A STEREOLOGICAL STUDY OF EFFECTS OF AQUEOUS EXTRACT OF *TAMARINDUS INDICA* SEEDS ON PANCREATIC ISLETS IN STREPTOZOTOCIN-INDUCED DIABETIC RATS

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ABSTRACT

Tamarindus indica Linn was used as a traditional medicine for the management of diabetes mellitus in human and experimental animals. This study investigated effects of aqueous extract of *Tamarindus indica* seeds (AETIS) against STZ-induced damages in pancreatic islands by means of stereological methods. sixty matured normoglycemic male Wistar rats, weighing 200- 250 gr, were selected and randomly divided into 6 groups (n=10). Control, STZ-induced diabetic; by intraperitoneal injection of 55 mg/Kg streptozotocin, Treated control group (TC); received AETIS at a dose of 200mg/kg/day, and AETIS treated diabetic groups (TD_{1-3}); received respectively AETIS at the dose of 50, 100,and 200 mg/kg/day by gavage from one week after induction of diabetes by STZ. After 8 weeks of experiment, stereological estimation of volume density and total volume of islets and beta cells, volume weighted mean islets volume, mass of beta cells, islets, and pancreas and total number of islets were done. Volume density and total volume of islets, volume weighted mean islets volume, volume density islets/pancreas, volume density beta cells/islet, mass of islets and pancreas of treated diabetic groups (TD_{1-3}) were significantly higher than untreated diabetic group ($P<0.001$), and in TD_3 group these values were comparable to controls. Although total volume and mass of beta cells in TD_{1-3} were significantly higher than D group but they were significantly lower than control group ($P<0.05$). Total number of islets, pancreas wet weight and volume did not show any significant changes between control and experimental groups ($P>0.05$). Results suggested that AETIS partially restores pancreatic beta cells and repairs STZ- induced damages in rats.

Keywords: Diabetes mellitus; *Tamarindus indica*; stereology; beta cell.

INTRODUCTION

As a devastating illness with significant morbidity and mortality, diabetes mellitus has increased steadily worldwide (Luo and Luo, 2006). It is estimated that 25% of the world population is affected by this disease (Maiti *et al*., 2004). Incidence of diabetes mellitus is increasing in Iran and according to studies done in the last two decades, the number of diabetics is estimated more than 1.5 million. On the whole, it seems that 14-23% of Iranian adults (>30 years) are diabetic or have impaired glucose tolerance(IGT) (Larijani *et al*., 2003). According to WHO forecast, prevalence of diabetes mellitus in years 1995, 2000, 2025 in Iran will be 5.5, 5.7, and 6.8%, respectively. This means that we will have 1.6, 1.9, 5.1 million affected Iranians in the mentioned years (King *et al*., 1998).

In modern medicine no satisfactory effective therapy is till available to cure the diabetes mellitus (Mallick *et al*., 2006). Though insulin therapy is also used for the management of diabetes mellitus but there are several drawbacks like insulin resistance (Piedrola *et al*., 2001), anorexia nervosa, brain atrophy and fatty liver (Yaryura-Tobias *et al*., 2001) after chronic treatment. Recently, the search for appropriate hypoglycemic agents has been focused on plants used in traditional medicine partly because of leads provided by traditional medicine to natural products that may be better treatments than currently used drugs (Ugochukwu *et al*., 2003), because they are more harmonious with biological systems (Erasto *et al*., 2005).

Free radicals released during oxidative stress are among the most widespread intracellular

DNA modifiers and their involvement in carcinogenesis, inflammation, diabetes, atherosclerosis, brain and heart ischaemia, ageing, etc. has been intensely addressed during the last years. Herbal remedies and phytotherapy drugs containing active principles are currently developed to protect against electrophile (e.g. free radical) attack to DNA and its widespread outcomes such as ageing and cancer. Even for populations which use herbs traditionally, encouraging the use of species with chemopreventive actions could be helpful as part of life

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expectancy improvement strategies: costs are significantly low, herbs have usually little or no toxicity during long-term oral administration and are relatively available at large scale (Ramos *et al*., 2003).

