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Research Article

Effect of fangchinoline on oxidant status in male albino rats with streptozotocin-induced diabetes

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ABSTRACT

Background: Diabetes is a metabolic disorder caused by defects in insulin production and activity. During disease progression, changes in lipid peroxidation cause structural modifications via production of free radicals. Fangchinoline is a well-known alkaloid present in *Stephaniae tetrandrine S. Moore*, which has demonstrated antioxidant, anticancer, and anti-inflammatory activities.

Results: The present study analyzed the anti-diabetic and antioxidant effects of fangchinoline in male rats with streptozotocin-induced diabetes. Rats were divided into the following groups: normal control, diabetic, diabetic + fangchinoline 100 mg/kg, diabetic + fangchinoline 200 mg/kg and diabetic + glibencla mide 600 μg/kg. The treatment was administered orally for 45 consecutive days. Lipid peroxidation was substantially increased by >50% in the serum, as well as the liver, kidney, and heart tissues of diabetic rats. However, fangchinoline supplementation significantly reduced lipid peroxidation to near normal levels. Reactive oxygen species levels were substantially increased by >500% in the serum, as well as the liver, kidney, and heart tissues of diabetic rats. Fangchinoline supplementation reduced reactive oxygen species to near normal levels. Fangchinoline supplementation significantly improved superoxide dismutase, glutathione peroxidase, catalase, and reduced glutathione levels in diabetic rats. Total hexoses, sialic acid, hexosamines, and fucose were increased in diabetic rats, whereas fangchinoline supplementation significantly reduced these total hexoses, sialic acid, hexosamines, and fucose to near normal levels

Conclusions: Supplementation with fangchinoline led to significant attenuation of the levels of lipid peroxidation, ROS, and glycoprotein components such as total hexoses, hexosamines, sialic acid, and fucose, while improving antioxidant marker levels.

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1. Introduction

Diabetes is a metabolic disorder caused by defects in insulin production and insulin activity [1]. Cellular proteins and lipids undergo various structural alterations during the course of disease [2]. During disease progression, lipid peroxidation changes cause structural modifications via production of free radicals [3]. Normal antioxidant and lipid peroxidation levels in animals are altered under disease conditions. Reduced glutathione (GSH), catalase, glutathione peroxidase (Gpx), superoxide dismutase (SOD), malondialdehyde, and 4-hydroxy-2-nonenol levels could reflect the antioxidant and lipid peroxidation statuses in animal tissue [4]. The production of advanced glycated end products induces oxidative stress, as do hyperlipidemia and hyperglycemia. These are key indicators of diabetic complications. Reduced antioxidant levels and the production of oxygen free radicals lead to late diabetic complications [5]. Higher levels of reactive oxygen metabolites have been correlated with the glucose levels in diabetic tissue and plasma [6]. Furthermore, reactive oxygen metabolites induce severe damage in terms of cellular lipids, proteins, and DNA [7]. Increased oxidative stress in diabetic conditions occurs due to reduced antioxidant and increased lipid peroxidation levels [8]. In addition, stress-induced signaling pathways are activated, which regulate selective gene expression patterns affecting cellular proteins and lipids [9]. Thus, there is a need for novel and potent anti-diabetic and antioxidant agents.

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Medicinal plants and plant-derived bioactive agents are widely used for the treatment of diabetes [10]. Fangchinoline is a primary alkaloid present in *Stephaniae tetrandrine S. Moore*. Fangchinoline has anti-inflammatory, antioxidant, anticancer and antidiuretic activities [11,12,13]. The crude extract of plant Cyclea peltata is known to contain fangchinoline, and exert antidiuretic activity [14,15]. Fangchinoline was effective in managing both oxidative stress and inflammation in diabetic rats [16]. Hence, the present study analyzed the anti-diabetic and antioxidant effects of fangchinoline in male rats with streptozotocin-induced diabetes.

2. Materials and methods

2.1. Rats

Male albino rats (180–200 g) were obtained from the animal house of Wuhan Petrochemical Hospital, Hubei, China and housed in polycarbonate cages under a 12 h light/dark cycle and standard atmospheric conditions. Rats were allowed free access to water and food. All the experiment was performed following the guidelines for the care and use of laboratory animals and institutional guidelines. All the animal experiments were approved (No: 2020/2TX2225) by the Research Review and Ethics Board of Wuhan Petrochemical Hospital, Wuhan City, Hubei, China.

2.2. Diabetes induction

Non-insulin dependent diabetes mellitus (NIDDM) or type 2 diabetes was induced using a previously described method [17]. Briefly, single intraperitoneal injection of freshly prepared streptozotocin (60 mg/kg b.w.) in 0.1 M citrate buffer (pH = 4.5) to overnight starved rats and experimental diabetes was induced within 72 h via the destruction of beta cells. Diabetes was defined as a blood glucose level >250 mg/dl. Rats were fed a diet with 5% glucose to avoid streptozotocin-induced hypoglycemia within 24 h.

