Chapter 2 Review of Literature

2.1 Diabetes

Diabetes mellitus is a multifaceted disease in which the body's ability for the insulin hormone production is impaired, effecting in anomalous metabolism of carbohydrates and increased levels of blood glucose (American Diabetes Association, 2010).

As per World Health Organization, there are several biochemical and physiological parameters entailed in retaining haemostatic limit of blood glucose level (American Diabetes Association, 2003).

2.1.1 Prevalence of Diabetes

The pervasiveness of diabetes worldwide projected in Brazil, the Russian Federation, India, China and South Africa (BRICS countries) is estimated to be 2.8% in 2000 and 4.4% in 2030 (Mujica et al., 2014). The prevalence of diabetes is found more potent in men than women estimated twofold amid 2000 to 2030. The estimated **prevalence of Diabetes mellitus** worldwide is approximately 150 million in 1995 and by the end of 2030 is estimated to achieve 366 million, with the maximum cases in India, China and USA. (Wild et al., 2004)

2.1.2 Type I Diabetes Mellitus

Type 1 diabetes, also known as juvenile diabetes, is usually diagnosed in children and adolescent adults. Barely 5% of communities with diabetes have this type of the disease. The body splits down the sugars and starches into glucose, which it utilizes for energy. In type I, insulin is a hormone that the body lacks, that is required to get glucose from the bloodstream into the cells of the body (Figure 2.1) .

2.1.3 Type II Diabetes Mellitus

Type II Diabetes Mellitus, also known as non-Insulin dependent Diabetes

Mellitus (NDDM) occurs as a result of insulin resistance and defective insulin secretion (Defective responsiveness of tissue to insulin) (Teo et al., 2013). Since the cells do not respond well to insulin, the pancreas increases the production of insulin to maintain the normal blood glucose level. But eventually it can't keep up and the sugar level in the blood increases.

2.1.4 Causes of Diabetes Mellitus

Diabetes Mellitus II can be caused in individuals who have a genetic predisposition. The different composition of DNA affects the production of insulin by the body. Being overweight can also contribute to insulin resistance, especially if there is extra fat around the waist. In the present day, type II diabetes affects teens and kids mainly due to childhood obesity. Insulin resistance is associated with a group of metabolic conditions such as high blood glucose, high blood pressure, high cholesterol and triglycerides. Excess production of glucose from the liver can also cause Diabetes mellitus. Generally, when the blood sugar is low, the liver produces glucose. After a meal, it slows down the production of glucose and stores the glucose in the form of glycogen. But in some individuals, the liver cannot slowdown the production of glucose and this result in increased blood sugar level (Teo et al., 2013). Apart from this, bad communication between the cells or malfunctioning beta cells can also cause diabetes. The cells sometimes send wrong signals or do not pick up messages correctly. This affects insulin production and a chain reaction can lead to diabetes. When malfunctioning beta cells secrete wrong amounts of insulin at the wrong time, there is disruption in the glucose level (Figure 2.1) .

2.1.5 Risk factors and Prevention

Certain factors make getting diabetes more likely. While these factors do not make getting the disease obligatory they have a certain predisposition to the disease. The more they apply to the individual the higher are the chances of acquiring the disease. Age (45 or older), family (a parent or sibling with diabetes), Ethnicity are some examples. Some factors related to health and medical history which make acquiring diabetes more likely are heart and blood vessel disease, high blood pressure (even if it's treated and under control), low HDL ("good") cholesterol, high triglycerides, being overweight or obese, having a baby that weighed more than 9 pounds, having gestational

