Oxidative Stress and Diabetes Mellitus: A Brief Overview

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Abstract

Through constant exposure to various stimuli, the human body produces reactive species known as free radicals (ROS/RNS), which oxidise cellular machinery by transferring their free unpaired electrons. To combat these harmful species, the body possesses endogenous antioxidant mechanisms or gets exogenous antioxidants from food, which counteracts these species and maintains the body's homeostasis. The growth of pathological conditions, including diabetes, is caused by "oxidative stress," which is created when there is an imbalance among the reactive species and antioxidants. The majority of research links oxidative stress to the pathophysiology of diabetes by examining alterations to enzymatic systems, peroxidation of lipids, poor glutathione metabolism, and reduced vitamin C levels. Several biomarkers of oxidative stress in patients with diabetes include protein, lipids, DNA damage, glutathione, catalase, and superoxide dismutase. Diabetes problems caused by oxidative stress can include retinopathy, nephropathy, stroke, and neuropathy. Providing a general overview of oxidative stress and its role in diabetes mellitus was the main goal of this review and we also covered a few medicinal plants in the review that have been shown to have anti diabetic properties effects due to their antioxidant properties. We also talked about the role of free radicals in diabetes and how the antioxidants found in the herbs scavenge them. Diabetes has a complicated and multidimensional relationship with oxidative stress and antioxidants. Despite the fact that oxidative stress also has a major effect, antioxidants are essential for preventing diabetes. In order to create customised antioxidant-based diabetes management and prevention methods and to completely understand the mechanisms driving oxidative damage in diabetes, more study is required.

***Keyword*:** Diabetes mellitus, oxidative stress, free radical, reactive species, herbs.

Introduction

Diabetes mellitus (DM) is a long-term, progressive metabolic disease that is characterised by increased blood glucose levels, or persistent hyperglycemia. Defects in either insulin action, secretion, or both can cause this syndrome. Blood glucose levels are controlled by the pancreatic hormone insulin. A variety of immediate and long-term issues result from diabetes, which affects the body's ability to use or produce insulin efficiently. A serious public health concern, diabetes mellitus (DM) is one of the most prevalent endocrine (hormone-related) illnesses in the world, contributing significantly to morbidity, death, and economic burden [1].

Types of diabetes mellitus

Diabetes mellitus can be classified in different ways butone form of classification is as follow (American Diabetes Association,2004):

1.Type I diabetes (Insulin dependent) is due to immune mediated beta-cells destruction, leading to insulin deficiency.

2. Idiopathic diabetes is the type1diabetes with no known etiologies and is strongly inherited.

3.TypeII diabetes (NonInsulin dependent) is due to insulin secretory defect and insulin resistance.

4.Gestational diabetes mellitus is any form of intolerance to glucose with onset or first recognition of pregnancy. However diabetes is mostly classified basically in to TWO major types: Type I Diabetes (IDDM) and Type II Diabetes (NIDDM) [2].

Epidemiology

By 2030, there will be 552 million people with diabetes mellitus, up from an estimated 366 million in 2011. Type 2 diabetes is becoming more prevalent worldwide, with 80% of those who have the disease residing in countries with low or middle incomes. In 2011, 4.6 million people died from DM. By 2030, 439 million individuals are predicted to develop type 2 diabetes. Risk factors related to lifestyle and the environment cause significant regional variations in the occurrence of type 2 diabetes. It is anticipated that within the next 20 years, the incidence of diabetes mellitus in adults—of which type 2 is becoming more prevalent—will rise, with developing nations accounting for the majority of these increases, where patients are primarily between the ages of 45 and 64 [3].

Etiology of Diabetes Mellitus

The word etiology is derived from Greek word “aetiologia”. Hence, etiology is defined as the science of finding causes and origins in which a disease is arise, It includes –

1.Nowadays, it is believed that the juvenile-onset (insulin-dependent) form has an auto-immune origins.

2.Like coxsackie B, viruses may also trigger the development of diabetes.

