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Implications of Dietary Vegetables on Glycemic Control- A Mechanistic Review

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Abstract

The global prevalence of diabetes mellitus is increasing day by day. Despite using synthetic anti-diabetic agents, diabetic patients must modify their lifestyle, including routine diet. Vegetables are the adequate source of vitamins, dietary fibres, minerals and Phytoconstituents. Use of vegetables is growing among the people as a part of the diet. They, with their antioxidant properties, can maintain good health and reduce the risk of chronic diseases. Besides, they contain many dietary fibres that are anti-diabetic. The constituents present in these vegetables help to reduce blood glucose level through several mechanisms such as alpha-amylase and alpha-glucosidase enzyme inhibition, Dipeptidyl peptidase IV (DPP IV) inhibition, enhancing the expression of peroxisome proliferator activator receptor gamma (PPAR) γ and glucose transporter 4 (GLUT4). Therefore the people must consume such vegetables with the proper knowledge to control diabetes mellitus and its complications. Hence the present review focuses on summarizing *in vitro* and *in vivo* anti-diabetic activity of most common dietary vegetables.

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INTRODUCTION

Diabetes mellitus is an autoimmune endocrine disorder characterized by insulin deficiency (type 1) or insulin tolerance (type 2) where the body lacks adequate utilization of carbohydrates, proteins and fat (Mathavan *et al.*, 2016). As per the World Health Organisation, global diabetes prevalence was approximately 171 million in the year 2000, and this could rise to 366 million in 2030 (Kanivalan *et al.*, 2014). In developing countries, people are using medicinal plants extensively for treating various ailments. Plants have the potential to produce an extensive range of Phytoconstituents, which offers a tremendous opportunity for the identification of anti-diabetic drugs (Qiang *et al.*, 2015).

Vegetables are the source of phyto neutraceuticals such as vitamins, dietary fibres, minerals and Phytoconstituents. People commonly use of vegetables every day as a part of the diet. They are necessary for the maintenance of good health. Through its anti-diabetic, antioxidant property, vegetables can reduce the risk of chronic diseases (Dias, 2012).

Dietary vegetables used regularly have substantial anti-diabetic property. Vegetables are involved in reducing blood glucose level in diabetes mellitus through various mechanisms such as alpha-amylase and alpha-glucosidase enzyme inhibition, Dipeptidyl peptidase IV (DPP IV) inhibition, enhancing the expression of peroxisome proliferator activator receptor gamma (PPAR) γ, glucose transporter 4 (GLUT4) and many more (Naveen and Baskaran, 2018).

Regular consumption of such dietary vegetables may provide a cost-effective beneficial effect on health. It also helps to control diabetes mellitus and its complications if administered with legitimate knowledge. Hence the present review focuses on summarizing *in vitro* and *in vivo* anti-diabetic activity of most common dietary vegetables.

In vitro anti-diabetic activities of dietary vegetables

Abelmoschus esculentus (Okara)

Table 1 *In vitro* anti-diabetic property of *A. esculentus* (Okara) peel and aqueous seed extract (AAPP and AASP) had been evaluated by performing α-amylase and α-glucosidase inhibition assay. Both AAPP and AASP demonstrated potent dose-dependent inhibition of α-amylase and α-glucosidase enzymes (Sabitha *et al.*, 2012).

Agaricus bisporus (mushroom)

Twelve different species of the ethanolic wild mushroom extract was evaluated for its *in vitro* antihyperglycemic potential by assessing glucose diffusion and α-amylase inhibition assay. These extracts are capable of inhibiting glucose diffusion and α-amylase enzyme (Maktoof *et al.*, 2019).

Allium cepa L. (onion)

Anti-diabetic activity of ethyl alcohol extract of Korean onion skin (*Allium cepa* L.) was investigated by assessing inhibition of rat intestinal α-glucosidases such as sucrose, maltase and porcine α-amylase. The extract showed a postprandial blood-glucose-lowering effect as compared to standard drug acarbose. This effect was attributed to the inhibition of α-amylase and α-glucosidases. Inhibition of these enzymes led to delayed carbohydrates absorption from the intestines (Kim *et al.*, 2011).

