IJPSR (2014), Vol. 5, Issue 11 **(Research Article)**

INTERNATIONAL JOURNAL OF PHARMACEUTICAL SCIENCES AND RESEARCH

Received on 23 April, 2014; received in revised form, 12 June, 2014; accepted, 19 July, 2014; published 01 November, 2014

ATTENUATION OF HYPERGLYCEMIA AND OXIDATIVE STRESS IN STREPTOZOTOCIN-INDUCED DIABETIC RATS BY AQUEOUS EXTRACT OF *AVERRHOA BILIMBI* LINN FRUITS

Surya B. Kurup* and S Mini

Department of Biochemistry, University of Kerala, Kariavattom, Trivandrum, Kerala, India.

Keywords:

Averrhoa bilimbi Linn (ABAE), antioxidant, blood glucose, diabetes mellitus, free radicals, oxidative stress

Correspondence to Author:
Surya B. Kurup

Ph.D Research Scholar,
Department of Biochemistry,
University of Kerala Kariavattom,
Thiruvananthapuram- 695 581
Kerala, India.

E-mail: suryabk88@gmail.com

ABSTRACT: In the present study, the antidiabetic and antioxidant effect of aqueous extract of *Averrhoa bilimbi* Linn (ABAE) fruits were evaluated. Diabetes mellitus was induced in male Sprague Dawley rats by a single intraperitoneal injection of streptozotocin (40 mg/kg body weight). Oral administration of aqueous extract of *Averrhoa bilimbi* Linn (ABAE) (50mg/kg body weight) and metformin (100 mg/kg body weight) to diabetic rats for 60 days significantly reduced the levels of blood glucose, lipids and lipid peroxidation, but increased the activities of plasma insulin and antioxidant enzymes, like catalase, superoxide dismutase, reduced glutathione and glutathione peroxidase. The cytotoxicity of hepatic and renal tissue were ameliorated by treatment with aqueous extract of *Averrhoa bilimbi* Linn (ABAE) and metformin on histopathological examination. The *Averrhoa bilimbi* Linn (ABAE) aqueous fruit extract supplementation is useful in controlling the blood glucose level, improves the plasma insulin, lipid metabolism and is beneficial in preventing diabetic complications from lipid peroxidation and antioxidant systems in experimental diabetic rats; therefore, it could be useful for prevention or early treatment of diabetes mellitus.

INTRODUCTION: Diabetes mellitus is a serious metabolic disorder with micro and macrovascular complications that results in significant morbidity and mortality. The increasing number of ageing populations, consumption of calorie rich diets, obesity and sedentary life-style has lead to a tremendous increase in the number of patients with diabetes worldwide[1]. The World Health Organization (WHO) has predicted that the worldwide number of patients with diabetes will double by the year 2025, from the current number of approximately 150 million to 300 million [2].

QUICK RESPONSE CODE

DOI: 10.13040/IJPSR.0975-8232.5(11).4981-88

Article can be accessed online on: www.ijpsr.com

DOI link: http://dx.doi.org/10.13040/IJPSR.0975-8232.5(11).4981-88

Streptozotocin-induced diabetes mellitus is associated with the generation of reactive oxygen species causing oxidative damage [3]. Oxygenated compounds, especially aldehydes such as malondialdehyde and conjugated dienes, are produced during the attack of free radicals to membrane lipoproteins and polyunsaturated fatty acids.

Thus oxidative stress plays an important contributory role in the process of aging and pathogenesis of numerous diseases like diabetes, cancer, neurodegenerative diseases, and respiratory tract disorders. Diabetics and experimental animal models exhibit high oxidative stress due to persistent and chronic hyperglycaemia, which there by depletes the activity of antioxidative defense system and thus promotes *de novo* free radicals generation [4]. In diabetes mellitus, protein glycation

and glucose auto-oxidation may generate free radicals, which in turn catalyse lipid peroxidation [5]. Chemicals with antioxidant properties and free radical scavengers may help in the regeneration of β-cells and protect pancreatic islets against the cytotoxic effects of streptozotocin [6, 7]. Under physiological conditions, a wide range of antioxidant defences protects against the adverse effects of free radical production *in vivo* [8]. Decreased lipid peroxidation and improved antioxidant status may be one mechanism by which dietary treatment contributes to the prevention of diabetic complications [9].