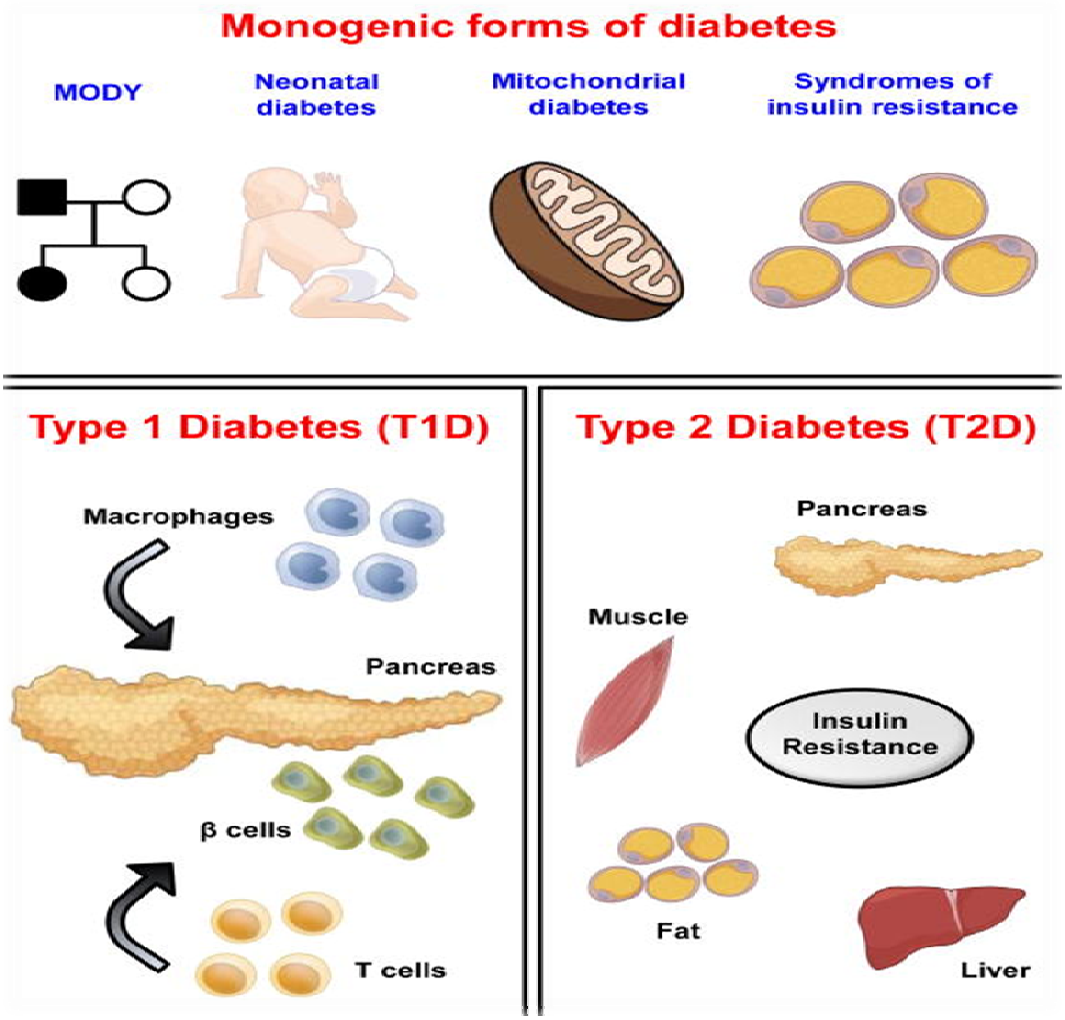

Figure 2.1: Types of diabetes and metabolic syndromes (Image courtesy : Teo et al., 2013)

diabetes during pregnancy, polycystic ovary syndrome (PCOS), acanthosis nigricans (a skin condition with dark rashes around your neck or armpits) and depression. Other factors related to lifestyle are getting little or no exercise, smoking, stress and sleeping little or too much.

Preventive measures can be taken to hamper diabetes. Losing 7-10% of body weight can cut the risk of diabetes by 50% in obese people. Exercising uses up insulin and will cut the risk of diabetes by a third. Regulating diet to avoid processed carbohydrates, sugary drinks and trans and saturated fats.

2.1.6 Symptoms

The symptoms of type II diabetes are usually mild and not easily noticeable. Some of them include being very thirsty, frequent urination, blurry vision, being irritable, tingling or numbness in

your hands or feet, feeling worn out, wounds that don't heal and yeast infections that keep coming back.

2.2 Diabetes and Oxidative Stress

Oxidative stress shares an undeniable association with Diabetes and its impediments like liver dysfunction, nephropathy, neuropathy, loss of immune potency and retinopathy. Free radical also induces organ dysfunction (Maiese et al., 2007). In all aerobic organisms, regular metabolism comprises alteration of oxygen to free radicals that include hydrogen peroxide (H_2O_2), hydroxyl ion (OH^-), peroxynitrite, superoxide free radicals and oxygen free radical (O_2^-). A balance survives between ROS creation and ROS removal in normal health state. Whereas, in the pathological condition, the balance is disrupted due the over production of free radicals, this consequently results in increase in oxidative stress (Chong et al., 2005). Many studies regarding Diabetes mellitus reveal that increase in antioxidant enzyme activity is a common defense mechanism employed by the body. In case of excess oxidative/nitrosative stress, the cellular antioxidants are inadequate to entirely inactivate the reactive oxygen species (ROS) and reactive nitrogen species (RNS) (Kelley et al., 2002). Damage to nucleic acids, lipids and proteins is a major consequence of oxidative/ nitrosative stress. This can seriously compromise the cell's health and viability or incite an array of cellular responses through the generation of secondary reactive species, eventually resulting in cell death by apoptosis or necrosis (Chong et al., 2005). An extensive amount of evidence certainly suggests that oxidative stress is linked with primary or secondary pathophysiologic conditions. (Halliwell et al., 1991; Chong et al., 2003; Bialy and Waldmann, 2005; Alonso *et al*., 2004). Several complications arise as a result of the macro and microvascular complications that result from diabetes. These shortcomings play a vital role in the tissue-damaging effects of chronic hyperglycemia (Maiese et al., 2004). The endothelial cells are more vulnerable to the toxic effects of hyperglycemia, since they are unable to limit glucose transport as efficiently as the other cells. Many studies have implicated that diabetes mellitus (types I and II) is associated with decreased antioxidant capacity and increased formation of free radicals, resulting in oxidative damage of cellular components (Maiese et al., 2004).

Diabetes induces production of reactive oxygen species from several sources, including those of mitochondrial and non- mitochondrial origins (Yamamoto et al., 2002; Rachek et al., 2006).

2.3 Free radicals

Several scientific studies suggest a direct link between pathogenicity, long term complications of diabetes mellitus and free radical mediated oxidative stress . (Halliwell et al., 1991; Chong et al., 2003; Bialy and Waldmann, 2005; Alonso et al., 2004). Biomolecules like proteins, DNA and carbohydrates are the major targets of free radical attack. To counter these ill effects of free radicals, biological systems have an antioxidant defense mechanism (Adams et al., 2001). Free radicals can be defined as molecules or atoms containing unpaired electrons in their outer orbit. Free radicals are highly reactive, they can either donate an electron to other molecules causing oxidation or accept an electron from other molecules resulting in reduction. Due to this high reactivity most free radicals have very short half-life (10^{-6} seconds or less) in biological systems (Figure 2.2).