Few of the plants used for the treatment of diabetes have received scientific or medical scrutiny and even the WHO expert committee on diabetes recommends that this area warrant further attention (Kesari *et al*., 2006; Chatterjee *et al*., 2009).

Tamarindus indica Linn was used as a traditional medicine for the management of diabetes mellitus in human and experimental animals (Maiti *et al*., 2004; Chatterjee *et al*., 2009; Maiti *et al*., 2005; Martinello *et al*., 2006). *Tamarindus indica* Linn is tree-type of plant belonging to the caesalpiniaceae family (Maiti *et al*., 2005) grows naturally in tropical and subtropical regions and now is one of the most important plant resources as food materials and is accepted as herbal medicine in parts of the world (Siddhuraju, 2007).

The potential antioxidant activity of Tamarind seeds have already been reported (Siddhuraju, 2007; Dighe *et al*., 2009; Luengthanaphol *et al*., 2004).

Tamarindus indica seed coat may play an important role in chemical protection from oxidative damage by possessing endogenous antioxidants such as phenolic compounds. The potential antioxidant activity of Tamarind seeds have already been reported and the isolated antioxidant components are, 2-hydroxy-30,40-dihydroxyacetophenone, methyl 3,4- ihydroxybenzoate, 3,4-dihydroxyphenylacetate and (-)-epicatechin in addition to oligomeric proanthocyanidins (Siddhuraju, 2007). Content of phenolic compounds in seeds of Tamarind indica: Procyanidin B2, -Epicatechin, Procyanidin trimer, Procyanidin tetramer, Procyanidin pentamer, Procyanidin hexamer, Polymeric tannins, Polymeric tannins (Sudjaroen *et al*., 2005).

It has been suggested that Polymeric tannins with their high molecular weight and the proximity of many aromatic rings and hydroxyl groups are also very important for the free radical scavenging (Siddhuraju, 2007).

It has been shown that aqueous extract of Tamarindus indica seeds have potent antidiabetic and antihyperlipidemic activities in STZ-induced diabetic male rat (Maiti *et al*., 2004; Maiti *et al*., 2005). The aim of present study was to find out the effects of aqueous extract of Tamarindus indica seeds on pancreatic islets and beta cells in STZ-induced diabetic rats by means of stereological methods.

MATERIAL AND METHOD

Plant material

Seeds of *Tamarindus indica* were obtained from a commercial source. The plant was identified and authenticated at the Herbarium of Botany Directorate in Sistan and Baluchestan University, Zahedan, Iran. A voucher specimen was deposited in the Botany Department of Sistan and Baluchestan University.

Preparation of aqueous extract of Tamarindus indica seeds

The seeds of *Tamarindus indica* were dried in an oven for 2 days at 40^{o}C, crushed in an electrical grinder and then powdered. Extraction was performed by taking 25 g powder in 250 ml of distilled water for 18 h in a soxhlet apparatus and a deep brown aqueous extract was obtained. The extract was dried at reduced pressure and finally lyophilized, as described previously (Maiti *et al*., 2005).

Animals

The study was performed on sixty matured normoglycemic male Wistar rats, weighing 200-250 g, which were separately housed in cages (one rat per cage) and had free access to water and food. Animals were maintained in a room at 23°C ± 2 with a fixed 12-h artificial light period and the air was adequately recycled. All animals were fed with standard rodent diet. All animals received humane care, as outlined in the guide for the care and use of laboratory animals. Ethical committee of Zahedan University of Medical Sciences approved this study.

Experimental design

Sixty rats were divided into six following groups (n=10):

(i) Control group (C): Rats of this group received standard rodent diet and tap water. After one week, they received intraperitoneal vehicle (0.15 M NaCl with 100 mM sodium citrate buffer).

(ii) Diabetic group (D): In this group diabetes was induced by a single intraperitoneal injection of streptozotocin (55 mg/Kg of body weight in 0.15 M NaCl with 100 mM sodium citrate buffer, pH 4.5).

