

Comparative Study on Antidiabetic Effects of Coenzyme Q10 and Quercetin on Streptozotocin-Induced Hyperglycemia in Rats

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Abstract

As estimated by Federation Diabetes Atlas, the number of diabetic patients will reach globally 592 million in 2035. Diabetes mellitus is a metabolic disorder characterized by hyperglycemia resulting from deficiency of insulin, its resistance or both. This investigation aimed to explore comparative the antidiabetic effect of coenzyme Q10 and quercetin on streptozotocin-induced hyperglycemia in rats. A sum of 24 adult male Albino rats weighing $200\pm 5g$ each were used and were divided into 4 groups ($n= 6$ rats). One group kept as (C -ve) and fed on basal diet all over the experimental period (28 days), while the other groups were intraperitoneal injected with streptozotocin (STZ) at a dose of 40 mg/kg once a week for two weeks. One of the diabetic groups was fed basal diet only (C +ve) and the other two diabetic groups were fed on Coenzyme Q10 and Quercetin at a dose of 100mg/kg body weight (b. wt.) each. At the end of the trial, rats were mercy sacrificed and the blood and organs were removed then serum glucose, insulin, TSH, LH, TC, TG, HDL, LDL, VLDL, T.P, Alb., T.B, AST, ALT, ALP, BUN, Creat., and uric acid were estimated. The results revealed that all hyperglycemic rats with orally administered Coenzyme Q10 and Quercetin at a dose of 100mg/kg b. wt. each, showed significant increase in BWG, FI, FER and HDL, whereas significant decreases in serum glucose, insulin, TSH, LH, TC, TG, LDL, VLDL, T.P, Alb., T.B, AST, ALT, ALP, BUN, Creat., and uric acid recorded compared to control positive groups. Furthermore, Coenzyme Q10 induced higher enhancing of improvement rather than quercetin inspite that quercetin has natural healing properties as it is a natural flavonoid. In conclusion, Coenzyme Q10 and Quercetin have antidiabetic effects on streptozotocin-induced hyperglycemia in rats, indicating higher effect for CoQ10 in spite of singularity for quercetin as a natural flavonoid.

Key words: Coenzyme Q10, Quercetin, STZ, diabetic rats.

Introduction

As estimated by Federation Diabetes Atlas, the number of diabetic patients will reach globally 592 million in 2035 (**IDF, 2013**). Diabetes mellitus is a metabolic disorder characterized by hyperglycemia resulting from deficiency of insulin, its resistance or both. Chronic hyperglycemia can lead to

severe damage and failure of many organs including liver, eyes, kidneys, heart, and blood vessels (ADA, 2014) and (Sreekutty and Mini, 2016). Diabetic type II patients are more likely to have cardiovascular complications associated with hyperglycemia such as heart disease, high blood pressure, stroke and nephropathy (WHO, 2016).

Coenzyme Q10 (CoQ10) is a fat-soluble compound and mainly synthesized by mitochondria in some body organs such as heart, liver, kidneys, pancreas, and muscles, where it is consumed in a large amount by the production of adenosine tri-phosphate (Acosta *et al.*, 2016 and Crane, 2001). CoQ10 (also known as Ubiquinone) is a water-insoluble component found in nearly all cell membranes, and has multiple metabolic functions (Quinzii *et al.*, 2007). It is a major component for the mitochondrial electron transport system (Crane, 2001 & Littarru and Langsjoen 2007). Accordingly, exogenous coenzyme Q10 supplementation may improve oxidative stress induced by abnormalities in mitochondrial function, thus improving glycemic control in type II diabetic patients. (Alam and Rahman 2014).

Quercetin dihydrate (3, 3', 4', 5', 7-Penta-hydroxy flavone) is a flavonoid or more specifically a subclass called flavonols which are widely distributed in the plant kingdom. It is found in many foods such as onions, cilantro, sweet potatoes, broccoli, and kale. It is widely used particularly, as has been traditionally reported to fight many diseases such as obesity (Rayalam *et al.*, 2008; Ahn *et al.*, 2008), Anti-diabetes (Di Carlo *et al.*, 1999; Vessal *et al.*, 2003), anti-fertility (Formica and Regelson 1995), and anti-sclerotic (Salvamani *et al.*, 2014 and Kleemann *et al.*, 2011).

Quercetin can regulate and normalize lipoprotein levels in blood plasma through antioxidants, which prevent elevated the accumulation of cholesterol and oxidized lipids as well as hypercholesterolemia inhibition as a risk factor for diabetes mellitus (Fuhrman and Aviram, 2001).

Therefore, this investigation aimed to compare the antidiabetic effects of coenzyme Q10 and quercetin on streptozotocin-induced hyperglycemia in rats.

