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RESEARCH ARTICLE

Effect of Aqueous Extract of *Syzygium cumini* Pulp on Antioxidant Defense System in Streptozotocin Induced Diabetic Rats

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ABSTRACT

The aqueous extract of *Syzygium cumini* (Pulp) was investigated for its possible hypoglycemic and anti-oxidant potentials in streptozotocin (STZ) induced diabetic wistar female rats. A single intraperitoneal injection of STZ at a dose of 55 mg/kg body weight elevated the glucose levels more than 230 mg/dl after 3 days. Treatment with the aqueous extract of *Syzygium cumini* (Pulp) at 100 mg/kg and 200 mg/kg body weight resulted in significant reduction ($p <0.001$) in blood glucose levels. Body weights were significantly reduced ($p <0.001$) in STZ Induced diabetic rats when compared to normal rats, while in diabetic rats *S.cumini* extract ($p <0.001$) prevented significantly the decrease in body weight in a dose dependant manner. Total cholesterol, phospholipids, triglycerides, LDL-c, HDL-c levels were altered in STZ induced diabetic rats, which were considerably restored to near normal in animals treated with *S.cumini* extract .The administration of aqueous extract of *Syzygium cumini* resulted in significant ($p <0.001$) increase in the levels of superoxide dismutase, catalase, glutahione peroxidase, glutathione-S-transferase and reduced glutathione (GSH), thus resulting in reduced free radical formation in liver tissues of the diabetic rats . The increased levels of lipid peroxidation and hydroperoxides in diabetic rats were reverted back to near normal levels after the treatment with aqueous extract of *Syzygium cumini*. These observations demonstrated that aqueous extract of *Syzygium cumini* (Pulp) have strong hypoglycemic effect and *in vivo* antioxidant activity in STZ-Induced diabetic rats and was dose dependent.

Keywords: *Free radical, Syzygium cumini, Diabetic rats*

Diabetes mellitus is a syndrome characterized by abnormal insulin secretion, derangement in carbohydrate and lipid metabolism, and is diagnosed by the presence of hyperglycemia [1]. The currently suggested mechanism underlying diabetes and diabetic complications is Oxidative stress [2]. In recent years, much attention has been focused on the role of oxidative stress, and it has been reported that oxidative stress may constitute the key and common event in the pathogenesis of secondary diabetic complications [3]. The role of free radical reactions in disease pathology is well established, suggesting that these reactions are necessary for normal metabolism but can be detrimental to health as well. During metabolism, oxygen consumption involves the constant generation of free radicals and reactive oxygen species. Free radicals are either generated by cellular metabolisms such as glycolysis, mitochonchrial respiration, and xenobiotic detoxification or by exogenous factors such as redox reactions. Some are extremely reactive and therefore interact with some "vital" macromolecules including lipids, nucleic acids and proteins [4]. There are many enzymatic and nonenzymatic antioxidant defence systems in the body that remove these toxic species. Enzymes such as superoxide dismutase, catalase, glutathione peroxidase, etc. are involved in this detoxification process [5]. Moreover, diabetes also induces changes in the activity of the antioxidant enzymes [6]. Accumulating evidence suggests that oxidative cellular injury caused by free radicals contributes to the development of diabetes mellitus [7]. Thus oxidative stress has been shown to have a role in the causation of diabetes type I and II and as such antioxidants may have a role in the alleviation of diabetes and related problems [8, 9].

Currently, there is growing interest in herbal remedies due to the side effects associated with the therapeutic agents (oral hypoglycemic agents and insulin) for the treatment of diabetes mellitus [10].

Recently, some synthetic antioxidants such as butylated hydroxytoluene (BHT) and butylated hydroxyanisole (BHA) have been suspected to be dangerous to human health [11]. Therefore there is an urgent need to search for novel antioxidants from natural sources, which could be used in medicine and additives to nutriceuticals [12]. Plants often contain substantial amounts of antioxidants, such as carotenoids, flavonoids and tannins [13] and we suggest that antioxidant action may be an important property of plant medicines for treatment of diabetes. Many indigenous Indian medicinal plants have been found to be useful to successfully manage diabetes [14].

