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ANTIOXIDANT AND HYPOGLYCEMIC EFFECTS OF BROCCOLI (*BRASSICA OLERACEA*) ON OBESE DIABETIC RATS

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ABSTRACT

The present work was aimed to investigate the possible antioxidant and hypoglycemic effects of broccoli on obese diabetic rats. Thirty adult male Sprague-Dawley rats were divided randomly into six equal groups (n=5) as follows: Group 1: negative control, was fed on a basal diet. Groups 2-6 were fed High fat diet (HFD) for 6 weeks to induce obesity. The obese rats were then rendered diabetic by subcutaneous injection with a single dose of alloxan (120 mg/kg). Group 2 was kept as a positive control group (obese diabetic rats) and groups 3, 4, 5 and 6 fed on HFDs-alloxan induced diabetic and supplemented with 2.5, 5, 7.5 and 10% dried broccoli. At the end of the experiment, rats were scarified and serum was collected for biochemical analyses. The administration of HFD-alloxan group (control positive) resulted in significant elevations in body weight gain, feed efficiency ratio, peritoneal fat pad, serum total cholesterol, triglyceride, LDL-c, VLDL-c, leptin, glucose, insulin, interleukin-1 beta and malondialdehyde levels compared to negative control, and levels of serum HDL-c and glutathione peroxidase activity were significantly decreased. On the other hand, a supplemented diet with dried broccoli powder attenuated these adverse effects and biochemical alterations caused by HFD-alloxan administration. In conclusion, broccoli exhibits an antioxidant and hypolipidemic activity and was effective in reducing glucose level in obese diabetic rats. The study recommends that intake of broccoli may be beneficial for patients who suffer from diabetes and obesity.

Key Words: Broccoli, Oxidative stress, Obesity, Diabetes, High fat diet, Rats.

INTRODUCTION

The prevalence of obesity and diabetes mellitus (DM) has been consistently increasing worldwide. Obesity has become a global pandemic threatening people's life by affecting almost every organ system and is now a severe public health problem as one of the most common non-communicable diseases (NCDs) **(Blüher, 2019 and Tsai and Bessesen, 2019)**. Sharing powerful genetic and environmental features in their pathogenesis, obesity amplifies the impact of genetic

susceptibility and environmental factors on DM. The ectopic expansion of adipose tissue and excessive accumulation of certain nutrients and metabolites sabotage the metabolic balance via insulin resistance, dysfunctional autophagy, and microbiome-gut-brain axis, further exacerbating the dysregulation of immunometabolism through low-grade systemic inflammation, leading to an accelerated loss of functional β-cells and gradual elevation of blood glucose. Given these intricate connections, most available treatments of obesity and type 2 DM (T2DM) have a mutual effect on each other **(Ruze *et al.*, 2023)**.

Broccoli (*Brassica oleracea*) is a member of the Brassicaceae family which is rich in potential health-boosting components like vitamins, minerals, dietary fiber, flavonol glycosides, hydroxycinnamic acids, and sulphur-containing compounds, such as the glucosinolates **(Lee *et al*., 2013 and El-Magd, 2013)**. Broccoli is also rich in vitamin C, a major antioxidant in Brassica vegetables **(Moreno *et al*., 2006 and Ares *et al*., 2013)**. Therefore, this study was conducted to evaluate the possible antioxidant and hypoglycemic effects of broccoli on the oxidative stress of obese diabetic rats.

MATERIALS AND METHODS

A. Materials

Fresh broccoli was purchased from a local market in Egypt. Biochemical kits, casein, cellulose, choline chloride, D-L methionine, vitamins and mineral constituents were purchased from El-Gomhoriya Pharmaceutical Company, Cairo, Egypt. Starch, soy oil, and sucrose were obtained from the Egyptian local market. Thirty adult male albino rats (Sprague Dawley strain), weighing about 200 ±10 g b.wt. were obtained from the Laboratory Animal Colony, Agricultural Research Center, Giza, Egypt. Alloxan monohydrate was purchased from Kemet Medical Company, Cairo, Egypt.