Materials and Methods

a. Materials:

- 1. Active ingredients:** Active ingredients consisted of Coenzyme Q10 a synthetic compound which was purchased from Al-Nahdy pharmacy and quercetin, in the form of quercetin hydrate $\geq 95\%$, which was purchased from Trust Company for Chemicals, Geddah, KSA.
- 2. Streptozotocin:** Fine pure chemical, used for inducing diabetes in this study, was purchased from Trust Company for chemicals, Geddah, KSA..
- 3. Rats:** Rats were obtained from animal house of Medical Biochemistry Department, Faculty of Medicine, Umm Al-Qura University, KSA.

4. Basal diet: Basal diet consisted of casein (12.5%), corn oil (10%), choline chloride (0.2%), vitamin mixture (1%) (**Campbell, 1963**), cellulose (5%), salt mixture (4%) and corn starch (up to 100%) according to the method described by **Hegsted *et al.*, (1941)**.

b. Methods:

1. Active ingredient preparation:

The first active ingredient, Coenzyme Q10, was dissolved in corn oil (**Jerine *et al.*, 2020**), while the second active ingredient, quercetin, was dissolved in ethyl alcohol (**Yang & Kang 2018**), in the ratio prescribed to be administered orally to rats by a dose of 100 mg/kg b. wt., each.

2. Preparation of diabetic rats:

Rats were received a dose of 40 mg/kg body weight via streptozotocin (STZ) injection. STZ was administered immediately after dissolving it in freshly prepared cold citrate buffer via intraperitoneal route used for Diabetes induction once a week for two weeks as the method prescribed by (**Vessal *et al.*, 2003**). Fasting blood glucose level greater than 160 mg/dL were considered as being diabetic.

3. Experimental Design:

Twenty four male albino rats Sprague Dawley strain weighing 200±5g each, were housed in the animal house of Medical Biochemistry Department, Faculty of Medicine, Umm Al-Qura University, Saudi Arabia. Rats were divided into two main groups, first group (6 rats) was fed on basal diet and left as negative control (Control -ve). The second group (18 rats) was inflicted by diabetes using the method prescribed by **Vessal *et al.*, (2003)**, then was divided into 3 groups (n=6 rats each) according to the following division:

- 1- Diabetic (control positive) group (+ve) which was fed on basal diet during the expeiremental period (28 days).
- 2- Diabetic rats fed on basal diet plus oral injection with Coenzyme Q10 at a dose of 100 mg/kg b.w., for 28 consecutive days as an experimental period.
- 3- Diabetic rats fed on basal diet plus oral injection with quercetin at a dose of 100 mg/kg b.w., for 28 consecutive days as an experimental period.

Rats body weights and food intake was recorded during the experimental period. At the end of the trial (28 days), rats were mercy sacrificed, blood sample were collected then centrifuged for 10 minutes at 4000 rotation per minute (r.p.m) for obtaining the serum. Liver and pancreas were removed and cleaned then weighed.

4. Biological evaluation:

Biological evaluation was carried out by the estimation of body weight gain (BWG), food intake (FI) evaluation and feed efficiency ratio (FER) estimation according to **Chapman *et al.*, (1950)** as follows: $FER = \frac{\text{Final weight} - \text{Initial weight}}{\text{Initial weight}} \times 100$. Moreover, liver and pancreas weight were recorded for every rat individually then their relative to body weights were calculated.

5. Biochemical analysis:

Fasting glucose and insulin serum levels were determined according to the methods of **Kaplan (1984)** and **Nakagawa *et al.*, (1973)**, respectively. Thyroid stimulating hormone (TSH) was determined according to **Matyjaszek-Matuszek *et al.*, (2013)** and luteinizing hormone (LH) according to **Soh and Aw (2019)**. Serum total cholesterol was determined according to **Allain (1974)** and serum triglycerides was according to **Young and Pestaner (1975)**. Determination of HDLc was carried out according to the method of **Friedewald (1972)**. The determinations of LDLc was carried out according to the method of **Nauck *et al.*, (2002)** and very low density lipoprotein (VLDLc) calculated as $\text{triglycerides}/5$. Serum total protein, albumin and total bilirubin (T.B) were determined according to **Gomal *et al.*, (1949)**, **Doumas *et al.*, (1971)** and **Doumas *et al.*, (1985)**, respectively. Colorimetric method was used to determine AST and ALT according to **Reitman and Frankel (1957)**; moreover, determination of alkaline phosphates ALP activity was according to **Haussament (1977)**. Blood urea nitrogen, creatinine and uric acid were determined according to **(Pattn and Crouch, 1977)**, **(Henry, 1974)** and **(Schultz, 1984)**, respectively.

6. Statistical Analysis:

Results were expressed as mean \pm standard error (SE) and statistically analyzed using Statistical Package for Social Sciences (SPSS, 2008). The double sample t-test was used to compare parameters between the positive control and diabetic rats with or without treatment groups. P-value less than 0.05 was considered statistically significant.