3. It has been demonstrated that the mumps and rubella viruses cause morphologic changes in the structure of the islet cells.

4. The genetic role in the etiology of diabetes is controversial. Possibly a genetic trait makes an individual’s pancreas more susceptible to one of the above viruses [4].

Some Common Sign and Symptoms

Cells with diabetes mellitus are essentially starving because they are unable to metabolise glucose normally. Diabetes mellitus's long-term effects include the progressive development of certain complications such as retinopathy, which can result in blindness, nephropathy, which can cause renal failure, and neuropathy, which can trigger foot ulcers, Charcot joints, autonomic dysfunction, and sexual dysfunction. People with diabetes are at increases risk of diseases [5]. Other, various symptoms are observed due to

i. Gluconeogenesis from body protein and amino acids, which raises blood glucose levels and causes tissue breakdown and muscle atrophy.

ii. Catabolism of body fat, releasing some of its energy and excess production of ketone bodies [6].

Causes of Diabetes Milliteus

Disturbances or abnormalities in the ß cell's gluco-receptor that cause them to react to elevated glucose levels or relative ß cell insufficiency. Either way, there is a reduction in insulin secretion, which could lead to ß cell failure. The direct effects of hyperglycemia on neuronal metabolism and the theory of principle in microvascular illness that causes neural hypoxia [9].

1.Decreased insulin sensitivity in peripheral tissues: fewer insulin receptors, or "down regulation" of insulin receptors. Many have normal glycaemic levels but are hypersensitive and hyperinsulinaemic; they also have dyslipidaemia, hyperuriemia, and abdominal obesity. Relative insulin resistance is thus present, especially at the liver, muscle, and fat levels. It has been suggested that hyperinsulinemia causes angiopathy [7].

2.Obesity and excess levels of the hormones glucagon and hyperglycemia lead to a relative lack of insulin, which leads the ß cells to lag behind. Two hypotheses have shown that changes in nitric oxide metabolism lead to nerve injury and altered perineural blood flow [8].

3. various uncommon types of diabetes mellitus include those caused by particular genetic flaws (type 3), such as gestational diabetes mellitus (GDM), pancreatectomy, various endocrine problems, and "maturity onset diabetes of young" (MODY) [7].

4. Diabetes mellitus may result from an imbalance in a particular receptor. Glucagon-like peptide-1 (GLP-1) receptor, peroxisome proliferator activated (γ) receptor (PPARγ), beta3 (ß3) ardent-receptor, and enzymes such as α glycosidase and dipeptidyl peptidase IV enzyme are a few examples of specialised receptors [7].

5. The polyol pathway, protein kinase C, advanced glycation-end products, and oxidative stress are the main topics of current research on diabetic neuropathy [9].

Oxidative stress in diabetes mellitus

Oxidative stress is thought to be a significant factor in the emergence of vascular problems in diabetes, especially type 2 diabetes [10]. ROS level increases India diabetes may be due to decrease in destruction or/and increase in produced by catalase (CAT–enzymatic/non-enzymatic), superoxide dismutase (SOD) and glutathione peroxidase (GSH–Px) antioxidants.Variations in these enzymes' levels expose the tissues to oxidative stress, which can result in the development of problems from diabetes [11]. Epidemiological research indicates that vascular diseases other than hyperglycemia are a significant contributing factor to diabetic mortality [10].

Pathophysiology of oxidative stress in diabetes

Evidence supporting the significance of oxidative stress in the pathophysiology of type 1 and type 2 diabetes has recently been reported. Non-enzymatic protein glycation, glucose oxidation, and elevated lipid peroxidation in diabetes cause free radical production, which damages enzymes and cellular machinery and increases insulin resistance as a result of oxidative stress [12]. Recent studies have shown that oxidative damage in diabetes complications is caused by both the lipid and the apolipoprotein component of LDL, which forms insoluble aggregates oxidatively due to cross-linking between apo-B monomers triggered by hydroxyl radicals The primary causes of oxidative stress in diabetes mellitus are mitochondria [13]. A portion of the oxygen used during oxidative metabolism in mitochondria is reduced to water, while the remaining oxygen is changed into oxygen free radical (O), a significant ROS that is then converted to other RS such ONOO, OH, and H2O2. ROS/RNS modulates insulin signalling in two ways.On one side, in response to insulin, the ROS/RNS are produced to exert its full physiological function and on the other side, the ROS and RNS have got negative regulation on insulin signaling, interpreting them to develop insulin resistance which is a risk factor for diabetes type 2 [14].