B. Methods

Preparation of Dried Broccoli

Broccoli was washed, sliced into small pieces, and oven-dried at 50°C **(El-Zoghbi *et al*., 2017)**. Dried broccoli was ground using a grinder into a fine powder that was used for both chemical composition and the isolation of phenolic compounds and for the preparation of a supplemented diet. The preparation of dried broccoli was conducted at the National Research Center, Egypt.

Chemical Analysis of Broccoli

The chemical analysis of broccoli was conducted in the Food Analysis Unit, Agricultural Research Center, Egypt.

- Chemical composition (carbohydrates, protein, fats, moisture and ash) was determined according to **AOAC, (2012)**.

- 1,1-diphenyl-2-picrylhydrazyl (DPPH) radical-scavenging activity was evaluated according to **Brand-Williams *et al.*, (1995)**.
- Total phenolic compounds were determined by a Spectrophotometer according to **Goupy *et al.*, (1999)**.

Induction of Obesity and Diabetes

Obesity and acute hyperlipidemia were induced by feeding rats on high-fat diet (HFD) containing (saturated fat 19%, soybean oil 1% to provide essential fatty acids, sucrose 10%, casein 20%, cellulose 5%, vitamin mixture 1%, salt mixture 3.5%, choline chloride 0.25% and the remainder is corn starch) for 4 weeks to induce obesity in rats **(Min *et al.*, 2004)**. A 3-6 weeks HFD feeding is sufficient to induce obesity, and this model of obese rats closely resembles the reality of obesity in humans **(Bhatt *et al.*, 2006)**. The obese rats were then rendered diabetic by subcutaneous injection with a single dose of alloxan (120 mg/kg) to induce diabetes **(Ashok *et al.*, 2007)**. Induction of obesity and diabetes of rats was conducted at the Research Labs, Agricultural Research Center, Giza, Egypt.

Diet Preparation and Experimental Animal Design

The basal diet was prepared according to the AIN-93M diet **(Reeves *et al.*, 1993)**. Thirty adult male albino rats were housed in well conditions and fed on a basal diet in Research Labs, Agricultural Research Center, Giza, Egypt. After one week of acclimatization, the rats were randomly divided into two main group as follows:

- **First group:** Negative control group, rats (n=5) fed on basal diet only during the experimental period.
- **second group:** Rats (n=25) were fed on HFD for 6 weeks to induce obesity. After six weeks, the obese rats were then rendered diabetic by subcutaneous injection with a single dose of alloxan (120 mg/kg). After 72 h of injection, fasting blood glucose level was measured. Blood glucose measurement was performed on tail-vein blood. The animals that did not develop more than 200 mg/dL glucose levels were omitted from the study **(Mendes *et al.*, 2012).** Rats were divided to five subgroups as follows:

Subgroup (1):	Rats (served as a positive control group or obese diabetic rats) were fed on HFD, alloxan-induced diabetic.
Subgroup (2):	Rats were fed on HFD - alloxan induced diabetic and supplemented with 2.5% dried broccoli powder (25g/kg HFD).

Subgroup (3):	Rats were fed on HFD, alloxan- and supplemented with 5% dried broccoli powder (50g/kg HFD).
Subgroup (4):	Rats were fed on HFD, alloxan-induced diabetic and supplemented with 7.5% dried broccoli powder (75g/kg HFD).
Subgroup (5):	Rats were fed on HFD, alloxan-induced diabetic and supplemented with 10% dried broccoli powder (100g/kg HFD).

During the experiment period, the quantities of diet, which were consumed and/or waste, were recorded every day. Water and basal diet had introduced under hygienic conditions. At the end of the feeding trial (10 weeks) rats were fasted overnight being scarifying and blood was collected, then centrifuged to obtain serum for biochemical analysis.