Results and Discussion

1. Comparative between the antidiabetic effects of Coenzyme Q10 and Quercetin on FI, FER and BWG of streptozotocin-induced hyperglycemic rats:

Data listed in table (1) show the comparative antidiabetic effects of Coenzyme Q10 (CoQ10) and Quercetin at a dose of 100mg/kg b. wt., each, on

body weight gain (BWG), feed intake (FI) and feed efficiency ratio (FER) on streptozotocin-induced hyperglycemia rats.

Table (1): Comparison between the effects of CoQ10 and Quercetin on BWG , FI and FER of streptozotocin-induced hyperglycemic rats

Groups	Parameters		
	BWG (g/28days) Mean ±SE	FI (g/day) Mean ±SE	FER Mean ±SE
Control (-)	39.00±0.12 ^a	9.73±0.07 ^a	0.143±0.003 ^a
Control (+)	18.00±0.08 ^d	6.09± 0.05 ^d	0.106±0.002 ^d
CoQ10 100 mg/kg b.w.	31.00±0.09 ^b	8.33±0.02 ^b	0.133±0.004 ^b
Quercetin 100 mg/kg b.w.	25.00±0.06 ^c	7.17±0.03 ^c	0.125±0.003 ^c
L.S.D	3.11	0.93	0.005

*Means with different letters (a, b, c, d) in the same column differ significantly, using one-way ANOVA test, while there were no significant difference for those with similar letters (P<0.05).

It could be noticed that for hyperglycemic rats without treatment (C +ve group) body weight gain (BWG), feed intake (FI) and feed efficiency ratio (FER) were 18.00±0.08g/28days, 6.09±0.05g/day and 0.106±0.002 compared to 39.00±0.12g/28days, 9.73±0.07g/day and 0.143±0.005 (C -ve) for normal rats, (P<0.05). These results declared that there were significant decrease in body weight gain, feed intake and feed efficiency ratio for hyperglycemic rats without treatment as compared with normal rats. All diabetic rats that were orally injected with CoQ10 and quercetin at a dose of 100mg/kg b. wt., each, showed significant increase in body weight gain, feed intake and feed efficiency ratio when compared to control positive group. All diabetic rats with orally administration by CoQ10 at a dose of 100mg/kg b. wt., showed the highest significant increase in all previously mentioned parameters as compared to control positive groups.

These results are confirmed by the findings of **Peter *et al.*, (2019)** who observed that rats with STZ-induced diabetes had a significant decrease (p <0.05) in body weights, which gradually decreased each week, furthermore, rats with diabetes that were treated with CoQ10 had an increase in body weight and the CoQ10 group only reached normal body weight.

Another study by **Al-Attar (2010)** suggested that Coenzyme Q10 has hypolipidemic effects in rats supplemented with a high cholesterol diet resulting in decreasing body weights in all treated rats.

Moreover, **Jung *et al.*, (2013)** concluded that quercetin supplementation significantly reduced the body and liver weight in rats induced weight gain in the high-fat diet.

2. Comparative between the antidiabetic effects of Coenzyme Q10 and Quercetin on relative liver and pancreas weights of streptozotocin-induced hyperglycemic rats:

Comparing the antidiabetic effects of Coenzyme Q10 (CoQ10) and Quercetin at a dose of 100mg/kg b. wt. each group on relative liver and pancreas weights of streptozotocin-induced hyperglycemia rats are illustrated in table (2).

Table (2): Comparison between the effects of CoQ10 and Quercetin on relative liver and pancreas weights of streptozotocin-induced hyperglycemic rats

Groups	Parameters	
	Liver (g) Mean ±SE	Pancreas (g) Mean ±SE
Control (-)	5.91±1.08 ^a	1.79±0.08 ^a
Control (+)	3.18±0.92 ^d	0.89±0.02 ^d
CoQ10 100 mg/kg b.w.	5.03±0.13 ^b	1.11±0.03 ^b
Quercetin 100 mg/kg b.w.	4.27±0.66 ^c	0.97±0.06 ^c
L.S.D	0.05	0.02

*Means with different letters (a, b, c, d) in the same column differ significantly, using one-way ANOVA test, while there were no significant difference for those with similar letters ($P < 0.05$).

It could be noticed for control positive (C +ve) group that there was significant decrease in relative liver and pancreas weights ($P < 0.05$) compared to control negative (C -ve) group. Moreover, there were significant increase in all diabetic rats with orally injection with CoQ10 and quercetin at a dose of 100mg/kg b. wt. each, compared to control positive group and the highest increase was recorded in CoQ10 group.