Out of a large number of herbal drugs stated to posses anti-diabetic activity in the Auyurvedic system of medicine of India, *Syzygium cumini* of family *Myrtaceae* is being widely used to treat diabetes by the traditional practiners over many centuries [15]. *Syzygium cumini* is commonly called as Jamun, Black plum or Indian Black berry. It is a large tree found in all forests over the greater part of India from the sub-Himalayan tract to extreme south. It is also found in Thailand and Philippines. The fruits of *Syzygium cumini* are oval to elliptical, 1.5–3.5 cm long, dark purple or nearly black, luscious, fleshy and edible [16]. The fruits are reported to contain vitaminC, gallic acid, tannins, anthocyanins, includes cyanidin-, petunidin, malvidin glucoside and other components. The juice of unripe fruits is used for preparing vinegar that is considered to be a stomachic, carminative and diuretic [17, 18]. So far the antihyperglycemic activity of seeds of *Syzygium cumini* has been well established [19-25] but there are only very few reports regarding the antihyperglycemic activity of fruit-pulp of *Syzygium cumini* [19, 22, 26]. Also studies' regarding the antioxidant potentials of *Syzygium cumini* pulp has not yet been reported. Thus an attempt was made to investigate the effect of *Syzygium cumini* pulp on antioxidant enzymes in liver of streptozotocin-induced diabetic rats. The efficacy was compared with the standard hypoglycemic drug, glyburide.

MATERIALS AND METHODS

Chemical

Streptozotocin (STZ) and glyburide were obtained from Sigma Chemical Co (St Louis, MO-USA). Biochemical kits and all other chemicals utilized were of analytical grade.

Plant Materials

The plant material of *Syzygium cumini* fruit was procured from local market during the month of June. This was identified and authenticated by Dr. P. Jayaraman, Director, Plant Anatomy Research Centre (PARC), Chennai. The voucher sample (No. PARC/2006/11) was kept in our laboratory for reference.

Preparation of Plant Extract

The ripe fruits of *Syzgium cumini* (1 Kg) were first washed well and the pulp was separated from the seeds. The pulp was ground for 10 min in a mixer along with the distilled water (500 ml). It was allowed to stand overnight and then filtered through several layers of muslin cloth. The whole procedure was carried out in the cold condition at 4 °C. The filtrate was centrifuged in a refrigerated centrifuge at 10,000 rpm. The supernatant was lyophilized to get a thick paste of water extract. The yield of lyophilized water extract was about 8.9 g from 650 g of pulp, obtained from 1 kg fruits of *Syzgium cumini*.

Animals

Female Wistar rats weighing 170±10 g obtained from Tamil Nadu Veterinary and Animal Sciences University, Chennai, India were used for the present investigation. The animals were maintained on standard rat feed supplied by Hindustan Lever Ltd., Bangalore, India. The experiments were conducted according to the ethical norms approved by Ministry of Social Justices and Empowerment, Government of India and Institutional Animal Ethics Committee Guidelines. Animals were housed in stainless steel cages and kept in a room where a 12 h light/dark cycle was maintained. Rats had free access to water and standard feed throughout the period of the experiment.

Induction of Diabetes in Rats

After one week of acclimatization, the rats were subjected to overnight fasting. Diabetes was induced with a single intraperitoneal injection of STZ at a dose of 55 mg/kg body weight. The STZ was freshly dissolved in citrate buffer (0.01M, pH 4.5) [27]. The injection volume was prepared to contain 1.0 ml/kg [28]. The animals were allowed to drink 5% glucose solution overnight to overcome the drug induced hypoglycemia. After 3 days, blood glucose levels were measured and the animals with a glucose concentration of more than 230 mg/dL were classified as diabetic [29] and taken for the experiment. Administration of the aqueous extract of *Syzygium cumini* was started on 4th day after STZ injection and this was considered to be the 1st day of treatment, which was continued for 15 days.

