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Effect of Different Percentage of the Jerusalem Artichoke Plant on Diabetic rats.

تأثير نسب مختلفة من نبات الطرطوفة على الفئران المصابة بمرض السكر

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Abstract:

Jerusalem artichoke is an untraditional vegetable crop that offers many health benefits to the human body. Therefore, the present study was carried out to estimate the effect of different ratios of Jerusalem artichoke powder on diabetic rats. Male albino rats (25 rats) weighting 160±10 g used in this study. The rats divided into two main groups. The first main group (5 rats) fed on a basal diet (as a negative control group). While the second main group (20 rats) was diabetic induced by a single intraperitoneal injection from alloxan (150 mg/kg b.w.) then divided into four subgroups. One of them fed on a basal diet as the positive control group and the other groups fed on a basal diet containing 10%, 15%, and 20% of Jerusalem artichoke powder for 28 days. The result of sensory evaluation for pan bread fortified with 10% Jerusalem artichoke powder was the best, this level showed non-significant changes, as compared with control pan bread. On the other hand, feeding rats with diets containing Jerusalem artichoke powder led to a marked improvement in all biochemical and biological parameters. The best results have recorded for the group treated with 20% JAT. Additionally, histopathological examination of the pancreas showed that the adding of Jerusalem artichoke tubers to the diets of diabetic rats improved the pancreatic tissue. Therefore, we recommended the use of the Jerusalem artichoke plant in the different food applications.

Key words:

Jerusalem artichoke, serum glucose, liver functions, serum lipid profile, kidney function.

تأثير نسب مختلفة من نبات الطرطوفة على الفئران المصابة بمرض السكر

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المستخلص:

الطرطوفة هي أحد محاصيل الخضر غير التقليدية والتي تقدم العديد من الفوائد الصحية لجسم الإنسان. لذلك، أجريت هذه الدراسة لتقييم تأثير النسب المختلفة من مسحوق الطرطوفة على الفئران المصابة بداء السكري. أستخدمت في هذه الدراسة عدد (25 فأرا) من فئران الألبينو أوزانهم (160 ± 10 جرام). تم تقسيم الفئران إلى مجموعتين رئيسيتين. المجموعة الرئيسية الأولى (5 فئران) تتغذى على النظام الغذائي الأساسي (كمجموعة ضابطة سالبة). بينما المجموعة الرئيسية الثانية فقد تم إصابتهم بالسكرعن طريق حقنهم بمادة الألوكسان (150 ملجم / كجم وزن الجسم) ثم قسمت تلك المجموعة الى أربع مجموعات فرعية. إحدى هذه المجموعات تم تغذيتهم على الغذاء الأساسي فقط واستخدمت كمجموعة ضابطة موجبة وباقي المجموعات تم تغذيتهم على غذاء أساسي يحتوى على 10٪ و 15٪ و 20٪ من مسحوق الطرطوفة لمدة 28 يومًا. كانت نتيجة التقييم الحسي لخبز التوست المدعم بـ 10٪ من مسحوق الطرطوفة هى الافضل حسياً ، حيث اظهر هذا المستوى تغيرات غير معنوية مقارنة بعينة خبز الكنترول. على الجانب الاخر، أدت تغذية الفئران على أنظمة غذائية تحتوي على مسحوق الطرطوفة إلى حدوث تحسن ملحوظ في جميع التقديرات البيولوجية والبيوكيميائية. تم تسجيل أفضل النتائج لمجموعة الفئران المعالجة بمستوى 20٪ طرطوفة بالإضافة إلى ذلك، أظهر الفحص الميكروسكوبي للبنكرياس أن إضافة مسحوق الطرطوفة إلى وجبات الفئران المصابة بداء السكري قد أدى الى تحسن ملحوظ لأنسجة البنكرياس. لذلك ، نوصي باستخدام نبات الطرطوفة فى التطبيقات الغذائية المختلفة.

الكلمات المفتاحية:

الطرطوفة، جلوكوز الدم، وظائف الكبد ، صورة دهون الدم، وظائف الكلى.