(iii) Treated control group (TC): Healthy rats received 200 mg/kg/day AETIS by gavage.

(iv-vi) Treated diabetic groups (TD_{1-3}): These groups received respectively AETIS at the dose of 50, 100, 200 mg/kg/day, by gavage from one week after induction of diabetes by streptozotocin.

The experiment was carried out for 8 weeks after STZ injection in diabetic groups. Food and fluid intake of all above rat groups were measured daily. Body weight, blood glucose and insulin were measured every week.

Glucose and insulin measurement

At the end of the experiment, and after overnight fast, all animals were sacrificed under light ether anesthesia. Immediately blood samples were collected from tail vein. Blood glucose levels were measured by standard method of oxidase-peroxidase paired enzyme adapted for a RA 1000 analyzer (Technicon, USA), and serum insulin levels were determined by ultra sensitive rat insulin kit (DRG, France) using double-antibody enzyme-linked immunosorbent assay (ELISA).

Preparation of tissues

The pancreases were quickly removed, placed in cold saline solution and trimmed of adipose tissue, weighed, and volumes were measured using immersion method and fixed in modified Lillie's solution for one week at room temperature. 10-12 isotropic uniform random sections were obtained using the orientator method (Gundersen *et al*., 1988; Cruz-Orive *et al*., 1990; Howard and Reed, 1998). Pancreatic sections stained with modified aldehyde fuchsin histochemical method (Bancroft and Gamble, 2002).

Stereological study

a) Total number of islets, volume weighted mean islets volume, pancreatic islets and beta cell volume density and total volume

Two sets of primary and reference sections through the pancreas were sampled using systematic uniform random sampling (SURS) (Partida-Hernandez *et al*., 2006; Barbera *et al*., 1997).

The total number of islets was determined as previously described by the so-called physical fractionator method (Gundersen *et al*., 1988; Bock *et al*., 2005) by this formula:

$$estN_{isl} = \frac{N_{sect(p-p)}}{N_{sect(p-r)}} \times \frac{\Delta X \times \Delta Y}{A_{frame}} \times \sum Q_{isl}$$

Where $N_{sect(p-p)}$ is the number of sections between the primary sections, $N_{sect(p-r)}$ is the number of sections between a primary section and the corresponding reference section, ΔX is the step length in the x direction, ΔY is the step length in the y direction, A_{frame} is the area of the sampling frame corrected for magnification, and $\sum Q_{isl}$ is the total number of islets counted (sampled in the primary section but absent in the reference section) from one pancreas (Bock *et al*., 2005).

To determine the volume weighted mean islets volume, Five to seven systematic random fields were sampled per each primary section. At a final magnification of 400, a grid of standard points and a set of parallel lines of random orientation were superimposed randomly onto the image and the volume weighted mean islets volume was estimated using the point sampled intercepts method (Gundersen *et al*., 1988; Gundersen and Jensen, 1985).

Measurements were performed using a 15-class ruler with a total length of 35 millimeters (Howard and Reed, 1998; Gundersen and Jensen, 1985; Skau *et al*., 2001; Mahmoudzadeh Sagheb *et al*., 2006; Heidari *et al*., 2008). In each animal, 100–200 islets were sampled (Gundersen *et al*., 1988). Coefficient error for point counting in each measurement was less than 0.05.

Data were entered into a result sheet and the volume weighted mean islets volume was estimated by this formula: $\text{estv}_v = \frac{\pi}{3} \cdot \ell_0^3 . F$

Where, vv is the volume weighted mean islets volume, ℓ_0^3 is the mean of the cubed measured intercepts length and *F* is $\left(\frac{1}{Magnification}\right)^3$ (Skau *et al*., 2001).