2.3. Experimental groups

Thirty male rats were randomized to the following groups ($n = 6$ rats per group): normal control, diabetic (control), diabetic + fang chinoline 100 mg/kg (low dose), diabetic + fangchinoline 200 mg/kg (high dose), and diabetic + glibenclamide 600 μg/kg. The treatment was administered orally for 45 consecutive days. Rats were carefully observed daily for mortality and clinical symptoms. At the end of the treatment, rats were euthanized using isoflurane. Their blood and organs (liver, kidney, and heart) were removed for analysis.

2.4. Determination of lipid peroxidation

Lipid peroxidation levels in serum and tissue homogenates were determined by measuring the malondialdehyde level based on assessment of thiobarbituric acid reactive substances. The end product of lipid peroxidation was measured at 534 nm [18].

2.5. Determination of reactive oxygen species (ROS)

ROS were measured in serum and tissue homogenates using the 6-carboxy-2′,7′-dichlorodihydrofluorescein diacetate method [18].

2.6. Determination of antioxidant markers

Determination of SOD activity was carried out by the addition of serum or tissue homogenate (0.1 ml), nitro blue tetrazolium (0.3 ml), phosphate buffer (1.2 ml), and NADH (0.2 ml). The reactant product was measured at 560 nm [18]. Determination of catalase activity was performed by the addition of 500 μl serum or tissue homogenate, 500 μl $TiOSO_4$, 500 μl phosphate buffer, and 500 μl water in a single reaction tube. The reactant product was measured at 420 nm. The reduced GSH level was measured using the Ellman reaction. The reactant product was determined at 412 nm [18]. Gpx activity was measured at 340 nm [18].

2.7. Determination of glycoproteins

Total hexose, fucose, hexosamine, and sialic acid levels were measured using previously reported methods [19].

2.8. Histopathological analysis

Histopathological analysis of pancreas and liver was carried out according to previously reported method [20]. Briefly, the pancreatic and liver section blocks were made with xylene, and 5 mm thickness sections were made by rotary microtome. Then, xylene was used to de-paraffinise the pancreatic and liver sections and hydrated in alcohol (descending grades). Then, hematoxylin and eosin were used for the staining the sections for 10 min, and viewed under a microscope.

2.9. Statistical analysis

Values are presented as mean ± standard error of the mean. The differences between the control and fangchinoline-treated groups were analyzed using Student's *t*-test and analysis of variance. $P < 0.05$ was considered to indicate statistical significance.

3. Results

This study investigated the anti-diabetic and antioxidant effects of fangchinoline in male rats with streptozotocin-induced diabetes. Lipid peroxidation was substantially increased by 115.6% in serum from diabetic rats. However, 100 mg/kg and 200 mg/kg fangchinoline supplementation significantly reduced lipid peroxidation by 21.6% and 37.1%, respectively (Fig. 1, $P < 0.05$). Lipid peroxidation was increased by 65.5% in liver tissues from diabetic rats, whereas 100 mg/kg and 200 mg/kg fangchinoline supplementation reduced lipid peroxidation by 21.1% and 30.5%, respectively (Fig. 1, $P < 0.05$). Lipid peroxidation was increased by 59% in kidney tissues from diabetic rats but reduced by 13.6% and 27.3% after supplementation with 100 mg/kg and 200 mg/kg fangchinoline, respectively (Fig. 1, $P < 0.05$). Lipid peroxidation was increased by 65.3% in heart tissues from diabetic rats but reduced by 8.9% and 28.5% after 100 mg/kg and 200 mg/kg fangchinoline supplementation, respectively (Fig. 1, $P < 0.05$). Glibenclamide treatment reduced lipid peroxidation by >30% in serum and tissues from diabetic rats.

The ROS level was substantially increased by 805.7% in serum from diabetic rats but significantly reduced by 14.5% and 54.2% after 100 mg/kg and 200 mg/kg fangchinoline supplementation, respectively (Fig. 2, $P < 0.05$). The ROS level was increased by 624.2% in liver tissues from diabetic rats but reduced by 15.9% and 55.3% after 100 mg/kg and 200 mg/kg fangchinoline supplementation, respectively (Fig. 2, $P < 0.05$). The ROS level was increased by 547% in kidney tissues from diabetic rats. However, 100 mg/kg and 200 mg/kg fangchinoline supplementation significantly reduced the ROS level by 16.1% and 57.2%, respectively (Fig. 2, $P < 0.05$). The ROS level was increased by 524.2% in heart tissues from diabetic rats, whereas 100 mg/kg and 200 mg/kg fangchinoline supplementation reduced the ROS level by 15.4% and 63.7%, respectively (Fig. 2, $P < 0.05$). Glibenclamide treatment

