The review of literature pertaining to the present study entitled “Nutraceutical Potentials of Black Rice (Oryza sativa L.) And Its Hypoglycaemic Activity in Streptozotocin Induced Diabetic Rats” is presented under the following headings:

2.1 Nutraceutical Potentials of Rice
2.2 Nutritional Facts on Rice
2.3 Diabetes Mellitus – An Overview
2.4 Free Radicals and Antioxidants
2.5 Black Rice and Diabetes Mellitus

2.1 NUTRACEUTICAL POTENTIALS OF RICE

2.1.1 Historical Perspectives of Rice

Rice is the major crop cultivated among many areas and a major source of agriculture in Asia and Africa. Rice belongs to grass family. It is classified under cereals. The two species of rice popular are Oryza sativa and Oryza glaberrima. Rice is the staple food and most of the calories are obtained from it. Many varieties of rice are grown across the world. According to Umadevi et al. (2012), rice is considered as a cultural food. About four-fifths of the world’s rice is produced by small-scale farmers and is consumed locally. Rice cultivation is the principal activity and source of income for about 100 million households in Asia and Africa (Ahuja et al., 2008).

Rice is the major crop among the cereal production in the world and second largest cereal produced in the world. At the beginning of the 1990s, annual production was around 350 million tons and by the end of the century, it had reached 410 million tons. Asia produces about 90 per cent of total rice production.
globally. Western and Eastern Asia produces more quantity of rice than other parts. Apart from Asia, Brazil is the leading producer after United States. Italy ranks first in Europe.

The description of the rice kingdom is:

<table>
<thead>
<tr>
<th>Kingdom</th>
<th>Plantae – Plants</th>
</tr>
</thead>
<tbody>
<tr>
<td>Subkingdom</td>
<td>Tracheobionta – Vascular plants</td>
</tr>
<tr>
<td>Superdivision</td>
<td>Spermatophyta – Seed plants</td>
</tr>
<tr>
<td>Division</td>
<td>Magnoliophyta – Flowering plants</td>
</tr>
<tr>
<td>Class</td>
<td>Liliopsida – Monocotyledons</td>
</tr>
<tr>
<td>Subclass</td>
<td>Commelinidae</td>
</tr>
<tr>
<td>Order</td>
<td>Cyperales</td>
</tr>
<tr>
<td>Family</td>
<td>Poaceae – Grass family</td>
</tr>
<tr>
<td>Genus</td>
<td>Oryza L. - rice</td>
</tr>
<tr>
<td>Species</td>
<td>Oryzasativa L. - rice</td>
</tr>
</tbody>
</table>

New varieties of rice have been developed by the most popular countries such as India and China. The cultivation of rice is a source of economic development. After wheat, rice is the most commonly consumed cereal in the world. Almost two million people in Asia obtain 80 per cent of total energy from rice. Rice contains 80 per cent carbohydrate, seven to eight per cent protein, almost three per cent of fat and three per cent fibre (Juliano, 1985; Umadevi et al., 2012). Even though the protein content of rice is low it is nutritionally superior. Rice is consumed as a whole grain and it is believed that whole grain gets digested quickly rather than flour (Chaudhary and Tran, 2001).

Rice is the only cereal that is eaten as a whole grain, and according to Ayurvedic concepts, the whole grain is more easily digested than flour (Ahuja et al., 2008). It is considered as the best food among all cereals. This quality has been lauded by various authors such as Charaka, Susruta, Kautilya, Varahamihira, and Panini in their respective treatises. The Ayurvedic treatises of Charaka (700 BC) and Susruta (400 BC) discuss rice under the cereals section of food articles. Recent studies have unraveled a number of unknown properties of rice, some of which have
been reported in ancient Indian Ayurvedic literature. According to Nene (2005), Kashyapiyakrishisukti is the only Sanskrit text which gives a clear idea about the state to which rice cultivation had evolved until more than 1000 years ago (Ayachit, 2002; Satya, 2014). Umadevi et al. (2012) mentioned that the great sage Parashara in the Sanskrit text Krishi-Parashara has aptly written in praise of this food grain. “Rice is vitality, rice is vigor too, and rice indeed is the means of fulfillment of all ends in life. Even Europeans preferred rice eventhough it is not their staple food. Jean Baptiste Tavernier commented that people who consumed wheat had more strength while people consumed rice had more stamina (Vir et al., 2005).

In China, the medicinal value of rice was known as far back as in 2,800 BC, when it was used by royal Chinese physicians for healing purposes. It was believed to restore tranquility and peace to those who were easily upset. Dried, sprouted rice grains were used to aid in digestion, toning muscles and expel gas from the stomach and intestines. The Chinese believe rice strengthens the spleen as well as stomach, increases appetite, and cures indigestion. They use red rice yeast for various ailments. Traditional Malaysian medical writings prescribe boiled rice ‘greens’ as an eye lotion and for use in acute inflammation of the inner body tissues. The application of dried powdered rice is recommended for skin ailments. In Cambodia, the hulls of mature plants are considered useful for treating dysentery. Hulls of three-month-old rice plants are diuretic. In the Philippines, rice polish (bran, tiki tiki) is extracted and used as an excellent source of vitamin B to prevent and cure beri-beri (Vir et al., 2005). In India, rice has enjoyed a unique status since ancient times because of its special qualities. Ancient Indian texts contain references to the special properties of rice.

2.1.2 Medicinal Uses of Rice in Indian System

Rice is used as medicine in pre-independent era. Rice is not only used as whole grain but it is used in various forms such as flour, paste, flattened, parched and fried rice for medicinal purpose. Gruel is considered to be best for treatment of diarrhea whereas flattened rice is mixed with curd and is recommended for treatment of dysentery. Rather than any other grain, rice is given importance during
sick and convalescent period. Indian pharmacopoeia recommends rice water as an excellent drink for febrile, dysuria and other inflammatory diseases.

The deep red colored and long-sized rice varieties of Chattisgarh and Jharkhand are reported to be more nutritious than the red, white, and coarse-grained varieties. Red rice varieties such as Bhama, Danigora, Karhani, Kalamdani, Ramdi, Muru, Hindmauri, and Punaigora are reported to be more nutritious and have higher satiety value. The starchy water prepared from cooking red rice help to quench thirst and it is reported to be refreshing. Table 1 gives the medicinal uses of rice varieties in the various states of India (Ahuja et al., 2008).

