The role of *Acacia Arabica* extract as an antidiabetic, antihyperlipidemic, and antioxidant in streptozotocin-induced diabetic rats

Gehan A. Hegazy, MSc, MD, *Amina M. Alnoury,* MSc, MD, *Hoda G. Gad,* MSc, MD.

ABSTRACT

الأهداف: التحقق من فعالية المستخرج من لحاء نبات أكاسيا ارابيكا كمضاد لارتفاع السكر و الدهون، وكمضاد للأكسدة في الفئران المصابة بالسكرى بعد حقنها بالستربتوزوتوسين.

الطريقة: أجريت هذه الدراسة التجريبية على الحيوانات فى مركز الملك فهد للبحوث بجامعة الملك عبد العزيز خلال الفترة من ديسمبر 2012م حتى يناير 2013م. تم ادراج 36 من إناث الفئران البيضاء في هذه الدراسة وقد تم تقسيم هذه الفئران إلى مجموعتين متساويتين: الأولى هي المجموعة الضابطة، والثانية هي المجموعة التي أصيبت بالسكرى نتيجة حقنها بالستربتوزوتوسين ثم تم تقسيم كل مجموعة إلى 3 مجموعات فرعية كل من 6 فئران وتركت المجموعة الأولى دون علاج، أما المجموعتين الثانية والثالثة فقد تم علاجهم لمدة 21 يوما بتناول 100 و 200 ملغم / كغم مستخرج أكاسيا أرابيكا، على التوالي عن طريق الفم. في اليوم الواحد و العشرين، تم أخذ عينات الدم من الفئران التي منعت من الأكل طول الليل لتحديد نسبة الجلوكوز، والانسولين، والكوليسترول الكلي، والدهون الثلاثية، والكولسترول في البروتينات الدهنية قليلة الكثافة، والكولسترول في البروتينات الدهنية عالية الكثافة، المالون داى الديهايد وأنزيم كو كيو10.

النتائج: لوحظ وجود انخفاض كبير في مستويات الجلوكوز، والمقاومة للأنسولين، والكوليسترول الكلى، والدهون الثلاثية، والكولسترول في البروتينات الدهنية قليلة الكثافة، والمالون داى الديهايد وزيادة الانسولين والكولسترول فى البروتينات الدهنية عالية لكثافة وأنزيم كو كيو 10 في مجموعة الفئران المصابة بالسكري والتى تم علاجها بمستخلص النبات بالمقارنة مع المجموعة غير المعالجة. و لوحظ أن درجة التحسن تعتمد على الجرعة فالتحسن الناتج عن الجرعة العالية من مستخلص أكاسيا أرابيكا كان أكبر من التحسن الناتج عن الجرعة الصغيرة.

خاتمة: نتائج هذه الدراسة التجريبية تشير إلى أن المستخرج من لحاء أكاسيا أرابيكا يستطيع خفض سكر وشحميات الدم والأنشطة المضادة للأكسدة، وبالتالي يمكن دراسة مدى نفعه لعلاج مرض السكري في الأنسان

Objectives: To investigate the role of *Acacia Arabica* extract as a hypoglycemic, antihyperlipidemic, and antioxidant agent in streptozotocin-induced diabetic rats.

Methods: This is an animal experimental study conducted in King Fahd Research Center, King Abdulaziz University (KAU), Jeddah, Kingdom of Saudi Arabia from December 2012 to January 2013. Thirty-six female albino rats were divided into 2 equal groups; the first served as control, and the second was the streptozotocin-induced diabetic group. Each group was subdivided into 3 subgroups, each of 6 rats; the first was left untreated, the second and the third were treated with *Acacia Arabica* extract orally for 21 days (100 mg/kg for the second group and 200 mg/kg for the third group). On the twenty-first day, blood samples were withdrawn through the retro-orbital plexus of overnight fasted rats under light ether anesthesia for determination of serum glucose, insulin, total cholesterol (TC), triglycerides (TG), high density lipoprotein cholesterol (HDL-C), low density lipoprotein cholesterol (LDL-C), malondialdehyde (MDA), and coenzyme Q10 (Co-Q10).

Results: A significant decrease in levels of serum glucose, insulin resistance, TC, TG, LDL-C, MDA and a significant increase in HDL-C and Co-Q10 was observed in the treated diabetic groups when compared to the untreated diabetic group. The changes were dose dependent.

Conclusion: The results found in this study indicate that *Acacia Arabica* extract has hypoglycemic, hypolipidemic, and antioxidant properties, therefore, it can be investigated for its efficacy in the treatment of diabetes in humans.

