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Effects of functional foods on *Diabetes mellitus*

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Abstract

Problem of diabetes is on an alarming situation at present globally. A lot of research work is being performed on different types of treatments or preventive measures to curb this menace worldwide. Our traditional functional foods are very popular in protective role for many ailments. Therefore, the present review article was prepared to collect information on role of different bioactive compounds or functional foods on control or prevention of *Diabetes mellitus*. It was observed in many researches that there are a lot of functional foods like tulsi, turmeric, onion, ginger, green tea, lemon, etc. that have direct or indirect effect in prevention of the diabetes.

Keywords

Functional foods, *Diabetes mellitus*, tulsi, flaxseeds, lemon, green tea, turmeric, ginger

Introduction

What is *Diabetes mellitus*

Diabetes mellitus is a degenerative non-communicable disease which is elevated blood glucose levels or Hyperglycemia for prolonged time period. Insulin is secreted by beta cell of pancreas. Deficient insulin secretion or action may cause Hyperglycemia. It is an anabolic hormone that is essential in metabolism or maintaining haemostasis of macronutrients. As in diabetes, enough insulin is not produced, therefore Hyperglycemia may occur. A many more morbidities and mortalities can be prevented by timely diagnosis and treatment of diabetes (Food & Nutrition Care Process, 15th Edition).

Prevalence

Prevalence of diabetes increases with age, affecting 12 million people above 65 years of age that accounts for 39.7%. This higher rate of prevalence can be due to drastic increase in diabetes in younger age groups. Type 2 diabetes has been newly diagnosed among 23% of youth. Figure 1 shows the prevalence of diabetes in India.

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	YEAR	
	2019	2045
Impaired glucose tolerance (estimates) [20-79 years]		
Number of people (million)	25.2	35.7
Rank	4	3
Diabetes (estimates) [20-79 years]		
Prevalence (%)	8.9	-
Age adjusted prevalence (%)	10.4	-
Number of people (million)	77.0	134.2
Rank	2	2
Diabetes (estimates) [>65 years]		
Number of people (million)	12.1	27.5
Rank	3	2
Undiagnosed diabetes (estimates)		
Prevalence (%)	57.0	-
Number of people (million)	43.9	-
Rank	2	
Healthcare expenditure on diabetes		
Mean expenditure per person with diabetes (USD)	92.0	-
Deaths related to diabetes		
Total deaths (million)	1.0	-

*USD - US dollars; Source IDF Diabetes Atlas 2019 (Ref No: 1)

Figure 1: Prevalence of diabetes in India. (Rajendra and Viswanathan, 2021)

Types of diabetes

1. **Prediabetes:** Condition of impaired glucose homeostasis including high fasting glucose (IFG) and increased glucose tolerance (IGT) is known as prediabetes. Prediabetic people are more prone to develop diabetes or Cardio vascular diseases in future. Prediabetes is diagnosed either as fasting plasma glucose ranging from 100 to 125 mg/dL or Impaired glucose tolerance between 140 to 199 mg/dL or a value of haemoglobin A1C in the range of 5.7% to 6.4%.

2. **Type 1 diabetes:** Diagnostic symptoms of T1DM include excessive thirst, increased frequency of urination and drastic loss in weight. Primary impairment include destruction of beta cells of pancreas that may lead to insulin deficiency. This deficiency of insulin results into higher blood sugar levels, increased frequency of

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urination, excessive thirst, excessive hunger, drastic loss of weight, dehydration, electrolyte imbalance and diabetic ketoacidosis (DKA).

3. **Type 2 diabetes:** It is recognized by a combination of insulin resistance and beta-cells inefficiency. Body's levels of insulin may be normal, decreased or increased, but it's efficiency is not as per desired standard. Initially insulin resistance contributes to enhanced postprandial glucose level that is followed by a rise in fasting glucose values. Hepatic glucose production is increased with a decrease in insulin secretion that causes an enhancement in fasting blood glucose.