TABLE 1
MEDICINAL USES OF RICE VARIETIES IN THE VARIOUS STATES OF INDIA

<table>
<thead>
<tr>
<th>S.No</th>
<th>State</th>
<th>Rice Variety</th>
<th>Medicinal Use</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Madhya Pradesh</td>
<td>Aalcha, Baissor, Gathuwanor, Karhani, Kalimoonch, Maharaji, Bhajari, Dhanwar</td>
<td>Pimples, small boils in Infant, Chronic headache, epilepsy, Rheumatism, Paralysis, Skin Disease, Post-natal tonic for women, Renewal of placenta in cows</td>
</tr>
<tr>
<td>2</td>
<td>Orissa</td>
<td>Mehar and Saraiphol</td>
<td>Post-natal tonic for women</td>
</tr>
<tr>
<td>3</td>
<td>Karnataka</td>
<td>Kari bhatta, Karikagga, Atikaya, Mullarya</td>
<td>Skin infections, increase milk in women, Cooling effect, Health tonic, Cooling effect</td>
</tr>
<tr>
<td>4</td>
<td>Kerala</td>
<td>Nivara, Erumakkari</td>
<td>Cure of tridoshas, Cough</td>
</tr>
<tr>
<td>5</td>
<td>Himachal &amp; Uttar Pradesh</td>
<td>Katheri, Kaufaya, Matali, Lal Dhan</td>
<td>Post-delivery restoration of size of reproductive organs, Leucorrhea, High blood pressure, fever</td>
</tr>
<tr>
<td>6</td>
<td>Tamil Nadu</td>
<td>Neelam Samba</td>
<td>To increase milk in women</td>
</tr>
</tbody>
</table>
Nutraceutical Potentials of Black Rice (*Oryza sativa* L.) and Its Hypoglycaemic Activity in Streptozotocin Induced Diabetic Rats

Pakheru, Saraiphool, Karia Gora, Dani Gora, and Punai Gora varieties of eastern India are traditionally used as tonic. Boiled rice along with its starchy water and a pinch of salt is given to weak persons (Rahman *et al*., 2006). In Karnataka, the rice varieties Karikagga and Atikaya help in cooling the body and act as a tonic.

### 2.1.3 Rice as Special Food for Lactating Mothers

Rice has been found beneficial for lactating mothers since it is believed to increase milk secretion. The Maharaji and Bhejri varieties from Chhattisgarh, Jonga in Bihar, Neelam Samba in Tamil Nadu, and Henati in Sri Lanka are used for this purpose (Das and Oudhia, 2000). Rice when consumed with fenugreek (*Trigonella foenum-graecum*) helps in milk secretion. Similarly, rice along with coconut milk also serves the same purpose (Nagnur *et al*., 2006). Moreover, sweet balls of roasted Jonga rice not only help in lactation but also provide better nourishment to infant via breast milk (Rahman *et al*., 2006). The knowledge of rice and lactation has been handed over to many generations.

Apart from lactation, rice also serves as an excellent food for women immediately after child birth. It has strengthening, hemostatic and expectorant property. Moreover, it is believed to stop bleeding. (Nagnur *et al*., 2006). In the Bhojpuri areas of Bihar and Uttar Pradesh, mothers are given a highly nourishing preparation called sathaura: Rice flour is mixed with ginger, gum of *Acacia arabica*/*Butea frondosa* and Bengal kino (seed kernel of *Buchanania latifolia* is known as chiraunji), coconut, and raisin, and made into balls with jaggery (Upadhyaya, 1993).

### 2.1.4 Other Medicinal Uses

In Himachal Pradesh, Matali and Lal Dhan rice varieties are considered beneficial for treatment of blood pressure and fever. Kafalya rice varieties grown in hilly regions is believed to cure leucorrhoea and also helpful in treating complications that occur during abortion. In Assam, Bora rice variety is considered to be effective in treatment of jaundice. In Bihar and Jharkhand, Karanga rice is given in all dysenteric complaints (Ahuja *et al*., 2008).

#### i. Skin care
Rice is also used to treat skin problems. The Layacha variety is used in treatment of boils on scalp of newborn. It is believed that if breast feeding mother consumed this variety of rice, the infant is expected to reap the benefits. Moreover, pregnant women are given cooked grain to help build resistance in the developing fetus against a skin infection known as the Laicha disease (Ahuja et al., 2008).

**ii. Rice beer and its medicinal uses**

The Bodo tribals of Assam consider rice beer to possess medicinal value, and used for stomach ailments (Ahuja et al., 2001). The Karhani rice variety is medicinally famous in Chattisgarh and Jharkhand. Tribals of Jharkhand traditionally use this variety for the preparation of a beer called Handia, which possess medicinal properties. Beer prepared from the Dani Gora rice is effective against gastric problems. Filtered water of Gudna rice, soaked in water overnight is given to patients suffering from gastric ailments.

**iii. Ethnobotanical medicine**

Rice root helps in the treatment of measles. In Orissa-West Bengal, root of rice is made into a paste with long pepper (*Piper longum*) (3:2) for the treatment of measles. They give grain powder with palm sugar (3:2) is used as an antidote to kuchila (*Strychnos nux-vomica*) seed poison. The Santhals use a mixture of water obtained after washing rice and common salt (2:1) as a cure for dyspepsia. The Mundas believes that 3–5 grains of rice with stale water in the morning help to cure gastric troubles. The Santhals and Oraons prescribe a powder obtained by burning old straw with curd (2:1) were given to women to induce abortion up to 2–3 months of pregnancy (Pal and Jain, 1998).

**2.2 NUTRITIONAL FACTS ON RICE**

Rice is a nutritious staple food for majority of people around the world. Rice has the following nutritional benefits:

Rice is a great source of complex carbohydrates, which is an important source of the fuel for our biological system.
Results and Discussion

Nutraceutical Potentials of Black Rice (*Oryza sativa L.*) and Its Hypoglycaemic Activity in Streptozotocin Induced Diabetic Rats

- Excellent energy source: Carbohydrates are broken down to glucose, most of which is used as energy for exercise and as essential fuel for the brain.
- Low fat and low salt: Rice has less fat, less cholesterol and less sodium. Rice is an excellent food to include in a balanced diet for those with hypertension.
- A good source of vitamins and minerals such as thiamine, niacin, iron, riboflavin, vitamin D, calcium, and fiber.
- Gluten free rice, best for people with gluten free dietary requirements.
- No additives and preservatives: Rice does not contain any added additives or preservatives.
- Resistant starch: Rice contains resistant starch and it resists digestion. It promotes the growth of beneficial bacteria to keep the bowel healthy.
- Rice is non-allergenic at almost all situations
- Cancer prevention and diet: Brown rice is rich in insoluble fibre, protects from various types of cancer
- Low Sodium: Rice has low sodium content, beneficial for hypertension.
- It is a fair source of protein containing all essential amino acids (http://plants.usda.gov)

2.2.1 Current Research

At present, rice is not only staple food and source of energy, its mineral content, starch quality, glycemic index, and antioxidant activity has made rice unique among cereals. Rice is entirely absorbed by the body rather than wheat, potato and maize (Strocchi and Levitt, 1991). Positive qualities of high digestibility of starch, high biological value of amino acids, high content of essential fatty acids and selenium, and anti-hypertension effect have been confirmed scientifically. Rice can therefore be described now as a functional food (Ahuja *et al*., 2008).