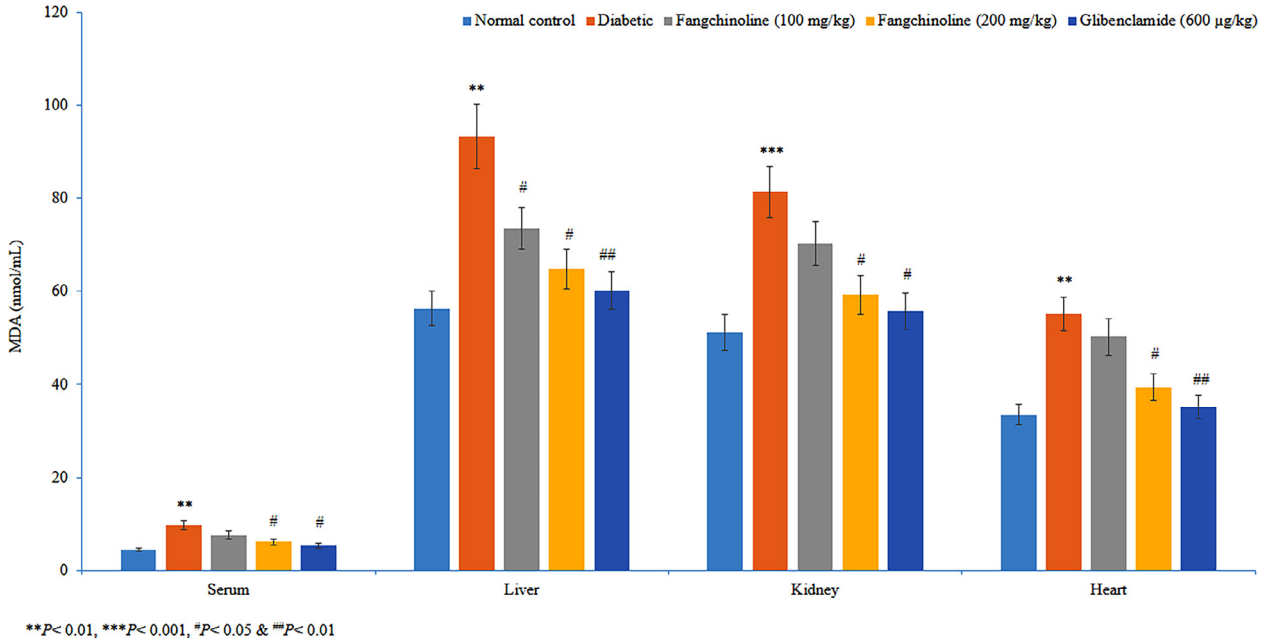

Fig. 1. Effects of fangchinoline supplementation on lipid peroxidation in male rats with streptozotocin-induced diabetes. Rats were treated with 100 mg/kg or 200 mg/kg fangchinoline for 45 d. $^{\#}P < 0.05$ and $^{\#\#}P < 0.01$ vs. diabetic rats. $^{**}P < 0.01$ and $^{***}P < 0.001$ vs. normal rats.