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From the Clinical Biochemistry Department (Hegazy, Alnoury, Gad), Faculty of Medicine, King Abdulaziz University, Jeddah, Kingdom of Saudi Arabia, and the Medical Biochemistry Department (Hegazy), National Research Center, Cairo, and the Medical Biochemistry Department Faculty of Medicine (Alnoury), Ain Shams University, and the Medical Biochemistry Department (Gad), Faculty of Medicine, Alexandria University, Egypt.

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Address correspondence and reprint request to: Dr. Gehan A. Hegazy, Clinical Biochemistry Department, Faculty of Medicine, King Abdulaziz University, Jeddah, Kingdom of Saudi Arabia. Tel. +966 542843217. E-mail: gehanhegazy@hotmail.com

Diabetes mellitus (DM) is a chronic disorder caused by insulin deficiency or insulin resistance or both.[1] The number of worldwide diabetic people in 2010 was estimated to be 285 million people with considerable differences between populations and regions.[2] Insulin and oral hypoglycemic drugs, which are considered the main line of treatment of diabetes, have many side effects and were not able to significantly control diabetic complications.[3,4] Recently, attention was paid again to alternative and natural therapies. Currently, it is estimated that many plants are used traditionally for the treatment of diabetes, but scientific research has only been performed on a small number of these plants.[5] Hyperglycemia, dyslipidemia, and increased oxidative stress are important characters of diabetes mellitus. Hyperlipidemia; one of the sequelae of diabetes[5,6] is mainly due to the removal of the inhibitory effect of insulin on the hormone-sensitive lipase with subsequent increase in lipolysis and mobilization of free fatty acids from fat depots. Also, insulin deficiency or resistance may be responsible for an increase in low density lipoprotein cholesterol (LDL-C) due to the decrease in the inhibitory action of insulin on 3-hydroxyl methyl glutaryl-CoA (HMG-CoA) reductase; a key enzyme in cholesterol metabolism.[7] Diabetes is considered as a risk factor for increased oxidative stress.[8] Hyperglycemia increases oxidative stress by several mechanisms including; nonenzymatic glycation of proteins, increased oxidative glucose metabolism in the mitochondria and activation of aldose reductase, the polyol pathway and protein kinase C (PKC).[9,10] The reactive oxygen species (ROS) produced from severe oxidative stress induces uncontrolled lipid peroxidation with formation of aldehydic products such as malondialdehyde (MDA). The uncontrolled lipid peroxidation can cause cell injury and death by damaging DNA and inhibition of proteins such as glutamate transporters and Na/K ATPases.[11] The hyperlipidemia, lipid peroxidation of cellular structures, and ROS caused by hyperglycemia have significant role in diabetic complications especially vascular complications.[12] Coenzyme Q10 (Co-Q10), a lipid-soluble component of the electron transport chain in the mitochondria is considered an antioxidant as it inhibits some of the enzymes responsible for free radicals formation and acts as a free radical scavenger.[13] In doing so, it protects membrane phospholipids and proteins and mitochondrial DNA from oxidative damage. In addition, Co-Q10 regenerates other antioxidants such as vitamin E and vitamin C.[14] Thus, deficiency of Co-Q10 contributes to the development of oxidative stress and diabetic complications.[15]

Acacia Arabica has been studied for its hypoglycemic effect. Different parts of the plant with different extraction methods have been studied.[16-18] Although *Acacia Arabica* was suggested as a hypoglycemic agent, very few studies measured its effect on insulin.[16,19] This study was conducted to examine the effect of *Acacia Arabica* bark extract on insulin, insulin resistance, Co-Q10, glucose, and lipid profile in streptozotocin (STZ)-induced diabetic rats. Hence, we can evaluate its role in the management of diabetes.

Methods. This animal experimental study (pre test-post test control group design) was conducted in King Fahd Research Center, King Abdulaziz University (KAU), Jeddah, Kingdom of Saudi Arabia from December 2012 to January 2013. The study protocol was approved by the Hospital Biomedical and Research Ethics Committee, Faculty of Medicine, King Abdulaziz University, Kingdom of Saudi Arabia, and the procedures were carried out according to the Guide for the Care and Use of Laboratory Animals by National Institutes of Health.

Experimental animals. Thirty-six female albino rats weighing 160-170 g and averaging 16 weeks old were obtained from the experimental animal house of King Fahd Research Centre, King Abdulaziz University. All the animals were maintained under laboratory conditions of temperature (22±2°C), humidity (45±5%) and 12 hour day: 12 hour night cycle, and were allowed free access to food (standard pellet diet) and water ad libitum.