Introduction

In the course of recent many years, ways of life have gotten progressively stationary, and dietary patterns have changed, prompting an expanded pervasiveness of diabetes and obesity **(Chang *et al.*, 2014)**. Diabetes mellitus (DM) is a common issue whose prevalence is increasing due to population aging and the developing problem of obesity **(Hewitt *et al.*, 2012)**. Diabetes mellitus is a chronic metabolic disorder, which not just affects human wellbeing and health yet in addition results in significant economic and social consequences. This illness is induced by under-creation or incapable use of insulin in the body **(Xu *et al.*, 2015)**. **(International Diabetes Federation IDF, 2019)** reported that diabetes has taken its toll on the lives of more than 463 million people between the ages of 20 and 79 years living with diabetes, half of these patients (232 million) remain undiagnosed, and the number of diabetes patients is predicted to increase to 700 million by 2045.

Jerusalem artichoke *(Helianthus tuberosus)*, which is also called sunroot, sunchoke, or earth apple, is a perennial herbaceous plant that belongs to the *Asteraceae* family, closely related to the sunflower. Well-known for its tubers rich in inulin **(Abdalla *et al.*, 2014)**. And is also known as topinambur (TPB) or wild sunflower **(Szewczyk *et al.*, 2019)**. Jerusalem artichoke tubers look like potatoes except that its carbohydrates, which compose, are in the form of inulin rather than starch **(Kim & Han, 2013)**, and its tubers can be produced worldwide, including Asia, North America, and Europe **(Takeuchi & Nagashima, 2011)**. Jerusalem artichoke is a plant with peculiar chemical properties. Inulin is stored as a reserve carbohydrate in the tubers; inulin gives Jerusalem artichoke tubers their unique value in the human diet. Furthermore, Jerusalem artichoke tubers have gotten increasingly popular in European cuisine, where they are normally consumed cooked or raw **(Bach *et al.*, 2013)**.

On the other hand, inulin and oligofructose belong to a class of carbohydrates known as fructans. One of the major sources of inulin and oligofructose that are using in food manufacture is Jerusalem artichoke. Inulin and oligofructose are considered functional food ingredients since they affect biochemical and physiological processes in people beings and, rats resulting in better health and lowering the risk of many illnesses **(Kaur & Gupta, 2002)**.

Jerusalem artichoke *(Helianthus tuberosus L.)* is presently a significant crop for the production of healthy food **(Eid, 2013).** Several researchers reported that Jerusalem artichoke an effect on lowering the concentration of serum glucose and improving insulin secretion; this effect may be related to its fructan that has a degree of polymerization from 2 to greater than 60 is labeled inulin, which is the main form in the Jerusalem artichoke **(Wang *et al.*, 2016)**, and improves the damaged liver in streptozotocin-induced diabetic mice, serum cholesterol, and triglycerides **(Yu *et al.*, 2018)**, Besides, Jerusalem artichoke has superior antioxidant activity **(Kim *et al.*, 2010)**.

Therefore, the current study aimed to study the effect of different ratios from Jerusalem artichoke powder on biological and biochemical parameters in alloxan-induced diabetic rats.

Material and Methods:

Materials:

Fresh Jerusalem artichoke Local type, harvested in December **2019-2020** were obtained from Al Qanater Charitable Horticulture Research Station Agriculture, Research Center Giza Egypt. Wheat flour, dry yeast, salt, sugar, skim milk powder, corn oil and Starch were obtained from the local market of Damietta governorate, Egypt. all vitamins, Casein, minerals, choline bitartrate , cellulose, and alloxan were obtained from ElGomhoria Company for Trading Drugs, Chemicals and Medical Instriments, Cairo, Egypt. Twenty-five male albino rats of (Sprague Dawley Strain) weighting (160 ± 10g) were be obtained from a laboratory animal colony. Ministry of health and population, Helwan, Cairo, Egypt. Kits used to determine cholesterol, triglycerides (TG), high-density lipoprotein cholesterol (HDL-c), serum glucose, alanine aminotransferase (ALT), aspartate aminotransferase (AST), urea nitrogen, creatinine and uric acid were obtained from Gama Company for Trading Drugs, Chemicals and Medical Instriments, Cairo, Egypt.

Methods:

Preparation of Jerusalem artichoke Tuber:

Jerusalem artichoke tubers were washed with faucet water and any deteriorated parts were removed, then the tubers were sliced in dividedly to a reasonable thickness by traditional food cutting machine. After that, the cut tubers were immersed immediately in cold citric acid solution (1%) to avoid enzymatic color changes. The slices of tuber were dried in an electronic air oven at 55 - 65˚C for 10 hrs **(El-Kholy& Mahrous., 2015)**. Dried particles were milled in a cereal mechanical mill to pass through a fine-mesh screen sieve (Mesh enwhite w=0.125mm, d=0.09mm). After that, the powder was kept in tight polyethylene bags and stored under freezing until use.