Allium sativum L.(Garlic)

In vitro anti-diabetic potential of *Allium sativum,* aqueous root extract at a concentration of 5, 10, 20 and 40g/L was studied by testing intestinal glucose diffusion. *Allium sativum* extract exhibited a potential reduction of glucose transportation across the diffusion membrane up to 54% in contrast to the control. Maximum inhibition of glucose movement was observed at higher doses (20 and 40 g/L). Consequently, *Allium sativum* is a better candidate for glucose homeostasis (Younas and Hussain, 2014).

Cucumis sativus (Cucumber)

Here *Cucumis sativus* fruit extract and its isolated component kaempferol were evaluated for *in vitro* anti-diabetic activity by performing alpha-glucosidase and alpha-amylase inhibition assay. Both the extract and its isolated component showed potent alpha-glucosidase and alpha-amylase inhibition activity (Ibitoye *et al.*, 2018).

Cucurbita maxima (winter squash)

Antihyperglycemic activity of *Cucurbita maxima* methanolic leaf extract was evaluated by assaying alpha-amylase inhibitory activity. The result showed potent inhibition of alpha-amylase activity (Al-Shaheen *et al.*, 2013).

Daucus carota (carrot)

In vitro glucose uptake and peroxisome proliferator-activated receptor (PPAR) γ agonistic activity of isolated polyacetylenes fractions (falcarindiol and falcarinol) of *Daucus carota* (carrot) dichloromethane root extract was investigated using porcine myotubes and 3T3-L1 adipocytes. Both the isolated fractions showed stimulation of insulin-dependent glucose uptake in a dose-dependent manner. Falcarinol enhances the activity of PPARγ at a concentration of 10 μM and Falcarindiol showed significant enhancement of PPARγ activity at 3, 10 and 30 μM. Docking studies revealed the binding of both the fractions to the ligand-binding site on PPARγ. The binding affinity of falcarindiol was little higher than falcarinol. This study confirmed the hypoglycemic activity of *Daucus carota* (El-Houri *et al.*, 2015).

Mentha (Mint)

Fresh mint leaf extract was evaluated for *in vitro* anti-diabetic activity by assessing alpha-glucosidase inhibition assay and HepG2 cells glucose uptake assay. The extract showed alpha-glucosidase enzyme inhibition by up to 90% and enhanced glucose utilization by 15%. Inhibition of alpha-glucosidase enzyme and increasing glucose uptake proved the anti-diabetic property of mint extract (Wadhawan *et al.*, 2018).

Momordica charantia (Bitter melon)

Antihyperglycemic activity of aqueous and chloroform extract of *Momordica charantia* fruit was studied by examining glucose uptake activity using L6 myotubes and also by assessing the activity of peroxisome proliferator activator receptor gamma (PPAR) γ, glucose transporter 4 (GLUT4) and phosphatidylinositol-3 kinase (PI3K). The extract showed glucose up-regulatory effect, which was compared with rosiglitazone and insulin.