4. **Gestational *Diabetes mellitus* (GDM):** A rise in blood sugar level during pregnancy is known as gestational diabetes. There is an enhanced risk of developing hypertension and requirement of caesarean section due to large baby size in gestational diabetes (Food & Nutrition Care Process, 2015).

What are functional foods

- Foods containing non-nutrient naturally occurring bioactive phytochemicals known to provide health benefits, are known as functional foods. These are mainly plant derived foods
- Functional foods can be synthetically designed also by fortifying natural phytochemical in existing product to enhance its functional capacity in comparison to existing food

Beneficial role of dietary phytoestrogens has been studied by Bhathena and Velasquez (2002) in Obesity and Diabetes. Phytochemicals are not life essentials like nutrients but they have important role to achieve good health by decreasing the risk of chronic degenerative ailments. Best sources of phytochemicals are colourful fruits and vegetables. Some important phytochemicals are as following -

Allyl sulfides: These are mainly detoxifying compounds that can be derived from bulbs e.g., onions, scallions, and leeks.

Dithiolthiones and isothiocyanates: These are mainly anticarcinogens. Cruciferous vegetables like broccoli, cabbage, cauliflower, turnips etc are good sources of dithiolthiones and isothiocyanates.

Indoles: Indoles have important role in functioning of estrogen, therefore are helpful in risk reduction of estrogen-related cancers. Cruciferous vegetables are good sources of indoles also.

Isoflavones: These are known as anticarcinogenic compounds found in soyabeans.

Lignans: These are obtained in rye and flaxseed. Lignans are helpful in risk reduction of breast cancer.

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Flavonoids: There is group of phytochemicals including hundreds of compounds, these are known as flavonoids. Majority of them are very nice antioxidants while majority of them have hormone related role also. Common flavonoids are -

a. Quercetin: Tomatoes, onions, potatoes and broccoli are rich sources
b. Kaempferol: It is found in kale
c. Carotenoids: Majority of them are present in colourful fruits and vegetables. These include beta-carotene, which is obtained from orange, yellow and green vegetables. These are known to reduce risk of lung cancer. Lycopene that is derived from tomatoes, has potential to prevent prostate cancer. Green leafy vegetables are rich in leutin that is known as anticarcinogenic and found good for vision problems

Benefits of Functional Foods

Functional foods help in achieving nutrients by fortification e.g., calcium fortified orange juice or foliate enriched flours. Dwivedi and Daspaul (2013) also worked in this direction and studied about many types of traditional herbs for cure of diabetes. A similar type of review article was prepared by Rizvi and Mishra (2013) performed their research on role of Indian traditional medicines for diabetes management. It was reported that there are more than 800 plants having anti-diabetic potential. This review presented potential of bioactive ingredients in management of diabetes e.g., *Ficus religiosa, Allium sativum, Pterocarpus marsupium, Eugenia jambolana, Trigonella foenum-graecum* and *Momordica charantia.*

Review of literature

Tulsi

Agrawal et. al (1996) did randomized control trial on diabetes and intervention with basil leaves. Study reflected hypoglycemic effect of leaf extract of *Ocimum sanctum* and *Ocimum album*. Results revealed a remarkable reduction in preprandial (21.0 mg/dl) and postprandial levels (15.8 mg/dl) of blood glucose after administration of holy basil leaves.

A research was performed by Hussain et. al (2001) on streptozotocin induced diabetes in rats. They performed their research on hypoglycaemic, hypolipidaemic qualities of tulsi. A significant reduction was found in fasting blood sugar and improvement was seen in glucose tolerance in this study after tulsi extract intervention.

In one more research trial, it was found that there was no remarkable alteration in blood glucose levels after 3 weeks of intervention with white *Ocimum sanctum* in diabetic rats, while glucose level was decreased in pre-treated diabetic rats. Drastically rise was observed in lipid profile and liver function tests in STZ-induced diabetes (Suanarunsawat and Songsak, 2005)

Das and Vasudevan (2006) also studied about holy powers of Tulsi. It was reflected in their research that its extract has many pharmacological properties like hypoglycaemic,

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immunomodulatory, antipyretic, stress relieving, pain killer, ulcer protective, radioprotective, antitumour and antihypertensive. The active functional group of tulsi are its volatile oils named eugenol and b-caryophyllene.

