha mediated downregulation of adiponectin expression via different mechanisms in 3T3-L1 adipocytes. *Biochemical and Biophysical Research Communications*. 2008;**373**(3):429-434

[44] Rani MP, Krishna MS, Padmakumari KP, Raghu KG, Sundaresan A. *Zingiber officinale* extract exhibits antidiabetic potential via modulating glucose uptake, protein glycation and inhibiting adipocyte

differentiation: An in vitro study. *Journal of the Science of Food and Agriculture*. 2012;**92**(9):1948-1955

[45] Sattar NA, Hussain F, Iqbal T, Sheikh MA. Determination of in vitro antidiabetic effects of *Zingiber officinale* Roscoe. *Brazilian Journal of Pharmaceutical Sciences*. 2012;**48**(4):601-607

[46] Andallu B, Radhika B, Suryakantham V. Effect of aswagandha, ginger and mulberry on hyperglycemia and hyperlipidemia. *Plant Foods for Human Nutrition*. 2003;**58**(3):1-7

[47] Mahluji S, Attari VE, Mobasseri M, Payahoo L, Ostadrahimi A, Golzari SEJ. Effects of ginger (*Zingiber officinale*) on plasma glucose level, HbA1c and insulin sensitivity in type 2 diabetic patients. *International Journal of Food Sciences and Nutrition*. 2013;**64**(6):682-686. DOI: 10.3109/09637486.2013.775223

[48] Arablou T, Aryaeian N, Valizadeh M, Sharifi F, Hosseini A, Djalali M. The effect of ginger consumption on glycemic status, lipid profile and some inflammatory markers in patients with type 2 diabetes mellitus. *International Journal of Food Sciences and Nutrition*. 2014;**65**(4):515-520

[49] Mozaffari-Khosravi H, Talaei B, Jalali BA, Najarzadeh A, Mozayan MR. The effect of ginger powder supplementation on insulin resistance and glycemic indices in patients with type 2 diabetes: A randomized, double-blind, placebo-controlled trial. *Complementary Therapies in Medicine*. 2014;**22**(1):9-16

[50] Khandouzi N, Farzad S, Asadollah R, Tayebbeh R, Payam H, Mohsen MT. The effects of ginger on fasting blood sugar, hemoglobin A1c, apolipoprotein B, apolipoprotein AI and malondialdehyde in type 2 diabetic patients. *Iranian Journal of Pharmacy Research*. 2015;**14**(1):131

[51] Shidfar F, Rajab A, Rahideh T, Khandouzi N, Hosseini S, Shidfar S. The effect of ginger (*Zingiber officinale*) on glycemic markers in patients with type 2 diabetes. *Journal of Complementary and Integrative Medicine*. 2015;**12**(2):165-170

[52] Arzati MM, Honarvar NM, Saedisomeolia A, Anvari S, Effatpanah M, Arzati RM, et al. The effects of ginger on fasting blood sugar, hemoglobin A1c, and lipid profiles in patients with type 2 diabetes. *International Journal of Endocrinology and Metabolism*. 2017;**15**(4):e57927. DOI: 10.5812/ijem.57927

[53] Koch W, Kukula-Koch W, Marzec Z, Kasperek E, Wyszogrodzka-Koma L, Szwerc W, et al. Application of chromatographic and spectroscopic methods towards the quality assessment of ginger (*Zingiber officinale*) rhizomes from ecological plantations. *International Journal of Molecular Sciences*. 2017;**18**(2):452

[54] Sharma PK, Singh V, Ali M. Chemical composition and antimicrobial activity of fresh rhizome essential oil of *Zingiber officinale* Roscoe. *Pharmacognosy Journal*. 2016;**8**(3):185-190

[55] Bnouham M, Ziyyat A, Mekhfi H, Tahri A, Legssyer A. Medicinal plants with potential antidiabetic activity—A review of ten years of herbal medicine research (1990-2000). *International Journal of Diabetes and Metabolism*. 2006;**14**:1-25

[56] Yattoo MI, Saxena A, Gopalakrishnan A, Alagawany M, Dhama K. Promising antidiabetic drugs, medicinal plants and herbs: An update. *International Journal de Pharmacologie*. 2017;**13**:732-745

[57] Dearlove RP, Greenspan P, Hartle DK, Swanson RB, Hargrove JL. Inhibition of protein glycation

by extracts of culinary herbs and  
spices. *Journal of Medicinal Food*.  
2008;**11**(2):275-281

[58] Son MJ, Miura Y, Yagasaki K.  
Mechanisms for antidiabetic effect of  
gingerol in cultured cells and obese  
diabetic model mice. *Cytotechnology*.  
2015;**67**:641

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