Biological Evaluation

Feed intake was recorded daily and animals were weighed at the beginning and twice a week throughout the experimental period. Body weight gain % (BWG%) and feed efficiency ratio were determined according to **Chapman *et al.*, (1959)** using the following equation:

BWG% = Error! × *100*

FER = ***Weight gain / Feed intake.***

Peritoneal fat pad % (PFP%):

At the end of the experimental period (the last 4 weeks), the percentage of peritoneal fat pad was calculated as follows:

$$\text{PFD \%} = \frac{\textit{Weight of peritoneal fat pad}}{\textit{Weight of rat}} \textit{ X 100}$$

Biochemical Analysis of Serum

Serum glucose, leptin and insulin levels were determined according to the methods described by **Trinder (1969); Zhang *et al.*, (1995) and (Held, 2019)**, respectively. Serum total cholesterol, triglyceride and high-density lipoprotein cholesterol were determined according to **Richmond, (1973); Wahlefeld, (1974) and Albers *et al.*, (1983),** respectively. Low density lipoprotein cholesterol and very low-density lipoprotein cholesterol were calculated according to **Friedewald *et al.*, (1972)**. Interleukin-1 beta, malondialdehyde and glutathione peroxidase were determined according to **Dinarello, (1996); Draper and Hadley, (1990)** and **Hissin and Hilf, (1970),** respectively.

Statistical Analysis

Results were expressed as the mean standard error ± SE. Data were statistically analyzed for variance using "ANOVA" test at $P \leq (0.05)$

using SPSS statistical software, version 20 according to **Armitage and Berry, (1987).**

RESULTS AND DISCUSSION

Chemical composition, total polyphenols, and antioxidant capacity of broccoli florets.

Results in **Table (1)** show the chemical composition of broccoli. Broccoli contained protein, carbohydrate, fiber, moisture, ash and fat with values of 33.2%, 30.64%, 13.42%, 10.2%, 8.78% and 3.76%, respectively. These results are in agreement with the **United States Department of Agriculture (USDA, 2014)** which concluded that the content of broccoli for moisture was (89.30), protein (2.82), fat (0.37), carbohydrate (6.64) and fiber (2.6). In another study, **Sigmond *et al.*, (2010)** showed that carbohydrate, fiber, ash, moisture, protein and fat of broccoli were 53.62, 11.00, 2.68, 2.40, 24.50 and 5.5%, respectively.

In addition to the results in **Table (1),** it was revealed that broccoli contained 12157 ppm (gallic acid equivalent) of total phenols and 3.58 mg/ml of DPPH. These findings approved with results in the study of **Campas-Baypoli *et al.*, (2016),** who indicated that total polyphenols (17.21 mg Gallic acid equivalent/g dry matter) and Antioxidant capacity (mmol TE/g dry matter) such as, DPPH Radical scavenging capacity (112).

Table (1): Chemical composition, total polyphenols and antioxidant capacity of broccoli.

Item	Amount
Moisture %	10.2
Protein %	33.2
Fat %	3.76
Carbohydrate, by difference%	30.64
Fiber %	13.42
Ash %	8.78
Total polyphenols (ppm galic acid equivalent)	12157
Antioxidant Capacity of broccoli DPPH (mg/ ml)	3.58

A strong link between consumption of fruits and vegetables and their health benefits are due to their high nutritional value and functional components with antioxidant properties. Antioxidants are compounds which control and scavenge oxidative damage in foods and biomolecules by slowing or inhibiting the oxidative process caused by ROS, thus enhancing the quality of the products **(Shofian *et al.*, 2011)**.

Results in **Table (2)** show the effect of broccoli on feed intake (FI), body weight gain % (BWG %), feed efficiency ratio (FER) and peritoneal fat pad% (PFP%) of obese diabetic rats. Results show that feed intake decreased in positive control rats compared with the negative control rats. On the other hand, BWG%, FER and PFP% significantly

increased (P≤0.05) in the +ve control group when compared to the -ve control group. Supplementation with broccoli on obese diabetic rats caused a reduction in BWG %, FER and PFP% when compared with the +ve control group.