Oxidative stress and diabetic complications

Numerous experimental findings have demonstrated a connection between diabetes and oxidative stress by the measurement of several biomarkers, such as lipid peroxidation products and DNA damage biomarkers [15]. Free radicals are thought to play a significant part in the development and advancement of late-stage diabetes complications because of their capacity to harm proteins, lipids, and DNA. Oxidative stress causes a number of clinical illnesses, including cancer, diabetes mellitus, and rheumatoid arthritis [16]. Cardiovascular disease, neuropathy, nephropathy, retinopathy [18] and stroke [17] are among the consequences of diabetes mellitus that are brought on by free radicals and oxidative stress. Studies conducted in vivo provide evidence that hyperglycemia contributes to the development of oxidative stress, which results in endothelial dysfunction in diabetes patients' blood vessels. Patients with diabetes who have elevated insulin and glucose levels and dyslipidaemia develop macroangiopathies, which result in oxidative stress and atherosclerosis.

The role of free radicals in diabetes that are scavenged by antioxidants found in herbs

Syzygium kanarense

Some Syzygium species have long been used to treat diabetes, and many species are being studied for their antidiabetic qualities. The purpose of this study is to assess Syzygium kanarense (Talbot) Raizada's antidiabetic effectiveness. The α-glucosidase and α-amylase-inhibitory assays were used to evaluate the antidiabetic efficacy of methanol and water extracts of the leaf (SKLM, SKLW) and the bark (SKBM, SKBW) in vitro. A non-obese type 2 diabetic rat model created by streptozotocin-nicotinamide (STZ) and the oral glucose tolerance test (OGTT) were used to assess the antidiabetic efficacy of the medication.The effectiveness of antioxidants was evaluated using the DPPH test. Talk about Plant secondary metabolites, such phenolic compounds, have a significant effect on antihyperglycemic action and shield cells from oxidative stress. In diabetic rats, flavonoids such as quercetin and myricetin that are isolated from a variety of Syzygium have been demonstrated to revitalise pancreatic cells and enhance insulin signalling, especially in type 2 diabetes. The existence of several phytochemicals was verified; in comparison to leaf extracts, phenols and flavonoids were the most prevalent in Syzygium kanarense bark extracts. One of the main causes of diabetes is oxidative stress, which is brought on by a change in the ratio of oxidants to antioxidant in cells and tissues. This leads to cellular damage. It is commonly known that Syzygium species have antioxidant properties.

Numerous Syzygium species have yielded well-researched antioxidant polyphenolic chemicals, including catechin, gallic acid, myricitrin, and quercitrin. Every extract examined in this investigation shown remarkable antioxidant activity [19].