In order to estimate the volume density of islets, ten to twelve sections were sampled from each gland by systematic uniform random sampling (Howard and Reed, 1998). In order to project, the whole section image onto the table, a BH2-Olympus light microscope with a projecting arm was used. On each sampled section five to seven fields were selected in a systematic random manner by movement of the microscope's stage in X and Y directions with the aid of vernier scale of the stage of a projection microscope (Olympus, Japan). A transparent test system was then superimposed on these fields and points hitting the various components of the gland were counted at a final magnification of 32. Then an estimate of the volume density, Vv, of the components in the reference space was obtained using:

$$\textbf{estVv} = \frac{\textbf{P(part)}}{\textbf{P(ref)}}$$

Where P (part) and P (ref) are the number of test points falling in all structure profiles and in the reference space, respectively (Gundersen *et al*., 1988; Howard and Reed, 1998; Gundersen and Jensen, 1985).

In order to estimate the absolute volume of a part, the volume density of that part is multiplied by the reference volume (Howard and Reed, 1998).

b) Total mass of Beta cells, islets, and pancreas

Total islet and beta cell mass were determined as previously described (Howard and Reed, 1998; Gundersen and Jensen, 1985; Mandarim-de-Lacerda, 2003). A point-counting grid with 99 points, 1 of them encircled (the unit point), was attached to the table, and for each pancreas the total number of grid points that hit beta cells and the total number of unit points that hit the

pancreas and islets were counted (Bock *et al*., 2005; Bock *et al*., 2003a; Bock *et al*., 2003b). The total beta cell mass for each pancreas was then estimated by:

$$estM_{\beta} = \frac{P_{\beta}}{99 \times (P_{tis})} \times M_{tis}$$

Where M_{β} is the total beta cell mass, P_{β} is total number of grid points that hit cells in all investigated sections from one pancreas, P_{tis} is the number of unit points that hits the removed tissue, and M_{tis} is the wet weight of it.

Mass of pancreas estimated from this formula:

$$estM_{pan} = \frac{P_{pan}}{P_{tis}} \times M_{tis}$$

P_{pan} is the number of unit points that hits the pancreatic tissue.

Statistics

Data are presented as means ± SE for each parameter investigated. One-way analysis of variance (ANOVA) followed by Tukey´s post hoc test for multiple comparisons were used to compare differences between experimental groups.

Significant level was set at P<0.05. All statistical analyses were performed using SPSS 11 for Windows software system.

RESULTS

a) Blood glucose levels

Figure 1 shows change in blood glucose levels of control and diabetic rats during the experimental period. After STZ injection, the blood glucose levels of D and TD groups significantly increased (P<0.001) when compared with controls. Treatment of TD rats with AETIS one week after diabetes induction, exhibited a significant, dose-dependent hypoglycemic effect in streptozotocin diabetic rats compared to the corresponding D rats (P<0.001). AETIS treatment compensated hypoglycemia in $TD_{1, 2, 3}$ after 6, 4 and 2 weeks respectively. No significant changes in blood glucose levels were observed after administration of AETIS in normal rats (TC group).

b) Blood insulin levels

Blood insulin level of control and diabetic rats during the experiment has shown in fig. 2. In control animals, blood insulin level was found to increase steadily over 8 weeks. Likewise, blood insulin levels in diabetic rats (D) significantly reduced when compared with controls over 8 weeks (P<0.001). However, treatment with AETIS in TD groups increased blood insulin compared to untreated diabetic rats. In $TD_{1, 2, 3}$ this difference was significant (P<0.001) after 5, 4 and 2 weeks of treatment respectively. No significant changes in blood insulin levels were observed after administration of AETIS in normal rats.

Figure 2

c) Stereological and mass analysis

As indicated in table 1, diabetes caused a significant(P<0.001) reduction of pancreatic mass (14%), islet mass (58%), beta cell mass (85%), volume density of islet/pancreas (50%), total islet volume (53%), volume density of beta cells/islets (64%), total beta cell volume (83%), and volume weighted mean islet volume (65%) compared with control group. Treatment with Tamarindus indica seed extract prevents from these diabetic changes.