Management of diabetes without any side effects is still a challenge to the biomedical application. This leads to increasing demand for natural products with anti-diabetic property and without adverse effects. Many synthetic drugs are used in treatment of diabetes, but plant drugs are frequently considered to be less toxic, and are free from side effects. Indian traditional medicines belong to one of the richest medicinal systems among those available in the world. *Averrhoa bilimbi* Linn commonly known as *bilimbi*, cucumber tree belongs family - Oxalidaceae. The fruits of *A.bilimbi* possess antibacterial, antiscorbutic, astringent and postpartum protective properties [10, 11].

This study was designed to investigate the protective effect of *Averrhoa bilimbi* Linn (ABAE) on lowering the blood glucose level, tissues lipid peroxides and enzymic antioxidants in STZ induced diabetic rats.

MATERIALS AND METHODS:

Preparation of aqueous extracts of *Averrhoa bilimbi* (ABAE):

Fresh fruits of *Averrhoa bilimbi* were obtained from Thiruvananthapuram, Kerala, India, during the fruiting season (July- December). Care was taken that the fruits, which were whitish- green in colour and approximately 5- 7.0 cm in size, were not overripe, spoilt or damaged. 5kgs of fruits were cut and shade dried. Shade dried fruits were ground in a blender to give 500g of fine powder. The aqueous extract was prepared by cold maceration of 500 g of the shade-dried fruits powder in 1000 ml of distilled water followed by filtration and lyophilisation (yield 26 g/100g shade dried *bilimbi* powder) and the residue stored in a refrigerator at 2-8°C for subsequent experiments.

Experimental Animals:

Male albino rats (Sprague - Dawley) of body weight 200 – 250gm, were used for this study. The rats were housed in polypropylene cages in a room maintained at 26 ± 1°C with a 12 hr light and dark cycle. The animal experiment were designed and conducted in accordance with the ethical norms approved by Institutional Animal Ethics Committee Guidelines [IAEC-KU-51/2011-12-BC-sm (17)].

Chemicals:

Streptozotocin was procured from SRL Chemicals. Kit for glucose and glycosylated hemoglobin estimation was purchased from Agappe Diagnostics, Thane, India. All other chemicals used for all the experiments were of analytical grade.

Induction of diabetes:

The animals fasted overnight and diabetes was induced by a single intraperitoneal injection of freshly-prepared STZ (40 mg/kg body weight of rats) in 0.1 M citrate buffer (pH 4.5) [12]. The animals were allowed to drink 5% glucose solution overnight to overcome the drug-induced hypoglycemia. The animals were considered as diabetic, if their blood glucose values were above 250 mg/dL on the third day after the STZ injection. The treatment was started on the fourth day after the STZ injection and this was considered the first day of treatment. The treatment was continued for 60 days.

Experimental procedure:

The rats were divided into four groups comprising eight animals in each group as follows:

Group 1: Control rats

Group 2: Diabetic controls (STZ 40 mg/kg body weight of rats)

Group 3: Diabetic rats treated with *Averrhoa bilimbi* Linn (ABAE) (50 mg/kg body weight of rats/day) in aqueous solution orally for 60 days

Group 4: Diabetic rats treated Metformin (100 mg/kg body weight of rats) orally for 60 days

After completion of treatment, the animals were sacrificed. Blood was collected in tubes containing potassium oxalate and sodium fluoride. Plasma was used for the estimation of blood glucose using the glucose oxidase method [13]. The levels of haemoglobin and glycosylated haemoglobin [14] were estimated. Plasma insulin level was assayed by enzyme-linked immuno sorbent assay kit (ELISA, Boerhringer Mannheim, Germany).

The liver and kidney tissues were excised and rinsed in ice cold saline. Tissues were cut into small pieces and homogenized. The homogenate was centrifuged and the supernatant was used for various measurements. The following analyses were carried out:

Serum total cholesterol (TC), high density lipoprotein (HDL-C) and triglycerides (TG) were estimated using the standard kit of Agappe Diagnostics, Pvt. Ltd., India. Low density lipoprotein (LDL-C) [15], Thiobarbituric acid reactive substances (TBRAS) [16], hydroperoxides [17], GSH [18], the activity of SOD [19], GPx [20] and CAT [21] were estimated.

All spectrophotometric measurements were carried out in a Camspec UV-Visible (Camspec M330B, UK) spectrophotometer.

Histopathological Studies:

Hepatic and Renal tissues from all groups were subjected to histopathological studies. The whole tissues from each animal was removed after sacrificing the animal under anesthesia, collected in 10% formalin solution and immediately processed by the paraffin technique. Sections of 5µm thickness were cut and stained with hematoxylin and eosin for histological examinations. Stained sections were qualitatively evaluated using a photo microscope (Zeiss Axioscope 2 plus, USA) equipped with Canon Zoom Browser EX digital camera (Japan).