Table 1: In vitro anti-diabetic activity of dietary vegetables

Sl. No	Plant Extract	Models	Results	References
1	Abelmoschus esculentus (Okara) peel and aqueous seed extract	α-amylase and α-glucosidase inhibition assay	Enzyme inhibition	(Sabitha *et al.*, 2012)
2	ethanolic wild mushroom (Agaricus bisporus) extract	glucose diffusion and α-amylase inhibition assay	Inhibition	(Maktoof *et al.*, 2019)
3	Ethyl alcohol extract of Korean onion skin (Allium cepa L.)	rat intestinal α-glucosidases (sucrase, maltase) and porcine α-amylase inhibition assay	Inhibition	(Kim *et al.*, 2011)
4	Allium sativum aqueous root extract	intestinal glucose diffusion	Reduction in glucose transportation	(Younas and Hussain, 2014)
5	Cucumis sativus fruit extract	alpha-glucosidase and alpha-amylase inhibition assay	Inhibition	(Ibitoye *et al.*, 2018)
6	Cucurbita maxima methanolic leaf extract	alpha-amylase inhibition assay	Inhibition	(Al-Shaheen *et al.*, 2013)
7	isolated polyacetylenes fractions (falcarindiol and falcarinol) of Daucus carota (carrot) dichloromethane root extract	glucose uptake and peroxisome proliferator-activated receptor (PPAR) γ agonistic activity using porcine myotubes and 3T3-L1 adipocytes	Increased glucose uptake and (PPAR) γ activity	(El-Houri *et al.*, 2015)
8	Fresh mint leaf extract	alpha-glucosidase inhibition assay and HepG2 cells glucose uptake assay	Alpha-glucosidase enzyme inhibition and increased glucose uptake in HepG2 cells	(Wadhawan *et al.*, 2018)
9	aqueous and chloroform extract of Momordica charantia fruit	glucose uptake activity using L6 myotubes and PPARγ, GLUT4, PI3K expression activity	Increase glucose uptake and expression of PPARγ, GLUT4, PI3K	(Kumar *et al.*, 2009)
10	Moringa oleifera leaf extract	α-glucosidase and pancreatic alpha-amylase activity	Inhibition	(Adisakwattana and Chanathong, 2011)
11	Pachyrhizus erosus (jicama) extract	Alpha-amylase activity, alpha-glucosidase activity	Inhibition	(Park and Han, 2015)
12	ethanolic extract of Raphanus sativus	α-glucosidase and α-amylase inhibitory activity	Inhibition	(Vadivelan *et al.*, 2012)
13	Zingiber officinale Roscoe rhizome extract	Glucose uptake activity in L6 myotubes	Increased glucose uptake	(Noipha and Ninla-Aesong, 2018)

Table 2: In vivo anti-diabetic activity of dietary vegetables

Sl. No	Plant Extract	Models	Results	References
1	Green and purple okara extract enriched with quercetin	Streptozotocin-induced diabetic rats	Increased protection of pancreatic beta cells and improved insulin production	(Anjani *et al.*, 2018)
2	Agaricus bisporus powder in 1 ml of distilled water	Streptozotocin-induced male Wistar diabetic rats	Reduction in glucose level	(Abou-Zaid *et al.*, 2017)
3	Aqueous extract of Allium cepa	Alloxan induced diabetic rats	Reduction in glucose level	(Ozougwu and Jevas, 2011)
4	Allium sativum ethanolic extract	Streptozotocin-induced diabetic rats	Decreased glucose level	Eidi *et al.* (2006)
5	Cynara scolymus (artichoke) aqueous leaf extract	Streptozotocin diabetic rats	Decreased glucose level	(Heidarian and Soofiniya, 2011)
6	Asparagus officinalis methanolic seed extract	streptozotocin-induced diabetic rats	Reduced glucose level, qualitative and quantitative improvements in the pancreatic beta cells	(Hafizur *et al.*, 2012)
7	aqueous fraction of Beta vulgaris	Laboratory mice	Increased plasma insulin, Increased level of Glucagon Like Peptide-1 (GLP-1)	(Kabir *et al.*, 2015)
8	Beta vulgaris (beetroot) ethanolic extract	Streptozotocin-diabetic rats	Reduced glucose level	Kumar *et al.* (2016)
9	Brassica nigra aqueous extract	streptozotocin-diabetic rats	Glycolytic enzyme enhanced, gluconeogenic enzyme reduced, decreased glucose level, raised insulin level	(Anand *et al.*, 2008)
10	Brassica oleracea var. capitata methanolic extract	Alloxan induced diabetic rabbits.	Lowered glucose level	Assad *et al.* (2014)
11	the ethanolic root extract of Brassica rapa (turnip)	type 2 diabetic mice (C57BL/KsJ-db/db (db/db) and db/+ mice)	Increased glucokinase activity, decreased glucose-6-phosphatase activity	(Jung *et al.*, 2008)