However, accumulation of high doses of radicals either due to increased

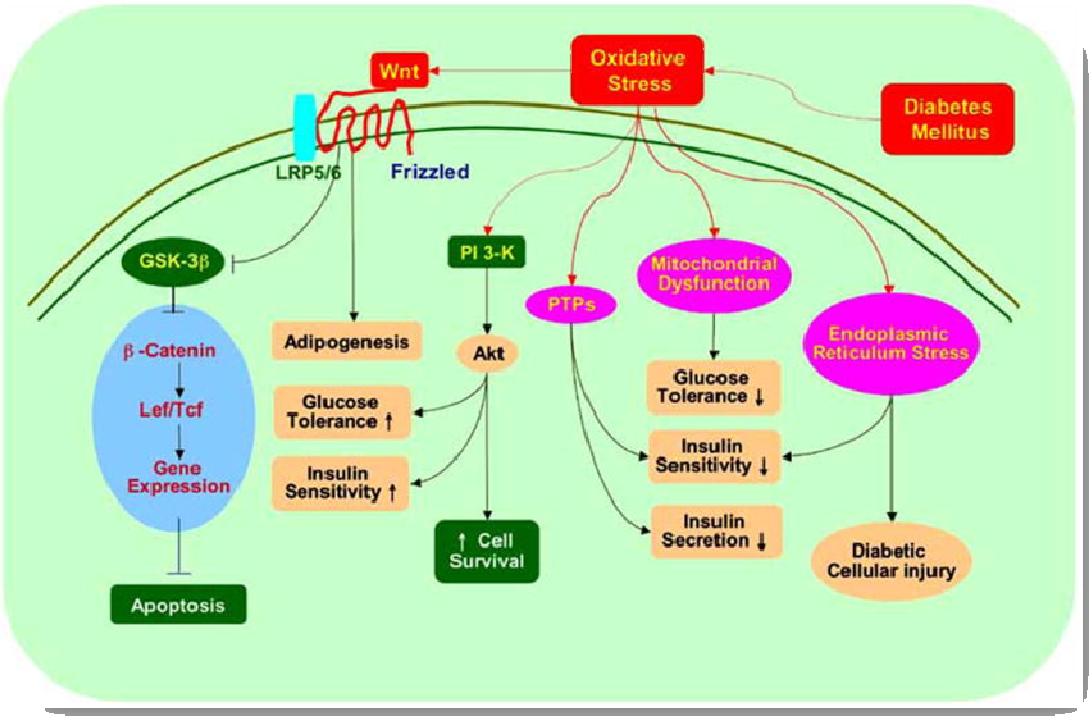

Figure 2.2: Diabetes mellitus integrates with a host of cellular pathways controlled by oxidative stress (Image Courtesy: Maiese et al., 2007)

production or inadequate removal leads to oxidative stress which acts as a precursor to several metabolic disorders (Sampayo et al., 2003). Free radicals in biological systems majorly consist of oxygen derivatives. Reactive oxygen species (ROS) but they also contain derivatives of Reactive Nitrogen species. ROS, superoxide anion ($O_2^{\cdot-}$) and hydroxyl ions ($OH^{\cdot}$) are the prominent radicals found in large quantities in a disease state of body.

Free radical formation in the body can occur by several mechanisms involving both endogenous and exogenous factors (Mikati et al., 2007). Most of the free radicals are produced by mitochondria and they damage the mitochondrial DNA and its membrane (Wei, 1999). All of the ROS are ultimately converted to hydroxyl radicals, which induces tissue damage, resulting in pathological effects (Rachek et al., 2006). Hydroxyl ($-OH^{\cdot-}$) radical, because of its ability to react with every type of molecules found in the living system, including carbohydrates, amino acids, nucleotides and lipid at a very high rate, is considered as the most powerful free radical. It acts as a final mediator of most free radical induced tissue damage (*Adams* et al., 2001). Another source of Hydroxyl ($-OH^{\cdot-}$) radicals is the Haber-Weiss reaction where superoxide and hydrogen peroxide react directly. During the absorption of dietary iron in the small intestine, it is bound to a protein transferrin and transported into the blood stream. The bound form therefore, is not available for free radical ($-OH^{\cdot-}$) formation. Nevertheless, cytoplasm and few sub-cellular organelles also contain a small pool of iron bound to different molecules like citrate, nucleosides and this iron could serve as a source for Fenton reaction of $-OH^{\cdot-}$ production. However in pathological conditions like inflammation, ischemia reperfusion, where there is a breakdown resulting in protective iron chelating effect, the bound protein releases iron to take part in the formation of reactive $-OH^{\cdot-}$ radicals which in turn contributes to tissue damage (Fubini and Hubbard, 2003)

2.3.1 Lipid Peroxidation

Reaction of Hydroxyl ($-OH^{\cdot-}$) radical with lipids of the cell membrane is called lipid peroxidation (LPx). It is one of the major markers for free radical damage. Lipid is an important constituent of the cell membrane and occurs as a fluid mosaic bilayer with

intertwined proteins that functions as receptors and transporters. Hydroxyl (-$OH^{\cdot -}$) radical reacts with polyunsaturated fatty acids in three main steps. In the first step, the Hydroxyl (-$OH^{\cdot}$) radical binds to the lipid in the presence of redox active metal like iron or copper. In the next step there is formation of lipid hydro-peroxide by interaction of molecular oxygen catalyzed by metal. In the final step, decomposition of hydro-peroxide occurs, leading to the formation of alkoxyl or peroxyl radical. The three carbon chain malondialdehyde (MDA) is one of the major aldehyde products and is used as a selective marker of oxidative stress which can be measured by spectrophotometer.

Lipid peroxidation is thought to be the major cause for oxidative damage to the cell membrane. It affects the vital functions of the cell membrane such as signal transduction, permeability and transport because of the change in membrane fluidity. Obesity, increased fat accumulation and consumption of high calorie/high fat diets are also correlated to increase in oxidative stress. Oxidative stress resistance and accumulation of oxidative damage in laboratory rodents can significantly be altered by modulation of oxidant protection through either genetic mutation or treatment with antioxidants (Memişoğullari and Bakan, 2004).