Experimental Design

Thirty female Wistar rats were used in this study. The rats were randomized and divided into five groups of six animals each.

Group I: Control rats, received citrate buffer (0.01M, pH 4.5).

Group II: Diabetic controls, received STZ (55 mg/kg body weight, i.p.) once.

Group III: Diabetic rats, receiving aqueous extract of *Syzygium cumini* (100 mg/kg body weight) orally for 15 days.

Group IV: Diabetic rats, receiving aqueous extract of *Syzygium cumini* (200 mg/kg body weight) Orally for 15 days.

Group V: Diabetic rats receiving 5 mg/kg body weight of Glyburide orally for 15 days.

At the end of the experiment, all the rats were decapitated after fasting for 16 hours. Blood was

Table 1. Effect of aqueous extract of *Syzgium cumini* on body weight in STZ induced diabetic rats.

Treatment	Body weight (g)			
	Initial	5th day	10th day	15th day
Vehicle control (group I)	174.38 ± 8.2	179.47 ± 6.8	183.26 ± 7.3	191.73 ± 9.4
Diabetic control (group II)	176.83 ± 7.1a*	142.14 ± 6.2a*	139.41 ± 5.8a*	132.14 ± 5.1a*
Diabetic + 100mg/kg *S.cumini* (group III)	175.37 ± 6.4b*	148.21 ± 7.6b*	157.6 ± 7.4b*	163.49 ± 6.1b*
Diabetic + 200mg/kg *S.cumini* (group IV)	175.23 ± 7.8c*	151.26 ± 5.1c*	161.91 ± 9.7c*	168.28 ± 7.2c*
Diabetic + 5mg/kg glyburide (group V)	178.28 ± 9.2d*	156.73 ± 6.3d*	164.14 ± 7.2d*	173.38 ± 5.4d*

Values are given as Mean ± SEM of six animals in each group.

a Comparison of Group I vs Group II.

b,c, d Comparison of Group III , Group IV & Group V vs Group II.

*p<0.001 statistically significant (ANOVA followed by Dunnet's t-test), when diabetic control was compared with the vehicle control and extract treated groups were compared with the diabetic control.

collected without anticoagulant to separate serum for various biochemical estimations. The liver was dissected out and cleared off blood. This was immediately transferred to ice-cold containers containing 0.9% NaCl and homogenized in 0.1N Tris-Hcl buffer (pH 7.4). The tissue homogenates were used for the following estimations: Thiobarbituric acid reactive substances (TBARS) and hydroperoxides were estimated according to method of Ohkawa et al [30] and Jiang et al [31] respectively. Reduced glutathione (GSH) was estimated by the method of Ellman [32]. Protein was estimated by the method of Lowry et al [33]. The activity of superoxide dismutase (SOD) was assayed by the method of Misra et al [34]. The activity of glutathione peroxidase (GPx) was assayed according to the method of Rotruck et al [35]. Catalase (CAT) activity was assayed by the method of Sinha [36]. Glutathione-S-transferase (GST) was estimated by the method of Habig et al [37].

Measurement of Body weight & Blood Glucose Level

The body weight and blood glucose level were measured at about every 5 days interval. Blood samples were obtained by tail vein puncture of both the normal and STZ induced diabetic rats. Blood glucose level was measured by single touch glucometer.

Serum Total Cholesterol

Serum total cholesterol (TC) was quantified by spec-

trophotometric method [38] by the addition of enzyme present in reagent kit. The absorbance of red quinoneimine complex was determined at 505 nm. The value of TC present in serum was expressed in mg/dL.

Serum Lipoprotein Cholesterol

Serum LDL-c was measured according to protocol of Friendswald et al [39]. Serum HDL-c was measured by the method of Waenic et al [40].

Serum Triglyceride

Serum triglyceride was measured by using kit. The absorbance was noted at 520 nm. The value was expressed in the unit of mg/dL [41].