Continued on next page

Table 2 continued

Sl. No	Plant Extract	Models	Results	References
12	Brassica rapa (turnip) aqueous leaf extract	alloxan-diabetic rats	Alloxan-diabetic male rats	(Fard *et al.*, 2015)
13	Cucumis sativus fruit extract and its isolated component kaempferol	alloxan-induced diabetic rats	Lowered glucose level	(Ibitoye *et al.*, 2018)
14	Cucurbita pepo powder (pumpkin)	Alloxan-diabetic male rats	Alloxan-diabetic male rats, improved pancreatic beta cells	(Sedigheh *et al.*, 2011)
'15	Daucus carota methanolic seed extract	streptozotocin-induced diabetic rats	reduction in glucose level, increased insulin level, improvements in pancreatic beta-cell	(Ranjbar *et al.*, 2010)
16	peppermint essential oil	streptozotocin-nicotinamide induced diabetic rats	reduced glucose levels, regeneration of pancreatic and hepatic tissues, enhancement of insulin expression	(Abdellatief *et al.*, 2017)
17	ethanolic and methanolic fruit extract of Momordica charantia	Alloxan induced diabetic rabbits.	Lowered glucose level, regeneration of pancreatic beta cells	(Assad *et al.*, 2014)
18	Moringa oleifera methanolic pod extract	Streptozotocin-diabetic rats.	Lowered glucose level, regeneration of pancreatic beta cells	(Gupta *et al.*, 2012)
19	Pachyrhizus erosus (jicama) extract	streptozotocin-diabetic rats	Decreased glucose level	(Park and Han, 2015)
20	Raphanus sativus root juice extract	Streptozotocin-induced diabetic rats	Decreased glucose level	(Shukla *et al.*, 2011)
21	Methanolic extract of Brassica oleracea	streptozotocin-induced diabetic rats	Lowered glucose level, increased insulin level	(Sahai and Kumar, 2020)
22	Zingiber officinale juice	alloxan-induced diabetic rat	reduction of blood glucose level	(Asha *et al.*, 2011)

Enhancement of glucose uptake and glucose homeostasis might be due to the expression of PPARγ, GLUT4 and PI3K (Kumar *et al.*, 2009).

Moringa oleifera (drumstick tree)

Moringa oleifera leaf extract was evaluated for alpha-glucosidase and pancreatic alpha-amylase activity. Findings revealed the property of the extract in inhibiting both the enzymes (Adisakwattana and Chanathong, 2011) **.**

Pachyrhizus erosus (jicama)

Pachyrhizus erosus (jicama) extract was assessed for its hypoglycemic effect. Alpha-amylase and alpha-glucosidase inhibitory activity had been estimated. Inhibition of both the enzymes was observed with the extract. It was, therefore declared that the extract proved its anti-diabetic activity (Park and Han, 2015).

Raphanus Sativus (R adish)

Here, ethanolic extract of *Raphanus sativus* was tested for α-glucosidase and α -amylase inhibitory activity. The extract showed a dose-dependent inhibition of both the enzymes, but the inhibitory activity was lesser than standard drug acarbose (Vadivelan *et al.*, 2012).

Zingiber officinale (Ginger)

In vitro hypoglycemic activity of *Zingiber officinale*, Roscoe rhizome extract was evaluated by testing its glucose uptake activity in L6 myotubes and assessing the expression of glucose transporter 1 (GLUT1) and glucose transporter 4 (GLUT4). At a dose of 400 mg/kg body weight, the extract demonstrated an impressive elevation of glucose uptake in L6 myotubes due to the enhancement of GLUT1 in a time-dependent manner (Noipha and Ninla-Aesong, 2018).