Preparation of Pan bread

Different batches of Pan bread were divided as follow:

1- **Control**: Control Pan bread was made from 100% soft wheat flour.
2- **Different formulas:**
   a. ***Treatment (1)*:** were made from adding Jerusalem artichoke Powder on wheat flour at ration of 10%.
   b. ***Treatment (2)*:** were made from adding Jerusalem artichoke powder on wheat flour at ration of 15%.
   c. ***Treatment (3)*:** were made from adding Jerusalem artichoke powder on wheat flour at ration of 20%**.**

Pan bread prepared by straight dough method as described in **A.A.C.C (2002)** as follows**:**

The ingredients consisted of wheat flour (200g), dry yeast (5g), water (110g), sugar (10g), salt (2g), skim milk powder (4g), and corn oil (10g). The ingredients were mixed for 4 minutes at slow speed (30 r.p.m) and for additional 6 minutes at a fast speed (60rpm) The resulted dough was let to rest for 20 min at 28- 30 ˚C (first proofing)then divided, rolled and molded automatically in a molding machine . Each piece was put in baking molds and let to ferment for 60 min at 36 ˚C (final proofing) then the baking process was carried out in electrical oven at 210-220 ˚C for 15-20 min. After baking, bread is allowed to cool at room temperature. Pan bread samples are then cut into slices by using an electric knife before organoleptic evaluation.

Chemical analysis

Moisture, fat, protein, ash and crude fiber, were determined as described in **(A.O.A.C., 2005)**, while total carbohydrates were calculated by the differences: Carbohydrates (%) = [100 – (moisture + fat + protein + crude fiber + ash)] .The energy values were calculated theoretically according to the method described by (**James, 1995)** as follows:

Energy value = 4(Protein g + carbohydrates g) + 9 (Fat g). Antioxidant capacity was determined by the method of **(Gaoa *et al*., 1998)**.

Sensory evaluation

Sensory evaluation was performed by invited eleven staff panelists from Home Economic Department, Faculty of Specific Education, Damietta University, Damietta, Egypt. Each panelist was asked to evaluate Pan bread (4 samples), according to color, odor, Texture, Taste, and general acceptability. The evaluation was carried out according to the method of **(Abd El – latif, 1990)**.

Biological experiments

Male albino rats Sprague Dawley Strain (25 rats) weighting 160±10g. Rats were preserved in individual stainless steel cages under healthy conditions and fed (one week) on a basal diet for adaption according to **Reeves et al., (1993)**. The experiment on rats was carried out according to the national regulations on animal welfare and Institutional Animal Ethical Committee

Experimental Design

After the period of adaptation on basal diet (one week), the rats were divided into two main groups as follows:

The first main group (5 rats) *Group (1)*: fed on basal diet (as a control negative group).The second main group (20 rats): the rats were injected by alloxan solution at a rate of 150 mg/kg body weight of recrystallized alloxan to induce hyperglycemia **(Buko *et al*., 1996)**. Then the rats were fed on the basal diet for 48 h during which

hyperglycemia was developed. To ensure the occurrence of diabetes in rats, blood samples were withdrawn after alloxan injection. The rats in the second main group were divided into four subgroups (n= 5) rats as follow:

- *Group (2)*: Fed on basel diet as positive control group
- *Group (3)*: Fed on basel diet containing 10% Jerusalem artichoke
- *Group (4)*: Fed on basel diet containing 15% Jerusalem artichoke
- *Group (5)*: Fed on basel diet containing 20 % Jerusalem artichoke

Biological Evaluation

During the experimental period (28 days), the amount of diet, which was consumed and /or wasted, was recorded every day. In addition, rats weight was recorded weekly to determine food intake and body weight gain% according to **(Chapman *et al*., 1959).** Body weight Gain % was determined using the following equation:

$$Body\ weight\ Gain = \frac{Final\ Weight\ (g) - initial\ weight\ (g)}{Initial\ weight\ (g)} \times 100$$

Organs: (liver and kidney) were separated, removed from each rat, cleaned from adhesive matter, weighed, then kept in formalin solution (10%) according to the method mentioned by **Drury and Wallington, (1980).**

$$Organs\ weight\ /\ Body\ weight\ \% = \frac{Organs\ weight}{Final\ weight\ (g)} \times 100$$

Blood Sampling

At the ends of the experimental period (4 weeks), the rats were fasted overnight before sacrificed, blood samples collected from the aorta. The blood samples were centrifuged for 20 min at 3000 rpm to separate the serum. After there, the serum was carefully separated into dry clean Wassermann tubes by using a Pasteur pipette and kept frozen until analysis at (-20°C).