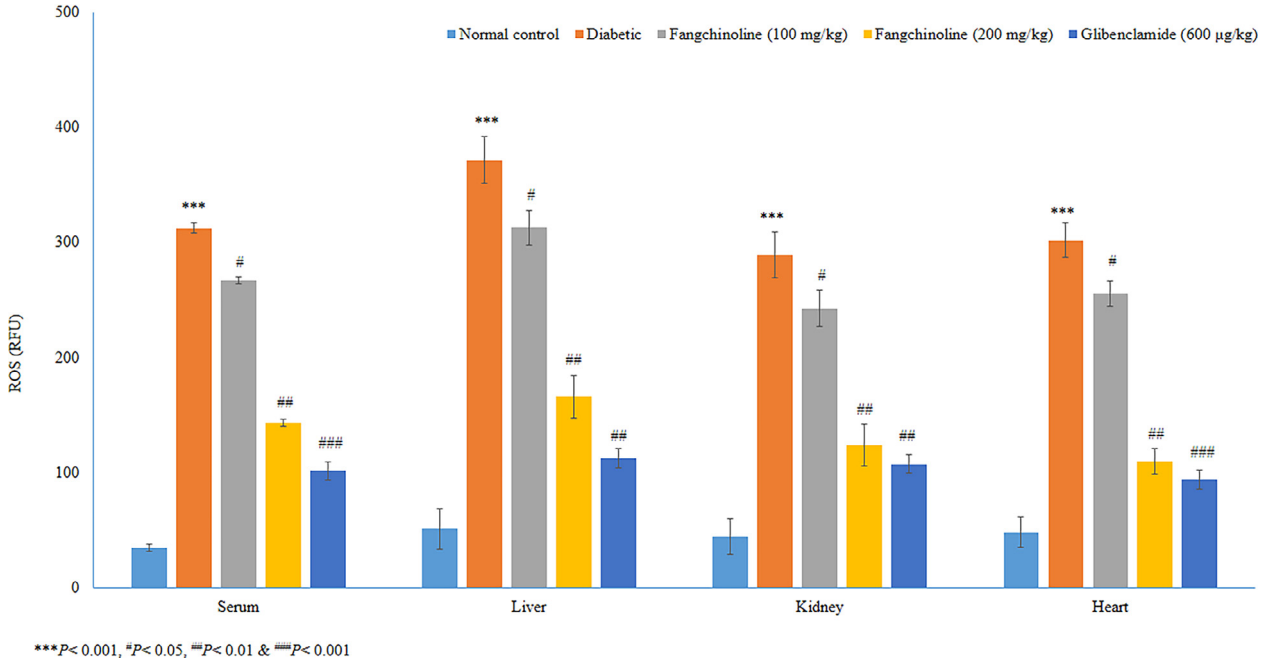

Fig. 2. Effects of fangchinoline supplementation on the reactive oxygen species (ROS) level in male rats with streptozotocin-induced diabetes. Rats were treated with 100 mg/kg or 200 mg/kg of fangchinoline for 45 days. $^{\#}P < 0.05$, $^{\#\#}P < 0.01$, and $^{\#\#\#}P < 0.001$ vs. diabetic rats. $^{***}P < 0.001$ vs. normal rats.

reduced the ROS level by >60% in serum and tissues from diabetic rats. Catalase, Gpx, SOD, and GSH levels were substantially reduced in serum, as well as in liver, kidney, and heart tissues from diabetic rats (Table 1, Table 2, Table 3 and Table 4, $P < 0.05$). However, fangchinoline supplementation improved the levels of these antioxidant markers. Glibenclamide treatment also improved these antioxidant marker levels in serum and tissues from diabetic rats.

The total hexose level was increased by 77.5% in serum from diabetic rats but reduced by 11.6% and 31.9% after 100 mg/kg and 200 mg/kg fangchinoline supplementation, respectively (Table 5, $P < 0.05$). The total hexose level was increased by 73.7% in liver tissues from diabetic rats, whereas 100 mg/kg and 200 mg/kg fangchinoline supplementation reduced the level by 13.6% and 31.5%, respectively (Table 5, $P < 0.05$). The total hexose level was increased by 69.5% in kidney tissues from diabetic rats. However, 100 mg/kg and 200 mg/kg fangchinoline supplementation reduced the total hexose level by 10.7% and 27.4%, respectively (Table 5, $P < 0.05$). The total hexose level was increased by 51.5% in heart tissues from diabetic rats but reduced by 7.5% and 27% after

Table 1
Effect of fangchinoline supplementation on antioxidant markers in the serum of streptozotocin induced diabetic rats.

Markers	Normal control	Diabetic	Diabetic + fangchinoline (100 mg/kg)	Diabetic + fangchinoline (200 mg/kg)	Diabetic + glibenclamize (600 μg/kg)
Catalase (U/ml)	43.1 ± 3	21.7 ± 2***	31.5 ± 2.1#	37.4 ± 3.1#	41.3 ± 3.2###
SOD (U/ml)	63 ± 4.8	24 ± 1.2***	32.4 ± 2.4#	49.5 ± 3.1#	56.3 ± 4.1###
Gpx (nmol/ml)	0.61 ± 0.03	0.21 ± 0.01***	0.24 ± 0.01#	0.47 ± 0.03#	0.53 ± 0.04###
GSH (nmol/ml)	0.72 ± 0.04	0.24 ± 0.02***	0.37 ± 0.02	0.56 ± 0.03#	0.66 ± 0.03###

*** $P < 0.001$.
# $P < 0.05$.
$P < 0.001$.

Table 2
Effect of fangchinoline supplementation on antioxidant markers in the liver tissue of streptozotocin induced diabetic rats.

Markers	Normal control	Diabetic	Diabetic + fangchinoline (100 mg/kg)	Diabetic + fangchinoline (200 mg/kg)	Diabetic + glibenclamize (600 μg/kg)
Catalase (U/mg of protein)	56.3 ± 3.6	25.6 ± 2.1***	37 ± 2.5#	44.4 ± 3.2#	52.6 ± 3.5###
SOD (U/mg of protein)	75.4 ± 5	29.4 ± 1.8***	39.7 ± 2.5#	56 ± 3.4#	65 ± 4.4###
Gpx (nmol/mg of protein)	0.67 ± 0.04	0.22 ± 0.01***	0.34 ± 0.01#	0.55 ± 0.04#	0.59 ± 0.04###
GSH (nmol/mg of protein)	0.65 ± 0.05	0.27 ± 0.02***	0.39 ± 0.02	0.55 ± 0.03#	0.61 ± 0.03###

*** $P < 0.001$.
# $P < 0.05$.
$P < 0.001$.

Table 3
Effect of fangchinoline supplementation on antioxidant markers in the kidney tissue of streptozotocin induced diabetic rats.