These results agree with **Zhang *et al.*, (2017)** who noticed HFD-alloxan led to a significant increase in body weight in the experimental mice**.** Moreover, **Aranaz *et al*., (2019)** reported that after 10 weeks of broccoli supplementation, animals exhibited reduced body weight gain and feed efficiency, retroperitoneal fat mass and adipocyte size. Another study showed that broccoli extract (florets and stalks), administered *per os* at a dose of 200 or 400 mg/kg/day for 1-month, reduced body weight gain and adipose tissue index in rats fed a HFD **(Aboreha *et al.*, 2016)**.

Table (2): Effect of broccoli on feed Intake, body weight gain%, feed efficiency ratio and peritoneal fat pad% of obese diabetic rats.

Parameter / Group	FI (g/d/rat)	BWG%	FER	PFP
G1: -Ve Control	21±0.1^{ab}	23.15±1.04^{ab}	0.085±0.001^{b}	4.64±0.18^{d}
G2: +Ve Control (obese diabetic rats)	20±0.12^{c}	35.52±1.77^{a}	0.129±0.001^{a}	9.23±0.38^{a}
G3: 2.5% DBP	21.5±0.11^{b}	23.83±1.85^{b}	0.081±0.001^{b}	8.98±0.29^{a}
G4: 5% DBP	22±0.12^{a}	21.21±1.54^{bc}	0.070±0.001^{c}	8.51±0.45^{ab}
G5: 7.5% DBP	23.5±0.13^{a}	16.33±0.85^{d}	0.053±0.001^{d}	7.53±0.32^{bc}
G6: 10% DBP	24±0.15^{a}	12.21±0.68^{e}	0.038±0.001^{e}	6.68±0.56^{c}

*Mean values are expressed as means ± SE.

*Mean values at the same column with the same superscript letters are not statistically significant at (P≤0.05).

* **DBP** = Dried Broccoli Powder.

Effect of broccoli on serum lipid profile of obese diabetic rats:

Results in **Table (3)** revealed that positive control rats had a significant (P≤0.05) increases in serum levels of TC, TG and LDL-c, VLDL-c and a significant decrease (P≤0.05) in HDL-c when compared to the negative control group. Obese diabetic rats treated with broccoli had a significant (*P≤0.05*) reduction in elevated serum TC, TG, LDL-c and VLDL-c levels and an increase in serum HDL-c when compared with positive control group.

The mice with HFD-alloxan-induced diabetes showed abnormalities in lipid metabolism, as evidenced by increased TG, TC and LDL-C levels and decreased HDL-C levels, similar to the characteristics of human type 2 diabetes **(Friedman, 1977 and Tang *et al.*, 2006)**. Hypertriglyceridemia may occur due to increased absorption and formation of triglycerides in the form of chylomicrons following

consumption of a diet rich in fat or through increased endogenous production of TG-enriched hepatic VLDL and decreased TG uptake in peripheral tissues **(Dixon *et al.*, 2002)**.

Table (3): Effect of broccoli on serum lipid profile of obese diabetic rats.

Parameter / Group	Total Cholesterol	Triglycerides	HDL-C	LDL-C	VLDL-C
	mg/dl				
G1: -Ve Control	170.27±0.91^{e}	137.59±4.51^{d}	60.49±1.17^{a}	82.26±1.00^{e}	27.52±0.90^{d}
G2: +Ve Control (obese diabetic rats)	236.71±1.65^{a}	183.96±3.83^{a}	36.08±0.93^{d}	163.84±1.16^{a}	36.79±0.76^{a}
G3: 2.5% DBP	214.45±3.49^{b}	165.19±2.33^{b}	55.07±0.84^{b}	126.33±3.60^{b}	33.04±0.46^{b}
G4: 5% DBP	191.05±3.32^{c}	152.29±1.77^{bc}	54.52±1.34^{bc}	106.07±2.37^{c}	30.45±0.35^{bc}
G5: 7.5% DBP	178.28±2.85^{d}	147.24±1.17^{cd}	52.18±1.08^{c}	96.65±1.66^{d}	29.44±0.23^{bc}
G6: 10% DBP	173.65±1.90^{de}	145.36±1.66^{cd}	51.08±1.67^{c}	93.50±0.45^{d}	29.07±0.33^{cd}

*Mean values are expressed as means ± SE.