Malondialdehyde (MDA) is a byproduct of arachidonate metabolism produced by peroxidative decomposition of unsaturated lipids. The excess MDA produced as a result of tissue injury can combine with free proteins, producing MDA-modified protein adducts. Modification of proteins by MDA could predominantly alter their biological properties. Furthermore, MDA-modified proteins are immunogenic (Memişoğullari and Bakan, 2004).

2.4 Antioxidants

Antioxidants are the molecules that neutralize the free radicals by eliminating the unpaired condition. The antioxidants accept or donate an electron from a free radical molecule and convert it to a non-free radical, in the process they themselves get converted to free radicals which are less reactive than ROS and RNS (Zhai et al., 2018).

Antioxidants create a steady equilibrium by maintaining a balance between the rate of generation and the rate of neutralization of free radicals. This equilibrium can be disturbed

during abnormal physiological conditions increasing the number of free radicals, then the tissue is said to be in oxidative stress. Antioxidants can be categorized into three groups (Middha et al., 2013).

1. Enzymatic antioxidants

2. Chain breaking Antioxidants

3. Transition metal binding protein

1. Enzymatic antioxidants (Vincent et al., 2013)

I. Super oxide dismutase (SOD)

SOD is one of the major antioxidant enzymes. It catalyzes the dismutation of superoxide to H_2O_2 and molecular oxygen. Catalase or GPx enzyme later removes H_2O_2. SOD is tissue specific and exists in 3 different forms.

i) **Cu/Zn SOD** occurs in cytosol and organelles of all mammalian cells. It consists of two protein subunits, containing Cu and Zn atom each, which is responsible for its catalytic activity.

ii) **Mn SOD** occurs in the mitochondria of all cell types. It consists of four protein subunits having a Mn atom each.

II. Catalase:

Catalase enzyme catalyzes the conversion of hydrogen peroxide to oxygen and water, thus preventing free radical OH- formation. It comprises of four protein subunits, each containing a haem group and a molecule of NADPH (Vincent et al., 2013). Although catalase is present in small quantities in all the tissues, its maximum activity is observed in liver and erythrocytes. Although a small amount of catalase occurs in mitochondria, majority of it can be found in peroxisomes that also generate hydrogen peroxide.

III. Glutathione peroxidase (GPx) is involved in catalyzing the oxidation of glutathione to glutathione disulphide using hydrogen peroxide and lipid hydroxy peroxide. It is followed by neutralization of H_2O_2 and ROOH.

The reduced Glutathione is regenerated

$$ROOH/H202 \rightarrow 2GSH \rightarrow GSSG + H2O + ROH$$

(Reduced) (Oxidized)

by glutathione reductase (GR) in the presence of NADPH.

The NADPH required for this

$$GSSG + NADPH + H^{+} \rightarrow 2GSH\_NADP$$

reduction reaction is provided by the pentose phosphate pathway. GPx is concentrated in the cytosol and mitochondria of the cells. Although GPx is widely distributed in all the

tissues, liver contains the highest concentration.

2.4.1 The chain breaking antioxidants

The chain breaking antioxidants are small molecules that can accept an electron from a free radical or donate an electron to a free radical, resulting in the formation of stable byproducts. They take part in neutralization of a series of free radicals generated during complex chain reaction like lipid peroxidation. These free radicals either combine with each other to form stable compounds or they are neutralized by antioxidants.

2.4.2 Lipid phase antioxidants

The lipid phase antioxidants neutralize the free radicals that initiate lipid peroxidation of lipids of the membrane. Vitamin E and vitamin A are the most common lipid phase antioxidants. Vitamin E occurs in 8 different forms, four tocopherols (alpha, beta, gamma and delta) that have chromanol ring that differ from each other in the position of methyl group in the ring and four tocotrienols (alpha, beta, gamma and delta). These molecules are lipid soluble and differ in their activity. Young et al., 2001 has discussed the role of vitamin E in humans and its uses as a major antioxidant in cell membranes and lipoproteins . Vitamin E does not inhibit the initial formation of carbon centered radicals in a lipid rich environment but reduces the formation of secondary radicals. Among the Tocopherols, α-Tocopherol is the most potent antioxidant and is also the most abundant in humans. It rapidly reacts with a peroxyl radical to form a relatively stable tocopheroxyl radical, in which the extra charge associated with the extra electron is dispersed across the chromanol ring and the radical is resonance stabilized. This might subsequently react in aqueous phase chain breaking antioxidant such as reduced glutathione (Kagan, 1998).

2.4.3 Aqueous phase antioxidants

Vitamin C is an ascorbate (AscH), having a property to scavenge free radicals in aqueous partition of the cell. Ascorbate is competent of donating hydrogen atom to a free radical molecule ($R^{\cdot}$) thereby counterbalancing the free radical while becoming an ascorbate radical itself (Asc-). But Asc- free radical is known to be steady. However Asc- free radical is impulsively translated into Asc- by NADH and NADPH dependent reductase. Ascorbate can diminish metal ions such as iron and copper,

which in-turn can make hydroxyl radicals by Fenton reaction. Thus Vitamin C, in the existence of metal ions, can perform as a hazardous pro-oxidant otherwise a influential antioxidant. It neutralizes O^{-}_{2}, H_2O_2, OH^{-}, aqueous peroxyl radicals, singlet oxygen and hypochlorous acid.

2.4.4 Transition metal binding protein

Transition metal binding proteins such as haemoglobin and ferretin have the ability to confiscate iron and copper, so there would not be any free radical generating Fenton's reaction. This is known to be a very crucial antioxidant defense method.