Statistical Analysis:

Results were expressed as mean ± SD for four rats in each experimental group. Statistical analysis was performed using SPSS 17 software. The data were analysed using one-way analysis of variance (ANOVA) and group means were compared with Duncan's Multiple Range Test (DMRT). P-values < 0.05 were considered as significant.

RESULTS:

A significant increase in the level of blood glucose and a decrease in body weight were observed in diabetic rats when compared to control rats. Administration of *Averrhoa bilimbi* (ABAE) and metformin to diabetic rats significantly decreased the level of blood glucose and increased body weight to near control level. The diabetic rats showed a significant decrease in the levels of total haemoglobin and plasma insulin level along with a significant increase in the level of glycosylated haemoglobin (HbA1c) and as compared to diabetic rats. Administration of *Averrhoa bilimbi* (ABAE) or metformin to diabetic rats restored the total haemoglobin, plasma insulin and HbA1c to almost control levels **(Table 1)**.

TABLE 1. EFFECT OF TREATMENT *AVERRHOA BILIMBI* (ABAE)FRUITS EXTRACT FOR 60 DAYS ON BLOOD GLUCOSE, BODY WEIGHT, TOTAL HAEMOGLOBIN, GLYCOSYLATED HAEMOGLOBIN AND PLASMA INSULIN OF CONTROL AND EXPERIMENTAL GROUPS OF RATS.

Group	Blood glucose (mg/dL)		Change in bodyweight (g)	Total haemoglobin (g/dL)	Glycosylated Haemoglobin (Hb %)	Plasma insulin (µU/ml)
	Initial	Final				
Control	76.0±5.6	87.0±5.7	32.4 ± 2.3	15.21 ± 1.12	7.4 ± 1.37	16.21 ± 0.69
Diabetic	269.8±8.0*	296.0±8.6*	-34.1 ± 2.0*	11.56 ± 0.71*	15.3 ± 1.56*	5.42 ± 0.31*
Diabetic + *Averrhoa bilimbi* (ABAE)	260.7±7.7*	90.6 ± 6.0*	20.0 ± 1.1*	15.20 ± 0.80*	8.2 ± 0.93*	12.11 ± 0.65*
Diabetic + Metformin	264.4±8.5*	98.1 ± 5.9*	21.6 ± 1.3*	14.66 ± 0.68*	8.5 ± 1.12*	11.30 ± 0.52*

Values are given as mean ± SD for groups of eight animals each. Values are statistically significant at *p<0.05. Diabetic rats were compared with control rats; *Averrhoa bilimbi* (ABAE) treated diabetic rats were compared with diabetic rats; metformin-treated diabetic rats were compared with diabetic rats.

The serum lipid profile is shown in **Table 2**. The values of TC, HDL-C and LDL-C of those treated with *Averrhoa bilimbi* (ABAE) extract and metformin returned to values nearing that of the control group. This showed that treatment with *Averrhoa bilimbi* (ABAE) significantly improved the lipid profile in diabetic animals.

TABLE 2. EFFECT OF TREATMENT *AVERRHOA BILIMBI* (ABAE) FRUITS EXTRACT FOR 60 DAYS ON SERUM LIPID PROFILE OF CONTROL AND EXPERIMENTAL GROUPS OF RATS.

Parameters	Control	Diabetic	Diabetic + *Averrhoa bilimbi* (ABAE)	Diabetic + Metformin
TC	129.2 ± 10.3	279.5 ± 13.2*	155.0 ± 10.5*	168.2 ± 7.8*
LDL – C	60.2 ± 4.5	185.4 ± 8.3*	73.1 ± 6.2*	78.7 ± 9.0*
HDL – C	58.6 ± 4.2	42.4 ± 5.1*	66.4 ± 6.8*	64.1 ± 5.6*
TG	88.0 ± 7.6	187.2 ± 10.5*	103.3 ± 9.5*	109.2 ± 10.6*

Values are given as mean ± SD for groups of eight animals each. Values are statistically significant at *p<0.05. Diabetic rats were compared with control rats; *Averrhoa bilimbi* (ABAE) treated diabetic rats were compared with diabetic rats; metformin-treated diabetic rats were compared with diabetic rats.

Table 3 shows the concentration of lipid peroxidation and hydroperoxides in the liver and kidneys of both control and experimental groups of rats. There was a significant elevation in tissue lipid peroxidation and hydroperoxides in diabetic rats. Administration of *Averrhoa bilimbi* (ABAE) or metformin to diabetic rats decreased the levels of tissue lipid peroxidation and hydroperoxides to normal levels. The concentration of tissues SOD, CAT, GSH and GPx were significantly decreased in diabetic rats when compared to the control group. Administration of *Averrhoa bilimbi* (ABAE) extract and metformin to diabetic rats tend to bring the activities of these enzymes to near normal level **(Tables 4 and 5)**.