Markers	Normal control	Diabetic	Diabetic + fangchinoline (100 mg/kg)	Diabetic + fangchinoline (200 mg/kg)	Diabetic + glibenclamide (600 μg/kg)
Catalase (U/mg of protein)	51.2 ± 3.2	23.1 ± 2.2***	35.2 ± 2.1#	42.4 ± 3.1#	47.1 ± 3.2###
SOD (U/mg of protein)	73.1 ± 5.3	27.2 ± 1.7***	41.7 ± 2.2#	56.8 ± 3.4#	64.2 ± 4.1###
Gpx (nmol/mg of protein)	0.64 ± 0.04	0.24 ± 0.01***	0.39 ± 0.01#	0.51 ± 0.04#	0.56 ± 0.04###
GSH (nmol/mg of protein)	0.61 ± 0.05	0.23 ± 0.02***	0.37 ± 0.03	0.53 ± 0.04#	0.56 ± 0.04###

*** $P < 0.001$.
# $P < 0.05$.
$P < 0.001$.

Table 4
Effect of fangchinoline supplementation on antioxidant markers in the heart tissue of streptozotocin induced diabetic rats.

Markers	Normal control	Diabetic	Diabetic + fangchinoline (100 mg/kg)	Diabetic + fangchinoline (200 mg/kg)	Diabetic + glibenclamide (600 μg/kg)
Catalase (U/mg of protein)	44.1 ± 2.2	21.5 ± 2.1***	32 ± 2#	39 ± 3.2#	41.2 ± 3.1###
SOD (U/mg of protein)	65.2 ± 4.1	25.2 ± 1.5***	36.3 ± 2.1#	49.2 ± 3.4#	52.3 ± 4.2###
Gpx (nmol/mg of protein)	0.61 ± 0.04	0.26 ± 0.01***	0.41 ± 0.01#	0.54 ± 0.04#	0.59 ± 0.04###
GSH (nmol/mg of protein)	0.54 ± 0.03	0.26 ± 0.02***	0.38 ± 0.03	0.57 ± 0.04#	0.51 ± 0.05###

*** $P < 0.001$.
# $P < 0.05$.
$P < 0.001$.

Table 5
Effect of fangchinoline supplementation on total hexoses in the serum, liver, kidney and heart tissue of streptozotocin induced diabetic rats.

Markers	Normal control	Diabetic	Diabetic + fangchinoline (100 mg/kg)	Diabetic + fangchinoline (200 mg/kg)	Diabetic + Glibenclamide (600 μg/kg)
Serum (mg/dL)	96.5 ± 6.7	171.3 ± 10.6***	151.5 ± 8.2#	116.7 ± 9.1#	103.2 ± 7.5###
Liver (mg/100 g)	27.4 ± 2.5	47.6 ± 2.1***	41.1 ± 2.5#	32.6 ± 3.4#	30.5 ± 2.6##
Kidney (mg/100 g)	22.6 ± 1.5	38.3 ± 2.8***	34.2 ± 2.9	27.8 ± 1.4#	25.4 ± 1.5###
Heart (mg/100 g)	19.3 ± 1	29.3 ± 1.1***	27.1 ± 1.2	21.4 ± 1.1#	20.5 ± 1.35##

*** $P < 0.001$.
# $P < 0.05$.
$P < 0.01$.
$P < 0.001$.

supplementation with 100 mg/kg and 200 mg/kg fangchinoline, respectively (Table 5, $P < 0.05$). Sialic acid, hexosamines, and fucose levels were substantially increased in serum, as well as in liver, kidney, and heart tissues, from diabetic rats. However, fangchinoline supplementation reduced hexosamines, sialic acid, and fucose to near normal levels (Table 6, Table 7 and Table 8, $P < 0.05$).

Table 6
Effect of fangchinoline supplementation on hexosamines in the serum, liver, kidney and heart tissue of streptozotocin induced diabetic rats.