Rice-based oral rehydration solutions (ORS) have been proved effective in decreasing stool output and improving intestinal absorption in acute diarrhea. Rice extracts were found to decrease intestinal losses by actively inhibiting chloride channels (Goldberg and Saltzman, 1996). Rice-based ORS are now preferred over
Results and Discussion

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Nutraceutical Potentials of Black Rice (Oryza sativa L.) and Its Hypoglycaemic Activity in Streptozotocin Induced Diabetic Rats

glucose-based ORS, and have been included in WHO (World Health Organization) programs (Gore et al., 1992). Rice is the least allergic food and is recommended for people afflicted with the irritable bowel syndrome. Colored rices (red and black) have been extensively studied and their anthocyanins or colored pigments and flavonoids are associated with antioxidant properties (Zhang et al., 2005).

Red and Black rice varieties are considered more nutritious, have been found to be rich in iron (Fe), zinc (Zn), and minerals, and possess antioxidant properties. These rices reduced atherosclerotic plaque by 50 per cent more than white rice in rabbits (Ling et al., 2001). The parboiled red rices of Sri Lanka have lower glycemic index than white rices, and have been recommended for diabetics (Hettiarachchi et al., 2001). The antioxidant and scavenging activity of red rice is higher than that of black rice and white rice (Shen et al., 2009; Oki et al., 2005). Clinical trials conducted in USA have concluded that red rice yeast reduces cholesterol and total triglyceride, providing a novel food-based approach to lowering cholesterol (Herber et al., 1999).

2.2.2 White Rice/Milled Rice

- White rice is milled rice from which husk, bran and germ are removed. White rice belongs to the India (long grain) category.

- To obtain white rice, the husks from rough or paddy rice should be removed first, leaving the brown rice kernel. The outer layers—the husk and the bran layer—are removed from the kernel through the milling process.

- After milling, the rice is polished, giving the resulting seed a bright, white, shiny coating.

- The white rice is little more than an empty starch because the bran which is removed contains much of the dietary fiber, the germ contains most of the vitamins and minerals, and the superficial aleurone layer removed during polishing contains the grain's essential fats.

- White rice is often artificially enriched with a few of the nutrients stripped from it during its processing.
The complete milling and polishing that converts brown rice into white rice destroys 67 per cent of the vitamin B3, 80 per cent of the vitamin B1, 90 per cent of the vitamin B6, half of the manganese, half of the phosphorus, 60 per cent of the iron, and all of the dietary fiber and essential fatty acids. Fully milled and polished white rice is required to be "enriched" with vitamins B1, B3 and iron. Enrichment of white rice with B1, B3, and iron is required by law in the United States.

Despite having little more nutritional value, white rice is the staple source of calories in many countries like Japan, Malaysia, and China. Almost all rice are consumed in the milled form. Billions of Asians survive on rice, which they mostly consume as white rice.

Plate 1 shows the various features of the white rice:

PLATE 1
VARIOUS FEATURES OF THE WHITE RICE VARIETY

Paddy
Dehusked White Rice
Polished White Rice
2.2.3 Black Rice/Forbidden Rice

Black Rice is known as forbidden rice with a thin layer of black bran present in it. Forbidden rice is black when raw and becomes dark purple when cooked. The name comes from the legend that it was reserved for emperors in ancient China because of its rich nutrients and rarity. Plate 2 shows the various features of the black rice:

PLATE 2

VARIous FEATURES OF THE BLACK RICE

With husk

In Field - Paddy

Black rice
**Characteristics of Black Rice**

- Black rice could be either medium or long grain.
- Precooked black rice has white kernels inside the black bran.
- When cooked, "forbidden rice" has the smell of freshly popped popcorn and turns the water that it is boiling into a brilliant purple color.
- Once cooked, the rice becomes a whole grain texture.
- Black rice can extremely reduced true digestibility of its protein (72.4 percent) and high digestibility of starch due to its high levels of phenolics (anthocyanin).

**Usage of Black Rice**

- Black rice is cohesive in nature and is made into various stir fry, stuffing, casseroles, and side dishes.
- It is rich in phytonutrients.
- Forbidden rice is rich in iron and considered a blood tonifier.
- The grain is high in fibre, it is not glutinous or rough.

### 2.3 DIABETES MELLITUS – AN OVERVIEW

Diabetes mellitus is a major public health problem affecting millions of people around globally. The human population worldwide appears to be in the midst of an epidemic of diabetes. Aretaeus, a Cappadocian physician of the second century A.D., wrote: “The epithet diabetes has been assigned to the disorder, being something like passing of water by a siphon”. The word diabetes means 'to run through' or 'a siphon' in Greek and the condition has been recognized since the time of the ancient Egyptians. Mellitus (from the Latin and Greek roots for 'honey') was later added to the name of this disorder and appreciated that diabetic urine tasted sweet.

Diabetes mellitus is a disorder resulting from both environmental favouring factors and genetic predisposition characterized by alterations in the metabolism of carbohydrate, fat and protein that are caused by a relative or absolute deficiency of insulin or by insulin resistance. This leads to pathogenesis of diabetes mellitus.
2.3.1 Prevalence

Globally 1.3 per cent of the population suffers from diabetes mellitus and considered as one of the most common metabolic disorder (Altan, 2003; Strojek, 2003). It is a global problem and number of those affected is increasing day by day (Mukherjee et al., 2007). Diabetes is the third widespread and serious disorder after cardiovascular disease and cancer. It is extrapolated that by 2030, about 552 million people will live with diabetes compared to 336 million in 2011 (Wild et al., 2004). The multicentre ICMR study showed a prevalence of 2.5 per cent in the Urban and 1.8 per cent in rural population above the age 15 years. One in every eight individuals in India is a diabetic. The revised WHO figures for the year 2025 is 57.2 million diabetics in India. The average age for onset of diabetes is around 40 years while it is around 55 years in other countries. Diabetes mellitus is classified to Type I and Type II diabetes mellitus.