*Mean values at the same column with the same superscript letters are not statistically significant at (P≤0.05)

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These findings are confirmed by **Ranaweera *et al.*, (2022),** who found that the treatment with broccoli extract significantly reduced (P≤0.05) TG content, LDL-c and total cholesterol. On the other hand, both animal and interventional studies have reported that broccoli consumption could contribute to reducing cholesterol blood concentration **(Lee *et al.*, 2009; Rodríguez-Cantú *et al.*, 2011)**. In an animal model, supplementation with 200 and 400 mg/kg of a broccoli extract reduced the levels of TG, total cholesterol, LDL-cholesterol and increased HDL **(Aborehab *et al.*, 2016)**.

Effect of broccoli on serum leptin, glucose and insulin of obese diabetic rats:

Table (4), indicated that the higher levels of in serum leptin, glucose and insulin in the obese diabetic rats group compared to the control group. Supplementation with broccoli diminished the increase in levels of leptin, glucose and insulin in the treated group compared with control group.

The effects of obesity-promoted increased leptin levels are often insufficient to mitigate increased body fat, potentially because individuals with overweight or obesity may be susceptible to "leptin resistance" **(Izquierdo *et al.*, 2019)**. It is more likely that the failure of physiologic and counter-regulatory mechanisms to prevent excessive body fat gain (e.g., release of leptin from hypertrophied adipocytes) is because other physiologic and environmental promoters of obesity overwhelm leptin's anti-obesity effects **(Christensen *et al.*, 2022)**.

Leptin may have mixed effects on glucose metabolism. Leptin may decrease insulin secretion and may contribute to insulin resistance. For

example, chronic leptin stimulation of the arcuate nucleus of the hypothalamus may promote protein tyrosine phosphatase 1B (PTP1B), which inhibits insulin activity **(Balland *et al.*, 2019)**. Increased leptin and insulin levels (along with postprandial effects) increase sympathetic nervous system activity, potentially contributing to insulin resistance. Conversely, leptin may increase glucose tissue uptake by muscle and brown adipose tissue, decrease glucagon secretion by the pancreas, decrease corticosterone by the adrenal gland, decrease lipolysis in white adipocytes, and decrease gluconeogenesis and glucose output by the liver **(Bays *et al.*, 2005; Bays and Ballantyne, 2006 and D'Souza *et al.*, 2017)**.

These findings agree with **Miao *et al.*, (2012) and Wang *et al.*, (2014)** who found that the hypoglycemic effect of dried broccoli may be due to the active component sulforaphane, a natural compound present in broccoli with many promising health benefits.

Previous studies performed in diabetic animal models **(Chen *et al.*, 2016 Cho *et al.*, 2006; Shah *et al.*, 2016)** and diabetic populations **(Mirmiran *et al.*, 2014)** have proposed broccoli as a functional food with nutritional and therapeutic values against insulin resistance. Broccoli has been previously proposed as an effective supplement for improving glycemic control. Interventional studies have suggested that the supplementation with broccoli (extracts or powder) could improve glucose tolerance and insulin sensitivity **(Bahadoran *et al.*, 2012 and De Nicola *et al.*, 2013)**.

Table (4): Effect of broccoli on serum leptin, glucose and insulin of obese diabetic rats

Parameter / Group	Leptin	Glucose	Insulin
	ng/ml	mg/dl	ng/ml
G1: -Ve Control	8.08±0.11^{d}	92.82±1.01^{e}	3.69±0.10^{e}
G2: +Ve Control (obese diabetic rats)	16.76±0.22^{a}	241.70±0.88^{a}	6.36±0.13^{a}
G3: 2.5% DBP	15.03±0.20^{b}	201.19±0.90^{b}	5.70±0.08^{b}
G4: 5% DBP	14.25±0.27^{b}	167.62±0.87^{c}	5.10±0.05^{c}
G5: 7.5% DBP	9.81±0.13^{c}	101.77±0.74^{d}	4.59±0.08^{d}
G6: 10% DBP	9.04±0.30^{cd}	98.33±0.65^{de}	4.12±0.03^{d}

*Mean values are expressed as means ± SE.