Similar results were obtained by **Martelli *et al.*, (2020)** who demonstrated that CoQ10 can withstand oxidation-reducing cycles, and its concentration is higher in organs of kidneys, heart and liver, which indicates a high metabolism rate and needs coenzyme Q10 as an adequate energy support system. In addition, **Casuso *et al.*, (2014)** evaluated weight gain, caloric intake, and feed efficiency in exercise and sedentary mice with quercetin showing that relative weight of the liver is higher in the quercetin group when compared to the other studied groups.

3. Comparative between the antidiabetic effects of Coenzyme Q10 and Quercetin on serum fasting glucose and insulin of streptozotocin-induced hyperglycemic rats:

Comparative antidiabetic effects of Coenzyme Q10 (CoQ10) and quercetin at a dose of 100mg/kg b. wt. each, on serum glucose and insulin on streptozotocin-induced hyperglycemia rats are recorded in table (3).

Table (3): Comparison between the effects of CoQ10 and Quercetin on serum fasting glucose and insulin of streptozotocin-induced hyperglycemic rats

Groups	Parameters	
	Glucose (mg/dL) Mean ±SE	Insulin (mg/dL) Mean ±SE
Control (-)	71.20±1.02 ^d	3.61±0.03 ^d
Control (+)	163.70±1.38 ^a	6.22±0.05 ^a
CoQ10 100 mg/kg b.w.	88.67±1.76 ^c	4.09±0.02 ^c
Quercetin 100 mg/kg b.w.	115.13±2.03 ^b	5.11±0.03 ^b
L.S.D	5.19	0.21

*Means with different letters (a, b, c, d) in the same column differ significantly, using one-way ANOVA test, while there were no significant difference for those with similar letters ($P < 0.05$).

It is clear from the table that serum glucose and insulin in hyperglycemic rats without treatment (C +ve group) were 163.70±1.38 and 6.22±0.05mg/dL, compared to 71.20±1.02 and 3.61±0.03mg/dL, respectively, in normal rats (C -ve group) showing significant increase in control positive compared to control negative group.

Rats inflicted with hyperglycemia then orally injected with CoQ10 and Quercetin at a dose of 100mg/kg b. wt., showed significant decrease in serum glucose and insulin serum levels when compared to control positive group. Also, hyperglycemic rats that were administered with CoQ10 at a dose of 100mg/kg b. wt., showed the highest significant decreases in serum glucose and insulin as compared to Quercetin and control positive groups.

These findings were in agreement with that of **Oyedemi *et al.*, (2020)** who showed that taking quercetin by mouth at a dose of 25 and 50mg/kg for 28 days significantly decreased the levels of serum glucose, glycosylated hemoglobin (Hb), and hepatic glycogen but with an enhanced plasma hemoglobin concentration..

Quercetin doses of 10-50 mg of body weight is able to normalize the serum glucose level, increase glycogen liver content and reduce serum cholesterol and low-density lipoprotein concentrations in diabetic rats (**Nuraliev and Avezov, 1992**).

Exposure of isolated rat langerhans islets to certain flavonoids including quercetin enhances insulin release by 44-70% via alteration in Ca²⁺ fluxes and in cyclic nucleotide metabolism (**Hii and Howell, 1985**).

Quercetin produces an increase in activity of pancreatic islets resulting in insulin release in STZ-diabetic rats and induces more glucokinase enzyme in the liver (**Vessal *et al.*, 2003**).

4. Comparative between the antidiabetic effects of Coenzyme Q10 and Quercetin on TSH and LH of streptozotocin-induced hyperglycemic rats:

Table (4) display the comparative between antidiabetic effects of Coenzyme Q10 (CoQ10) and Quercetin at a dose of 100mg/kg b. wt. each, on thyroid-stimulating hormone (TSH) and luteinizing hormone (LH) on streptozotocin-induced hyperglycemia rats.

Table (4): Comparison between the effects of CoQ10 and Quercetin on TSH and LH of streptozotocin-induced hyperglycemic rats

Groups	Parameters	
	TSH (mIU/ml) Mean \pm SE	LH (mIU/ml) Mean \pm SE
Control (-)	7.63 \pm 0.02 ^a	8.98 \pm 0.05 ^a
Control (+)	2.19 \pm 0.03 ^d	3.31 \pm 0.03 ^d
CoQ10 100 mg/kg b.w.	4.09 \pm 0.01 ^b	4.59 \pm 0.03 ^b
Quercetin 100 mg/kg b.w.	3.82 \pm 0.03 ^c	4.01 \pm 0.04 ^c
L.S.D	0.13	0.28

*Means with different letters (a, b, c, d) in the same column differ significantly, using one-way ANOVA test, while there were no significant difference for those with similar letters ($P < 0.05$).

It could be observed that there were significant decreases in thyroid-stimulating hormone (TSH) and luteinizing hormone (LH) in hyperglycemic rats without treatment as compared to normal rats. Meanwhile, there were significant increases in these hormones in rats inflicted with hyperglycemia then orally injected with CoQ10 and Quercetin at a dose of 100mg/kg b. wt., compared to control positive group.