Serum Phospholipids

Serum phospholipids was determined by the method of Zilversmit et al [42]

Statistical analysis

Statistical evaluation of data was performed by using one-way analysis of variance (ANOVA) followed by Dunnet's t-test [43]. p-values < 0.05 were considered as significant.

RESULTS

Blood Glucose Level and Body Weight Changes

The body weight changes in diabetic group was significantly decreased (p <0.001) when compared with the

Table 2. Effect of aqueous extract of *Syzgium cumini* on blood glucose levels in STZ induced diabetic rats.

Treatment	Blood glucose level (mg/dL)				
	Initial day	1st day	5th day	10th day	15th day
Vehicle control (group I)	88.32 ± 5.2	86.91 ± 6.4	87.51 ± 4.8	89.26 ± 3.2	86.72 ± 4.8
Diabetic control (group II)	87.21 ± 5.6a*	239.78 ± 9.4a*	256.32 ± 8.1a*	274.28 ± 6.2a*	281.63 ± 6.9a*
Diabetic + 100mg/kg *S.cumini* (group III)	85.61 ± 4.8b*	236.81 ± 7.2b*	192.23 ± 4.1b*	159.23 ± 8.2b*	127.16 ± 5.4b*
Diabetic + 200mg/kg *S.cumini* (group IV)	87.30 ± 4.2c*	234.91 ± 6.2c*	166.27 ± 5.3c*	127.42 ± 5.8c*	114.56 ± 5.1c*
Diabetic + 5mg/kg glyburide (group V)	86.49 ± 5.8d*	198.38 ± 4.1d*	142.29 ± 6.2d*	112.3 ± 5.4d*	98.68 ± 4.7d*

Values are given as Mean ± SEM of six animals in each group.

a Comparison of Group I vs Group II.

b,c, d Comparison of Group III , Group IV & Group V vs Group II.

*p<0.001 statistically significant (ANOVA followed by Dunnet's t-test), when diabetic control was compared with the vehicle control and extract treated groups were compared with the diabetic control.

Table 3. Effect of aqueous extract of *Syzgium cumini* on serum lipid profile in STZ induced diabetic rats.

Treatment	Serum Total cholesterol (mg/dL)	Serum HDL (mg/dL)	Serum LDL (mg/dL)	Serum Triglycerides (mg/dL)	Serum Phospholipid (mg/dL)
Vehicle control (group I)	128.72 ± 4.8	45.73 ± 3.2	46.56 ± 5.2	78.63 ± 6.1	104.61 ± 5.9
Diabetic control (group II)	233.61 ± 7.2a*	27.91 ± 4.8a*	126.62 ± 4.7a*	183.16 ± 9.2a*	63.28 ± 4.7a*
Diabetic + 100mg/kg *S.cumini* (group III)	188.82 ± 6.1b*	34.57 ± 5.3b*	83.38 ± 4.2b*	131.56 ± 4.8b*	85.41 ± 4.9b*
Diabetic + 200mg/kg *S.cumini* (group IV)	164.48 ± 5.2c*	40.22 ± 4.6c*	48.26 ± 3.8c*	98.23 ± 5.1c*	91.58 ± 5.6c*
Diabetic + 5mg/kg glyburide (group V)	136.28 ± 5.9d*	41.27 ± 3.8d*	42.81 ± 3.2d*	70 22 ± 4.6d*	99.23 ± 5.4d*

Values are given as Mean ± SEM of six animals in each group.

a Comparison of Group I vs Group II.

b,c, d Comparison of Group III , Group IV & Group V vs Group II.

*$p<0.001$ statistically significant (ANOVA followed by Dunnet's t-test), when diabetic control was compared with the vehicle control and extract treated groups were compared with the diabetic control.

normal control, which then returned to near normal in diabetic rats treated with aqueous extract of *Syzygium cumini* at a dose of 100 and 200 mg/kg body weight. The results were shown in (Table 1).