TABLE 3. EFFECT OF TREATMENT *AVERRHOA BILIMBI* (ABAE) FRUITS EXTRACT FOR 60 DAYS ON LEVEL OF TBARS AND HYDROPEROXIDES IN LIVER AND KIDNEY OF CONTROL AND EXPERIMENTAL GROUPS OF RATS

Group	TBARS (mM TBARS/100 g of wet tissue)		Hydroperoxides (mM hydroperoxides/100 g of wet tissue)	
	Liver	Kidney	Liver	Kidney
Control	0.93 ± 0.07	1.30 ± 0.14	73.4 ± 3.4	56.4 ± 4.6
Diabetic	1.71 ± 0.45*	2.28 ± 0.31*	99.2 ± 5.2*	80.3 ± 3.4*
Diabetic + *Averrhoa bilimbi* (ABAE)	0.97 ± 0.05*	1.41 ± 0.10*	73.1 ± 3.9*	69.1 ± 2.1*
Diabetic + Metformin	1.05 ± 0.31*	1.59 ± 0.11*	76.2 ± 4.5*	71.20 ± 3.0*

Values are given as mean ± SD for groups of eight animals each. Values are statistically significant at *p<0.05. Diabetic rats were compared with control rats; *Averrhoa bilimbi* (ABAE) treated diabetic rats were compared with diabetic rats; metformin-treated diabetic rats were compared with diabetic rats.

TABLE 4. EFFECT OF TREATMENT *AVERRHOA BILIMBI* (ABAE) FRUITS EXTRACT FOR 60 DAYS ON SUPEROXIDE DISMUTASE, CATALASE, GLUTATHIONE PEROXIDASE AND REDUCED GLUTATHIONE IN LIVERS OF CONTROL AND EXPERIMENTAL GROUPS OF RAT

Parameters	Control	Diabetic	Diabetic + *Averrhoa bilimbi* (ABAE)	Diabetic + Metformin
SOD (U/mg protein)	22.56 ± 1.76	15.63 ±1.38*	18.52 ± 2.00*	18.34 ± 1.45*
CAT (U/mg protein×103)	0.231 ± 0.025	0.117 ±0.014*	0.179 ±0.022*	0.201 ± 0.018*
GPx (U/mg protein)	0.195 ± 0.042	0.138 ±0.031*	0.163 ±0.047*	0.179 ± 0.060*
GSH (mg/100 g tissue)	55.6 ± 3.00	30.3 ± 2.34*	54.4 ± 3.20*	51.0 ± 1.64*

Values are given as mean ± SD for groups of eight animals each. Values are statistically significant at *p<0.05. Diabetic rats were compared with control rats; *Averrhoa bilimbi* (ABAE) treated diabetic rats were compared with diabetic rats; metformin-treated diabetic rats were compared with diabetic rats.

TABLE 5. EFFECT OF TREATMENT *AVERRHOA BILIMBI* (ABAE) FRUITS EXTRACT FOR 60 DAYS ON SUPEROXIDE DISMUTASE, CATALASE, AND GLUTATHIONE PEROXIDASE AND REDUCED GLUTATHIONE IN KIDNEYS OF CONTROL AND EXPERIMENTAL GROUPS OF RATS.

Parameters	Control	Diabetic	Diabetic + *Averrhoa bilimbi* (ABAE)	Diabetic + Metformin
SOD (U/mg protein)	13.14 ± 1.61	9.24 ±1.28*	13.16 ± 1.40*	12.16 ± 1.40*
CAT (U/mg protein×103)	0.121 ± 0.19	0.080 ± 0.008*	0.134 ± 0.030*	0.116 ± 0.027*
GPx (U/mg protein)	0.064 ± 0.007	0.044 ± 0.006*	0.058 ± 0.009*	0.051 ± 0.005*
GSH (mg/100 g tissue)	40.3 ± 2.25	29.0 ± 1.26*	38.7 ± 2.17*	36.2 ± 1.95*

Values are given as mean ± SD for groups of eight animals each. Values are statistically significant at *p<0.05. Diabetic rats were compared with control rats; *Averrhoa bilimbi* (ABAE) treated diabetic rats were compared with diabetic rats; metformin-treated diabetic rats were compared with diabetic rats.