Fibraurea tinctoria Lour

Akar Kuning, or yellow root, is a yellow vine Fibraurea tinia that has long been used by indigenous tribes in Kalimantan as a traditional treatment for a number of ailments, including diabetes, jaundice symptoms, and malaria. Often utilised for medicinal purposes are the stems, bark, roots, and leaves. Known to produce roughly 22 different types of alkaloids, it is categorised as a member of the Menispermaceae family. The pharmacological properties of berberine and other protoberberine alkaloids, including their antidiabetic and antioxidant actions, have been demonstrated. A quaternary ammonium salt found in a variety of plants, berberine is a yellow alkaloid that belongs to the protoberberine group of isoquinoline alkaloids. Palmatine is one berberine derivative among many others. Rats with STZ-induced diabetes exhibited increased insulin levels and decreased blood glucose levels when administered palmatine (10 mg/kg for six weeks). These changes are associated with reduced oxidative stress, as indicated by higher SOD enzyme activity and lower MDA levels. In a related study, palmatine at a dose of 2 mg/kg for 90 days mitigated oxidative stress in animal models of STZ-induced diabetes mellitus, evidenced by decreased MDA levels and increased GSH, SOD, CAT activity Palmatine the potential to activate antioxidant-related proteins, which protect cells ROS andoplasmic stress animal models of STZ-induced diabetes mellitus. By preventing the production of free radicals, which are crucial for glucose auto-oxidation and non-enzymatic protein glycation, palmatine's potent antioxidant action reduces insulin resistance and the antioxidant defence system. The production of advanced glycation end products (AGEs), which contribute to the pathological consequences of diabetes mellitus, is also said to be effectively inhibited by palmatine's capacity to chelate metal ions and minimise and prevent lipid peroxidation. By reacting with the carbonyl groups of reducing sugars and dicarbonyl intermediate molecules, palmatine can prevent the formation of AGEs. Because of its antioxidant qualities and capacity to absorb reactive carbonyls, palmatine is said to have anti-glycation activity [20].

Withania somnifera

The current investigation shows that phenolic chemicals, flavonoids, and antioxidant activities are present in WSREt and WSLEt. It also offers proof that rats can recover from the diabetes damage that alloxan causes. Moderate islet enlargement and a considerable reduction in the extent of pancreatic lesions were observed upon administration of WSREt, WSLEt, and glibenclamide. This could be because β-cell renewal and regeneration result in more insulin being produced and secreted. These liver and pancreatic outcomes were comparable to those seen in diabetic rats treated with plant drugs and given alloxan. According to the current study, oxidative stress and free radical production can be effectively prevented by using W. somnifera roots and leaf extracts as a chronic treatment for diabetes. while compared with normal control rats, diabetic rats' liver, kidney, and heart showed decreased SOD, CAT, and GPx activities, respectively. The inactivation of the enzyme by the action of hydrogen peroxide or glycation, which often occurs during diabetes, may be partially responsible for the decrease in SOD and GPx activity in diabetic rats. By scavenging free radicals, it is thought that both WSREt and WSLEt may have contributed to the recovery from diabetes conditions. By absorbing and converting superoxide to hydrogen peroxide—which is readily converted to water by CAT and GPx in mammals—SOD plays a crucial part in oxygen defence metabolism. convert organic hydroperoxides, including hydrogen peroxide, into non-toxic byproducts. Because of the buildup of harmful compounds, the reduction in GST activity may cause harmful oxidative alterations. GSH is changed into an oxidised form during this process. A high level of GSH may activate GPx, which lowers lipid peroxidation in diabetic rats. GSH also functions as a free radical scavenger and helps eliminate reactive intermediates by reducing hydrogen peroxide. According to the current study, GSH and GPx levels in the liver, kidney, and heart decline during the diabetes era, but they significantly increase after receiving WSREt and WSLEt treatment. GPx and GST activity will inevitably be impacted by decreased GSH levels in diabetic animals since glutathione-dependent enzymes depend on GSH availability. The activity of GST was likewise significantly reduced in diabetic rats in this investigation; however, the decline returned to almost normal after WSREt and WSLEt treatment. Withania extracts have strong antioxidant properties, as evidenced by the considerable ($p<0.05$) rise in plasma vitamin C and E in diabetic rats following WSREt and WSLEt administration. When plasma is exposed to reactive oxygen species, vitamin C is a great hydrophilic antioxidant because it vanishes more quickly than other antioxidants. Because GSH is necessary for the re utilisation of vitamins C and E, a decrease in GSH levels could be the cause of the drop in plasma levels of these nutrients, or it could be the result of their greater use as antioxidant defences against elevated reactive oxygen species [21].