Modak et. al (2007) studied about Indian medicinal herbs for diabetes management. These included *Tinospora cordifolia*, *Eugenia jambolana*, , *Pterocarpus marsupium, Ocimum sanctum*, *Phyllanthus amarus*, A*llium sativum*, *Trigonella foenum* and *Withania somnifera*. Damage from free radicals was found a major contributing risk factor for diabetes and its complications. Therefore compounds rich in antioxidants prove to be beneficial.

Similarly Kochhar et. al (2009) performed a research on tulsi (*Ocimum sanctum*) and neem (*Azadirachta indica*) leaf powder supplementation on symptoms of diabetes, anthropometry and stage of hypertension in Non-insulin dependent *Diabetes mellitus* (NIDDM) patients. Significant reduction was noted in diabetic symptoms. Remarkable decline was observed in polydypsia, polyphagia and symptom of headache.

Flaxseeds

Effect of flaxseeds was studied by Thakur et. al (2009) on blood glucose and cholesterol in type-2 diabetic patients. The blood biochemistry showed a significant decrease in fasting blood sugar (154±8 mg/dl to 136±7 mg/dl (*P*=0.03). Simultaneously, a reduction of 11% was noticed in total cholesterol levels.

Abuelgassim (2010) conducted study on effect of flaxseeds and date palm leaves on glucose and lipids serum profile of Alloxan diabetic rats. It was reported that concentration of glucose in these rats remarkably decreased after intervention of flaxseed extract.

Flaxseeds contain 32 - 45% oil, 50% of which mainly comprise of alpha linolenic acid. Flaxseeds have antioxidant hypolipidemic and hypoglycemic properties. Dusane and Joshi (2013) studied about glucose levels of streptozotocin induced diabetic mice after flax seeds extract intervention. *Linum usitassimum* brought about a significant decline in pancreatic and intestinal glucosidase inhibitory activity. Flax seeds are the source of flax lignan complex and secoisolariciresinol diglucoside (SDG). Prasad and Dhar (2016) observed in their research that SDG administration declined diabetes incidence by 75% in the streptozotocin model and by 72% in the BBdp rat model. Rehman et. al (2021) stated that different amounts of these seed extracts resulted in better glycaemia control in rats and humans, which proves anti-diabetic properties of flax seed.

Onions

Kumari (2002) studied medicinal properties of S-methyl cysteine sulfoxide (SMCS) derived from onions (*Allium cepa* Linn). It was found that standard drugs had a better action in amelioration of diabetes, while SMCS proved better as an antioxidant.

Ozougwu (2011) studied effects of *Allium cepa* extracts on alloxan-induced diabetic rats and reported in their research that a significant ($P<0.05$) reduction in blood glucose and

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total serum lipid profile was noted with increased dosages of *Allium cepa* extract. The dose of 300 mg/kg brought best percentage reduction in the sugar profile.

Similarly effect of *Allium cepa* was studied by Anthony et. al (2015) on Streptozotocin induced diabetes. Results showed that there was a reduction of 50% in fasting blood glucose levels at the dose of 0.4g/100gbw and 35.05% on administration of 0.6g/100gbw dose of *Allium cepa* respectively.

Lamiaceae family

Kwon et. al (2006) studied about effect of herbs from Lamiaceae family in controlling diabetes and blood pressure. Similarly Oboh et. al (2017) studied role of essential oils from peels of orange and lemon on enzymes suppression that were causative factor for diabetes and hypertension. It was demonstrated that the essential oils decreased enzymatic activities. Research findings showed that essential oils obtained from both lemon and orange peels have potential anti-diabetic and anti-hypertensive properties with better performance of lemon peels in comparison to orange peels.