Histopathology of Kidney and Liver:

Streptozotocin induced diabetic rats showed occational degeneration of tubules, mild segmental sclerosis of glomerular capsule and mild interstitial oedema in kidney and mild sinusoidal dialatation, focal inflammatory hepatic cell infiltration in liver. But the ABAE and metformin treatment showed restoration of altered architecture towards the normal histology of Kidney and Liver **(Fig 1 and 2)**.

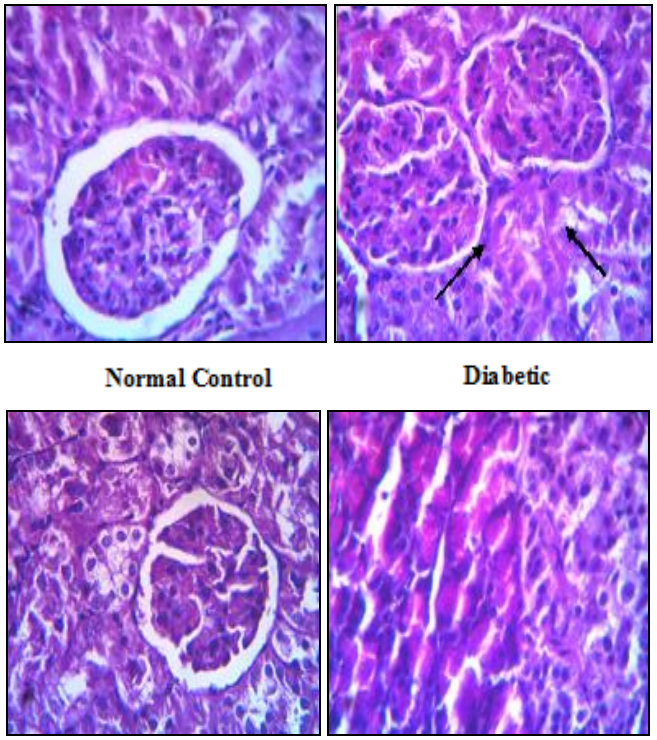

Fig 1. Photographs of Kidney stained with Haemotoxylin – Eosin (40 X)

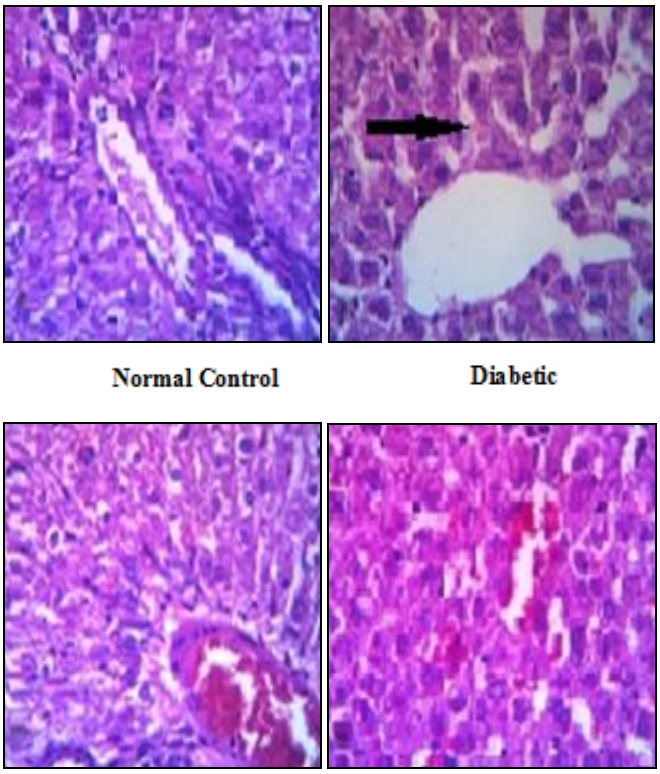

Fig 2. Photographs of Liver stained with Haemotoxylin – Eosin (40 X)

DISCUSSION: Currently-available drug regimens for management of diabetes mellitus have certain drawbacks and therefore, there is a need for safer and more effective antidiabetic drugs [23]. This study was undertaken to assess the antidiabetic and anti oxidant effect of *Averrhoa bilimbi* Linn (ABAE) fruits. In the present study, the oral treatment of *Averrhoa bilimbi* (ABAE) fruits extract decreased the blood glucose levels in diabetic rats. It has been

reported that using medicinal plant extract to treat STZ-induced diabetic rats results in activation of ß-cells and insulinogenic effects [24].