Allium cepa L

A member of the Amaryllidaceae family, Allium cepa L is a widely consumed vegetable that is rich in nutrients and antioxidants. The nutritional and medicinal potential of onion bulbs is still being investigated, albeit at a very modest pace, despite the valuable dietary applications of these bulbs. The peel and exterior fleshy layers are typically considered waste. The goal of the current study was to compare the antioxidant capacity of two components of Allium cepa: the edible bulb and the inedible outermost fleshy layer and dry peels. Additionally, the inhibitory impact of onion bulb and peel extracts on rat intestinal α-glucosidase and pig pancreatic α-amylase was further assessed. H_2O_2 radical scavenging activity, ferric-reducing antioxidant power assay (FRAP), 2,2-diphenyl-1-picryl hydrazyl (DPPH), 2,2'-azino-bis-3-ethylbenzothiazoline-6-sulfonic acid (ABTS) radical scavenging assay, and Fe^{2+} chelating activity were used to assess the antioxidant potential of onion peel and bulb extracts. Onion peel ethanolic extract has a substantially higher total flavonoid and phenolic content than onion bulb extract. While the aqueous extract of the bulb showed the weakest antioxidative potential, the ethanolic extract of onion peel likewise shown superior antioxidants and free-radical scavenging activity. The phenolic and flavonoid levels of onion peel extract were also linked to its ability to inhibit α-glucosidase. According to the current research, onion peel may include phenolic compounds and antioxidative agents that could help prevent the onset of a number of prevalent chronic illnesses that may be linked to oxidative stress. In addition, the onion's fleshy peels and outer dry layers had higher levels of antioxidant activity and phenolic content than the core bulb [22].

Table 1. Several plants that have been found to have anti-diabetic qualities due to their antioxidant capacities are listed below.

S.NO	AUTHORS	TITLE OF WORK	PART USED	IN-VITRO MODELS USED	IN-VIVO MODELS	CONCLUSIONS
1	Aminu Ibrahim et al.,	In Vitro Antioxidant and Anti-Diabetic Potential of GymnemaSylvestre Methanol Leaf Extract	Leaves	DPPH Spectrophotometric Assay, Hydrogen Peroxide Scavenging Effects, Hydroxyl Radical Scavenging Activity,Estimation of Reduced Glutathione, Assay of Catalase,Assay of Superoxide Dimutase, alfa-Amylase and alfa-glucosidase Inhibition Assay	Alloxan monohydrate induced diabetes	In conclusion, It is proved that methanolic leaf extract of Gymnema Sylvestre is a potential antioxidant and hypoglycemic effects in treating diabetes induced by alloxan. we put this forward due to presence of phytochemical constituents like saponins, flavanoids and phenolic compounds like catechol and resorcinol. Works as an efficient alternative inhibitor of alpha amylase and alpha glucosidase enzymes in management of non-insulin dependment diabetes mellitus [23].
2	Iran J et al.,	Influence of Total Anthocyanins from Bitter Melon [Momordica charantia Linn] as Antidiabteic and radical scavenging agent	Fruit	alfa-Amylase and alfa-glucosidase Inhibition Assay; DPPH, DMPD, ABTS radical scavenging activity;	-	M.charantia fruits are proven for treatment of diabetes by reduction of alpha-amylase and alpha-glucosidase enzymes activities due to their presence of anthocyanin contents in it. In addition to this TAMC samples demonstatred scavenging activities depended on DPPH, DMPD, ABTS regulating oxidative stress [24].
3	Debidas Ghosh et al.,	Antidiavbetic and Antioxidant effects of aqueous	seed	Lipid peroxidation level in hepatic tissue,	Streptozotocin induced diabetes	It is proved that composite extracts of above plants parts have more potential antidiabetogenic activity than separate extract by