Moreover, hyperglycemic rats which were administered with quercetin at a dose of 100mg/kg b. wt., showed some improvement in both hormones, it could be noted the singularity for quercetin as a natural flavonoid than CoQ10 as a drug in adjusting these hormones in human body.

These findings were in agreement with that of **Lee *et al.*, (2012)** who demonstrated that Coenzyme Q10 is an intracellular antioxidant that protects cells by blocking lipid peroxidation and replenishing other antioxidants that prevent oxidative damage caused by free radicals.

Moreover, **Tušimová *et al.*, (2017)** concluded that the stimulatory effect was observed on FSH secretion at a higher dose of quercetin. Likewise, LH increased at concentrations of 100 mcg/kg and 1000 mcg/kg, indicating the potential effect of quercetin on the secretion of selected pituitary hormones.

5. Comparative between the antidiabetic effects of Coenzyme Q10 and Quercetin on TC and TG of streptozotocin-induced hyperglycemic rats:

Comparing antidiabetic effects of Coenzyme Q10 (CoQ10) and Quercetin at a dose of 100mg/kg b. wt. each, on total cholesterol (TC) and triglyceride (TG) on streptozotocin-induced hyperglycemia rats are recorded in table (5).

Table (5): Comparison between the effects of CoQ10 and Quercetin on TC and TG of streptozotocin-induced hyperglycemic rats

Groups	Parameters	
	TC (mg/dl) Mean ±SE	TG (mg/dl) Mean ±SE
Control (-)	51.98±1.02 ^d	25.20±1.25 ^d
Control (+)	73.90±1.38 ^a	45.95±0.59 ^a
CoQ10 100 mg/kg b.w.	55.27±1.06 ^c	31.40±1.71 ^c
Quercetin 100 mg/kg b.w.	60.57±1.33 ^b	35.10±1.04 ^b
L.S.D	2.19	1.98

*Means with different letters (a, b, c, d) in the same column differ significantly, using one-way ANOVA test, while there were no significant difference for those with similar letters (P<0.05).

It could be noticed from the table that serum total cholesterol (TC) and triglyceride (TG) in normal rats (C -ve group) was significantly increased in (C +ve) compared to (C -ve) which was 73.90±1.38, 45.95±3.59, 51.98±1.02 and 25.20±1.25 mg/dl, respectively. Hyperglycemic rats with orally fed by CoQ10 and Quercetin at a dose of 100mg/kg b. wt. each, showed significant decrease in serum TC and TG as compared to control positive group. The highest significant decrease occurred in CoQ10 at a dose of 100mg/kg b. wt., when compared to control positive group.

Quercetin-rich supplementation decreases serum levels of TC and increases serum concentrations of high density lipoprotein (HDL)-cholesterol (Igarashi and Ohmuma, 1995; Kamada *et al.*, 2005; Gnoni *et al.*, 2009; Lee *et al.*, 2011). Furthermore, quercetin had significantly increased liver glucokinase activity and reduced serum cholesterol and triglycerides (TG) in diabetic animals (Hii and Howell 1985).

The mechanism of action of natural antioxidants including quercetin in reducing lipids occurred due to inhibition of glycosylated lipoproteins, enzymes and proteins involved in the metabolism of fats and lipoproteins in the body (Carrier *et al.*, 2014). Another explanatory mechanism is that CoQ10 increases fatty acid oxidation by activating the peroxisome-dependent protein kinase-activated alpha receptor (Lee *et al.*, 2012).

6. Comparative between the antidiabetic effects of Coenzyme Q10 and Quercetin on HDL, LDL and VLDL of streptozotocin-induced hyperglycemic rats:

Data illustrated in table (6) show the comparative antidiabetic effects of Coenzyme Q10 (CoQ10) and Quercetin at a dose of 100mg/kg b. wt. each, on high density lipoprotein (HDL), low density lipoprotein (LDL) and very low density lipoprotein (VLDL) on streptozotocin-induced hyperglycemia rats.

Table (6): Comparison between the effects of CoQ10 and Quercetin on HDL, LDL and VLDL of streptozotocin-induced hyperglycemic rats

Groups	Parameters		
	HDL (mg/dl) Mean ±SE	LDL (mg/dl) Mean ±SE	VLDL (mg/dl) Mean ±SE
Control (-)	27.91±0.87 ^a	19.03± 0.33 ^d	5.04±0.05 ^d
Control (+)	19.13±1.03 ^d	45.58±0.93 ^a	9.19±0.09 ^a
CoQ10 100 mg/kg b.w.	23.29±0.94 ^b	25.70±0.17 ^c	6.28±0.04 ^c
Quercetin 100 mg/kg b.w.	21.33±1.08 ^c	32.22±0.02 ^b	7.02±0.03 ^b
L.S.D	1.09	3.39	0.71

*Means with different letters (a, b, c, d) in the same column differ significantly, using one-way ANOVA test, while there were no significant difference for those with similar letters (P<0.05).