Biochemical analysis of serum

- Serum glucose was determined in the serum according to the method described by (**Trinder, 1959).**
- Serum total cholesterol, TG and HDL-C were determined according to the method described by **(Allain *et al*., 1974)**, **(Fossati and Principe, 1982)** and (**Burstein, 1970)**, respectively. Serum LDL-C and VLDL-C were determined according to the method described by **(FriedWald *et al*., 1972)**.

- Serum uric acid, urea nitrogen and Creatinine were determined by **(Fossati *et al.*, 1980)**, (**Patton and Crouch, 1977)** and (**Bohmer, 1971)**, respectively.
- Aspartate amine transaminase (AST), Alanine amine transaminase (ALT) and alkaline phosphatase (ALP) activities were measured according to the method described by **(Reitman and Frankel, 1957) & (Bergmeyer and Brent, 1974**), respectively.

Histopathological Examination

Specimens from pancreas tissues were taken directly, after sacrificing an animal and fixed in 10% buffered neutral formalin solution. After there, fixed Specimens were then trimmed, washed, and dehydrated embedded in paraffin, cut in sections of 46 microns thickness, and stained with hematoxylin and eosin stain, according to **Sheehan and Hrapechak, (1980)**.

Statistical Analysis

The data of the current study were statistically analyzed by using a computer. The results were expressed as mean ± standard deviation "SD" and tested for significance using one-way analysis of variance "ANOVA" test, according to **Armitage and Berry, (1987)**.

Results and Discussion.

Chemical composition of Jerusalem artichoke tubers.

Data in Table (1) showed the chemical composition of Jerusalem artichoke powders. The total carbohydrates represented the major component in Jerusalem artichoke, it contains a high proportion of total carbohydrates reach to72.57%, followed by protein 10.2 %, ash 4.61%, crude fibers 4.06% and contains a low proportion of lipid content 1.36%. On the other hand, the amounts of total antioxidant capacity were 2482.2mg/100g and 343.32kca/100g total Energy. Our results in the line with those found by **Sayed, (2017)**. With regard to total antioxidant capacity, it content of our samples were also in accordance with findings of which was reported by **Puyanda *et al.*, (2020)** as 2,712.88± 356.95 mg Trolox/100g dry mass of JA tuber powders.

Table 1. Chemical composition of Jerusalem artichoke tubers. (On dry weight basis).

Nutrient	**Amount** (%)
Moisture	7.2
Protein	10.2
Ash	4.61
Fat	1.36
Dietary Fiber	4.06
Carbohydrate	72.57
Total antioxidant capacity	2482.2mg/100g
Total Energy	343.32kca/100g

Sensory evaluation of pan bread fortified with different levels of Jerusalem artichoke powder.

The average scores obtained by pan bread product in the sensory evaluation are presented in Table (2). Data showed that, the mean (value ± SD) of the Color, Smell, Taste, Texture, General acceptable and total scores in all fortified pan bread with different levels of Jerusalem artichoke powder decreased significantly ($p<0.05$), except pan bread fortified with 10%JAT, as compared with the control (unfortified pan bread), The data in this table showed non-significant changes ($p\leq0.05$) among pan bread fortified with 10%JAT and control. The lowest score was recorded for pan bread fortified with the highest levels from Jerusalem artichoke powder (20%JAT).

Table 2. Sensory evaluation score (Mean± SD) of pan bread fortified with different levels of Jerusalem artichoke powder.

Groups	**Color**	**Smell**	**Taste**	**Texture**	**General**	**Total**
	Mean ± SD	**Mean ± SD**	**Mean ± SD**	**Mean ± SD**	**Mean ± SD**	**Mean ± SD**
Control	19.64^{a} ±0.50	19.64^{a}± 0.92	18.62^{a}± 3.58	19.73^{a}± 0.65	19.41^{a}± 0.66	**97.03^{a}± 3.94**
GAT (10%)	18.32^{a} ±1.06	18.75^{a}± 0.91	18.32^{a}± 1.31	18.91^{a}± 0.54	18.45^{a}± 0.69	**92.75^{a}± 3.22**
GAT (15%)	17.09^{b} ±1.51	18.00^{b}± 1.67	16.27^{b}± 1.85	17.09^{b}± 1.22	17.05^{b}± 1.23	**85.50^{b}± 6.05**
GAT (20%)	16.23^{c} ±2.21	17.32^{b}± 1.98	15.23^{c}± 2.70	15.77^{c}± 1.33	16.09^{b}± 1.64	**80.64^{b}± 8.42**
F	11.38	5.20	4.64	35.24	18.59	**17.68**
P-value	0.001	0.004	0.007	0.001	0.001	**0.001**

JAT, Jerusalem artichoke tubers. **Means under same column have the different letters are significant different at p≤0.05.**

Fig (1): pan bread fortified with different levels of Jerusalem artichoke tuber.