*Mean values at the same column with the same superscript letters are not statistically significant at (P≤0.05)

* **DBP** = Dried Broccoli Powder.

Effect of broccoli on serum glutathione peroxidase (GPx) activity, malondialdehyde (MDA) and interleukin-1 Beta (IL-1β) of obese diabetic rats:

The effects of broccoli on glutathione peroxidase (GPx), malondialdehyde (MDA) and interleukin-1 beta (IL-1β) of obese diabetic rats are recorded in **Table (5)**. Results showed that the positive control

group had a significant reduction (P≤0.05) in the levels of GPx while having a significant (P≤0.05) elevation in serum IL-1β and MDA concentrations when compared with the negative control group. It was observed that, there was a significant increase (P≤0.05) in GPx activity and significant a decrease in IL-1β and MDA content for obese diabetic rats that were treated with broccoli when compared to the positive control group.

The results of the present study are in line with those of **Mohammed *et al.*, (2015),** who reported that broccoli an increase in the levels of superoxide dismutase (SOD) and total glutathione and caused a reduction in the level of MDA when compared to the injected group. On the other hand, **Sharma and Sangha (2016)** revealed that oxidative stress biomarkers such as, SOD and GPx activity were improved with broccoli supplementation. The total antioxidant activity was also significantly increased in all the treated rats with broccoli while significantly reducing lipid peroxidation levels as compared to positive control group.

TNF-α and IL-1β are members of a group of cytokines that are involved in systemic inflammation, act synergistically and stimulate acute phase reaction. They are produced mainly by macrophages, but a broad variety of other cell types is also involved in their production. They are inducers of endothelial adhesion molecules, which are essential for the adhesion of leukocytes to the endothelial surface prior to their migration into the tissues **(Dinarello, 2000)**. They also augment neutrophil–derived superoxide generation **(Yoshikawa *et al.*, 1992),** leading to oxygen radical-mediated tissue damage. Stimulation of intestinal epithelial cells with TNF-α has also induced apoptosis **(Ramachandran *et al.*, 2000).** Previous studies showed a significant increase in proinflammatory cytokines in response to Cis (**Faubel *et al.*, 2007 and Mostafa *et al.*, 2018**).

Epidemiological studies have shown that the consumption of fruits and vegetables could control the morbidity and mortality rates of certain types of diseases. This is due to the presence of bioactive components, namely fibers, polyphenol compounds, flavonoids, isoflavones, tocopherols and ascorbic acid **(Lima *et al*., 2014 and Tlili *et al*., 2014)**. These positive effects could be due to the dietary antioxidants which play a significant role in protecting against reactive oxygen species **(Alfadda and Sallam, 2012)**.

Broccoli constitutes a good candidate of functional food, based on its high content in glucosinolates that can be hydrolyzed to the lipophilic isothiocyanates, with reported benefits against certain forms of cancer, as well as with antioxidant activity **(Bahadoran *et al.*, 2011; Bahadoran *et al.*, 2012; Latté *et al.*, 2011 and Suresh *et al.*, 2017)**.

Studies have confirmed the synergistic effect of dietary antioxidants with cellular reductants in scavenging free-radicals and chelating transition metals that are catalysts in lipid peroxidation **(Guizani *et al*., 2013)**. On the other hand, administration of broccoli extracts restored GSH and TAC. These effects may be due to its hypoglycemic and free radical scavenging properties based on the fact that broccoli contains several compounds such as total polyphenol, flavonoids, and other components that can act as a potent antioxidant **(Tiveron *et al*., 2012)**.