Oxidative stress has been reported earlier to have a pre-dominant task in diabetes and its string of obstacles; Hyperglycemia-induced fabrication of superoxide (in mitochondria) has been projected as the machinery for the patho-biology of diabetes and its complications (Giacco and Brownlee, 2010). Ceriello et al. (2004) reported the glucose-induced free radical production because of glucose impairment in type 1 and in type 2 diabetes. The glutathione (GSH) (an antioxidants) has exposed to defend the diabetes and its and complications (Ullah et al., 2016).

2.4.5 Glutathione (GSH)

GSH is a ubiquitous tripeptide (γ-Glu-Cys-Gly), which executes many cellular meaning and most sought antioxidant in mainly mammalian cells. The thiol enclosing moiety in fastidious is a effective reducing agent (Cheseto et al., 2017). In most cells, GSH is created intracellular by γ–glutamylcysteine synthetase, using cysteine, glycine and glutamate. During this reaction, an α-peptide bond is formed between one cysteine and one glutamate residue. Next, glycine is added by GSH synthetase. However, some cells like the Neurons do not contain the γ-glutamylcysteine synthetase enzyme and so require the dipeptide to be secreted from glial cells (Giacco and Brownlee, 2010).

GSH also conjugates with toxic complexes like xenobiotics under the charge of glutathione-*S*-transferase (GST) to encourage their removal from the cells (Lushchak, 2012). The GSSG reductase enzyme act on the GSSG produced and renews GSH using decreased nicotinamide adenine dinucleotide phosphate (NADPH) as a cofactor.

Weighting in the cell, mainly the mitochondria, with GSH can avert

neuronal apoptosis made by ischemia. Over-expression of GST in neuroblastoma cells augments its resistance to oxidative stress (Lu, 1999). Whereas diminution of GSH can be a reason to be the cells getting liable to oxidative damage (Cheseto et al., 2017). The agent 3-hydroxy-4-pentenoate particularly exhausts mitochondrial GSH and improves cell death persuaded by pro-oxidants such as *tert*-butyl hydroperoxide (Giacco and Brownlee, 2010).

2.5 Diabetes and Organs

The pancreas is customary known as the foremost organ for the insulin production.

2.6 Remedial approaches for Diabetes

It is of key trepidation that type 2 diabetes and its impediments are presently being analyzed in younger inhabitants which were not frequent earlier. Therefore, the avoidance which are including lifestyle alteration, in addition to effectual and pharmacological deeds.

2.6.1 Most commonly used animal mo dels for antidiabetic activity

2.6.1.1 Alloxan Induced Diabetes

Alloxan also known as mesoxalylurea, 2, 4, 5, 6-tetraoxopyrimidine has shown to produce hyperglycemia and glycosuria in most of the experimental animals except the guinea pig. It acts by the production of DNA lesions involving free radical formation.

ALX actively generates ROS, which mediate β-cell toxicity by generating hydroxyl radicals in an iron-catalyzed reaction, targeting glucose transporter 2 (GLUT2) and glucokinase (GK).

2.6.1.2 Streptozotocin Induced Diabetes

STZ [2-deoxy-2-(3-methyl-3-

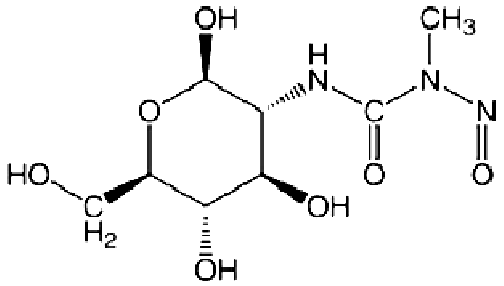

Figure 2.3: Chemical structure of alloxan

nitrosourea) -1-D-glucopyranose] is a broad-spectrum antibiotic and has a greater selectivity towards β-cells, lower mortality rate, longer or irreversible diabetes induction (Figure 2.4).

2.6.1.3 Dexamethasone Induced Diabetes

Dexamethasone is another popular method of inducing Diabetes. (Figure

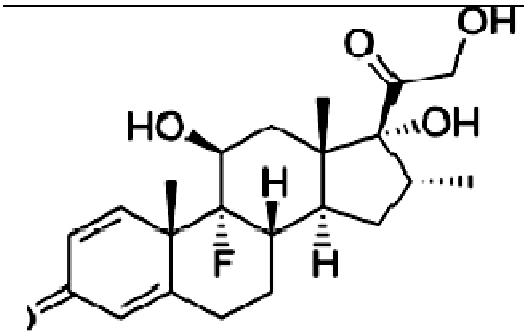

Figure 2.4: Chemical structure of streptozotocin

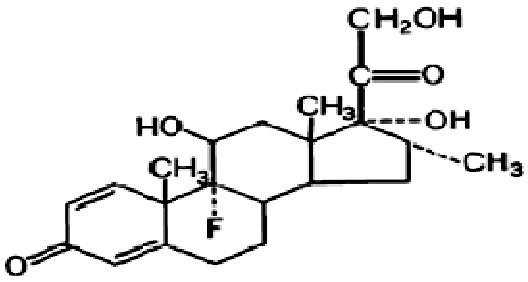

Figure 2.5: Chemical structure of dexamethasone

2.5).

2.7 Alternative medicines

"Traditional medicine" (TM) is a term used to refer the various traditional medicinal systems such as traditional Chinese medicine, Indian ayurveda and Arabic unani medicine and several forms of indigenous medicines. Traditional medicinal therapies include medication therapies like herbal medicines, animal parts and/or minerals and non-medication therapies or if they are carried out primarily without the use of medication such as in the case of acupuncture, manual therapies and spiritual therapies. In countries where the dominant health care system is based on allopathic medicine or where traditional medicine has not been incorporated into the national health care system, traditional medicine is often termed "complementary", "alternative" or "non-conventional" medicine (WHO, 2002).