Preparation of extract. Dried powder of 100 g of *Acacia Arabica* bark was extracted with chloroform by Soxhlet extraction for 6 hours. The solvent was evaporated and concentrated extract was dried on a water bath at controlled temperature to yield *Acacia Arabica* bark 12.30% w/w.[17]

Induction of diabetes. Diabetes mellitus was induced by a single intraperitoneal injection of freshly prepared STZ (Sigma, St. Louis, MO, USA), with a dose of 50 mg/kg body weight, freshly dissolved in 0.1 M citrate buffer (pH-4.5). The STZ is dissolved so that 50 mg/kg body weight is equivalent to a volume of 1 ml/kg body weight.[20] Diabetes was developed and stabilized in these STZ-treated rats over a period of 5 days after which diabetes was confirmed by measuring blood glucose concentrations. Rats with blood glucose levels of above

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200 mg/dl were considered to be diabetic and used for the study. The control animals were given the citrate buffer (pH-4.5).

Experimental design and treatment schedule. In the experiment, a total of 36 rats were used (18 normal; 18 STZ-diabetic rats). The rats were divided into 6 groups each consisting of 6 rats: group 1 consisted of untreated normal rats; group 2 and group 3 consisted of normal rats treated with 100 mg/kg (group 2) and 200 mg/kg (group 3) of *Acacia Arabica* extract. Group 4 consisted of untreated STZ-diabetic rats. Group 5 and group 6 consisted of STZ-diabetic rats treated with *Acacia Arabica* extract (100 mg/kg [group 5] and 200 mg/kg [group 6]). Treated groups were given the extract orally using an intra-gastric tube once daily for 21 days consecutively.

Biochemical assays. At the end of the experiment (21 days), rats were fasted overnight and blood samples were withdrawn through the retro-orbital plexus under light ether anesthesia using a glass capillary and collected in tubes. Blood was allowed to clot and serum separated by centrifugation at 4000 rpm for 10 minutes. Concentrations of glucose, TG, TC, LDL-C and HDL-C were measured by enzymatic colorimetric methods using commercial kits (Randox Laboratories, Ltd., Antrim, UK). Serum insulin level was estimated by enzyme-linked immunosorbent assay, using the Boehringer-Mannheim Kit with a Boehringer model ES300 analyzer (Boehringer, Germany). Insulin resistance was calculated as follows: Insulin resistance = fasting blood glucose (mg/dl) X fasting insulin (μIU/ml) divided by 405.[21] Serum MDA was determined calorimetrically.[22] The Co-Q10 serum level was estimated by enzyme-linked immunosorbent assay, using My BioSource Kit, San Diego, CA, USA.

Statistical analysis. The Statistical Package for Social Science version 16 (SPSS, Chicago, IL, USA) was used for data analysis. Data are expressed as means ± standard deviation (SD) and minimum - maximum. Data were analyzed using one-way analysis of variance [ANOVA] and comparison between data was carried out using post hoc tests; LSD when equal variances were assumed, and Dunnett's T3 when equal variances were not assumed. Values of $p<0.05$ (2-tailed) were considered statistically significant.

Results. Regarding the control groups, there were no significant differences in all parameters between the untreated control group and control groups treated with different doses of *Acacia Arabica* extract. Data are shown in **Table 1**. There was a significant increase in serum glucose, insulin resistance, TC, LDL-C, TG, and MDA ($p=0.0001$), and significant decrease in insulin, HDL-C, and Co-Q10 ($p=0.0001$) in the untreated diabetic rats group when compared to the control group (**Tables 2, 3,** and 4). After treatment of diabetic rats with 100 mg/kg *Acacia Arabica* extract for 21 days, there was a significant decrease in serum level of: glucose ($p=0.014$); LDL-C, TG, MDA ($p=0.0001$); and TC and insulin resistance ($p=0.007$) when compared to the non-treated diabetic group. Inspite of this decrease, their level were still significantly higher than those in the control group: glucose ($p=0.009$); LDL-C, TG, TC, and insulin resistance ($p=0.0001$); and MDA ($p=0.019$). Treatment also resulted in a significant increase in insulin, HDL-C and Co-Q10 ($p=0.0001$) when compared to the untreated diabetic group, but also the levels were still significantly lower than the normal control group ($p=0.0001$) except for HDL-C, which nearly returned to the control level and the difference was non-significant from the control group ($p=0.098$) (**Tables 2, 3,** and 4). The group of diabetic rats treated with 200 mg/kg *Acacia Arabica* extract showed further significant decrease in: TC, LDL-C, TG ($p=0.0001$); MDA ($p=0.003$), and further significant increase in insulin and Co-Q10 ($p=0.0001$) when compared to the diabetic group treated with 100 mg/kg Acacia Arabica extract. The effect of increased dose was not significant on serum glucose ($p=0.240$); HDL-C ($p=0.369$). Serum TC ($p=0.002$), LDL-C ($p=0.015$), and TG ($p=0.0001$) were still significantly higher than that in the control group. On the contrary, serum glucose ($p=0.119$), insulin ($p=0.067$), MDA ($p=0.43$), and Co-Q10 ($p=1.000$) nearly returned to the control levels and the differences were non-significant (**Tables 2, 3,** and 4).