In vivo anti-diabetic activities of dietary vegetables

Abelmoschus esculentus (Okara)

Table 2 Streptozotocin-induced diabetic rats were treated with quercetin-enriched green and purple okara extract for 14 days, and pancreatic histopathology was measured for each rat. Destruction of pancreatic cells by streptozotocin had been repaired by both the extract as compared to diabetic control rats. Specifically, purple okara extract at a dose of 5 mg/kg body weight showed better protection of pancreatic beta cells and improved insulin production. Hence anti-diabetic property of okara extract was verified (Anjani *et al.*, 2018).

Agaricus bisporus (mushroom)

Streptozotocin-induced male Wistar diabetic rats had been treated with 200 mg/kg body weight *Agaricus bisporus* powder in 1 ml of distilled water for 21 consecutive days, and their hypoglycemic activity was evaluated. Results showed the extract's potential to lower the raised blood glucose level. Pancreatic beta cells damaged by streptozotocin were restored, production and release of insulin were enhanced after extract treatment (Abou-Zaid *et al.*, 2017).

Allium cepa L. (onion)

Aqueous extract of *Allium cepa* has been studied for antihyperglycemic activity against alloxan-diabetic rats at varying doses (200, 250 and 300 mg/kg). Extract influenced dose-dependent blood lowering effect. The most significant hypoglycemic activity was observed at a dose of 300 mg/kg body weight (Ozougwu and Jevas, 2011).

Allium sativum L.(Garlic)

Streptozotocin-induced diabetic rats were treated with *Allium sativum* ethanolic extract orally, and its anti-diabetic activity was evaluated. Extract treatment reduces blood glucose level significantly as compared to standard drug glibenclamide (Eidi *et al.*, 2006).

Cynara scolymus (artichoke)

Streptozotocin-diabetic rats were treated with 200 and 400 mg/kg body weight of *Cynara scolymus* (artichoke) aqueous leaf extract for 21 days, and their hypoglycemic effect was observed. The extract exhibited potential hypoglycemic effect by reducing fasting blood glucose level (Heidarian and Soofiniya, 2011).

Asparagus officinalis (garden asparagus)

Anti-diabetic activity of *Asparagus officinalis* methanolic seed extract (250 and 500 mg/kg per day) was examined in streptozotocin-diabetic rats. Blood glucose level had been estimated after treating rats with the extract for 28 days. Both the doses of extract displayed a potential hypoglycemic effect dose-dependently which is almost identical to standard oral hypoglycemic drug glibenclamide. Histopathology of pancreas showed qualitative and quantitative improvements in the pancreatic beta cells of diabetic rats treated with 500 mg/kg of extract. Therefore the plant exhibited significant anti-diabetic activity (Hafizur *et al.*, 2012).

Beta vulgaris (beetroot)

Hypoglycemic activity of aqueous fraction of *Beta vulgaris* was investigated in laboratory mice. Administration of 200 mg/kg body weight of extract showed raised levels of plasma insulin after 30 minutes of treatment. The exact mechanism behind increased level of insulin was confirmed by assaying extract-treated mice with Glucagon Like Peptide-1 (GLP-1), plasma Acetylcholine, Gastric Inhibitory Peptide (GIP), Insulin-Like Growth Factor-1 (IGF-1), Pituitary Adenylate Cyclase-Activating Peptide (PACAP), Vasoactive Intestinal Peptide, Somatostatin and Pancreatic Polypeptides (PP). Quantification of glucose transporters (GLUT1 and GLUT4) and their glucose uptake activity was also measured in skeletal myocytes. Increased level of GLP-1 and plasma Acetylcholine was observed in *Beta vulgaris* treated mice. Raised level of GLUT4 and increased consumption of glucose were also observed. From the findings, it was confirmed that insulin secretion is regulated by an increased level of GLP-1and plasma acetylcholine.