WHO therefore defines traditional medicine as including diverse health practices, approaches, knowledge and beliefs incorporating plant, animals, and/or mineral based medicines, spiritual therapies, manual techniques and exercises applied singularly or in combination to maintain well-being, as well as to treat, diagnose or prevent illness.

70% of the Indian population still trusts traditional medicine rather than allopathy (WHO, 2002). Presently there is an increased global interest due to the recognition that "nutraceuticals" play a major role in health enhancement. Dr Stephen DeFelice, Chairman of the Foundation for Innovation in Medicine coined the term "Nutraceutical by combining the terms "Nutrition" and "Pharmaceutical" in 1989 (Brower, 1998). "Nutraceutical" is basically a marketing term developed for nutritional supplement that is sold for prevention of diseases

and therefore has no exact definition (Zeisel, 1999). Thus, a "nutraceutical" is any substance that may be considered a food or part of a food and provides medical or health benefits, encompassing, prevention and treatment of diseases. These products include isolated nutrients, dietary supplements and diets to genetically engineered "designer" foods, herbal products and processed foods such as cereals, soups and beverages. Over 470 nutraceutical and functional food products with documented health benefits are available today (Eskin and Tamir, 2006).

There seems to be a thin dividing line in the interchangeable usage of terms "nutraceuticals", "functional foods", "dietarysupplements" "designer foods", "medical foods", "pharmafoods", "phytochemicals" etc. "Pharmaceuticals" are drugs used mainly to treat diseases, while "nutraceuticals" are those that are intended to prevent diseases. The above distinction between pharmaceuticals and nutraceuticals is attractive, however superficial and erroneous.

Pharmaceutical entities such as oral hypoglycemic compounds can be developed from traditional antidiabetic plants which may also serve as simple dietary adjuncts to existing therapies (Bailey et al., 1992).

Lifestyle factors in particular diet, have extensively been implicated in pathological conditions. Modern scientific investigation now seeks to uncover, demystify and validate the idea that proper diet is the best medicine. Therefore these foodstuffs are under investigation as tools for the management of numerous pathologic states like metabolic and inflammatory disorders, cardiovascular disease and cancer. Indeed our best medicines may still be within our botanical food chain, awaiting discovery and development. The concept of a functional food is evolving into an important clinical tool.

Natural products and their derivatives have extensively served as remedies for several diseases and a vast proportion of contemporary drugs consist of natural compounds or their analogs. Traditional approaches utilizing extracts of different plant parts to treat diabetes have been known for a long time, although their mechanism of action has not always been clear. There are many medicinal plants which exhibit antidiabetic activities and are extensively studied for their properties. 52% of the drugs

approved in the U.S.A from 1981-2002 were natural products or derived from them and 26 plant based drugs were approved during 2000-2006, including novel-molecular based drugs. In the near future, multicomponent botanical therapeutics are bound to experience an increasing interest in biomedicine. Nutraceuticals/Alternative medicines are currently being identified as beneficial and therapeutic to many diseases such as coronary heart disease, obesity, diabetes, cancer, osteoporosis and other chronic and degenerative diseases such as Parkinson's and Alzheimer's diseases.

2.8 Bamboo

Over the past decade, Bamboo is known as green gold because of its various properties. It is a native from Iran to the Himalayas in northern India.

Around 780 genera and 12000 species makes the family Poaceae or Gramineae fifth largest genus known as grasses, after Asteraceae, Orchidaceae, Fabaceae and Rubiaceae. These grasses have hollow stems except at the nodes. Theses grasses form a leaf sheath.

2.8.1 Taxonomy of Bambusa tulda Roxb (Bamboo)

Kingdom: **Plantae**

Clade: **Monocots**

Order: **Cyperales**

Family: **Poaceae**

Genus: ***Bambusa***

Species: ***B. tulda*** **(Roxb.)**

2.8.2 Botanical aspect of Bambusa tulda

From time immemorial the human civilization is continuously challenged with changing food, climate, natural source of energy, ecological and economical security and many more. The emerging trends in the health sector with growing awareness amongst the human population have encouraged the research in functional foods and also focused on a balanced diet for the improved health. (Chongtham et al., 2011; German et al., 2004). Around 2 billion people from the underprivileged countries in the world do not have sufficient food to meet their daily intake and are therefore deficient of micronutrients (Basumatary et al., 2015; Kotecha, 2008). According to the World Bank report, India is ranked first to contain largest number of under weighing children in comparison with Sub-Saharan Africa. This type of starvation will largely impact the social behavior and also leads to insecurity among

these populations (Satya et al., 2012). There have been drastic changes in the pattern of cropping due to various environmental factors like depleting ground water, water pollution, air pollution, reduced soil fertility, soil erosion, changes in temperature. Due to the food constrains, the local households have adopted the usage of the underutilized crops to satisfy their basic needs and bamboo is one such crop. Bamboo is utilized by a wide variety of tribes all over the world because of its immense potential to improve social and economical life. (Yengkopam, 2013).