The results of blood glucose level changes in normal, STZ induced diabetic rats and *Syzygium cumini* treated diabetic rats were shown in (Table 2). There was a significant ($p <0.001$) increase in blood glucose levels in STZ induced diabetic rats (group II) when compared with normal rats. Administration of aqueous extract of *Syzygium cumini* at a dose of 100 and 200 mg/kg body weight significantly ($p <0.001$) decreased blood glucose level in STZ induced diabetic rats (group III and IV). The results were found to be in a dose dependent manner, comparable with that of standard glyburide.

Serum Lipids

The changes in the level of serum lipids in control and experimental rats are illustrated in (Table 3). The total-cholesterol, LDL-Cholesterol and triacylglycerol significantly increased and HDL-Cholesterol, pholipids significantly decreased in STZ induced diabetic rats (group II) ($p <0.001$) when compared with the normal (group I) rats. The aqueous extract of *Syzygium cumini* (100 mg/kg and 200 mg/kg body weight) offered a significant protection against alteration in the serum

lipids of diabetic rats. The results were also dose dependent. The results were comparable with that of standard glyburide.

Lipid peroxidation and Hydroperoxides

The levels of MDA in liver were significantly ($p<0.001$) increased in STZ induced diabetic rats as compared to normal rats. Treatment with aqueous extract of *Syzygium cumini* resulted in significant decrease in the level of lipid peroxidation products (MDA) and Hydroperoxides in diabetic rats. The results were shown in (Fig. 1 & 2).

Antioxidant enzymes

A significant decrease ($p <0.001$) in the activities of antioxidant enzymes such as SOD and CAT were observed in the liver of STZ induced diabetic rats when compared with that of normal rats. Upon administration of 100 and 200mg/kg body weight of aqueous extract of *Syzygium cumini*, the activities of both SOD and CAT were significantly reversed to near normal. The levels of reduced glutathione, Glutathione peroxidase, Glutathione-S-transferase were significantly depleted in STZ induced diabetic rats. Treatment with aqueous extract of *Syzygium cumini* significantly increased the levels of these antioxidant enzymes in diabetic rats. The results were shown in (Table 4).

Table 4. Effect of aqueous extract of *Syzgium cumini* on antioxidant enzymes in STZ induced diabetic rat liver.

Treatment	SOD	CAT	GPx	GSH-Rase	GST
Vehicle control (group I)	7.31 ± 0.13	54.62 ± 6.2	7.63 ± 0.21	0.971 ± 0.06	8.15 ± 0.61
Diabetic control (group II)	3.72 ± 0.08a*	18.59 ± 6.8a*	5.19 ± 0.34a*	0.492 ± 0.05a*	4.58 ± 0.47a*
Diabetic + 100mg/kg *S.cumini* (group III)	4.87 ± 0.25b*	36.38 ± 7.3b*	6.25 ± 0.25b*	0.710 ± 0.02b*	6.24 ± 0.43b*
Diabetic + 200mg/kg *S.cumini* (group IV)	5.94 ± 0.16c*	49.26 ± 5.6c*	6.92 ± 0.38c*	0.823 ± 0.04c*	7.53 ± 0.53c*
Diabetic + 5mg/kg glyburide (group V)	6.98 ± 0.15d*	51.83 ± 5.9d*	7.12 ± 0.12d*	0.91 ± 0.05d*	7.89 ± 0.58d*

Values are given as Mean ± SEM of six animals in each group.

a Comparison of Group I vs Group II.

b,c, d   Comparison of Group III , Group IV & Group V vs Group II.

*$p<0.001$ statistically significant (ANOVA followed by Dunnet's t-test), when diabetic control was compared with the vehicle control and extract treated groups were compared with the diabetic control.

Units

SOD - Units/mg protein.

1 unit - The amount of enzyme required bring about 50% of inhibition of autooxidation of epinephrine.

GPx - μ moles of GSH oxidized/min/mg protein.

GSH - n moles of DTNB conjugated /mg protein.

CAT - n moles of hydrogen peroxide decomposed/min/mg protein.