Along with GLP-1and plasma acetylcholine, GLUT4 is also responsible for the hypoglycemic activity of *Beta vulgaris* extract (Kabir *et al.*, 2015). *Beta vulgaris* (beetroot) ethanolic extract (400 mg/kg) was administered to streptozotocin-diabetic rats for 21 days, and their anti-diabetic activity was compared with that of standard glibenclamide (5 mg/kg). Marked reduction in blood glucose level was observed on day 21 in diabetic rats treated with the extract. This showed potential anti-diabetic activity of *Beta vulgaris* (Kumar *et al.*, 2016).

Brassica nigra (black mustard)

Brassica nigra aqueous extract was administered orally to streptozotocin-diabetic rats for two months. Anti-diabetic activity of extract and its mode of action had been explored. The activity of the gluconeogenic and the glycolytic enzymes in the liver and kidney cells were examined. The activity of the glycolytic enzyme was reduced, and the gluconeogenic enzyme was enhanced in diabetic rats. Still, after treating diabetic rats with *Brassica nigra* the activity of these enzymes had been reversed. After two months of extract treatment, plasma glucose level was reduced, insulin level was raised, and the pancreatic release of insulin was enhanced. Hence *Brassica nigra* has been proven for its hypoglycemic activity (Anand *et al.*, 2008).

Brassica oleracea var. *capitata* (cabbage)

Alloxan induced diabetic rabbits were provided with *Brassica oleracea* var. *capitata* methanolic extract and its antihyperglycemic activity had been tested and contrasted with standard glibenclamide. Blood glucose lowering ability of extract was almost similar to glibenclamide (Assad *et al.*, 2014).

Brassica rapa (turnip)

The antihyperglycemic effect of ethanolic root extract of *Brassica rapa* (turnip) was evaluated and compared with rosiglitazone in type 2 diabetic mice (C57BL/KsJ-db/db (db/db) and db/+ mice). As per observation, the glucokinase activity was lesser, and glucose-6-phosphatase activity was more significant in the liver of the db/db mice than the db/+ mice. After extract treatment, these activities had been reversed. It also increases the ratio of insulin/glucagon and enhances the glycogen content in the liver (Jung *et al.*, 2008). *Brassica rapa* (turnip) aqueous leaf extract was administered to alloxan-diabetic rats for 28 days at a dose of 200 and 400 mg/kg body weight. Blood glucose level was estimated on 1^{st}, 14^{th} and 29^{th} day of treatment. Both the extract dose demonstrated a substantial reduction in blood glucose level after 28 days of its treatment in a dose-dependent fashion. Hence *Brassica rapa* proved its hypoglycemic activity (Fard *et al.*, 2015).

Cucumis sativus (Cucumber)

Anti-diabetic activity of *Cucumis sativus* fruit extract and its isolated component kaempferol was evaluated against alloxan-diabetic rats. Both extract and kaempferol exhibited a marked reduction in blood glucose level (Ibitoye *et al.*, 2018).

Cucurbita pepo (pumpkin)

Alloxan-diabetic male rats were treated with assorted doses of *Cucurbita pepo* powder (pumpkin). Hypoglycemic activity of pumpkin powder was compared with that of standard glibenclamide. Pancreatic histopathology was also performed. Pumpkin has proven hypoglycemic activity by reducing the level of glucose and increasing quantity and size of beta cells of islets of Langerhans of the pancreas (Sedigheh *et al.*, 2011).

Daucus carota (carrot)

Anti-diabetic activity of different doses of *Daucus carota* methanolic seed extract (100, 200 and 300 mg/kg body weight) was evaluated against streptozotocin-diabetic rats. All the doses of extract and standard drug glibenclamide (600 μg/kg) were administered to diabetic rats orally for six days. Animals were sacrificed, and serum glucose and insulin level were estimated. Histopathological study of the pancreas was also performed. All the doses of extract and glibenclamide displayed a marked reduction in glucose level. However, the raised level of insulin was observed in glibenclamide as well as the extract at a dose of 300 mg/kg body weight. Qualitative and quantitative improvements in pancreatic beta-cell were observed in 100 mg/kg of extract. Therefore *Daucus carota* seeds have exhibited potential hypoglycemic activity (Ranjbar *et al.*, 2010).