Green tea

Role of green tea polyphenols was studied by Sabu et. al (2002). It was found that elevated liver and kidney enzymes produced by alloxan were reduced significantly (P<0.001) by Green Tea Polyphenol (GTP). Green tea polyphenols increased the liver glycogen significantly (P<0.001) which was decreased from alloxan administration. Rue et. al (2006) also investigated role of green tea in resistance to insulin in type 2 diabetic patients. It was found that inflammatory markers like hsCRP and IL-6 didn't change after green tea ingestion. Similarly, no change was observed in blood glucose levels, lipid biochemistry and serum adiponectin levels.

No link was found between risk of diabetes and consumption of black or oolong teas (Hiroyasu et. al, 2006). Another study conducted by Toolsee et. al (2013) indicated a reduction in waist-hip ratio of women after consumption of green tea and a reduction in mean arterial pressure of men and women was also seen after 14 week consumption. Park et. al (2014) reviewed an article on impact of green tea or coffee consumption on type 2 diabetes. They reported that daily consumption of tea catechins contributed in diabetes control. However, different researches have exhibited that green tea consumption for long duration may result in liver damage, nerves problems and increase in risk of diabetes, it suggests that there are large inter individual variations.

Turmeric

Arun and Nalini (2002) studied about effect of turmeric or curcumin on diabetic rats and found a significant reduction in the blood sugar and glycosylated hemoglobin levels. Curcumin consumption caused a reduction in the oxidative stress also. Lower stress levels was measured in terms of TBARS (thiobarbituric acid reactive substances), that may be contributed to reduced influx of glucose into the polyol pathway. It leads to an enhanced

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ratio of NADPH/NADP and enhanced antioxidant enzyme GPx. Similar type of research was performed by Mohan Kumar and McFarlane (2011) on effect of *Curcuma longa* rhizome extract on insulin haemostasis.

Gupta et. at (2012) studied involvement of turmeric at molecular level in cell-signalling pathways. In many clinical trials, its efficacy has been observed in lupus nephritis, acne, cancer, fibrosis, diabetes and many more diseases. Lekshmi et. al (2012) investigated role of turmeric volatile oil in type 2 diabetes. Glucosidase enzymes inhibition was more prominent by turmeric volatile oils in comparison to reference standard drug acarbose.

Role of turmeric and it bioactive constituents was studied by Zhang and Kitts (2021) against diabetes and cardiovascular problems. Curcuminoids and essential oils obtained from turmeric are known to have good bioactive functions. Curcumin play a very important role in many cell signalling pathways that are linked to the heart and diabetes.

Ginger

Gingerol and shogaol, the pungency producing ingredients of ginger, have important role in many problems including diabetes (Li et. al, 2012). Roufogalis (2014) also studied that ginger extract lowered the level of fatty liver in rats who were on high fat diet. The major active component of ginger, i.e. gingerol inhibited inflammation and protected from the reactive oxygen species (ROS) pathways.

Huang et. al (2019) worked on dietary ginger as a traditional therapy for control of blood sugar in diabetic patients. It was quoted in their research that no remarkable change was observed on fasting blood sugar in type 2 diabetic patients who did not consume ginger. A significant improvement in HbA1c was observed in the experimental group, who consumed ginger in comparison to control group, where no significant difference was found in HbA1c levels.

Conclusion

Diabetes is a global problem now-a-days. Tremendous researches have been carried out on different preventive measures to control diabetes and other non-communicable degenerative diseases. As functional foods are very popular having protective role for many ailments. Therefore, the present review article was prepared to collect information on role of different bioactive compounds or functional foods on control or prevention of *Diabetes mellitus*. Above researches revealed there is a lot of potential in functional foods like tulsi, turmeric, onion, ginger, green tea, lemon etc. in prevention of the diabetes. Therefore the best approach to manage diabetes is timely diagnosis with proper treatment including healthy diet with moderate use of functional foods.

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