2.3.2 Type I Diabetes

Destruction or losses of beta cells of islets of langerhans are the main reason. As a result there is a deficiency of insulin. Type I diabetes is further classified as immune-mediated and idiopathic (Ria, 2007).

2.3.3 Type II Diabetes

Type II diabetes mellitus is due to insulin resistance that is insulin insufficiency. In other words, the beta cells of islets of langerhans in pancreas donot produce sufficient amount of insulin. About 90-95 per cent of diabetic people falls under this category. Both impaired insulin action (insulin resistance) and reduced insulin secretion (insulin deficiency) may contribute to the development of type 2 diabetes. It is now accepted that in type 2 diabetes, the situation may range from predominantly insulin resistance with relative insulin deficiency to a predominant secretory defect with insulin resistance. It is noteworthy that recent data would suggest that the hyperinsulinemia of insulin resistance may result from an increase in insulin secretion secondary to increased β-cells mass is reduced by about 50 per cent, which is known from experimental pancreatectomy to be not enough to cause fasting hyperglycemia. Therefore, in most type 2 patients a functional defect in β-
cells may occur, leading to insulin secretory defect. This is confirmed by the almost absent acute insulin response to glucose (AIR\(_G\)), diminished maximal acute insulin response to non glucose stimuli (AIR\(_{MAX}\)), decreased insulin secretory capacity, with normal β-cell sensitivity to the potentiation effect of glucose.

In type 2 diabetes, an incomplete activation of the insulin receptor tyrosine kinase appears to contribute to the pathogenesis of the signaling defect. Available data suggest that the impaired tyrosine kinase function of the insulin receptor is not due to an inherited defect but rather is caused by a modulation of insulin receptor function. The B isoform is increased in the skeletal muscle in type 2 diabetes, which may not have significant functional significance. Hyperglycemia might directly inhibit receptor tyrosine kinase activity and the receptor function. This appears to be mediated by activation of certain protein kinase C isoforms which form stable complexes with the insulin receptor and modulate the tyrosine kinase activity of the insulin receptor through serine phosphorylation of the receptor β- subunit. Finally, in type 2 diabetic patients the oscillations in insulin secretion, which are significant for glycemic control, cannot be detected, even in the patients with mild form of the disease (Belfore and Mogensen, 2000). Figure 1 shows the pathophysiology of type II diabetes mellitus.

**FIGURE 1**

**PATHOPHYSIOLOGY OF HYPERGLYCAEMIA AND INCREASED CIRCULATING FATTY ACIDS IN TYPE 2 DIABETES**
2.3.4 Complications of Diabetes Mellitus

Diabetes can be caused by both acute and chronic long term complications. The principal complications associated with diabetes are retinopathy, neuropathy, nephropathy and atherosclerosis etc. Figure 2 shows the complications of diabetes mellitus.

FIGURE 2
COMPLICATIONS OF DIABETES MELLITUS

i. Retinopathy

Long term complications of diabetes mellitus are retinopathy with potential loss of sight. It is the most well known complication that causes blindness among the people of 20-60 years of age. Control of glucose and blood pressure has been postulated to reduce the risk of retinopathy and associated blindness (Ziyadeh, 2000).
Diabetes mellitus (DM) is a major cause of blindness in both the developing and the developed countries. Diabetic retinopathy possess 25 times more burden on diabetic people than non-diabetics. Diabetic retinopathy is one of the complications in type I and type II. The duration of diabetic and the level of glycemic control is the most important factors in the development of retinopathy. Around 25 per cent of the patients with type I have shown incidence of retinopathy after 5 year and 10-15 years of affliction. Type II diabetes mellitus accounts for a higher proportion of population with visual impairment (Sulochana et al., 2001). Blindness among diabetic people may occur due to the reasons like cataract and glaucoma.

**ii. Neuropathy**

Diabetic neuropathy is another long term complication of diabetes. Around 60 per cent to 70 per cent of diabetes has mild to severe form of nervous damage. Nerve damage in diabetic patients is also caused by disease of small blood vessel and often known as diabetic retionpathy. Symptoms of diabetic nerve damage include numbness, burning and aching of the feet and lower extremities. Because of poor blood circulation, diabetic foot injuries can lead to serious infection, ulcers and even gangrene increasing chances for surgical amputation of toes feet and other infected parts.

Diabetic nerve damage can lead to ED1 impotence. Due to poor blood flow, erectile dysfunction occurs. Diabetic neuropathy can also affect nerves to the stomach and intestine, causing nausea, weight loss and diarrhoea (Reiber et al., 1999).

**iii. Cardio vascular disease, coronary heart disease and atherosclerosis**

Diabetes is an independent risk factor for cardiovascular disease. About 80 per cent of diabetic people suffer from CVD. Moreover, death rates are considerably high among diabetic people suffering from stroke rather than people suffering from stroke alone (Goldstein et al., 2001). Type 2 diabetes is a heterogeneous disorder characterized by insulin resistance and β cell dysfunction (Olefsky, 1989). Insulin resistance in turn is associated with several risk factors including hypertension, hypertriglyceridemia, low HDL cholesterol, small LDL particles, visceral obesity,
increased fibrinogen, and plasminogen activator inhibitor 1 (PAI-1). This is known as insulin resistance syndrome, metabolic syndrome, and more recently, cardiovascular dysmetabolic syndrome. In developed countries, coronary heart disease is a leading cause of morbidity and mortality (Yussoff et al., 2002). In India, the prevalence of CHD is much higher in south when compared to north (Gupta et al., 2002).

Atherosclerosis, macrovascular disease, occurs prematurely and is more common in patients with diabetes. The data postulates that endothelial cell dysfunction plays a vital role in the initiation of atherosclerotic vascular disease (Cosentino and Luscher, 1998). Diabetic patients are more prone to development of atherosclerosis. Premature atherosclerosis is a risk factor for cardiovascular disease, particularly coronary artery disease and often related to the change in plasma lipid profile and poor metabolic control. Qualitative and quantitative abnormalities of lipids and disturbance in lipid metabolism are shown by diabetic children and adolescents (Buston et al., 2005). The level of dyslipidemia predicts macrovascular complications such as coronary artery disease in patients with type 1 diabetes mellitus (Weis et al., 2001).

iv. Nephropathy

Diabetes is often linked with development end stage renal disease (ESRD) in the USA, Japan and most nations in industrialized Europe. Kidney disease develops as a result of chronic uncontrolled diabetes type I and II (Sperling, 1996).