Discussion. Drugs available for the treatment of diabetes mellitus have side effects, so, there is a need for safer and more effective drugs. In this study, we tried to evaluate the role of *Acacia Arabica* in the management of STZ-induced diabetes in rats. The experimental diabetic model used in this study was type 2 diabetes since a low dose of STZ (50 mg/kg) destroys only part of the pancreatic beta cells population leaving few beta cells, which secrete an inadequate amount of insulin.[23] The STZ-induced diabetic rats, as expected, showed hyperglycemia, hypoinsulinemia, dyslipidemia (increased TC, TG, and LDL-C and decreased HDL-C) and increase in MDA, which agrees with previous studies,[16,17,19,24,25] and decrease in Co-Q10, an antioxidant which has been recorded in some clinical trials that its supplementation can improve glucose levels.[13]

Table 1 - Effect of oral administration of *Acacia Arabica* extract for 21 days on glucose, insulin, insulin resistance, total cholesterol, triglycerides, LDL-C, HDL-C, MDA, and Co-Q_{10} in non-diabetic rats (n=6 for each group).

Variables	Control group	Non-diabetic group treated with extract (100 mg/kg body weight)	Non-diabetic group treated with extract (200 mg/kg body weight)
Glucose (mg/dl)			
Mean ± SD	89.67 ± 12.06	94.83 ± 4.75	94.50 ± 8.98
Minimum-maximum	73.00-109.00	87.00-101.00	82.00-106.00
P-value		*0.986	*0.999
Insulin (µIU/ml)			
Mean ± SD	8.97 ± 0.50	8.95 ± 0.84	8.32 ± 0.69
Minimum- maximum	8.30-9.50	7.60-9.90	7.60-9.50
P-value		*0.961	*0.067
Insulin resistance			
Mean ± SD	1.98 ± 0.31	2.07 ± 0.12	1.78 ± 0.26
Minimum- maximum	1.69-2.44	1.90-2.25	1.42-2.23
P-value		*0.796	*0.543
Total cholesterol (mg/dl)			
Mean ± SD	87.83 ± 8.06	88.50 ± 8.02	86.33 ± 5.82
Minimum- maximum	80.00-103.00	78.00-99.00	78.00-93.00
P-value		*0.879	*0.732
Triglycerides (mg/dl)			
Mean ± SD	89.00 ± 14.07	94.33 ± 8.17	96.00 ± 7.93
Minimum- maximum	68.00-109.00	86.00-105.00	88.00-109.00
P-value		*0.307	*0.183
HDL-C (mg/dl)			
Mean ± SD	57.50 ± 5.09	56.50 ± 6.41	54.33 ± 5.08
Minimum- maximum	52.00-64.00	49.00-65.00	48.00-62.00
P-value		*0.735	*0.288
LDL-C (mg/dl)			
Mean ± SD	15.80 ± 2.69	13.17 ± 1.89	12.80 ± 2.16
Minimum- maximum	10.40-17.50	10.60-15.80	10.40-15.60
P-value		*0.465	*0.405
MDA (nmol/ml)			
Mean ± SD	199.93 ± 17.01	197.73 ± 19.28	200.57 ± 16.14
Minimum- maximum	176.90-216.40	174.30-222.40	180.30-226.40
P-value		*0.794	*0.940
Co-Q_{10} (µmol/l)			
Mean ± SD	0.71 ± 0.04	0.69 ± 0.04	0.75 ± 0.05
Minimum- maximum	0.68-0.80	0.60-0.71	0.69-0.80
P-value		*0.274	*0.200