Biological Evaluation:

Body weight gain% and feed intake: Data presented in Table (3) revealed a significant decrease in feed intake and body weight gain in the positive control group, as compared to the negative control group. Among all groups, the highest increase in BWG% was noticed in the treated group with (20%) Jerusalem artichoke compared with the positive control group. Moreover, treating diabetic rats with Some Levels of Jerusalem artichoke led to a slight increase in the mean value ± SD of feed intake, as compared to the positive control group. The highest increase in the mean value of feed intake was recorded for the group fed on a diet containing (15%JAP).

Table 3. Effect of Some Levels of Jerusalem artichoke on feed intake and body weight gain% of diabetic rats.

Parameters / Groups	Feed Intake g/day/rat	B.W.G Mean ± SD
Control (-)	16.0	22.23^{a} ± 2.83
Control (+)	14.25	3.91^{e} ± 0.45
10%JAT	15.6	6.58^{d} ± 0.56
15%JAT	18.6	10.35^{c} ± 0.79
20%JAT	15.7	16.07^{b} ± 1.08

JAT, Jerusalem artichoke tubers. **Means under same column have the different letters are significant different at p≤0.05.**

Organs Weight/Body Weight%: Data in Table (4) showed the mean ± SD values of organs weight (liver and kidney) of the tested groups. The mean value ± SD of liver weight/body weight % in diabetic rats increased significantly ($p<0.05$) than that of the healthy rats. Non-significant changes in the mean values of Liver weight/body weight% between the groups treated with (15% and 20% Jerusalem artichoke) as compared to the negative control group. Also, no significant differences in kidney weight/body weight % among all groups treated with (10, 15% and 20% Jerusalem

artichoke) and the control groups. These results agree with those obtained by **Zaky, (2009)** who reported that, the diets fortified with Helianthus tuberosus at different levels improved the body weight gain and feed efficiency ratio of diabetic rats than that of the positive control group, in addition to, Jerusalem artichoke don't change the organs weight/body weight% of diabetic rats. **Yokozawa *et al*., (2002)** indicated that inulin at a high level restores the decrease in body weights and organ weights in diabetic rats. Also, **Byung-Sung, (2011)** reported that the weights of kidney and liver were dense significantly in the diabetic group, as compared to the inulin administration groups.

Table 4. Effect of Some Levels of Jerusalem artichoke on Organs Weight/Body Weight% of diabetic rats.

Parameters / Groups	Organs Weight/ Body Weight%	
	Liver	Kidney
	Mean ± SD	Mean ± SD
Control (-)	2.05^{c} ± 0.09	0.57 ± 0.06
Control (+)	2.54^{a} ± 0.11	0.63 ± 0.07
10%JAT	2.34^{b} ± 0.09	0.61 ± 0.09
15%JAT	2.07^{c} ± 0.04	0.62 ± 0.05
20%JAT	2.12^{c} ± 0.12	0.60 ± 0.12
F	24.55	0.39
P-value	0.001	0.815

JAT, Jerusalem artichoke tubers. **Means under same column have the different letters are significant different at p≤0.05.**

Biochemical analysis:

Serum Glucose:

Data in Table (5) showed the effect of feeding Jerusalem artichoke powders on serum glucose in diabetic rats. The results indicated that serum glucose increased significantly ($p<0.05$) in the control positive groups (diabetic rats), as compared to control negative groups. Serum glucose increased by about 137.5% in the positive control group, than that of the negative control group. The increase in serum glucose may suggest disrupted carbohydrate metabolism because of the enhanced breakdown of liver glycogen **(Abd el Halim, 2020).** Serum glucose decreased gradually with increasing the levels of Jerusalem artichoke in treated groups. The highest decrease in serum glucose recorded for the group fed on 20%JAT. These results are in agreement with those found by **Zhao et al., (2017)** who mentioned that giving Jerusalem artichoke led to a significant decrease in serum glucose concentrations in type I and type II diabetic rats. Following 50, 100 and 150 mg/kg Jerusalem artichoke treatment

for indicated weeks. Also, **Cani *et al*., (2005)** reported that adding Inulin as a source of carbohydrates for diabetic patients during 4 to 6 weeks improves glucose tolerance, partly restores insulin excretion, and decreases glycemia.