Diabetic nephropathy is defined by persistent albuminuria, declining glomerular filtration rate and using blood pressure (William and Pickup, 1992). Nephropathy in diabetic correlates with genetic predisposition of type of diabetes and control of compound risk factors especially hypertension and hyperglycemia.

v. Ketoacidosis

Ketoacidosis is one of the common complications of diabetes. The blood glucose level become very high and causes dehydration. This leads to build up of substances called ketones in the blood and makes acidic. This will result in headache, drowsiness and semi-consciousness. The person may also have an acetone smell on their breath (Belfore and Mogensen, 2000).
**vi. Hypertension**

Hypertension is most prevalent in diabetic people. Both hypertension and diabetes are independent risk factors for microvascular and macro vascular disease (Gilbert et al., 1995). In type I diabetes, hypertension is well correlated with diabetic nephropathy and positive family history of hypertension. In Type II diabetes, hypertension indicates evolving diabetic nephropathy or that may be due to metabolic syndrome (Williams, 1994). It is noted that often isolated systolic hypertension, is present in elderly subjects (Tuomilento et al., 1999).

**vii. Oral complication**

About 30 per cent of the people above 19 years of age report any one form of periodontal disease leads to tooth loss occurs with greater frequency severity among diabetics.

2.3.5 Oxidative Stress in Disease

The imbalance that occurs due to insufficient antioxidant defense capacity and presence of highly reactive oxygen species. This results in oxidative stress that is related to advancing age, degenerative diseases like cancer, cardiovascular disease, diabetes mellitus, etc. Figure 3 shows the damage of oxidative stress.

**FIGURE 3**

OXIDATIVE STRESS
2.3.6 Oxidative Stress and Insulin Resistance

Insulin resistance as well as defective insulin secretion plays a vital role in the pathophysiology of diabetes. Various factors such as obesity, secondary lifestyle, pregnancy and excess hormone activity contribute to insulin resistance. Increase in insulin, abnormally high glucose level, high free fatty acid will subsequently lead to increased production of reactive oxygen species as well as oxidative stress through active stress-sensitive pathways. A number of substrate (potential targets) of activated kinase are provided by the insulin signaling pathways. For IRS-1 and IRS-2, an increase in serine phosphorylation decreases the extent of tyrosine phosphorylation and is consistent with attenuation of insulin action (Vasan et al., 2003).

2.3.7 Free Radicals, Diabetes and Advanced Glycation End Products

Free radical generation indicates the onset of diabetes as well as complications. It is important to note that free radical scavenging activity have to be addressed at the earliest possible in order to effectively prevent diabetes and reducing the severity of complications. Hyperglycemia results in oxidative stress due to a) auto oxidation of glucose b) non- enzymatic glycosylation and c) polyol pathway. Spontaneous reduction of molecular oxygen is autooxidation that are highly reactive and further involves all biomolecules. It accelerates the formation of advanced glycation end products (AGEs). AGEs such as pyrroles and imidazoles tend to accumulate in the tissue. Crosslinking AGE-protein with other macromolecules in tissues results in abnormalities in the cell and tissue function. Polyol pathway is the third mechanism by which free radicals are generated in the tissues (Glugliano et al., 1995). Antioxidant generation of glutathione is impaired since numerous NADPH molecules are deleted in this pathway. Antioxidants are diverted to protein glycosylation rather than scavenging activity. Vasodilation activity is also reduced since free radicals reacts with nitric oxide in endothelial cells. Continuous non – enzymatic cross linking of structural protein such as collagen and elastin takes place during ageing and in diabetic people. This abnormal protein crosslinking is mediated by AGEs generated by nonenzymatic glycosylation of proteins by glucose.
2.4 FREE RADICALS AND ANTIOXIDANTS

The events of World War II (1939-1945) led directly to the birth of free radical biochemistry. The two atom bombs (6th August 1945, Hiroshima and 9th August 1945, Nagasaki) led to massive deaths to entire population, and the survivors had shortened life-span. Details on some of the biologically important reactive species are presented as Table 2 (Devasagayam et al., 2004).

**TABLE 2**

**REACTIVE OXYGEN SPECIES OF BIOLOGICAL INTEREST**

<table>
<thead>
<tr>
<th>Reactive species</th>
<th>Symbol</th>
<th>Half life in sec</th>
<th>Reactivity remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Superoxide</td>
<td>O²</td>
<td>10⁻⁶</td>
<td>Generated in mitochondria, in cardiovascular system and others</td>
</tr>
<tr>
<td>Hydroxyl radical</td>
<td>.OH</td>
<td>10⁻⁹</td>
<td>Very highly reactive, generated radical during iron overload</td>
</tr>
<tr>
<td>Hydrogen Peroxide</td>
<td>H₂O₂</td>
<td>Stable</td>
<td>Formed in our body by large peroxide number of reactions and yields potent species like _OH</td>
</tr>
<tr>
<td>Peroxyl radical</td>
<td>ROO.</td>
<td>Stable</td>
<td>Reactive and formed from lipids, proteins, DNA, sugars etc. during oxidative damage</td>
</tr>
<tr>
<td>Organic Hydroperoxide</td>
<td>ROOH</td>
<td>Stable</td>
<td>Reacts with transient metal hydroperoxide ions to yield reactive species</td>
</tr>
<tr>
<td>Singlet Oxygen</td>
<td>¹O₂</td>
<td>10⁻⁶</td>
<td>Highly reactive, formed during photosensitization and chemical reactions</td>
</tr>
<tr>
<td>Ozone</td>
<td>O₃</td>
<td>Stable</td>
<td>Present as an atmospheric pollutant, can react with various molecules, yielding ¹O₂</td>
</tr>
</tbody>
</table>
In 1954, Gershman and Gilbert speculated that the lethal effects of ionizing radiation might be ascribed to formation of reactive oxygen species (ROS). Since then free radicals (atoms with an unpaired electron) such as reactive oxygen species and reactive nitrogen species (RNS) have gained importance (Gilbert, 1981). The term ‘free radical’ is used in a broad sense and also includes related reactive species such as ‘excited states’ that generate free radicals. Free radicals are very short lived, with half-lives in milli-, micro- or nanoseconds. Table 3 show the reactive nitrogen species of biological interest.