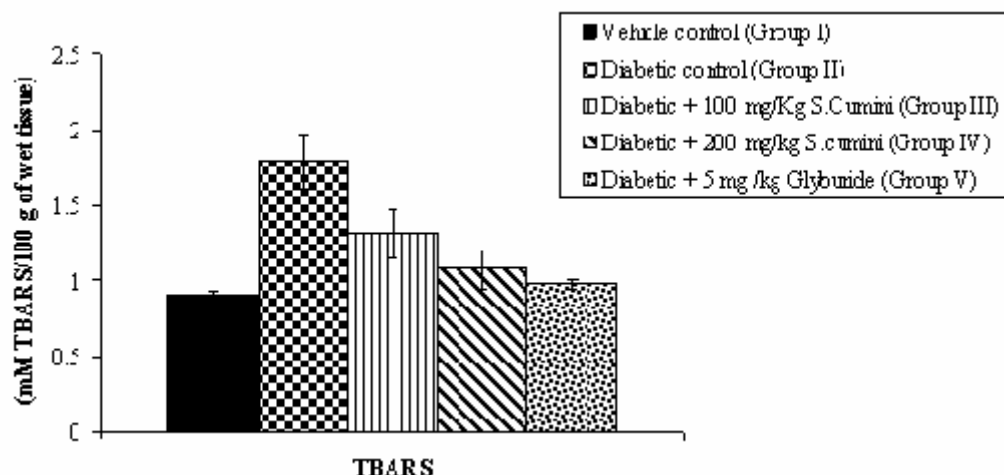GST - n moles of CDNB conjugate formed/min/mg protein.

Fig 1. Effect of aqueous extract of *Syzgium cumini* on lipid peroxiation in STZ induced diabetic rat liver

DISCUSSION AND CONCLUSION

The present study is assessment of antioxidant and antihyperglycemic activity of aqueous extract of pulp of *Syzygium cumini* on female wistar rats. STZ is toxic to pancreatic β-cells and is thus widely used for induction of experimental diabetes mellitus in animals, resulting in the production of ROS [44]. STZ causes a significant elevation in the level of blood glucose in rats. Administration of 100 and 200 mg/kg body weight of aqueous extract of *Syzygium cumini* Pulp significantly decreased the blood glucose level in these rats suggesting that it has hypoglycemic properties. The decreased body weight in diabetic rats is due to excessive breakdown of tissue proteins [45]. Treatment with *Syzygium cumini* improved body weight significantly in a dose dependent manner, indicating prevention of muscle wasting due to hyperglycemic condition.

The rise in blood sugar is accompanied with the increase in TC, LDL-c, TG and fall of HDL-c & phospholipids. Diabetes is also known to be associated with an increase in the synthesis of cholesterol, which may be due to the increased activity of HMG CoA reductase [46]. Increased LDL-cholesterol may arise from glycosylation of the lysyl residues of apoprotein B as well as from decreasing affinity for the LDL receptor and hence, decreased metabolism [47]. A number of observations indicate that plasma HDL cholesterol is low in untreated insulin-deficient diabetics [48], which was associated with a decline in HDL-turnover rate. Further the HDL-cholesterol levels correlate with lipoprotein lipase (LPL) levels in IDDM patients [49]. Hypertriglyceridemia is a common finding in patients with diabetes mellitus and is responsible for vascular complications [50]. It has been reported that deficiency of lipoprotein lipase (LPL) activity may contribute significantly to the elevation of triglycerides in diabetes [51]. However, Oral administration of aqueous extract of pulp exhibited hypocholesterolemic and hypotriglyceridemic effects while at the same time increasing HDL-c, possibly by controlling the hydrolysis of certain lipoproteins and their selective uptake and metabolism by different tissues. This implies that *Syzygium cumini* pulp can prevent or be helpful in reducing the complications of lipid profile seen in some diabetics in whom hyperglycaemia and hypercholesterolemia coexist quite often.