Table 5. Effect of Some Levels of Jerusalem artichoke on Serum Glucose of diabetic rats.

Parameters / Groups	Glucose Mean ± SD	F	P-value
Control (-)	72.00^{c} ± 10.07	29.85	0.001
Control (+)	171.00^{a} ± 24.08		
10%JAT	115.40^{b} ± 13.16		
15%JAT	112.20^{b} ± 9.34		
20%JAT	87.80^{c} ± 15.71		

JAT, Jerusalem artichoke tubers. **Means under same column have the different letters are significant different at p≤0.05.**

Liver Enzymes:

From the data presented in table (6), it could be observed that, the mean value of serum (AST, ALT and ALP) in the control positive group increased significantly ($p<0.05$), as compared to the control negative group. Injected rats with alloxan to induce hyperglycemia led to increased (AST, ALT and ALP) Enzymes by about 98.01%, 133.65% and 60% in the positive control group than that of the negative control group. Treating rats on diet containing different levels of Jerusalem artichoke led to a significant decrease in serum AST, ALT and ALP enzymes, as compared to the non-treated group. The highest level of Jerusalem artichoke (20%) recorded the best results in AST, ALT and ALP enzyme, where, this group showed non-significant differences, as compared with the negative control group. The study was in agreement with **Abul-Fadl *et al*., (2016)** who reported that, diabetic rats fed on a basal diet (diabetic rat) recorded the highest ($P < 0.05$) activities of AST and ALT, whereas, the diabetic rats fed on pan bread containing 6 and 9 % JAF recorded the lowest ($P < 0.05$) activities of AST and ALT.Also, **Kaur and Gupta (2002)** and **Daubioul *et al*., (2005)** indicated that, adding inulin to the diet led to decreased triacylglycerol accumulation in the liver tissue and decreased significantly serum aminotransferase and aspartate aminotransferase after3weeks in the serum of diabetic rats.

	AST (U/l)	Alt (U/l)	ALP (U/l)
Control (-)	$30.20^{d} \pm 4.76$	$20.80^{d} \pm 4.32$	$357.00^{b} \pm 66.49$
Control (+)	$59.80^{a} \pm 1.92$	$48.60^{a} \pm 0.55$	$571.20^{a} \pm 59.90$
10%JAT	$46.60^{b} \pm 2.79$	$41.20^{b} \pm 4.38$	460.80 ± 182.99
15%JAT	$37.80^{c} \pm 4.09$	$36.40^{c} \pm 1.67$	$375.60^{b} \pm 77.38$
20%JAT	$32.40^{d} \pm 4.22$	$24.20^{d} \pm 4.60$	$351.80^{b} \pm 110.12$
F	53.22	54.34	3.68
P-value	0.001	0.001	0.021

Table 6. Effect of Some Levels of Jerusalem artichoke on Liver Enzymes of diabetic rats.

JAT, Jerusalem artichoke tubers. **Means under same column have the different letters are significant different at p≤0.05.**

Lipid Profile:

Effect of Jerusalem artichoke on blood lipid profile is presented in Table 7. The results showed that Levels of total cholesterol triglyceride, LDL-c, and VLDL-c were higher in the positive control group compared with the negative control group. While treatment with Jerusalem artichoke led to a significant ($P < 0.05$) decreased in the total cholesterol, triglyceride, LDL-c, and VLDL-c of all treated groups as compared to the positive control group. In contrast, the value of (HDL-c) decreased in the positive control group compared with the control negative group, while increased in all treated groups comparing that the positive control. The highest improvement of serum cholesterol, triglycerides, HDL-c, LDL-c, and VLDL-c recorded for the treated group with the highest levels of Jerusalem artichoke but this improvement was no better than

the negative control group. These results were in agreement with the data of **Osman *et al.*, (2013)**, who found that feeding rats on diet containing Jerusalem artichoke led to a decrease in the level of total cholesterol, LDL-c, triglyceride and increased HDL cholesterol. Also, **Cieslik *et al.*, (2005)** in their nutritional experiment with rats found that, total cholesterol level was lowering with growing proportions of Jerusalem artichoke powder supplement in the diet.