### TABLE 3
**REACTIVE NITROGEN SPECIES OF BIOLOGICAL INTEREST**

<table>
<thead>
<tr>
<th>Reactive species</th>
<th>Symbol</th>
<th>Half life in sec</th>
<th>Reactivity remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nitric oxide</td>
<td>NO⁺</td>
<td>Stable</td>
<td>Neurotransmitter and bloodpressure regulator, can yield potent oxidants during pathological states</td>
</tr>
<tr>
<td>Peroxynitrite</td>
<td>ONOO⁻</td>
<td>$10^{-3}$</td>
<td>Formed from NO⁺ and superoxide, highly reactive</td>
</tr>
<tr>
<td>Peroxynitrous acid</td>
<td>ONOOH⁺</td>
<td>Fairly Stable</td>
<td>Protonated form of ONOO</td>
</tr>
<tr>
<td>Nitrogen di oxide</td>
<td>NO₂</td>
<td>Stable</td>
<td>Formed during atmospheric pollution</td>
</tr>
</tbody>
</table>

Free radicals are the main contributing factor in several human diseases as well as ageing (Halliwell and Gutteridge, 1997). But reactive oxygen species and reactive nitrogen species are produced in a regulated manner to help maintain homeostasis at cellular level in normal healthy tissues and plays a vital role as signaling molecules. On demand, superoxide ($O_2^-$), hydrogen peroxide ($H_2O_2$) and nitric oxide (NO) are produced. Hence, it is worth emphasizing the important beneficial role of free radicals.
1. Generation of ATP (universal energy currency) from ADP in the mitochondria: oxidative phosphorylation

2. Detoxification of xenobiotics by Cytochrome P₄₅₀ (oxidizing enzymes)

3. Apoptosis of effect or defective cells

4. Killing of micro-organisms and cancer cells by macrophages and cytotoxic lymphocytes

5. Oxygenases (eg. COX: cyclo-oxygenases, LOX: lipoxygenase) for the generation of prostaglandins and leukotrienes, which have many regulatory functions. Radical formation in the body occurs by several mechanisms, involving both endogenous and environmental factors (Figure 4).

**FIGURE 4**

**MAJOR SOURCES OF FREE RADICALS IN THE BODY AND THE CONSEQUENCES OF FREE RADICAL DAMAGE**

**ENDOGENOUS SOURCE**
- Mitochondrial Leak
- Respiratory burst
- Enzyme reactions

**ENVIRONMENTAL SOURCES**
- Cigarette smoking
- Pollutants
- UV light, Xenobiotics

Free radical production

\[O_2, H_2O_2\]

Transition

\[OH\]

Lipid peroxidation

Modified DNA bases

Protein damage

Tissue damage
It has become clear that the reactive oxygen species act as second messengers. Reactive oxygen species plays an important role in modulating cellular function. Further studies shows that the exogenous hydrogen peroxide mimic the action of insulin growth factors. The free radical nitric oxide (NO) produced enzymatically play a pivotal role in vasodilation and neurotransmission via guanylated cyclase activation while reactive oxygen species and reactive nitrogen species that modulate signaling pathway and act as secondary messengers.

This led to the renaissance of the field of redox signaling and with the accumulation of data in various systems, a clearer picture is emerging of the signaling pathways and specific targets affected by ROS/RNS (Yoshikawa et al., 2000).

2.4.1 Concept of Oxidative Stress

Sies (1986) elaborates the oxidative stress as a relation between free radicals and disease. Antioxidant defense mechanism protects the cell from pro oxidants such as reactive oxygen species and reactive nitrogen species. However, when it gets exposed to adverse physicochemical, environmental or pathological agents such as atmospheric pollutants, cigarette smoking, ultraviolet rays, radiation, toxic chemicals, overnutrition and advanced glycation end products (AGEs) in diabetes, this delicately maintained balance is shifted in favor of pro-oxidants resulting in ‘oxidative stress’. This occurs during ageing process and is the major cause of numerous diseases.

2.4.2 Major Targets of Oxidative Activity

Free radicals affects all the biological molecules resulting in impairment of their respective function and further regulates in apoptosis. Lipid peroxidation takes place in polyunsaturated fatty acid in the presence of oxygen. Further rapid free radical chain reaction takes place thus disturbing membrane function. Figure 5 shows the disruptions of cell membranes.
2.4.3 Lipid Peroxidation

Free radical causes damage to lipid membrane. Lipid peroxidation takes place when lipids react with free radicals and it occurs as a chain reaction. As a result of it, toxic byproducts are formed and behave as secondary messengers. Ultimately, lipid peroxidation affects the functions of cell. Figure 6 shows the flowchart of lipid peroxidation.
Lipid peroxidation is a free radical mediated process. Initiation of peroxidative sequence is due to the attack by any species, which can abstract a hydrogen atom from a methylene group (CH$_2$), leaving behind an unpaired electron on the carbon atom (’CH). The resultant carbon radical is stabilized by molecular rearrangement to produce a conjugated diene, which then can react with an oxygen molecule to give a lipid peroxy radical (LOO$^\cdot$). The radicals can further abstract hydrogen atoms from other lipid peroxides (LOOH) and at the same time propagate lipid peroxidation further. The peroxidation reaction can be determined by a number of reactions. The major one involves the reaction of LOO$^\cdot$ or lipid radical (L$^\cdot$) with a molecule of antioxidant such as vitamin E or α-tocopherol (α-TOH) forming more stable tocopherol phenoxy radical that is not involved in further chain reactions. This can be ‘recycled’ by other cellular antioxidant or GSH (Devasagayam et al., 2004).

The process of lipid peroxidation, give rise to many products of toxicological interest like malondialdehyde (MDA), 4-hydroxynonenal (4-HNE) and various 2-alkenals, isopropatanus are unique products of lipid peroxidation of arachidonic acid and recently tests such as mass spectrometry and ELISA assay kits are available to detect (Yoshikawa et al., 2000).

**i. Carbohydrates**

Carbon centered radical is produced when free radicals reacts with carbohydrate. This cleaves important molecule such as hyaluronic acid. Neutrophils gets activated and accumulated during inflammation of joints due to formation of significant amount of oxygen radicals (Devasagayam et al., 2004).

**ii. DNA**

Oxidative damage to DNA is a result of interaction of DNA with ROS or RNS. Free radical induced damage to DNA may cause destruction of bases and deoxy ribose sugars or single or double strand breaks. Oxidative DNA damage can also be indirect e.g, the action of peroxy radicals free by endogenous lipid peroxidation or derived from the metabolism of classical chemical carcinogens (Devasagayam et al., 2004).

**iii. Protein**
Free radicals when reacts with protein results in fragmentation, aggregation or cross linkages, thereby interfering ion channel.

2.4.4 Antioxidants

Antioxidants are substances that act against the action of free radicals. Naturally all organisms possess protective mechanism against free radicals and serves as buffering system in every cell. For instance, vitamin E plays a vital role as a bond cleaving antioxidant thus preventing free radical propagation. Vitamin C is also part of the normal protecting mechanism. Other non-enzymatic antioxidants include carotenoids, flavonoids and related polyphenols, lipoic acid, glutathione etc.