Mentha piperita (peppermint)

Here, the hypoglycemic impact of different doses of peppermint essential oil (40 and 80 mg/kg body weight) was studied among streptozotocin-nicotinamide induced diabetic rats. Diabetic rats fed with extract showed reduced blood glucose level.

Histopathology revealed pancreatic and hepatic tissues recovery and enhancement of insulin expression. The finding thereby revealed the potential hypoglycemic activity of peppermint essential oil (Abdellatief *et al.*, 2017).

Momordica charantia (Bitter melon)

Alloxan induced diabetic rabbits were treated with ethanolic and methanolic fruit extract of *Momordica charantia* for 14 days, and their anti-diabetic activity was performed.

Both the extracts of *Momordica charantia* showed potential hypoglycemic activity after 14 days of treatment which was comparable with glibenclamide. Histopathology of pancreatic cells proved beta cell regeneration (Tahira and Hussain, 2014).

Moringa oleifera (drumstick tree)

Anti-diabetic activity of *Moringa oleifera* methanolic pod extract was studied in streptozotocin-diabetic rats. Serum glucose level was elevated in diabetic rats, and pancreatic beta cells have degenerated. The dose of 150 and 300 mg/kg body weight of extract was administered to diabetic rats for 21 days.

Extract treatment demonstrated a substantial reduction of serum glucose level. Pancreatic histopathology revealed beta cell regeneration of pancreas following extract therapy (Gupta *et al.*, 2012).

Pachyrhizus erosus (jicama)

Pachyrhizus erosus (jicama) extract was assessed for its hypoglycemic effect. Blood glucose level was estimated in streptozotocin-diabetic rats following extract treatment.

Suppression of increased glucose level was observed in a diabetic population treated with extract relative to the diabetic control group (Park and Han, 2015).

Raphanus Sativus (Radish)

Streptozotocin-induced diabetic rats were treated with different doses (100, 200, 300, 400 mg/kg of body weight) of *Raphanus sativus* root juice extract and their hypoglycemic potential was evaluated and compared with glibenclamide.

The dose of 300 mg/kg body weight had been lowered the blood glucose level dramatically by 33.4% (Shukla *et al.*, 2011).

Brassica oleracea sprouts (Brussels sprouts)

Variable doses of methanolic extract of *Brassica oleracea* sprouts were administered to streptozotocin-diabetic rats for 28 days, and anti-diabetic activity was observed. Extract treatment produced positive outcomes in terms of reduction of blood glucose and enhancement of insulin level, which was comparable with glibenclamide. Among all the scheduled doses, 200 mg/kg of body weight displayed an unusual activity (Sahai and Kumar, 2020).

Zingiber officinale (Ginger)

Zingiber officinale juice was administered to alloxan-induced diabetic rats, and their antihyperglycemic activity was evaluated by comparing with metformin and glibenclamide. Blood glucose level was determined on day 1, 3, 7, 14, 21, 28, 35 and 42. *Zingiber officinale* juice exhibited a significant reduction of blood glucose level in a time-dependent manner. The finding of the study evidenced its antihyperglycemic potential (Asha *et al.*, 2011).

CONCLUSIONS

In current scenarios, the incidence of diabetes mellitus is increasing globally. Despite the use of synthetic anti-diabetic medicines, everyone needs to maintain diabetes mellitus in a regular diet. Dietary vegetables play a crucial role in enhancing the health of an individual. It is claimed that the constituents present in certain vegetables have anti-diabetic property. Routine consumption of vegetables with proper knowledge may help to manage diabetes mellitus and their associated risk through various mechanisms. Nutritional benefits, low cost and least adverse effects may promote the consumption of vegetables by the people. Further clarification and advice for the routine use of vegetables in diabetes management are required and to be researched.

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Conflict of interest

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