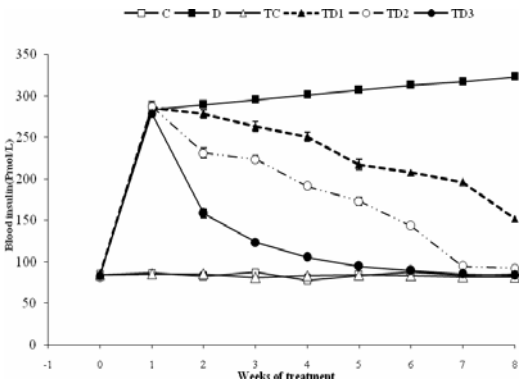

Fig. 1: Changes in blood glucose levels in control and diabetic rats during the experiment. The values represent the mean ± SE. C = control; D = diabetic; **T**C = treated control; **TD_{1-3}** = diabetic rats treated respectively with 50,100 and 200 mg/kg *Tamarindus indica* seed extract. (0 week, initial time of STZ injection in diabetic rats and 1 week initial time of *Tamarindus indica* seed extract treatment).

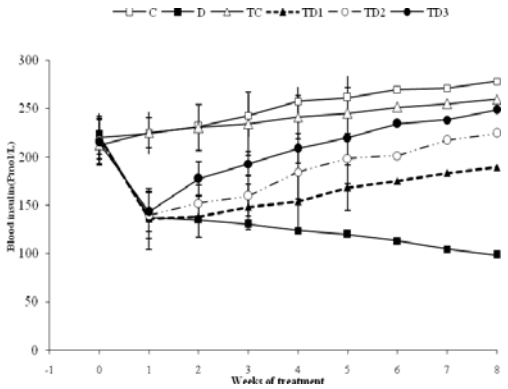

Fig. 2: Change in blood insulin levels in control and diabetic rats during the experiment. The values represent the mean ± SE. C = control; D = diabetic; **T**C = treated control; **TD_{1-3}** = diabetic rats treated respectively with 50,100 and 200 mg/kg *Tamarindus indica* seed extract. (0 week, initial time of STZ injection in diabetic rats and 1 week initial time of Tamarindus indica seed extract treatment).

Table 1: Body weight, pancreas wet weight, mass and volume and stereological parameters of islets and beta cells in experimental groups.

Groups / Parameter	**C** (n=10)	**D** (n=10)	**TC** (n=10)	**TD_1** (n=10)	**TD_2** (n=10)	**TD_3** (n=10)
Body mass (g)	381.3±11.1	321.1±12.2[a]	382.5±10.8	343.2±10.4[ab]	370.4±8.8[b]	372.5±9.8[b]
Pancreas Wet Weight (g)	1.13±0.02	1.07±0.02	1.12±0.02	1.08±0.02	1.06±0.01	1.07±0.01
Pancreatic Mass (mg)	552.3±3.8	477±5.9[a]	549±4.9	493.8±6.1[a]	496.3±8.6[a]	534.2±5.9[b]
Pancreas Volume (Cm^3)	2.03±0.03	1.94±0.04	2.03±0.02	1.93±0.02	1.95±0.02	1.99±0.05
Islets Mass (mg)	63.7±1.7	26.6±1.1[a]	63.2±1.7	40.7±1.9[ab]	48.2±1.7[ab]	58.9±1.5[b]
Beta Cell Mass (mg)	44.8±1.9	6.8±0.6[a]	45.0±1.8	27.7±1.7[a b]	35.8±1.2[a b]	37.4±1.1[a b]
Volume Density Islets/Pancreas (%)	28.5±0.8	14.2±0.9[a]	28.8±0.8	23.7±1.1[ab]	24.3±0.8[b]	25.6±0.9[b]
Total Volume of Islets ($\times 10\ mm^3$)	58.0±2.1	27.5±1.9[a]	58.4±1.9	35.7±1.4[ab]	42.8±1.8[ab]	50.7±2.1[b]
Volume Density Beta Cells/Islet (%)	70.2±1.5	25.3±1.8[a]	70.5±0.9	45.1±2.2[ab]	53.2±2.3[ab]	63.7±1.4[b]
Total Volume of Beta Cells ($\times\ 10\ mm^3$)	4.06±0.14	0.69±0.07[a]	4.0±0.10	2.69±0.19[ab]	2.8±0.17[ab]	3.33±0.10[ab]
Volume Weighted Mean Islet Volume ($\times 10^6 \mu m^3$)	4.00±0.06	2.11±0.11[a]	4.1±0.51	3.03±0.17[a b]	3.4±0.15[a b]	3.65±0.11[b]
Total Islet Number ($\times 10^3$)	24.7±1.1	22.4±0.8	25.8±0.9	23.1±0.4	23.8±0.5	23.2±1.0