It is clear from table (6) that diabetic rats without treatment (C +ve) showed significant decrease in serum high density lipoprotein (HDL) but significant increase in low density lipoprotein (LDL) and very low density lipoprotein (VLDL) as compared to normal rats (C -ve). All treated groups showed significant increase in serum HDL and significant decrease in LDL and VLDL as compared to (C+ve) group. Hyperglycemic rats when orally administered with CoQ10 and Quercetin at the same dose of 100mg/kg b.wt. each, showed reducing action in serum VLDL, indicating same effect when compared with control positive rats.

The results obtained agreed with **Littarru, et al., (2011)** and **Song et al., (2017)** who revealed that dietary supplementation with CoQ10 is recommended to improve clinical and metabolic disorders of cardiovascular disease regarding abnormal conditions such as aging and oxidative stress.

Coenzyme Q10 can provide protective enhancing for membrane phospholipids, mitochondrial membrane protein, and low-density lipoprotein (LDL-c) against oxidation (**Lee et al., 2013**). Moreover, quercetin is a powerful antioxidant with peroxy radical cleaning activity (**Ioku et al., 1995**). It prevents low-density lipoprotein oxidation (**Safari and Sheikh, 2003; Kerry and Abbey, 1997**). Also, quercetin used in doses of 10-50 mg of body weight, has

ability in normalizing blood glucose level, increasing liver glycogen content and decreasing blood cholesterol and low-density lipoprotein concentration in diabetic rats (Nuraliev and Avezov, 1992).

7. Comparative between the antidiabetic effects of Coenzyme Q10 and Quercetin on T.P, Alb, and T.B of streptozotocin-induced hyperglycemic rats:

Data illustrated in table (7) show the comparative between the antidiabetic effects of Coenzyme Q10 (CoQ10) and Quercetin at a dose of 100mg/kg b. wt. each, on serum total protein (T.P), albumin (Alb.), and total billirubin (T.B) on streptozotocin-induced hyperglycemia rats.

Table (7): Comparison between the effects of CoQ10 and Quercetin on T.P, Alb, and T.B of streptozotocin-induced hyperglycemic rats

Groups	Parameters		
	T.P (g/dL) Mean \pm SE	Alb. (g/dL) Mean \pm SE	T.B (g/dL) Mean \pm SE
Control (-)	9.70 \pm 0.03 ^a	4.79 \pm 0.03 ^a	0.15 \pm 0.01 ^d
Control (+)	3.69 \pm 0.06 ^d	2.15 \pm 0.09 ^d	0.39 \pm 0.02 ^a
CoQ10 100 mg/kg b.w.	7.20 \pm 0.05 ^b	3.08 \pm 0.02 ^b	0.29 \pm 0.02 ^{bc}
Quercetin 100 mg/kg b.w.	6.03 \pm 0.06 ^{bc}	2.93 \pm 0.04 ^{bc}	0.31 \pm 0.01 ^b
L.S.D	1.25	0.17	0.03

*Means with different letters (a, b, c, d) in the same column differ significantly, using one-way ANOVA test, while there were no significant difference for those with similar letters ($P < 0.05$).

It could be concluded from the table that serum total protein (T.P) and albumin (Alb.) mean values were significantly decreased but significantly increased in serum total billirubin (T.B) in (C +ve) compared to (C -ve). All tested groups showed significant increase in serum total protein (T.P) and albumin (Alb.) but significant decrease in serum total billirubin (T.B) as compared to (C+ve) group. Hyperglycemic rats with orally injection with CoQ10 and Quercetin at a dose of 100mg/kg b. wt. each, showed non-significant differences neither in serum total protein (T.P) and albumin (Alb.) nor in serum total billirubin (T.B) compared with control positive group.

Coenzyme Q10 is responsible for energy production in body cells, moreover, it is responsible for ameliorating endothelial dysfunction as well as important for activating mitochondrial separation proteins (Turunen *et al.*, 2004).

A recent study declared that CoQ10 supplementation increases cyclic adenosine monophosphate production, reflecting that cAMP is an important intracellular second messenger that is involving in the regulation of AMP-activated protein kinase activity (Xu *et al.*, 2017).

Furthermore, administration of quercetin with carbon tetra chloride reduced the levels of elevated liver enzymes, lipid peroxidation and elevated the levels of low antioxidants to reach normal range (Anim *et al.*, 2020).

8. Comparative between the antidiabetic effects of Coenzyme Q10 and Quercetin on AST, ALT and ALP of streptozotocin-induced hyperglycemic rats:

Data presents in table (8) show the comparative between the antidiabetic effects of Coenzyme Q10 (CoQ10) and Quercetin at a dose of 100mg/kg b. wt., each on liver enzymes (AST, ALT and ALP) of streptozotocin-induced hyperglycemic rats.