Table (5): Effect of broccoli on serum glutathione peroxidase (GPx) activity, malondialdehyde (MDA) and interleukin-1 Beta (IL-1β) of obese diabetic rats

Parameter / Group	GPx U/ml	MDA ng/ml	IL-1β pg/ml
G1: -Ve Control	166.58±5.96^{a}	60.22±2.83^{e}	235.78±1.69^{e}
G2: +Ve Control (obese diabetic rats)	92.26±6.55^{e}	427.08±3.85^{a}	414.57±3.59^{a}
G3: 2.5% DBP	97.46±9.40^{d}	414.93±4.11^{a}	389.04±2.02^{b}
G4: 5% DBP	99.06±6.41^{d}	387.62±2.44^{b}	373.15±1.48^{c}
G5: 7.5% DBP	117.21±10.62^{c}	358.74±1.27^{c}	252.45±1.80^{d}
G6: 10% DBP	122.87±8.69^{b}	336.51±3.96^{d}	244.10±1.38^{de}

*Mean values are expressed as means ± SE.

*Mean values at the same column with the same superscript letters are not statistically significant at (P≤0.05)

* **DBP** = Dried Broccoli Powder.

CONCLUSION

The present findings illustrate that broccoli is promising for the control of obese diabetics by reducing blood glucose and oxidative stress. This may be due to the presence of active components that have antioxidant activity.

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التأثيرات المضادة للأكسدة وانخفاض السكر في الدم للبروكلي على الفئران البدينة المصابة بالسكري

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تهدف هذه الدراسة للتعرف على التأثيرات المحتملة لمضادات الأكسدة ونقص السكر في الدم للبروكلي في الفئران البدينة المصابة بالسكري. تم تقسيم ثلاثين ذكرًا بالغًا من فئران سبراغ داولي عشوائيًا إلى 6 مجموعات متساوية (العدد = 5) على النحو التالي: المجموعة 1: الضابطة السالبة، تم تغذيتها على نظام غذائي أساسي. تم تغذية المجموعات 2–6 على نظام غذائي عالي الدهون لمدة 6 أسابيع للاصابة بالسمنة. تم اصابة الفئران المصابة بالسمنة إلى اصابتها بالسكري عن طريق الحقن تحت الجلد بجرعة واحدة من الألوكسان (120 ملجم / كجم). تم الاحتفاظ بالمجموعة 2 كمجموعة ضابطة موجبة (الفئران المصابة بالسمنة والسكري) والمجموعات 3 و4 و5 و6 مكملة بـ 2.5 و5 و7.5 و10% من مسحوق البروكلي المجفف لكل كيلو جرام من وزن الوجبة العالية فى الدهون. في نهاية التجربة، تم تشريح الفئران وجمع المصل لإجراء التحاليل البيوكيميائية. أدى استخدام النظام الغذائي عالي الدهون والحقن بالألوكسان إلى ارتفاع ملحوظ في زيادة وزن الجسم، ونسبة كفاءة التغذية، والدهون البريتونية، والكوليسترول الكلي في الدم، والدهون الثلاثية، وLDL–c، وVLDL–c، واللبتين، والجلوكوز، والأنسولين، ومستويات بيتا إنترلوكين 1 والمالونديالدهيد في المجموعة الضابطة الموجبة بالمقارنة مع الضابطة السالبة. وانخفضت مستويات HDL–c في الدم ونشاط انزيم الجلوتاثيون بيروكسيديز بشكل ملحوظ. من ناحية أخرى، أدى النظام الغذائي المكمل بمسحوق البروكلي المجفف إلى تخفيف هذه التأثيرات الضارة والتغيرات البيوكيميائية التي تسببها استخدام النظام الغذائي عالي الدهون والحقن بالألوكسان. في الختام، أظهر البروكلي نشاطًا مضادًا للأكسدة وخافضًا للدهون وفعالًا في تقليل مستوى الجلوكوز في الفئران المصابة بالسمنة والسكري. وتوصي الدراسة بأن تناول البروكلي قد يكون مفيداً للمرضى الذين يعانون من مرض السكري والسمنة.