Values are mean ± SE. "n" stands for number of rats in each group. CEs for point counting in each measurement are less than 0.05.
C = control; D = diabetic; **TC** = treated control; **TD_{1-3}** = diabetic rats treated respectively with 50,100 and 200 mg/kg Tamarindus indica seed extract. [a] P<0.001 compared to control group. [b] P<0.001 compared to diabetic.

Thus in TD_{1-3} groups in comparison with D there is a significant increase (P<0.001) in islet mass (53, 81.2 and 121% respectively), beta cell mass (307, 426 and 450%), volume density of islet/ pancreas (66.9, 71.1 and 80.3%), total islet volume (29.8, 55.6 and 84.4%), volume weighted mean islet volume (43.6, 61.1, and 73%), volume density of beta cells/islets (78.2, 110.3 and 151.8%), and total beta cell volume (289.6, 305.8 and 382.6%). Pancreatic mass increased in TD_{1-3} groups (3.5, 4 and 12%), but only in TD_3 group this increase was significant from D group (P<0.001). The total number of islets, pancreas wet weight and volume did not show any significant changes between experimental groups (P>0.05).

DISCUSSION

The present study showed treatment of diabetic rats with Tamarindus indica seed extract, from one week after diabetes induction, compensated hypoglycemia in TD_{1-3} groups after 6, 4 and 2 weeks, and increased blood insulin compared to the corresponding diabetic rats, this difference in TD_{1-3} groups was significant from diabetic group after 5, 4 and 2 weeks of treatment respectively.

Streptozotocin injection results diabetes mellitus, which may be due to selective destruction of beta cells of pancreatic islets as proposed by others (Kavalali *et al*., 2002).

Reports indicated that aqueous extract of *Tamarindus indica* seed attenuate hyperglycemia and hyperlipidemia in streptozotocin-induced diabetic rats (Maiti *et al*., 2004; Maiti *et al*., 2005).

In agreement with our study Maiti *et al*., (2004) showed that supplementation of 80mg/0.5ml distilled water/100gr body weight/day of aqueous extract of seed of *Tamarindus indica* after 7 days and 14 days resulted significant diminution of fasting blood glucose level and significant increase of insulin level in respect to diabetic rat, and symptoms like loss of body weight, weakness, polyuria and polyphasia that accompany type-I diabetes mellitus were significantly absent in Tamarindus indica treatment diabetic groups. Moreover, improvement of body weight of the supplemented groups further supports the antidiabetogenic effect of this extract. From such information it may be stated primarily that the aqueous extract of seed of *Tamarindus indica* may contain some biomolecule(s) that may stimulate the beta stem cell of islets of pancreas in streptozotocin-induced diabetic rat that may restore plasma level of insulin (Maiti *et al*., 2004). In TD_{1-3} groups (50, 100, and 200 mg/kg/day) a dose dependent increase of blood insulin was seen compared to the corresponding diabetic rats. The possible mechanism of antihyperglycemic action of this extract appears to be both pancreatic and extra pancreatic. The extra pancreatic effect may be by the sensitization of insulin receptor in target organs or by inhibiting insulinase activity in both liver and kidney (Maiti *et al*., 2005). In this study we focused on pancreatic effects of AETIS using stereological methods.