2.4.5 Levels of Antioxidant Action

Antioxidants acts on free radicals at various stages. They act at the levels of prevention, interception and repair. Formation of reactive oxygen species are interrupted by preventive antioxidants. These include superoxide dismutase (SOD) that catalyses the dismutation of superoxide to H$_2$O$_2$ and catalase that breaks it down to water (Sies, 1996; Cadenas and Packer, 1996). Interception of free radicals is mainly by radical scavenging, while at the secondary level scavenging of peroxyl radicals are affected. The effectors include various antioxidants like vitamins C and E, glutathione, other thiol compounds, carotenoids, flavonoids, etc. At the repair and reconstitution level, mainly repair enzymes are involved (Halliwell and Aruoma, 1993; Cadenas and Packer, 1996; Sies, 1996). Free radicals have the capacity to react in an indiscriminate manner leading to damage to almost any cellular component, an extensive range of antioxidants defenses, both endogenous and exogenous, are present to protect cellular components from free radicals induced damage. These can be divided into 3 main groups.

- Antioxidant enzymes
- Chain breaking antioxidants
- Transition metal binding protein

Figure 7 shows the free radical damage and Antioxidant action (Halliwell and Gutteridge, 1989).
2.4.6 Enzymatic antioxidants

i. Superoxide dismutase

The superoxide dismutases catalyses the dismutation of superoxide to hydrogen peroxide. The hydrogen peroxide must then be removed by catalase or glutathione peroxidase.

\[ O_2^- + O_2^- + 2H^+ \rightarrow H_2O_2 + O_2 \]
SOD is endogenously produced intracellular enzyme present essentially every cell in the body. SOD is the most important enzyme because it is found virtually in all aerobic organisms. There are three forms of superoxide dismutase in mammalian tissues each with subcellular location and different tissue distribution.

1. Copper zinc superoxide dismutase (Cuzn-SOD)
2. Manganese superoxide dismutase (Mn-SOD)
3. Extracellular SOD (EC-SOD)

**ii. Catalase**

Catalase was the first antioxidant enzyme to be characterized and catalyses the two stages of conversion of hydrogen peroxide to water and O₂.

\[
\begin{align*}
\text{Catalase-Fe (III) + H}_2\text{O}_2 & \rightarrow \text{Compound I} \\
\text{Compound I + H}_2\text{O}_2 & \rightarrow \text{Catalase-Fe (III) + 2H}_2\text{O}^+ \text{O}_2.
\end{align*}
\]

Catalase consists of four protein subunits each containing a haem group and a molecule of NADPH. The rate constant for the reaction described above is extremely high (approximately \(10^7/\text{sec}\)). Catalase located within cells in peroxisomes, which also contain most of the enzymes capable of generate hydrogen peroxide. The greater activity is present in liver and erythrocytes but some catalase is found in tissues (Krikman et al., 1987).

**iii. Glutathione peroxidase**

Glutathione peroxidases catalyses the oxidation of glutathione at the expense of a \(\text{H}_2\text{O}_2\) which might be \(\text{H}_2\text{O}_2\) or another species such as a lipid hydroperoxide (Takahashi and Cohen, 1986). Glutathione peroxidase requires selenium at the active site (Nakane et al., 1998). Within cells the highest concentrations are found in liver although glutathione peroxidase is widely distributed in almost all tissues. The activity of enzyme is dependent on the constant availability of reduced glutathione (Holben and Smith, 1999).

**iv. Glutathione reductase**

Glutathione reductase requires NADPH to replenish the supply of reduced glutathione. Glutathione reductase is a flavine nucleotide dependant enzyme and has a similar tissue distribution to glutathione peroxidase (Gibsonand McCay, 1985).
v. Glutathione –S-transferase

GST are a multigene family of enzymes presents in all cells and have been implicated in protecting cells from the toxic and carcinogenic manifestation of various xenobiotics. Glutathione reductase is a flavine nucleotide dependant enzyme and has a similar tissue distribution to glutathione peroxidase ((Gibson and McCay, 1985).

2.4.7 Non Enzymatic Antioxidants
i. Reduced glutathione

Reduced glutathione (GSH) is a major source of thiol groups in the intracellular compartment GSH might function directly as an antioxidant, scavenging a variety of radical species, as well as acting as an essential factor for glutathione peroxidase (Arrigo, 1999).

ii. Vitamin A

The carotenoids are a group of lipid soluble antioxidant based around an isoprenoid carbon skeleton. β-carotene and other carotenoids such as α-carotene, γ-carotenoids and β-cryptoxanthin, are potent antioxidants of plant origin. β-caroteine reacts with peroxy radical to form a resonance-stabilised carbon centered radical with its conjugated alkyl structure, thereby inhibiting the chain propagation effects of ROS.

iii. Vitamin E

Tocopherols are typical and important antioxidants in humans. Tocopherol can protect PUFA with the membrane and LDL and inhibit smooth muscle cell proliferation and protein kinase C activity.

2.4.8 Role of Food / Diet in Type II Diabetes Mellitus

Goals of dietary therapy in diabetes are to reach and maintain ideal body weight (IBW), to maintain fasting and postprandial glycemic levels as close as possible to normal and to achieve optimal blood lipid values, while providing adequate caloric intake as required for the various metabolic needs. Dietary caloric restriction ameliorates hyperinsulinemia and hyperglycemia in obese type 2 diabetics (and improves other metabolic parameters; such as low in Insulin resistance, Hyperglycemia, Hypertriglyceridermia, total hypercholesterolemia, LDL
cholesterol, Hypertension and high in HDL cholesterol). Modern recommended diet for diabetes is relatively high in complex carbohydrates (55-60 per cent of total calories) and fibers, low in fats (25-30 per cent) especially saturated (< 10 per cent, to reduce dyslipidemia and atherosclerosis associated to diabetes) and limited, but adequate, in proteins (15 per cent).

Noticeably, dietary restriction may improve metabolic control even before weight loss is attained. In diabetics, simple carbohydrates should be restricted. The formerly claimed diabetogenic effect of sucrose over consumption has not been confirmed by epidemiological or experimental studies. However, in diabetic patients, sucrose rich foods cause a rapid rise in glycemic values, which can be prevented by consuming these foods as part of a mixed meal. In diabetics with insulin deficiency and impaired hepatic glycogen synthesis, fructose derived glucose contributes to the hyperglycemia. Thus, the safety of fructose use in diabetes is a debated topic. Starches are hydrolysed to dextrans, then to maltose and finally to glucose (through the effect of gastric acid and intestinal enzymes). They are useful in the diabetic diet because they are slowly digested and absorbed, inducing lower increments of the glycemic and insulminic values than equivalent amounts of glucose or simple sugars. In type II diabetes, elevated plasma levels of triglycerides and cholesterol frequently occur. Both hypertriglyceridemia and hypercholesterolemia respond in part to diet alterations. Low fat diets are often high in carbohydrate (being the proportion of proteins relatively constant), which may favour hypertriglyceridemia. This effect may be attenuated by supplementation with fibers.