Table 7. Effect of Some Levels of Jerusalem artichoke on Lipid Profile of diabetic rats.

Groups	Parameters				
	Chol.	T.G.	HDL	LDL	VLDL
	(mg/dl)				
Control (-)	$125.20^{d} \pm 8.35$	$98.40^{d} \pm 11.80$	$47.60^{a} \pm 0.89$	$57.92^{e} \pm 6.80$	$19.68^{d} \pm 2.36$
Control (+)	$208.80^{a} \pm 6.53$	$183.20^{a} \pm 11.26$	$31.80^{b} \pm 4.09$	$140.36^{a} \pm 3.76$	$36.64^{a} \pm 2.25$
10%JAT	$165.20^{b} \pm 8.56$	$138.60^{b} \pm 12.10$	$36.20^{bc} \pm 5.89$	$101.28^{b} \pm 5.20$	$27.72^{b} \pm 2.42$
15%JAT	$159.40^{b} \pm 4.51$	$128.60^{bc} \pm 7.96$	$40.40^{ac} \pm 4.67$	$93.28^{c} \pm 5.45$	$25.72^{bc} \pm 1.59$
20%JAT	$138.40^{c} \pm 15.11$	$116.80^{c} \pm 11.73$	$43.60^{ac} \pm 9.40$	$71.44^{d} \pm 7.73$	$23.36^{c} \pm 2.35$
F	58.80	41.07	5.87	141.43	41.07
P-value	0.001	0.001	0.003	0.001	0.001

JAT, Jerusalem artichoke tubers. **Means under same column have the different letters are significant different at p≤0.05.**

Kidney Functions:

Statistical analysis in table (8) indicated that, the mean value of serum urea nitrogen, uric acid, and creatinine increased significantly ($p<0.05$) in the control (+) group, as compared to the negative control group. Meanwhile, All treated groups revealed a significant decrease in this parameter compared with the untreated group(positive control group).The highest improvement of serum urea, uric acid, and creatinine recorded for the group which treated with 20% JAT, non-significant changes in the mean value of serum urea nitrogen were observed between the groups treated with (15% and 20% Jerusalem artichoke). Additionally, non-significant differences in the mean value of serum uric acid were observed between the group which treated with (20%JAP) and the negative control group. These results are in agreement with the data of **EI Gindy, (2016)** who found that bread substituted with Jerusalem artichoke powder, barley flour and a mixture of both induced significant reduced in plasma levels of urea, and creatinine in the hyperglycemic groups in comparison with control group. According to **Kaur and Gupta, (2002)** that inulin is efficacious in reducing the serum uric acid and urea levels, thereby keeping the nitrogen balance. In contrast, an increase significantly in serum urea companion by a

lower significantly in serum creatinine was noticed when Jerusalem artichoke was supplemented in diabetic rats, this result was previously **Zaky, (2009).**

Table 8 .Effect of Some Levels of Jerusalem artichoke on Kidney Functions of diabetic rats.

Parameters / Groups	U.A. (mg/dl)	Urea (mg/dl)	Creat. (mg/dl)
Control (-)	$3.22^{c} \pm 1.08$	$31.00^{b} \pm 4.00$	$0.60^{d} \pm 0.07$
Control (+)	$5.66^{a} \pm 0.49$	$49.60^{a} \pm 8.53$	$0.94^{a} \pm 0.05$
10%JAT	$5.06^{ab} \pm 0.47$	$43.40^{ac} \pm 12.90$	$0.90^{a} \pm 0.12$
15%JAT	$4.66^{b} \pm 0.27$	$38.60^{bc} \pm 2.41$	$0.76^{b} \pm 0.15$
20%JAT	$3.60^{c} \pm 0.16$	$35.80^{bc} \pm 4.76$	$0.68^{bd} \pm 0.08$
F	14.99	4.49	9.75
P-value	0.001	0.009	0.001

JAT, Jerusalem artichoke tubers. **Means under same column have the different letters are significant different at p≤0.05.**

Histopathological examination of pancreas:

Pancreas of rats from group 1 revealed normal pancreatic acini and normal islets of Langerhan's **photo (1)**. On the other hand, pancreas of rats from group 2 showed vacuolations of cells of islets of Langerhan's **photo (2)**. However, examined sections from group 3 revealed no histopathological alterations except vacuolations of some cells of islets of Langerhan's **photo (3)**. Moreover, pancreas of rats from group 4 showed marked improved picture, few examined sections from those groups revealed necrosis of sporadic cells of islets of Langerhan's **photo (4)**, whereas, pancreas of rats from group 5 showed no histopathological changes and normal pancreatic tissue **photo (5)**.