Induction of diabetes in rats with STZ uniformly results in an increase in lipid peroxidation (TBARS), an indirect evidence of intensified free radical production [52]. Most of the tissue damage is considered to be mediated by these free radicals by attacking membranes through peroxidation of unsaturated fatty acids [53]. The concentration of lipid peroxidation products may reflect the degree of oxidative stress in diabetes [54]. In the present study the concentrations of lipid peroxides and hydroperoxides were significantly increased in liver of diabetic rats, indicating an increase in the generation of free radicals. An observed increase in the level of TBARS in liver may be due to increased susceptibility of the tissue of diabetic rats to lipid peroxidation [55]. Administration with *Syzygium cumini* protects the cells through attenuation of lipid peroxidation and decreased the production of free radical derivatives, as evident from the decreased levels of liver MDA and hydroperoxides. This suggests protective role of fruit pulp, which could be due to the antioxidative effect of polyphenols [56] present in the fruit pulp, which may act as strong superoxide radical and singlet oxygen quenchers.
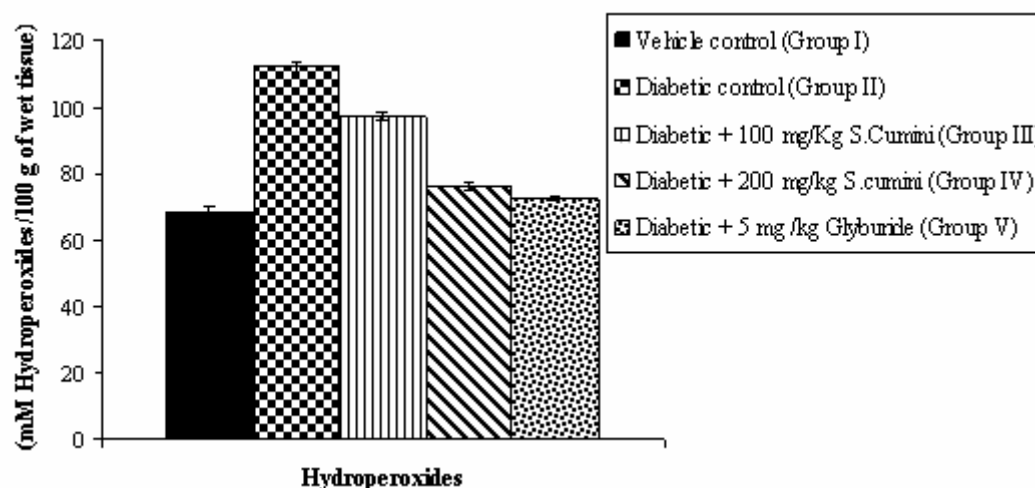
Fig 2. Effect of aqueous extract of *Syzgium cumini* on hydroperoxides in STZ induced diabetic rat liver.

Values are given as Mean ± SEM of six animals in each group.

a Comparison of Group I vs Group II.

b,c, d Comparison of Group III , Group IV & Group V vs Group II.

*p<0.001 statistically significant (ANOVA followed by Dunnet's t-test), when diabetic control was compared with the vehicle control and extract treated groups were compared with the diabetic control.

Reduced activities of SOD and CAT in liver of diabetic rats have been observed in our study. The decreased activities of SOD and CAT in liver during diabetes may be due to increased production of reactive oxygen radicals that can themselves reduce the activity of these enzymes [57]. SOD is an important defense enzyme, which converts superoxide radicals to hydrogen peroxide [58]. Increase in SOD activity could be due to its induction by increased production of superoxide, which has been implicated in cell dysfunction. H_2O_2 has been reported to act as an inducer of tissue SOD [59]. CAT is a hemeprotein, which decomposes hydrogen peroxide and protects the tissues from highly reactive hydroxyl radicals [60]. The reduction in the activity of these enzymes may result in a number of deleterious effects. Any compound, natural or synthetic, with antioxidant properties, might contribute towards the partial or total alleviation of this damage. Therefore, removing $O_2^.$ and $OH^.$ probably one of the most effective defenses of a living body against diseases [61]. Administration of *Syzygium cumini* increased the activity of enzymes and may help to avoid the free radicals generated during diabetes. The result of SOD and CAT activity clearly shows that the *Syzygium cumini* contains a free radical-scavenging activity, which could exert a beneficial action against pathological alterations caused by the presence of $O_2^.$ and $OH^.$. This action, predominantly due to the extract, could involve mechanisms related to scavenging activity.