Markers	Normal control	Diabetic	Diabetic + fangchinoline (100 mg/kg)	Diabetic + fangchinoline (200 mg/kg)	Diabetic + Glibenclamide (600 μg/kg)
Serum (mg/dL)	51.5 ± 4.2	78.4 ± 5.2***	71.3 ± 4.4#	57.3 ± 3.8#	53.2 ± 4.1##
Liver (mg/100 g)	8.6 ± 0.5	16.1 ± 1.1***	13.7 ± 1.4#	9.5 ± 0.8#	10.1 ± 1.1##
Kidney (mg/100 g)	7.5 ± 0.5	16.3 ± 1.5***	13.1 ± 1.5	8.7 ± 0.7#	8.4 ± 0.5###
Heart (mg/100 g)	8.4 ± 0.6	14.8 ± 1.1***	11.5 ± 1.1	9.6 ± 0.6#	8.9 ± 0.7##

*** $P < 0.001$.
# $P < 0.05$.
$P < 0.01$.
$P < 0.001$.

Table 7
Effect of fangchinoline supplementation on sialic acid in the serum, liver, kidney and heart tissue of streptozotocin induced diabetic rats.

Markers	Normal control	Diabetic	Diabetic + fangchinoline (100 mg/kg)	Diabetic + fangchinoline (200 mg/kg)	Diabetic + glibenclamide (600 μg/kg)
Serum (mg/dL)	53.3 ± 4.5	81.3 ± 6.1***	69.2 ± 4.9#	59.4 ± 3.7#	56.5 ± 4.1##
Liver (mg/100 g)	8.2 ± 0.5	19.4 ± 1.4***	14.5 ± 1.5#	9.8 ± 0.8#	9.1 ± 0.7##
Kidney (mg/100 g)	7.7 ± 0.6	18.5 ± 1.4***	13.6 ± 1.2	8.6 ± 0.6#	8.1 ± 0.5##
Heart (mg/100 g)	7.3 ± 0.5	17.2 ± 1.4***	11.1 ± 1.2	9.2 ± 0.6#	8.4 ± 0.5##

*** $P < 0.001$.
# $P < 0.05$.
$P < 0.01$.

Table 8
Effect of fangchinoline supplementation on fucose in the serum, liver, kidney and heart tissue of streptozotocin induced diabetic rats.

Markers	Normal control	Diabetic	Diabetic + fangchinoline (100 mg/kg)	Diabetic + fangchinoline (200 mg/kg)	Diabetic + glibenclamide (600 μg/kg)
Serum (mg/dL)	14.5 ± 1.3	27.6 ± 2.1***	22.5 ± 2.2#	16.3 ± 21.3#	16.6 ± 1.4##
Liver (mg/100 g)	9.7 ± 0.8	17.3 ± 1.2***	14.7 ± 1.3#	11.5 ± 0.8#	10.2 ± 0.8##
Kidney (mg/100 g)	8.4 ± 0.7	19.4 ± 1.5***	13.2 ± 1.2	9.7 ± 0.5#	8.9 ± 0.6##
Heart (mg/100 g)	9.9 ± 0.9	19.6 ± 1.7***	14.1 ± 1.3	10.4 ± 0.8#	10.1 ± 0.7##

*** $P < 0.001$.
# $P < 0.05$.
$P < 0.01$.

Glibenclamide treatment also reduced the levels of total hexoses, hexosamines, sialic acid, and fucose in serum and tissues from diabetic rats (Table 6, Table 7 and Table 8, $P < 0.05$). Histopathological analysis showed normal cellular population and normal acni in normal rats (Fig. 3). The reduced and minute number of islet cells were noted in streptozotocin-induced diabetic rats. Diabetic rats treated with fangchinoline significantly increased regeneration of the normal size and cell count of islet cells in the β-cell region. Diabetic rats treated with glibenclamide showed restoration of normal size and cell count and of islets (Fig. 3). Histopathological analysis of liver tissue of streptozotocin-induced diabetic rats showed the microvesicular fatty alterations in the centrilobular areas of the liver, focal necrosis, mild congestion and focal fibrosis. Fangchinoline treated rat liver tissue significantly reduced microvesicular fatty alterations in the centrilobular areas of the liver, focal necrosis, mild congestion and focal fibrosis (Fig. 4).

4. Discussion

In this study, we investigated the anti-diabetic and antioxidant effects of fangchinoline in male rats with streptozotocin-induced diabetes. Diabetes is a metabolic disorder caused by defects in insulin production and activity [1]. Cellular proteins and lipids undergo various structural alterations during the course of disease [2]. During disease progression, changes in lipid peroxidation cause structural modifications via production of free radicals [3]. Normal antioxidant and lipid peroxidation levels in animals are altered under disease conditions. The levels of reduced GSH, catalase, Gpx, SOD, malondialdehyde, and 4-hydroxy-2-nonenol could reflect the antioxidant and lipid peroxidation statuses in animal tissues [4]. The production of advanced glycated end products induces oxidative stress, as do hyperlipidemia and hyperglycemia. These are key indicators of diabetic complications [21].