*significance versus control, HDL-C - high density lipoprotein cholesterol, LDL-C - low density lipoprotein cholesterol, MDA - malondialdehyde, Co-Q10 - Coenzyme Q-10, SD - standard deviation

After administration for 21 days of different doses (100 and 200 mg/kg) of the chloroform extract of *Acacia Arabica* bark to normal control and STZ-induced diabetic rats, the results showed that the extract did not cause any change in lipid profile, glucose, MDA, or Co-Q10 levels in the normal control rats. The previous study, which reported the hypoglycemic effect of *Acacia Arabica* in normal control rats,[19] examined only the acute effect within few hours of administration of the plant extract in normal control animals, and it suggested that the plant stimulates insulin secretion. This effect seemed to be counteracted by the regulatory mechanisms in case of chronic administration, which was observed in our study.

In the group of diabetic rats, oral administration of two different doses (100 and 200 mg/kg) of *Acacia Arabica* extract for 21 days increased serum insulin, reduced the elevated serum glucose and insulin resistance, and improved the lipid profile. It seems that all these effects are secondary to increased insulin level. The increase in serum Co-Q10, which has antioxidant properties together with the decrease in the level of MDA, the index of lipid peroxidation, indicate reduction in oxidative stress. The high dose of *Acacia Arabica* extract (200 mg/kg) was more effective than the low dose as it returned insulin, HDL-C, MDA, and Co-Q10 to nearly normal levels. These results confirm the earlier results which showed hypoglycemic

Table 2 - Effect of oral administration of *Acacia Arabica* extract for 21 days on glucose, insulin, and insulin resistance in different groups.

Variables	Control group n=6	Untreated diabetic group n=6	Diabetic group treated with extract (100 mg/kg body weight) n=6	Diabetic group treated with extract (200 mg/kg body weight) n=6
Glucose (mg/dl)				
Mean ± SD	89.67 ± 12.06	378.17 ± 61.90	228.67 ± 51.35	155.33 ± 44.25
Minimum- maximum	73.00-109.00	279.00-434.00	166.00-308.00	112.00-206.00
		*0.001	*0.009	*0.119
P-value			†0.014	†0.001
				‡0.240
Insulin (µIU/ml)				
Mean ± SD	8.97 ± 0.50	5.05 ± 0.45	6.78 ± 0.44	8.32 ± 0.52
Minimum- maximum	8.30-9.50	4.30-5.60	6.30-7.40	7.60-9.10
			*0.0001	*0.067
P-value		*0.0001	†0.0001	†0.0001
				‡0.0001
Insulin resistance				
Mean ± SD	1.98 ± 0.31	4.67 ± 0.52	3.72 ± 0.97	3.17 ± 0.84
Minimum- maximum	1.69-2.44	3.86-5.25	2.66-4.93	2.27-4.07
		*0.0001	*0.0001	*0.001
P-value			†0.007	†0.0001
				‡0.099

*significance versus control group, †significance versus untreated diabetic group, ‡significance versus diabetic group treated with 100mg/kg body weight *Acacia Arabica* extract, SD - standard deviation

Table 3 - Effect of oral administration of *Acacia Arabica* extract for 21 days on total cholesterol, triglycerides, HDL-C and LDL-C in different groups.

Variables	Control Group n=6	Untreated diabetic group n=6	Diabetic group treated with extract (100 mg/kg body weight) n=6	Diabetic group treated with extract (200 mg/kg body weight) n=6
Total cholesterol (mg/dl)				
Mean ± SD	87.83 ± 8.06	196.17 ± 9.85	120.50 ± 7.99	102.33 ± 3.83
Minimum- maximum	80.00-103.00	181.00-211.00	108.00-130.00	98.00-107.00
		*0.0001	*0.0001	*0.002
P-value			†0.007	†0.0001
				‡0.0001
Triglycerides (mg/dl)				
Mean ± SD	89.00 ± 14.07	193.00 ± 5.40	144.67 ± 6.71	113.33 ± 8.52
Minimum- maximum	68.00-109.00	187.00-202.00	137.00-156.00	102.00-125.00
		*0.0001	*0.0001	*0.0001
P-value			†0.0001	†0.0001
				‡0.0001
HDL-C (mg/dl)				
Mean ± SD	57.50 ± 5.09	38.50 ± 4.51	52.50 ± 4.09	55.17 ± 4.92
Minimum- maximum	52.00-64.00	33.00-46.00	48.00-60.00	51.00-64.00
		*0.0001	*0.098	*0.431
P-value			†0.0001	†0.0001
				‡0.369
LDL-C (mg/dl)				
Mean ± SD	15.80 ± 2.69	122.25 ± 11.74	39.40 ± 7.04	24.98 ± 4.95
Minimum- maximum	10.40-17.50	107.80-133.60	26.20-46.60	21.40-33.80
		*0.0001	*0.0001	*0.015
P-value			†0.0001	†0.0001
				‡0.0001