On the other hand, previous studies showed that the seed coat extract of Tamarindus indica contains high amounts

of polyphenolic flavonoids which are known to exhibit strong antioxidant scavenging activity (Dighe *et al*., 2009). Potential antioxidant activity of AETIS Siddhuraju, 2007; Luengthanaphol *et al*., 2004) and its anti-inflammatory effects (Fook *et al*., 2005) may prevent from progressive STZ induced damages of beta cells. Pimple *et al*., 2007 showed also that aqueous extracts of tamarind seeds had a significant hepatoregenerative effect against paracetamol-induced hepatotoxicity in rats (Pimple *et al*., 2007).

Based on stereological methods, we found significant increase in volume weighted mean islet volume, volume density of beta cells/islets and islets/pancreas, total volume of islets and beta cells, islet and beta cell mass in TD_{1-3} groups in comparison with diabetic group, in a dose dependent manner. In TD3 group these values were comparable to controls. Although total volume and mass of beta cells in TD_{1-3} were significantly higher than D group but they were significantly lower than controls. We suppose that these increase entirely caused by islet size due to partial restoration of beta cells after STZ induced damages.

As previously reported by Skau *et al*., 2001, there is a linear correlation between the volume-weighted mean islet volume and the total islet volume in rats, an observation that suggests that the increase in the total islet volume during physiological growth in rats is attributable to islet hypertrophy with no contribution from islet hyperplasia. This is exactly what we found in this study using a direct stereological measurement of the total number of islets in experimental groups. Possibly, the architecture (i.e., the intra-islet vascular structure) of the islets is complex to a degree that it only allows new islets to be formed during the formation, growth, or regeneration of the pancreas, as occurs during fetal life or after partial pancreatectomy (Bock *et al*., 2003a). The number of pancreatic islets seems especially to be under tight genetic control (Bock *et al*., 2005) and STZ evoke selective deleterious changes in the beta cells (Takasu *et al*., 1991), it cannot cause completely disappearance of the entire islet. Thus the number of islets in all experimental groups is almost constant in this study.

An increased total volume of a cell population can be due to, an increased number of cells, an increased mean cellular volume, or a combination of them. If increase in total islet volume is caused entirely by the growth of existing islets, beta cells are primary sources for the new cells. This could be achieved by intra-islet beta cell mitosis, an event that definitely occurs based on the presence of mitotic figures in intra-islet beta cells. The new cells could be derived from intra-islet stem/progenitor cells (Skau *et al*., 2001).

The mass of pancreatic islets is dynamic and can be modified to maintain normoglycaemia in response to changes in metabolic demand. Islet mass depends on, among other factors, the changes in beta and alpha cells formation, individual cell size and rate of cell death. The balance between these elements determines whether islet mass is increased, remains stable or is reduced. STZ injection can cause beta cell death, and induce diabetes (Inuwa and El Mardi, 2005; Inuwa, 2005).

In AETIS treated diabetic groups, increase of pancreatic islets mass is probably due to an increase in the mass of beta cells because they are the predominant cell type in the islet. Islet-cell mass is a critical factor in the regulation of glucose homeostasis. The islet-cell mass consists of a dynamic cell population that either expands or declines to adapt to altered physiological conditions. Because beta cells are the most abundant cell type in the endocrine pancreas, changes in their biological dynamics are the most important factors that determine islet morphology (Inuwa and El Mardi, 2005).

CONCLUSION

We concluded that aqueous extract of *Tamarindus indica* seed had potent antidiabetogenic efficacy in STZ- induced diabetic rats. It partially restores pancreatic beta cells and repairs STZ-induced damages in rats. Further comprehensive chemical and pharmacological investigations with isolated active principles of the plant may throw more light on the use of Tamarindus indica seeds for antidiabetic activity in diabetic animals and patients.

ACKNOWLEDGEMENT

The Deputy research of Zahedan university of medical sciences supported this study financially. The authors wish to acknowledge Dr. Mehdi Harati, for his brilliant ideas.

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