		extract of seed of Psoralea corylifolia and seed of Trigonella foenum-graecum in Separate and composite manne		activities of carbohydrate metablic enzymes in hepatic tissue, Activity of Serum GOT and GPT		effecting the activities of key carbohydrate metabolic enzymes like hexokinase, glucose-6-phophatase and antioxidant enzymes like catalase, peroxidase and superoxide dismutase along with lipid peroxidation level in hepatic tissue and serum transaminase activity [25] .
4.	Ahutosh gupta et al.,	Antioxidant and Antidiabetic activities of Terminalia bellirica fruit in alloxan induced diabetic rats	Fruit	DPPH radical scavenging activity,Reducing power assay,Hydroxyl radicak scavenging activity,IN-vitro alpha-amylase inhibitory assay,Total antioxidant capacity determination by phosphomolybdate	Alloxan –induced diabetes in rats	The study revealed that ethyl acetate and aqueous extracts of T. bellirica fruit have considerable antioxidant and a-amylase inhibitory activity. In diabetic rats, both the extracts have shown blood glucose lowering activity coupled with improvement in body weight, lipid profile and renal function. The activity of ethyl acetate extract was superior to aqueous extract [26].
5	H.Kirana, SS Agarwal et al.,	Aqueous extract of Ficus religiosa Linn. Reduces oxidative stress on experimentally induced type 2 diabetes rats	DriedBark	Determination of catalase activity, Determination of superoxide dismutase activity,glutathione peroxidasein erythrocyte lysate,	Streptozotocin induced neonatal rat model	This study demonstrates the aqueous extract of F. religiosa had significant antidiabetic activity and had been reported to contain phytosterols, flavanoids, tannins, furanocoumarin dvt namely bergapten and bergaopyol. Flavanoids isolated from the bark have insulin secretogogue action. Antioxidant property of flavanoids coupled with their nutritional value may be responsible for rejuvenation of pancreas [27]

6	Gunawan p. widodoa et al.,	Antihyperglycemic, antioxidant, and pancreas regeneration activities of black cumin (nigella sativa l.) seeds ethanol extract in alloxan-induced diabetic rats	seeds	Standard SOD measurement method,GPx activity determination	Alloxan induced diabetic condition rats	N. sativa seeds extract dose of 125 and 250 mg/kg showed antihyperglycemic effect, enhanced antioxidant activity, as well as pancreas regeneration from organ damage on an alloxan-induced diabetic rat. Further studies are needed to investigate and elucidate the mechanism of action of active compounds of NSE [28].
7	Rashmi Goswami et al.,	Unveiling the Medicinal potential of Berberis aristate: A traditional native plant of Uttarakhand	Root	DPPH radical scavenging FRAP assay Hydroxyl radical scavenging	alloxan induced diabetic rats	Berberis aristata is a valuable medicinal plant with a rich heritage and significant potential for treating various health conditions. The various phytoconstituents present in the plant make it a good source of antioxidants. Its diverse pharmacological properties and studies shows that it has good anti-diabetic activity. These properties make it a suitable plant for herbal therapy as an alternative to conventional medicine [29].
8	HP Gajera Shila N et al.,	Antidiabetic and Antioxidant functionality associated with phenolic constituents from fruit parts of indigenous black jamun(Syzygium cumini L.)landraces	Fruit parts	Alpha-Amylase inhibitory activity, DPPH radical scavenging activity	Streptozotocin (STZ) induced diabetic rats, Alloxan induced diabetic rats	The six black jamun landraces produces different size of fruits. Fruit size was negatively correlated with antidiabetic, antioxidant activities and phenolic acids. Smaller fruits showed higher antidiabetic and antioxidant activities in their fruit part compared to larger one. The methanolic kernel extract of BJLR-6 evidenced lowest IC_{50} value followed by seed, seed coat and pulp. Methanolic extracts of discarded seed and kernel of BJLR-6, showing high inhibition of PPA, could be considered the better source for herbal