Reduced antioxidant levels lead to increased production of superoxide radicals [22]. Reduced antioxidant levels and the production of oxygen free radicals lead to late diabetic complications [5]. A higher level of reactive oxygen metabolites has been correlated with glucose levels in diabetic tissue and plasma [6]. Furthermore, reactive oxygen metabolites induce severe damage in terms of cellular lipids, proteins, and DNA [7]. Increased oxidative stress in diabetic conditions occurs due to reduced antioxidant and increased lipid peroxidation levels [8]. In addition, stress-induced signaling pathways are activated, which regulate selective gene expression patterns affecting cellular proteins and lipids [9].

Reduced lipid peroxidation and increased antioxidant levels following fangchinoline supplementation have been observed in experimental rheumatoid arthritis-induced rats [14]. Daicheng et al. [23] reported that fangchinoline supplementation reduced lipid peroxidation and increased SOD activity in brain tissue from neonatal rats. Gülçin et al. [24] reported enhanced antioxidant activity after fangchinoline treatment *in vitro*. Chen et al. [25] found enhanced SOD activity and reduced lipid peroxidation levels in rats with endotoxemia. Koh et al. [26] showed that fangchinoline supplementation inhibited ROS in cultured rat cerebellar

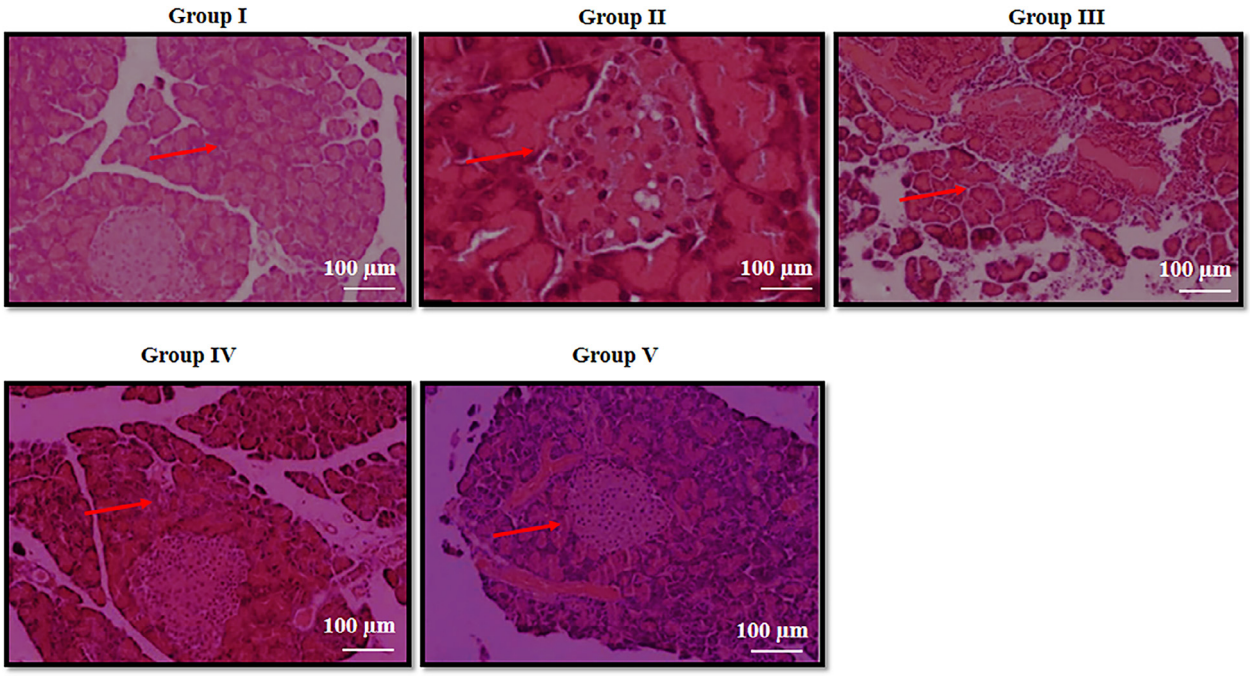

Fig. 3. Histopathological analysis of pancreas following fangchinoline supplementation in male rats with streptozotocin-induced diabetes. Rats were treated with 100 mg/kg or 200 mg/kg fangchinoline for 45 d. $^{\#}P < 0.05$ and $^{\#\#}P < 0.01$ vs. diabetic rats. $^{**}P < 0.01$ and $^{***}P < 0.001$ vs. normal rats. $N = 6$. Scale bar is 100 μm.