Diets high in saturated fat are atherogenic (increasing total and LDL cholesterol levels) and favor insulin resistance; thus, a diet restricted in saturated fats is recommended. A diet high in monounsaturated fatty acids of MUFA does not increase LDL levels, may improve insulin sensitivity, glycemic control and HDL cholesterol levels and decreases plasma triglycerides. On the contrary, a diet high in polyunsaturated fatty acids reduces total and LDL cholesterol but decreases HDL cholesterol as well: moreover, some data from the literature would suggest that they may promote carcinogenesis in experimental animals. Recently, new fat substitutes were proposed for use in the diet of diabetic patients. One of these products is
named Olestra and is made from sucrose and long chain fatty acids, is heat stable, tastes like vegetable oil, promotes cholesterol excretion and is calorie free being not metabolized or absorbed.

Leucine and arginine have important biologic effects, stimulating insulin secretion, while other amino acids are gluconeogenic and ketogenic. In diabetic patients, a high protein diet can increase renal blood flow, glomerular filtration rate and intra glomerular pressure, accelerating glomerulosclerosis to end stage renal failure (Brenner’s hypothesis). To maintain energy balance, a low protein diet must be high in carbohydrates and fats and may exacerbate hyperglycemia, hypertriglyceridemia or hyperinsulinemia, increasing total and LDL cholesterol and decreasing HDL cholesterol. Moreover, in diabetic patients, a low protein dietary content may favor a negative nitrogen balance and muscle wasting.

Several studies demonstrated an improvement of glucose tolerance and a reduction of insulin secretion when a diet high in fiber was consumed. The physiological effects of fibers are influenced by osmolality or pH, mixtures of fibers and foods, water retention, fermentation by bacteria, etc. high fiber diets can cause (especially in the first 7-10 days) cramping, abdominal discomfort, flatulence and diarrhoea. These diets may also impair absorption of minerals and vitamins if used for a long time (in which instance, supplementation of calcium, traces elements and vitamins may be required). They may also increase the risk of bezoar formation, especially when a diet high in fibers is contraindicated (patients with gastrointestinal dysfunction, gastroparesis or altered absorption from pancreatic enzyme deficiency).

Diabetic patients may also suffer from associated diseases which require special modified diets. In the presence of congestive heart failure, hypertension and kidney disease, dietary sodium should be restricted. The sodium restriction may range from 500 to 1000 mg/day (maximum intake <3 g/ day), although the use of diuretics may reduce the need for a severe sodium restriction, which makes foods less palatable and may provoke hypotension and fluid or electrolyte disorders. Exercise is a relevant component in a program of weight loss in diabetic patients. It improves glucose tolerance, lowers glycemia, increases peripheral insulin sensitivity.
and reduces risk factors for coronary heart disease (ameliorating hypertension and blood lipid profile). Long term weight loss is possible only with combined effect of diet and exercise rather than diet or exercise alone. It also helps to reduce the dose of hypoglycemic drugs. A proper nutritional management of diabetic patients is the most important factor of treatment (even if often patients are unable to lose weight or to maintain the reduced weight). Management of diabetes is a greater challenge due to the burden of side effects caused by diabetic drugs (Zhang and Moller, 2000; Sy et al., 2005).

2.5. BLACK RICE AND DIABETES

Work done by Kim et al. (1999); Hu et al. (2003); Han et al. (2007); Han et al. (2009) Tsuda et al. (2004) and Acquaviva et al. (2003) reported the high content of cyanidin-3-β-D-glucoside (C3G) in black rice (BR) and the properties exhibited includeas antioxidant, anti-inflammatory, antianaphylactic and antiscratching. According to Han et al. (2007), orally consumed C3G will be converted to cyanidin and protocatechuic acid by intestinal microflora and its metabolites and are detected in the blood and urine as reported by Vitaglione et al. (2007) and Hassimotto et al. (2008). If black rice consumed orally, its major component, C3G gets converted to cyanidin and/or PA, which are extends strong anti-inflammatory actions by changing NF-κB and MAPK activation

Earlier studies conducted by Tsuda et al. (2004); Chen et al. (2005); Guo et al. (2008); Dani et al. (2008); Chun et al. (2008); Cvorovic et al. (2010); Cheetham and Katz (2011); Abdel (2011) and Yao et al. (2011), reported that natural constituents present in the food serves as major mediators in the prevention of degenerative disorders. Anthocyanins are water soluble pigments belonging to flavonoids and depending on their presence, plant materials appear in various colours such as red, purple, and blue (Qin et al., 2009). The main anthocyanin component present in black rice is cyanidin-3-glucoside (C3G) (Ichikawa et al., 2001; Zhang et al., 2010). Recent studies conducted by Sasaki et al. (2007); Nasri et al. (2011) reported that treating high-fat diet-fed mice and diabetic and hyperglycemic mice with purified C3G improves adipose inflammation and hepatic steatosis. Apart from these, black rice contains diverse bioactive phytochemicals,
such as phenolic compounds, tocopherols, tocotrienols, oryzanol and vitamin B complex (Jang et al., 2009; Zhang et al., 2010).

Liu (2004) proved that crude black rice extract (BRE) may perhaps generate more potential impact rather than the purified compounds, sine crude extracts will make use of the additive or combined action of various phytochemicals. According to Tanaka et al. (2011), *in vitro* and *in vivo* models, the activity of black rice and its components such as anthocyanidins (cyanidin and peonidin), will protect retinal cells from light-induced photoreceptor degeneration.

Many studies on the chemical composition and biological activities of black rice and its constituents have indicated this rice to have a number of beneficial properties including antioxidant (Ichikawa et al., 2001; Chiang et al., 2006; Jang and Xu, 2009), α-glucosidase inhibitory (Yao et al., 2009), antimitagenic (Nam et al., 2005; Chen et al., 2006), hepatoprotective (Hou et al., 2010), hyaluronidase inhibitor (Bralley et al., 2008), anti-inflammatory (Hu et al., 2003) effects and has been reported to protect A2E-laden retinal pigment epithelial cells against blue light-induced damage and retinal damage (Jang et al., 2005) and antidiabetic activity (Guo et al., 2008).