Averrhoa bilimbi (ABAE) may also have brought about hypoglycaemic action through stimulation of surviving ß cells of islets of Langerhans to release more insulin. This was clearly evidenced by the increased levels of plasma insulin in diabetic rats treated with *Averrhoa bilimbi* (ABAE). Since the percentage fall in plasma glucose levels was different in models with varying intensity of hyperglycaemia, it implies that the anti hyperglycaemic effect of that plant is dependent on the dosage of diabetogenic agent, which in turn leads to ß-cell destruction [25]. A number of other plants have also been observed to exert hypoglycaemic activity through insulin release stimulatory effects [26, 27]. The decreased level of total haemoglobin in diabetic rats is mainly due to the increased formation of HbA1c. HbA1c was found to increase in patients with diabetes mellitus and the amount of increase is directly proportional to the fasting blood glucose level [28].

During diabetes mellitus, the excess glucose present in the blood reacts with haemoglobin to form HbA1c [29]. HbA1c is used as a marker for estimating the degree of protein glycation in diabetes mellitus. Administration of *Averrhoa bilimbi* (ABAE) fruits to diabetic rats reduced the glycosylation of haemoglobin by virtue of its normoglycaemic activity and thus decreases the levels of glycosylated haemoglobin in diabetic rats. This normalisation of glycosylated haemoglobin indicates decreased glycation of proteins. **(Table 1)** The concentrations of lipids, such as cholesterol, TG and LDL- C were significantly higher in diabetic rats than in the control group where as the level of HDL-C was significantly decreased in diabetic rats than in the control group, A variety of derangements in metabolic and regulatory mechanisms, due to insulin deficiency, are responsible for the observed accumulation of lipids [30].

The impairment of insulin secretion results in enhanced metabolism of lipids from the adipose tissue to the plasma. Further, it has been reported that diabetic rats treated with insulin shows normalised lipid levels [31]. Thus, the results indicate that *Averrhoa Bilimbi* (ABAE) shows insulin-like action by virtue of its lipid lowering levels. (**Table 2)**

Oxidative stress has been shown to play a role in the causation of diabetes mellitus. Antioxidants have been shown to have a role in the alleviation of diabetes mellitus [32]. In diabetes mellitus, oxygen free radicals (OFRs) are generated by stimulating H_2O_2 *in-vitro*, as well as *in-vivo*, in pancreatic ß-cells [33]. OFR-scavenging enzymes can respond to conditions of oxidative stress with a compensatory mechanism that increases the enzyme activity in diabetic rats [34].

In our study, concentrations of lipid peroxides and hydroperoxides were increased in liver and kidneys of diabetic rats, indicating an increase in the generation of free radicals. Increased lipid peroxidation in diabetes mellitus can be due to increased oxidative stress in the cell as a result of depletion of antioxidant scavenger systems. The present finding indicates significantly increased lipid peroxidation of rats exposed to STZ and its attenuation by *Averrhoa bilimbi* (ABAE) treatment. This suggests that the protective role of *Averrhoa bilimbi* (ABAE) fruits extracts could be due to the antioxidative effect of flavonoids and phenolics present in the fruits, which in turn act as strong superoxide radicals and singlet oxygen quenchers. **(Table 3)**

Numerous studies have revealed lowered antioxidant and enhanced peroxidative status in diabetes mellitus [35]. In the current study, the SOD, CAT and GPx activities were significantly reduced in the liver and kidneys of diabetic rats. These observations emphasise the critical importance of maintaining the antioxidant potential of the pancreatic ß cell in order to ensure both its survival and insulin secretion capacity during times of increased oxidative stress. The decreased activities of SOD and CAT in both liver and kidneys during diabetes mellitus may be due to the production of reactive oxygen free-radical that can themselves reduce the activity of these enzymes.

Reduced glutathione is a potent-free radical scavenger (GSH) within the islet of ß-cell and is an important factor against the progressive destruction of the ß-cell following partial pancreatectomy [36].

Depletion of GSH results in enhanced lipid peroxidation. This can cause increased GSH consumption and can be correlated to the increase in the level of oxidized glutathione (GSSG). Treatment of *Averrhoa bilimbi* (ABAE) resulted in the elevation of the GSH levels, which protect the cell membrane against oxidative damage by regulating the redox status of protein in the membrane [37].