Table (8): Comparison between the effects of CoQ10 and Quercetin on AST, ALT and ALP of streptozotocin-induced hyperglycemic rats

Groups	Parameters		
	AST (U/L) Mean ±SE	ALT (U/L) Mean ±SE	ALP (U/L) Mean ±SE
Control (-)	45.06±1.11 ^d	39.00±1.09 ^d	87.39± 1.16 ^d
Control (+)	83.01±2.32 ^a	95.00±2.36 ^a	126.55±2.96 ^a
CoQ10 100 mg/kg b.w.	49.08±1.55 ^c	43.00±1.64 ^c	91.13±2.18 ^c
Quercetin 100 mg/kg b.w.	53.12±2.33 ^b	58.00±2.01 ^b	99.87±1.08 ^b
L.S.D	3.01	5.33	3.09

*Means with different letters (a, b, c, d) in the same column differ significantly, using one-way ANOVA test, while there were no significant difference for those with similar letters (P<0.05).

Relating serum levels of liver enzymes (AST, ALT and ALP), values mentioned in table (8), there were significantly increase (P<0.05) in control positive group compared to normal rats. All diabetic rats with orally injection with CoQ10 and Quercetin at a dose of 100mg/kg b. wt. each, showed significant decreases in all liver enzymes (AST, ALT and ALP) compared to control positive group. Rats with orally administration with CoQ10 at a dose of 100mg/kg b. wt., showed higher significant decrease in AST and ALT as compared to quercetin and control positive groups.

Coenzyme Q10 can protect the liver from oxidative damage due to improving antioxidant enzyme activities and reducing lipid peroxidation which consider a therapeutic intervention to protect liver injury (Samanta *et al.*, 2021).

Furthermore, CoQ10 supplement might directly enhance antioxidant defense system via potentiating electron transport chain in liver mitochondria

(Novoselova *et al.*, 2009). Instead, modifying the expression of antioxidant enzymes in animals insists that dietary CoQ10 directly affects the expression of antioxidant enzymes in tissues (Sohal *et al.*, 2006 and Novoselova *et al.*, 2009).

Moreover, quercetin has the potential to mitigate high cholesterol diet induced lipid oxidative injury in rat livers due to antioxidant and increased nitrogen oxide bioavailability (Mariee *et al.*, 2012).

9. Comparative between the antidiabetic effects of Coenzyme Q10 and Quercetin on BUN, Creat., and U. Acid of streptozotocin-induced hyperglycemic rats:

Data recorded in table (9) show the comparative antidiabetic effects of Coenzyme Q10 (CoQ10) and quercetin on blood urea nitrogen (BUN), creatinine (Creat.) and uric acid (U. Acid) of streptozotocin-induced hyperglycemic rats.

Table (9): Comparison between the effects of CoQ10 and Quercetin on BUN, Creat. and U. Acid of streptozotocin-induced hyperglycemic rats

Groups	Parameters		
	BUN (mg/dl) Mean ±SE	Creat. (mg/dl) Mean ±SE	U. Acid (mg/dl) Mean ±SE
Control (-)	15.38±0.07 ^d	0.71±0.02 ^d	1.53±0.03 ^d
Control (+)	38.90±0.23 ^a	0.98±0.03 ^a	3.01±0.04 ^a
CoQ10 100 mg/kg b.w.	19.00±0.53 ^{bc}	0.79±0.02 ^{bc}	1.95±0.06 ^c
Quercetin 100 mg/kg b.w.	21.43±0.12 ^b	0.81±0.01 ^b	2.02±0.02 ^b
L.S.D	2.93	0.05	0.08

*Means with different letters (a, b, c, d) in the same column differ significantly, using one-way ANOVA test, while there were no significant difference for those with similar letters (P<0.05).

Regarding kidney functions including blood urea nitrogen (BUN), creatinine (Creat.) and uric acid (U. Acid), there were significant increase (P<0.05) in control positive compared to control negative group. All diabetic rats with orally administered with coenzyme Q10 (CoQ10) and quercetin at a dose of 100mg/kg b. wt. each, showed significant decrease in BUN, Creat., and U. Acid compared to control positive group. All diabetic rats with orally injection with CoQ10 and quercetin at a dose of 100mg/kg b. wt., showed the same significant difference as compared to (C +ve) group.

There is an evidence that CoQ10 supplementation may improve renal function and reduce the need for dialysis in patients with CKD (Singh *et al.*, 2000).

In a study of the antidiabetic effects of quercetin in streptozocin-induced diabetic rats by Vessal *et al.*, (2003), results revealed that quercetin, a flavonoid with antioxidant properties, leads to regeneration of pancreatic islets and

increases insulin secretion in diabetic rats induced by streptozocin; exerting its beneficial anti-diabetic effects.