						formulations of antidiabetic drugs [30].
9	IIhami Gulcin Ruya Kaya et al.,	Antidiabetic and Antioxidant activities of cinnamon (Cinnamomum verum) bark extracts: polyphenol content analysis by LC-MS/MS	Dried cinnamon (lyophilised aqueous extraction)	Reducing ability assay, Radical scavenging activity(DPPH)	Alloxan induced diabetic models	The evaluation of the bioactivity and phytochemical screening of WEC and EEC had great importance. The WEC and EEC, as natural sources of phenolic compounds, were examined for their biological activities including antioxidant activities and some metabolic inhibitory properties. The WEC and EEC were found as having potent antioxidant properties in several bioanalytical assays including Fe^{3+} and Cu^{2+} reducing abilities, as well as DPPH· and ABTS•+ radical scavenging activities. In addition, both extracts were found as having powerful antioxidant activity and inhibitory effects on the indicated metabolic enzymes. Ethanol was efficient for the extraction of phenolics with the effective α-glycosidase, AChE, and α-amylase inhibition [31].
10	Yousif Y. et al.,	Antioxidant related effects of Zingiber officinale Roscoe (Ginger) extracts in humans	Ginger extract	DPPH radical scavenging	Determination of serum total antioxidant status (TAS) Determination of serum	The antioxidant related effects of ginger on healthy humans that have been obtained by the present in vivo study are comparable with that reported in animals exposed to oxidative stress. Ginger have efficient antioxidant related effects on humans with no adverse

					biochemical parameters	effects, indicating that this plant might be helpful in preventing the occurrence or progress of pathological conditions related to oxidative stress [32].
11	Nithin Sharma et al.,	Evaluation of the Antifungal, Antioxidant, and Anti-Diabetic potential of the essential oil of Curcuma longa leaves from the North-Western Himalayas by In Vitro and In Silico Analysis	leaves of C. longa	DPPH radical scavenging and Ferric Reduction capacity (FRAP) method	Alloxan induced diabetic rats, High-fat diet and low dose STZ	Traditional medicinal herbs offer a wealth of phytocompounds, including essential oils. Essential oil of C. longa leaves Antidiabetic activity. 3,7-cyclodecadien-1-one,3,7-dimethyl10(1methylethylidene) of CLO showed higher interaction towards the antidiabetic receptors [33].
12	Mater H et al.,	Phytochemistry,anti-diabetic and antioxidant potentials of Allium consanguineum Kunth	Fresh leaves and Rhizomes	Alpha-amylase inhibition assay, Alpha-glycosidase inhibition assay, DPPH radical scavenging activity, FRAP assay	Streptozotocin (STZ) induced diabetic rats	It can be assumed that the most of plant fraction that were examined herein have strong antioxidant activity. The plant shows does-dependent inhibitory action against alpha glucosidase and alpha amylase enzymes. Phyto-fractions were semi-purified based on the relative potency of chloroform fractions CHF-1 to 5. CHF-3 was dominant in activities due to the presence of bioactive compounds [34].
13	Vineet Mehta et al.,	Antioxidant, Anti-Inflammatory and Anti-Diabetic activity of hydroalcoholic extract	Whole plant extract	DPPH radical scavenging activity Inhibition of Alpha-glycosidase activity	Streptozotocin induced diabetic rats	Present findings provide an experimental justification to the traditional use of this plant for the management of hyperglycemia and provide preliminary insite into the possible mechanisms through which *O. sanctum* may aid to overcome

		of Ocimum sanctum: An in-vitro And in-silico study		Inhibition of Alpha-amylase activity		diabetes and associated complications. Plant extract exhibited good antioxidant and anti-inflammatory properties which may result in preventing diabetic complications that are generally attributed to excessive oxidative and inflammatory stress during hyperglycemia. Further antidiabetic effect of *O. sanctum* may be attributed to its strong inhibitory effect on α-glucosidase enzyme and presence of rosmarinic acid, stigmasterol, linalool, bieugenol, and aesculin, which were predicted to be potentially antidiabetic moieties of this plant [35].

Conclusion

In diabetes, oxidative stress and antioxidants have a complex and multifaceted relationship. In diabetes, oxidative stress plays a major role in the pathogenesis. On the other hand, antioxidants are important protective factors. In order to prevent and manage diabetes, further research is required to pinpoint the exact pathways driving oxidative damage and to create targeted antioxidant-based therapy.

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