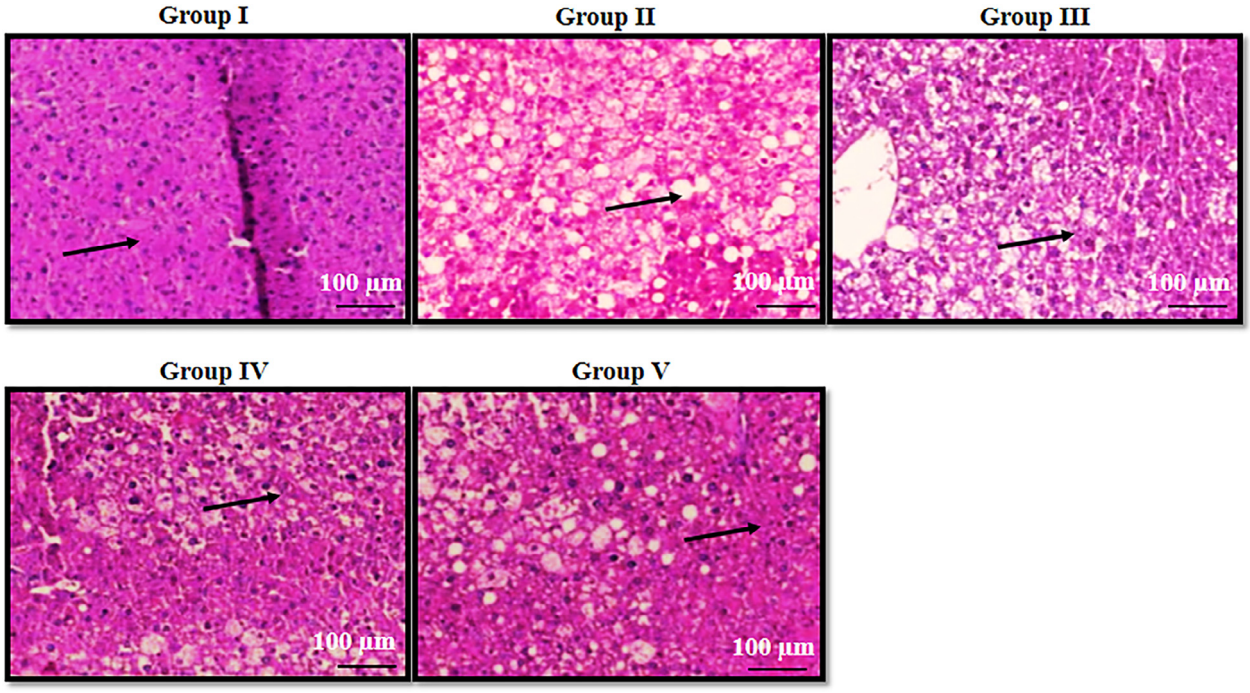

Fig. 4. Histopathological analysis of liver following fangchinoline supplementation in male rats with streptozotocin-induced diabetes. Rats were treated with 100 mg/kg or 200 mg/kg fangchinoline for 45 d. $^{\#}P < 0.05$ and $^{\#\#}P < 0.01$ vs. diabetic rats. $^{**}P < 0.01$ and $^{***}P < 0.001$ vs. normal rats. $N = 6$. Scale bar is 100 μm.

granule cells. In our study, fangchinoline supplementation also reduced lipid peroxidation and ROS levels, while enhancing catalase, SOD, Gpx, and GSH levels, in rats with streptozotocin-induced diabetes. Researchers have reported the protective effect of berberine chloride on the liver and lipid profile, oxidant status and insulin signaling molecules of streptozotocin-induced diabetic rats [27,28].

Hyperglycemia results from insulin deficiency or reduced insulin activity, which leads to reduced glucose utilization and the formation of glycoproteins [29]. Sialic acid and fucose form glycanic chains composed of linked proteins and lipids inside the cells [30]. Researchers have reported that increased biosynthesis of glycoproteins leads to deposition of these materials on the pancreatic cell basal membrane [31]. Increased levels of glycoproteins can

cause liver diseases and related diabetic complications involving heart and kidney tissues [32]. In this study, we observed higher levels of hexosamines, total hexoses, fucose, and sialic acid in streptozotocin-induced diabetic rats; however, fangchinoline supplementation reduced these levels.

5. Conclusion

To our knowledge, this is the first report concerning the effects of fangchinoline on glycoprotein components such as total hexoses, hexosamines, sialic acid, and fucose in streptozotocin-induced diabetic rats. Supplementation with fangchinoline led to significant attenuation of the levels of lipid peroxidation, ROS, and glycoprotein components such as total hexoses, hexosamines, sialic acid, and fucose, while improving antioxidant marker levels.

Ethical approval

All the animal experiments were approved (No: 2020/2TX2225) by the Research Review and Ethics Board of Wuhan Petrochemical Hospital, Wuhan City, Hubei, China.

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Conflict of interest

All authors declare that they have no conflicts of interest.

Data availability

The data and material during the current study are available from the corresponding author on reasonable request.

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