*significance versus control group †significance versus untreated diabetic group, ‡significance versus diabetic group treated with 100mg/kg body weight *Acacia Arabica* extract. HDL-C - high density lipoprotein cholesterol, LDL-C - low density lipoprotein cholesterol, SD - standard deviation

Table 4 - Effect of oral administration of *Acacia Arabica* extract for 21 days on MDA, and Co-Q_{10} in different groups.

Variables	Control group n=6	Untreated diabetic group n=6	Diabetic group treated with extract (100 mg/kg body weight) n=6	Diabetic group treated with extract (200 mg/kg body weight) n=6
MDA (nmol/ml)				
Mean ± SD	199.93 ± 17.01	296.52 ± 13.53	220.53 ± 7.07	193.27 ± 9.86
Minimum- maximum	176.90-216.40	284.20-321.10	211.30-230.00	178.10-206.50
		*0.0001	*0.019	*0.43
P-value			†0.0001	†0.0001
				‡0.003
Co-Q10 (µmol/l)				
Mean ± SD	0.71 ± 0.04	0.38 ± 0.04	0.59 ± 0.03	0.71 ± 0.05
Minimum- maximum	0.68-0.80	0.30-0.42	0.55-0.64	0.65-0.80
		*0.0001	*0.0001	*1.000
P-value			†0.0001	†0.0001
				‡0.0001

*significance versus control group, †significance versus untreated diabetic group; ‡significance versus diabetic group treated with 100mg/kg body weight *Acacia Arabica* extract. MDA - malondialdehyde, Co-Q_{10} - Coenzyme Q-10, SD - standard deviation

effect and normalization of the lipid profile after administration of different extracts of *Acacia Arabica* to diabetic rats.[17,19,25,26] This study also verified the results of Asad et al,[16] who reported decreased blood glucose and increased insulin levels after administration of methanol extract of *Acacia Nilotica* leaves for 3 weeks. The increase in the level of MDA and the decrease in Co-Q10 level in STZ-induced diabetic rats indicate the presence of oxidative stress, which increases free radical production with reduction in the antioxidant levels.[24,27]

Acacia Arabica extract was suggested to have insulin-like action by enhancing glucose uptake into the muscle and adipose tissues, and by inhibiting hepatic gluconeogenesis.[23] It was also suggested that *Acacia Arabica* exerts its hypoglycemic effect through the activation of insulin receptors.[28] The results of this study suggest that these are minor mechanisms and the major mechanism occurs through revitalization and may be regeneration of the damaged beta cells,[19] as indicated by the increased serum insulin level in the diabetic rats treated with *Acacia Arabica* extract. The antioxidant effect of *Acacia Arabica* extract, indicated by reduced MDA and elevated Co-Q10 level may explain this mechanism.[24]

Plants are rich sources of flavonoids, gallotannins, amino acids and other related polyphenols which have hypoglycemic, antihyperlipidemic, and antioxidant action.[29,30] *Acacia Arabica* was reported to contain many ingredients such as polyphenols, tannins and flavonoids (for example, quercetin).[31] The tannins were found to restore the function of pancreatic beta cells and enhance their release of insulin. Quercetin is an antioxidant that acts by several mechanisms including oxygen radicals scavenging, hence, it protects against lipid peroxidation and metal ions chelation.[24] The presence of these substances with their anti-oxidant properties may explain the anti-diabetic effect of this plant as indicated by some recent studies.[16]

Our results need farther support for the proposed mechanism of *Acacia Arabica* anti-diabetic effect. It is recommended to investigate the effect of the plant extract on pancreatic B-cells by histopathological examination. Also, more studies are needed to investigate the side effects of *Acacia Arabica* as it has been reported to have an adverse effect on electrolyte balance and vitamin D in mice, and to cause hypersensitivity in humans.[32]

In conclusion, in this study we found that extracts of *Acacia Arabica* improve glucose levels and metabolic abnormalities in lipid metabolism and oxidative stress caused by STZ-induced diabetes in rats through increasing insulin levels, therefore, it can be investigated for its efficacy in the treatment of diabetes in humans.

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