SOD, CAT and GPx are enzymes that destroy the peroxides and play a significant role in providing antioxidant defences to an organism. GPx and CAT are involved in the elimination of H_2O_2. SOD acts to dismutate superoxide radical to H_2O_2, which is then acted upon by GPx. The functions of all three enzymes are interconnected and a lowering of their activities results in the accumulation of lipid peroxides and increased oxidative stress in diabetic rats. Treatment of *Averrhoa bilimbi* (ABAE) increased the activity of these enzymes and thus may help to avoid the free radicals generated during diabetes mellitus. **(Table 4 & 5)**

Protective effect of aqueous fruits extract of *Averrhoa bilimbi* were also evident from the histopathological analysis of the Liver and Kidney. Streptozotocin induced diabetic rats showed occational degeneration of tubules, mild segmental sclerosis of glomerular capsule and mild interstitial oedema in kidney and mild sinusoidal dialatation, focal inflammatory hepatic cell infiltration in liver. ABAE and metformin treatment for 60 days helped to restore the renal and hepatic tissue integrity and was able to regenerate the STZ damaged renal and hepatic cells. **(Fig 1 & 2)**

The study suggested that diabetic animals are exposed to oxidative stress and *Averrhoa bilimbi* (ABAE) can partially reduce the imbalances between the generation of reactive oxygen species (ROS) and the scavenging enzyme activity. According to these results, *Averrhoa bilimbi* (ABAE) could be a supplement, as an antioxidant therapy, and may be beneficial for correcting the hyperglycaemia and preventing diabetic complications due to lipid peroxidation and free radicals. The *Averrhoa bilimbi* (ABAE) fruit is not only similar to metformin in having a hypoglycaemic effect; it also controls the hyperglycemic and antioxidant level and could be used to improve the lipid metabolism. Longer duration studies of *Averrhoa bilimbi* (ABAE) and its isolated compounds on chronic models are necessary to develop a potent antidiabetic drug.

CONCLUSION: It can be concluded from the data that *Averrhoa bilimbi* (ABAE) fruits extract supplementation is beneficial in controlling the blood glucose level, improves the lipid metabolism and prevents diabetic complications from lipid peroxidation and antioxidant systems in experimental diabetic rats. This could be useful for prevention or early treatment of diabetic disorders.

ACKNOWLEDGEMENT: The authors are thankful to the Muraleedhara Kurup, Professor and Head, Department of Biochemistry, University of Kerala, Kariavattom Trivandrum providing the necessary lab facilities to carry out the work successfully.

REFERENCES:

1. Simpson JE, Shaw JE and Zimmet PZ: The prevention of type 2 diabetes-lifestyle change or pharmacotherapy? A challenge for the 21st century. Diab. Res. Clin. Pract, 2003; 59: 165–180.
2. World Health Organization: Diabetes mellitus. Fact sheet no. 138, 2002.
3. Szkudelski T: The mechanism of alloxan and streptozotocin action in b-cells of the rat pancreas. Physiol. Res, 2001; 50: 536–546.
4. Baynes JW, Thorpe SR: The role of oxidative stress in diabetic complications. Curr. Opin. Endocrinol, 1997; 3: 277–284.
5. Baynes JW: Role of oxidative stress in development of complications of diabetes mellitus. Diabetes. 1991; 40: 405–412.
6. Alvarez JF, Barbera A, Nadal B, Barcelo-Batllori S, Piquer S, Claret M, Guinovart JJ andGomis R: Stable and functional regeneration of pancreatic beta-cell population in nSTZ-rats treated with tungstate. Diabetologia, 2004; 47: 470–477.
7. Coskun O, Kanter M, Korkmaz A and Oter S: Quercetin, a flavonoid antioxidant, prevents and protects streptozotocin-induced oxidative stress and b-cell damage in rat pancreas. Pharmacol. Res, 2005; 51: 117–123.
8. Halliwell B and Gutteridge JMC: Free Radicals in Biology and Medicine. 2nd ed. Oxford: Clarendon Press, 1989.
9. Armstrong A, Chestnutt J, Gormley M and Young I: The effect of dietary treatment on lipid peroxidation and antioxidant status in newly diagnosed non-insulin dependent diabetes. Free Radic. Biol. Med, 1996; 21: 719–726.
10. Wee YC: A guide to medicinal plants. Singapore Science Center, Singapore. 1992, p. 21.
11. Goh SH, Chuah CH, Mok JSL and Soepadmo E: Malaysian medicinal plants for the treatment of cardiovascular diseases. Pelanduk, Malaysia, 1995, p. 63.