The north eastern states of India are gifted with this lush green bamboo crop. Bamboo is gaining amplified attention as a plant of '*global interest'* due to its enormous range of uses for the mankind (Bhatt et al., 2003; Goyal and Sen, 2016). In view of phenotypic characterization, bamboo is a group of tall woody grass. It belongs to poaceae and is widely known for its timber usage in housing sector (Brahma et al., 2014). However today, Bamboo is considered as a low or no cost, versatile, widespread, easily accessed, natural, renewable environment-enriching resource. From age old times the juvenile shoot is consumed in tribal diet and also has remained as one of the delicious foods in delicacies (Benzhi et al., 2005). The edible part of the bamboo shoot can be obtained by removing the leaf sheath which encloses the shoot. The commonly available edible verities of bamboo in northeastern states of India are *Bambusa balcooa*, *Bambusa pallida* and *Melocanna baccifera.* Presently approximately 3000 companies around the world are involved in the production of various bamboo products such as daily use articles, panels, pulp, flooring charcoal etc. (Pandey et al., 2012). Due to its diverse variety of uses, the bamboo tall woody grass popularly addressed earlier as *'poor man's timber'* is now known with different names such as *'green gold of forests'*, '*the plant with thousand faces'*, *'friend of the people'*, and many more (Goyal and Brahma, 2014). From age old times, bamboo is documented as a valuable and vital commodity. In China and Southeast Asia, the bamboo shoots have been in use as a source of medicine and food (Bao, 2006). Bamboo shoots are a rich source of dietary fiber and other nutritional components and very low in cholesterol. In case of cuisines, the unparalleled savor and acerbic taste

makes it exceptionally one of its kind (Pande and Pandey, 2008). Bamboo shoots are consumed as raw canned, boiled, dried, fermented food. The bamboo shoots are used to prepare about 11 different popular international dishes in Indian restaurants. Besides this, they are used as an ingredient in many other dishes to add a flavor to the food. Bamboo shoot *halwa*, *chutney*, *pulao*, *curry*, *bhaji*, *keema*, *manchurian* etc. are few of the popular dishes (Wang and Ng, 2003).

In spite of the fact that bamboo shoots are rich source of dietary fiber, some nutrient components and medicinal properties, there is a lack of sufficient awareness among the world wide human population (Shanmughavel, 2004). Therefore, this thesis the chapter of review of literature focuses on the nutritional value of bamboos and its scenario of utilization as a dietary supplement.

2.9 Phytochemistry of Bamboo Shoots

"Nutraceutical" refers to a product derived from food sources that are generally sold in medicinal forms and are purported to have a physiological benefit in addition to the basic nutritional value found in foods or protect from chronic disease, delay the aging process, increase life expectancy or support the structure or function of the body. Bamboo, also referred to as "green gold", is considered as one of the most versatile multi utility forest tree grass, is one such nutraceutical source. Bamboo shoots have immense potential of being used as important health food as they contain high proteins, amino acids, carbohydrates, many important minerals, vitamin and anti-oxidants. On reviewing literature, it's clear that a number of studies have been carried out to study the therapeutic properties of bamboos.

Plant food also contain certain bioactive compounds in abundance, in addition to those nutrients which are considered to be traditional, which are produced with the help of secondary metabolism. These physiologically active compounds are produced in small amounts and are known as "phytochemicals". It is one of the important source of bioactive compounds as they exhibit strong natural antioxidative and anti-inflammatory properties and sometimes antimicrobial activities as well. An idiosyncratic anti-fungal protein dendrocin, is also isolated from

shoots (Wang and Ng, 2003).

Through supercritical CO_2 extraction followed by subsequent hydrothermal treatment, many antimicrobials and antioxidants have been isolated. Penicillin is proved to be less effective while inhibiting *Staphyllococcus aureus* when compared to the leaves of bamboo which consists of antibiotic properties (Sharma and Borthakur, 2008). From moso bamboo (*P. pubescenes),* an antitumor agent has been prepared (Quitain et al*.,* 2004)

The phenolic compounds are commonly referred to as polyphenols and their subcategory flavonoids are found in different concentration in all parts of bamboo. The polyphenols are secondary metabolites that inhibits the lipid peroxidation and can potentially act as an antioxidant in the biological system. In the shoots of *Phyllostachys pubescence*, eight phenolic acids are present amongst which a few were considered to be almost ubiquitous such like p-hydroxybenzoic acid. The phenolic acids that are present in tender shoots helps in preventing injuries to blood vessels that may further cause atherosclerosis.

Bamboo leaves of *Phyllostachys nigra* var. henonis bamboo from China have been utilized as source of phenols and flavonoids that exhibit antioxidant activity. Phenolic content of other Chinese bamboos (*Yushania chungii, Fargesia robusta, Fargesia denudata, Fargesia rufa, Fargesia seabrida*) were characterized using HPLC. It is shown that individual species, sampling site and the age, effect the phenolic content in bamboo (Keski and Saari, 2008). Flavonoids and phenols were shown to reduce inflammation, promote overall cardiovascular health and circulation and even protect against certain kinds of cancer (Garcia-Lafuente et al., 2009).

During extraction of bio active compounds, prolonged exposure to oxygen and light may lead to the oxidation of phenolics. Thus numerous methods were developed for extraction of bio active compounds from the shoots. Three potential bioactive compounds were detected in the leaves and the shoot of *Bambusa textilis* through NMR spectra. They are identified as (*Z*)-*p*-coumaric acid, (*E*)-*p* -coumaric acid and apigenin-8-*C*-β-D-(2"-*O*-α-L-rhamnosyl)-glucopyranoside (Satya et al., 2012). Using GC-MS method, in methanol-ethanolic extract of *Dendrocalamus asper* leaves, about 20 organic

compounds have been identified. The growth of total anaerobic bacteria and *E. coli* is arrested/ hindered by the caprylic acid because of its antimicrobial activity. Moreover, in most of the bamboo species, the phenolic acids namely vanillic acid, gallic acid and caffeic acid are documented (Sarangthem and Singh, 2003).

The bamboo species, *Moso (Phyllostachys edulis)* which is harvested in China has been tested for its antioxidant activity (Kweon, 2001) It showed significant inhibitory effect on superoxide radical, hydroxyl radical, DPPH radical and ferrous metal chelating capacities (Park and Jhon, 2010).