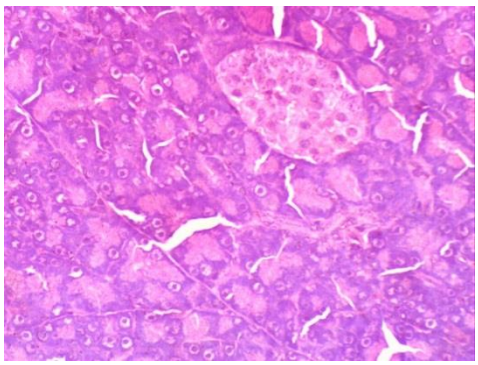

Photo (1): Pancreas of rat from group 1(normal control group) showing normal pancreatic acini and normal islets of Langerhan's (H & E X 400).

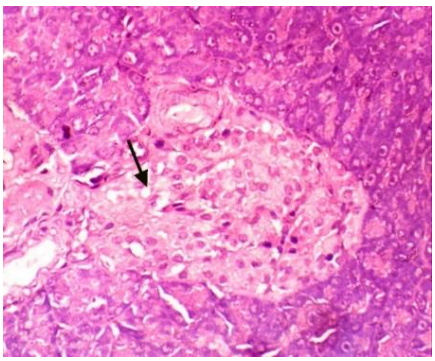

Photo (2): Pancreas of rat from group 2 (positive control group) showing vacuolations of cells of islets of Langerhan's (H & E X 400).

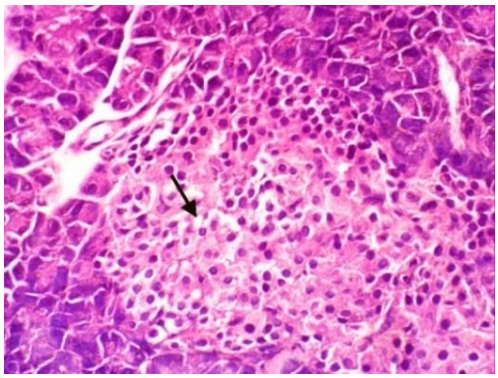

Photo (3): Pancreas of rat from group 3 (fed on diet contening 10%JAT) showing vacuolations of some cells of islets of Langerhan's (H & E X 400).

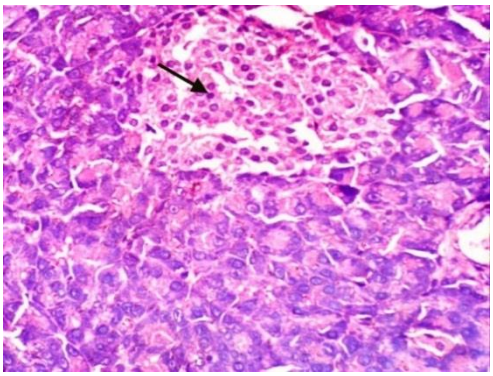

Photo (4): Pancreas of rat from group 4(fed on diet contening 15%JAT) showing necrosis of sporadic cells of islets of Langerhan's (H & E X 400).

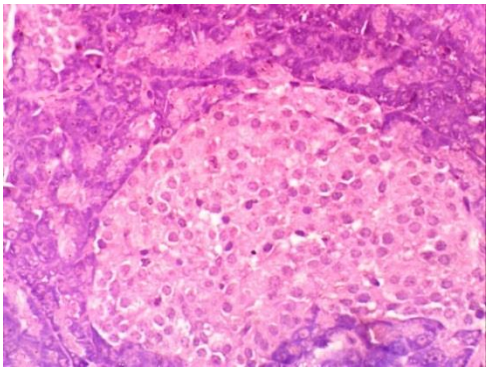

Photo (5): Pancreas of rat from group 5 (fed on diet contening 20%JAT) showing no histopathological changes and normal pancreatic tissue (H & E X 400).

Conclusion

The results of the present study indicated that Jerusalem artichoke powder improved serum glucose levels, liver functions, serum lipid profile, and kidney functions in diabetic rats. Such improvements were increased with the increasing of the tested plant concentration. This confirms the nutrition and health benefits of the Jerusalem artichoke plant. Therefore, we recommended the use of Jerusalem artichoke powder as food additives in our daily dishes and different food applications.

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