12. Chattopadhyay S, Ramannadhan M, Das J and Bhattacharya SK: Animal models in Diabetes mellitus. Indian Journal of Experimental Biology, 1997; 35: 1141-1145.
13. Hugget A and Nixon DA: Use of Glucose Oxidase, Peroxidase and O-Dianisidine in Determination of Blood and Urinary Glucose. The Lancet, 1957; 270: 360–370.
14. Trivelli, Lia et al: New Eng.J.Med. 1971; 284: 353.
15. Friedewald WT, Levi RI and Fredrickson DS: Estimation of concentration of low-density lipoprotein cholesterol in plasma without use of the preparative ultracentrifuge. Clin Chem, 1972; 18: 499-502.
16. Ohkawa H, Ohishi N and Yagi K: Assay for lipid peroxides in animal tissues by thiobarbituric acid reaction. Anal Biochem, 1979; 95: 351-8.
17. Jiang ZY, Hunt JV and Woff SP: Ferrous ion oxidation in the presence of xylenol orange for detection of lipid peroxide in low density lipoprotein. Anal Biochem, 1992; 202: 384-9.
18. Patterson JW and Lazarow A: Determination of glutathione. Meth. Biochem. Anal, 1955; 2: 259.
19. Kakkar P, Das B and ViswanathanPN: Indian J Biochem Biophys**,** 1984, 2: 130–132.
20. Lawrence RA and Burk RF: Glutathione peroxidase activity in selenium-deficient rat liver. Biochem Biophys Res Commun, 1976; 71: 952-8.
21. Maehly AC and Chance B: The assay of CAT and peroxides. Methods of biochem Anal, 1954; 1: 357-424.
22. Lowry OH, Rosebrough NJ, Farr AL and Randall RJ: Protein measurement with the Folin phenol reagent. J Biol Chem, 1951; 193: 265-75.
23. Grover JK, Yadav S and Vats V: Medicinal plants of India with antidiabetic potential. J Ethnopharmacol, 2002; 81: 81-100.
24. Padmini K and Chakrabarti CH: Effects of Bittergourd (Momordica charantia) seed and glibenclamide in streptozotocin-induced diabetes mellitus. Indian J Exp Biol, 1982; 20: 232-5.
25. Grover JK, Vats V and Rathi SS: Anti-hyperglycemic effect of Eugenia jambolana and Tinospora cordifolia in experimental diabetes and their effects on key metabolic enzymes involved incarbohydrate metabolism. J Ethnopharmacol, 2000; 73: 461-70.
26. Pari L and Uma Maheswari J: Antihyperglycaemic activity of Musa sapientum flowers: effect on lipid peroxidation in alloxan diabetic rats. Phytother Res, 2000; 14: 136-8.
27. Stanley P, Prince M and Menon VP: Hypoglycaemic and other related actions of Tinospora cordifolia in alloxan-induced diabetic rats. J Ethnopharmacol, 2000; 70: 9-15.
28. Al-yassin D and Ibrahim K: A minor haemoglobin fraction and the level of fasting blood glucose. J Fac Med Baghdad, 1981; 23: 373- 80.
29. Koening RL, Peterson CM, Jones RL et al., Correlation of glucose regulation and haemoglobin AIc in diabetes mellitus. New Engl J Med, 1976; 295: 417-20.
30. Rajalingam R, Srinivasan N and Govindarajulu P: Effect of alloxan induced diabeties on lipid profiles in renal cortex and medulla of mature albino rats. Indian J Exp Biol, 1993; 31: 577-9.
31. Pathak RM, Ansari S and Mahmood A: Changes in chemical composition of intestinal brush border membrane in alloxan induced chronic diabetes. Indian J Exp Biol, 1981; 19: 503-5.
32. Oberley LW: Free radicals and diabetes. Free Radic Biol Med, 1988; 5: 113-24.
33. Halliwell B and Gutteridge JM: Role of free radicals and catalytic metal ions in human disease: An overview. Meth. Enzymol, 1990; 186: 1–85.
34. Yam J, Frank L and Roberts RJ: Oxygen toxicity: comparison of lung biochemical responses in neonatal and adult rats. Pediatr Res, 1978; 12: 115-9.
35. Giugliano D, Ceriello A and Paolisso G: Oxidative stress and diabetic vascular complications. Diabetes Care, 1996; 19: 257-67.
36. McLennan SV, Heffernan S, Wright L et al., Changes in hepatic glutathione metabolism in diabetes. Diabetes, 1991; 40: 344-8.
37. Inove M, Saito Y, Hirato E et al., Regulation of redox status of plasma proteins by mechanism and transport of glutathione and related compounds. J Protein Chem, 1987; 36: 169-73.

How to cite this article:
Kurup and SB and Mini S: Attenuation of Hyperglycemia and Oxidative Stress in Streptozotocin-Induced Diabetic Rats by Aqueous Extract of *Averrhoa Bilimbi* Linn Fruits. Int J Pharm Sci Res 2014; 5(11): 4981-88.doi: 10.13040/IJPSR.0975-8232.5 (11).4981-88.