The anticancer property of bamboo shoots might be attributed to the presence of lignans and phytosterols. It serves as a cure for irregular menstrual cycle, heavy bleeding after delivery, infertility problems, reducing labor pain and also in inducing puberty in young female . Though scientifically not proven, some tribes believe that bamboo shoot causes abortion in pregnant women. They are often advised not to consume bamboo shoot during the first trimester of pregnancy. They contain dietary fibers which has a number of health benefits as they control blood pressure, hypertension, obesity, cardioprotective, antithrombotic, vasodilatory effects (Lehane and Saliba, 2008) and potential carcinogens apart from possessing antimicrobial quality. Lignin, one of the key ingredients of dietary fiber, is found in bamboo shoots in considerable amounts. It also helps in improving lipid profile and bowel movements in young, healthy women when bamboo shoots are consumed on regular basis.

Phytosterols with its structure similar to cholesterol are extensively found in plants and their presence in fresh or fermented bamboo shoots is very prominent. A diet rich in Phytosterol helps in discounting colon, breast and prostate cancer. The progression of tumour growth is inhibited by interfering the cell cycle, apoptosis and tumour metastasis. The cholesterol level in blood is reduced as presence of phytosterol inhibition. 200 different kinds of phytosterols have been reported in plants of which sitosterol is the most abundant phytosterol. B-sitosterol, stigmasterol and campesterol are the predominant sterols in bamboo shoots (He and Lachance, 1998). To facilitate dietary recommendations, the

phytosterol content and composition in shoots were examined using ultra performance liquid chromatography (UPLC) with mass spectrometry (MS).

The growing health consciousness in today's fast growing world has led to the increasing public demand of bamboo shoots due to its therapeutic and nutritional values. Bamboo shoots are the young, immature and tender culms of the bamboo used for preparing various food items after being harvested. It is a reservoir of several nutritional components such as carbohydrates, enzymes, co-enzymes, fats, minerals, proteins, vitamins, reducing, non-reducing sugars, citric acid and lactic acid (fermented products) etc. It is also rich in dietary fibers such as cellulose, lignin, hemicelluloses and pectin (Park and John, 2009). Due to the availability of these wide range of components, extensive research is being carried out on its nutritional significance. While few studies on dried or processed bamboo shoots report an increase in the value of protein content by 29.6%, it is also reported that juvenile shoots of *Dendrocalamus hamiltonii* have highest protein content followed by *Bambusa bambos*. They are also found to be a good source of Vitamin E (ά –Tocopherol), Vitamin C (3.0 - 12.9%), Vitamin B6 (0.01%), Thiamin (0.05%), Riboflavin (0.01%), and niacin (0.03%) alongwith Vitamin A (20 IU), Vitamin B1 (0.15 mg/100g), Vitamin B3 (0.60mg/100g) (Choudhury et al., 2010; Nirmala et al., 2007).

Also, it is revealed that the shoots have much higher contents of free amino acid, protein and dietary fiber as compared to all other vegetables. The shoots are rich source of different types of mineral elements i.e. potassium (K), chromium (Cr), zinc (Zn), manganese (Mn), calcium (Ca), iron (Fe), phosphorous (P) (Choudhury *et al*., 2010). In the shoots of *Denrocalamus giganteus*, magnesium (Mg) is found in higher content ranging from 5.38- 140 mg/100g, a major element that plays an indispensable role in body metabolism (Nirmala and Sharma, 2008). Some of the shoot species also show the presence of 'selenium' in higher amount of which is essential for fertility & normal growth. It is associated with Vitamin E for curing diseases which is why it is also known as ***'miracle life element'.*** Being an excellent nutritional source, these shoots help the rural poor to elude the ill effects of malnutrition (Giri and

Janmejoy, 1992).The excellent anti-microbial quality of bamboo shoots with different flavones and glycosides makes it a rising natural medicine (Park and John, 2009).

2.10 Bamboo as Nutraceutical

Studies depict bamboo as a natural medicine or neutraceutical for more than 2000 years in the traditional system of medicine as they store nutrients bearing wide range of health profits. It has been used for treating various diseases like paralysis, sweating, preventing and curing cardiovascular disease (CVDs), cancers and peristalsis of the intestine, relieve hypertension in South-Asian countries, prevents constipation and decreases body fat (Chongtham et al., 2011). Sap inside the shoots of *Bambusa vulgaris* is also used for curing jaundice in Java (Choudhury et al., 2010). However, until now, less scientific evidence has supported those claims (Bhargava et al., 1996). Bamboo derived pyrolysates possessing antimicrobial and antifungal activities protect neurons from oxidative stress (Akao et al., 2004). The shoots of the bamboo are reported the presence of lignins which are an important component of fiber, to have anticancer, antiviral and antibacterial activity making them a regular part of the diet. (Tamang et al., 2012). It is also labeled as a '*heart protective vegetable'* as it helps in maintaining normal blood pressure because of its high potassium (K) content.

A hard to get siliceous concentration found in shoots known as '*bamboo manna'* is well known for its unique healing properties (Choudhury et al., 2010). In the Indo-Persian and Tibetan System of medicine it is called 'tabashir' or 'tawashir', while in the traditional system of Indian medicine it is called as 'banslochan' (Biswas, 1994). Intake of juice of pressed bamboo shoots that contains protease activity helps in triggering digestion of proteins. Besides, the shoots of few bamboo species such as *Bambusa bambos* are used in treating thread worm, cough and diarrhea due to the presence of glucosides, betain, urease, cynogens, nuclease, choline etc. The decoction of shoots are used for cleaning maggot infected sores, wounds, ulcers etc. as it is believed to induce abortion and parturition. As a result, being a good source of phytosterols, fiber and antimicrobial qualities, the bamboo shoots can qualify as neutraceuticals (Sarangthem and Singh, 2003).