Furthermore, Treatment with quercetin improves kidney functions and reduces oxidative stress factors and kidney inflammation (**Yang *et al.*, 2018**).

Conclusion

This investigation concluded that Coenzyme Q10 and Quercetin have antidiabetic effects on streptozotocin-induced hyperglycemic rats, indicating higher effect for CoQ10 in spite of the singularity for quercetin as a natural flavonoid.

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ملخص البحث

دراسة التأثيرات المقارنة المضادة لمرض السكري لمرافق الإنزيم كيو ١٠ والكويرستين في الفئران المصابة بالسكري بواسطة الاستربتوزوتوسين

حسب تقديرات اتحاد أطلس السكري، سيصل عدد مرضى السكري عالمياً إلى ٥٩٢ مليوناً في عام ٢٠٣٥، ويتميز مرض السكري باضطراب استقلابي لفرط سكر الدم الناتج عن نقص الأنسولين أو مقاومته أو كليهما. استهدف البحث دراسة التأثير المقارن المضاد لمرض السكر لمرافق الإنزيم كيو ١٠ والكويرستين في الفئران المصابة بالسكري بواسطة الاستربتوزوتوسين. تم استخدام عدد ٢٤ فأر ذكر من نوع الالبينو بمتوسط وزن 200 ± 5 جم تم تقسيمهم لاربعة مجموعات (٦ فئران بكل مجموعة). تركت احدهم (٦ فئران) كمجموعة ضابطة سالبة وتغذت على العليقة الاساسية طوال فترة التجربة (٢٨ يوم)، بينما تم حقن المجموعات المتبقية بمادة الاستربتوزوتوسين بجرعة ٤٠ ملجم من وزن الجسم مرة أسبوعياً لمدة أسبوعين ثم تركت احدهم بدون علاج لتمثل المجموعة الضابطة الموجبة والتي تم تغذيتها على العليقة الأساسية طوال فترة التجربة، أما المجموعتين المتبقيتين فتم حقنهما فمياً عن طريق الفم باستخدام مرافق الإنزيم كيو ١٠ والكويرستين عند جرعة ١٠٠ ملجم من وزن الجسم عن طريق الحقن الفموي لكل منهما على حده. وفي نهاية فترة التجربة تم ذبح الفئران ثم تم تجميع الأعضاء وعينات سيرم الدم لتحليل مستويات الجلوكوز والأنسولين في الدم وهرمون الغدة الدرقية (TSH) والهرمون المنشط للجسم الاصفر (LH) والكوليسترول الكلي والدهون الثلاثية والليبيروتينات المرتفعة والمنخفضة والمنخفضة جداً في الكثافة والبروتين الكلي والاليومين والبيليروبين الكلي والاسبارتات أمينو ترانس أمينيز والألانين أمينو ترانسفيريز وإنزيم الفوسفاتيز القلوي ونيروجين اليوريا في الدم والكرياتينين وحمض البوليك. وقد أظهرت النتائج أن جميع الفئران المصابة بارتفاع مستوى السكر في الدم والتي تم حقنها عن طريق الفم بمرافق الإنزيم كيو ١٠ والكويرستين بجرعة ١٠٠ مجم / كجم من وزن الجسم زيادة معنوية في الوزن المكتسب والمأخوذ الغذائي ومعدل الاستفادة من الغذاء والليبيروتينات مرتفعة الكثافة، في حين حدوث انخفاض معنوي في مستويات الجلوكوز والأنسولين في الدم وهرمون الغدة الدرقية (TSH) والهرمون المنشط للجسم الاصفر (LH) والكوليسترول الكلي والدهون الثلاثية والليبيروتينات منخفضة ومنخفضة جداً في الكثافة والبروتين الكلي والاليومين والبيليروبين الكلي والاسبارتات أمينو ترانس أمينيز والألانين أمينو ترانسفيريز وإنزيم الفوسفاتيز القلوي ونيروجين اليوريا في الدم والكرياتينين وحمض البوليك، علاوة على ذلك، أحدث مرافق الإنزيم كيو ١٠ تعزيز أعلى من الكويرستين بالرغم من أن الثاني له خصائص علاجية طبيعية لأنه فلافونويد طبيعي. ويمكن استنتاج أن مرافق الإنزيم كيو ١٠ و الكويرستين قد يكون لهما تأثيرات مضادة لمرض السكري في الفئران المصابة بالسكري بواسطة الاستربتوزوتوسين، مما يشير إلى تأثير وتحسين أعلى لمرافق الإنزيم كيو ١٠ على الرغم من تفرد الكويرستين باعتباره فلافونويد طبيعي.

الكلمات المفتاحية: مرافق الإنزيم كيو ١٠، الكويرستين، الاستربتوزوتوسين، الفئران المصابة بداء السكري.