Reduced glutathione (GSH) is a major endogenous antioxidant which counterbalance free radical mediated damage and it is well known that GSH is involved in the protection of normal cells structure and function by maintaining the redox homeostasis, quenching of free radicals and by participating in detoxification reactions [62]. GSH is also known to protect the cellular system against the toxic effects of lipid peroxidation [63]. The decrease in GSH level in liver during diabetes is proba-

bly due to its increased utilization by the hepatic cells which could be the result of decreased synthesis or increased degradation of GSH by oxidative stress in diabetes [64]. A relative depletion of NADPH due to aldose reductase activation and secondary to reduced production through the pentose cycle impairs GSH regeneration and leads to depletion of this free radical scavenger [65]. GSH reacts with free radicals and is a crucial substrate for GPx and GST, which takes part in the cellular defense mechanisms against intermediate oxygenated products of metabolism. GPx, an enzyme with selenium and GST, catalyzes the reduction of hydrogen peroxide to non-toxic compounds [66]. GPx metabolizes hydrogen peroxide to water by using GSH as a hydrogen donor [67]. The reduced activity of GPx may result in the accumulation of toxic products due to oxidative damage. The activities of GPx and GST were observed to decrease significantly in diabetic rats. Treatment with *Syzygium cumini* significantly recovered the GSH content and increase in the levels of GSH dependent enzymes GPx, GST, which clearly indicates the protective effect of *Syzygium cumini* on antioxidants.

Hyperglycemia is the prominent cause for the production of free radicals, which leads to development of diabetic complications. Oxidative stress is currently suggested as mechanism underlying diabetes and diabetic complications. Many of the complications of diabetes including retinopathy and atherosclerotic vascular disease, the leading cause of mortality in diabetes have been linked to oxidative stress and antioxidants have been considered as treatments [68, 69]. Flavonoids, tannins, anthocyanins, ß-carotene and other phenolic constituents present in food of plant origin are potential antioxidants and may play a beneficial role in the prevention of several chronic disorders [70, 71].

The fruits of *Syzygium cumini* are reported to contain vitamin C, gallic acid, tannins, anthocyanins cyanidin,

glucoside, petunidin, malvidin and other components [18]. Several authors reported that, saponins, flavonoids, phenolic compounds, glycosides, triterpenoids and vitamin C have potent antioxidant, hypolipidemic and hypocholesterolemic effects [72, 73, 74, 75]. *Syzygium cumini* kernels have been reported to ameliorate the oxidative stress in diabetic condition [76] and also the fruit skin of *Syzygium cumini* has been reported to possess *invitro* antioxidant activity [77]. In our present investigation treatment with *Syzgium cumini* pulp in rats induced with STZ restored the fatty acid composition to near normal level and this may be due to the decreased toxicity of reactive oxygen species by its anti-oxidant property. Further it can resist, to an extent, the formation of lipid peroxy radicals in a number of tissues, thereby protecting these tissues. In this context a number of other plants have also been observed to have hypoglycaemic and insulin-release stimulatory effects [78]. The results obtained suggest that pulp of *Syzygium cumini* possesses potent antioxidant and antidiabetic activity; this may be due to the antioxidant phytochemicals present in the fruit of *Syzygium cumini*, which can scavenge free radicals and prevent the depletion of endogenous antioxidants. Thus consumption of *Syzyium cumini* pulp may be considered as a potential source of natural antioxidant and antihyperglycemic activity that helps in reducing oxidative stress in diabetic condition, which may provide beneficial role in the management of diabetes.

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