Influence of Jerusalem Artichoke Tubers (*Helianthus tuberosus L.*) on Rats Suffering from Diabetes and its Complications

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Abstract

The present study evaluated the protective potential of Jerusalem Artichoke Tubers powder (JAP) on diabetes and its complications. Thirty male albino rats weighing (150±10g) were divided into two main groups. The first group, 6 rats, was kept as a negative control group fed on a basal diet. The second group, 24 rats, was injected by alloxan to induce diabetes and divided into four equal subgroups as follow; subgroup (1) was fed on the basal diet and kept as a positive control group and subgroups (2,3 and 4) were fed on a basal diet containing 5, 10 and 15% JAP. The obtained results showed that the chemical composition of JAP contained 7.40, 8.21, 1.07, 5.38, 6.15 and 71.79% for moisture, protein, fat, ash, crude fiber and total carbohydrates, respectively. While caloric value recorded 329.63 kcal/100g. The amount of total antioxidant capacity was 2482.5mg/100g, and it was toxics-free. Injected animals with alloxan exhibited hyperglycemia, elevation in the liver enzymes activity (AST, ALT, and ALP), lipid fractions (TC, TG, LDL-c, and VLDL-c) and kidney functions (urea, uric acid and creatinine), while observing a reduction in HDL-c and the activity of the antioxidant enzymes (SOD, GPx, and CAT). Treatment with different levels of JAP recorded a gradual improvements in all parameters when compared to the untreated diabetic group. The histological examination of the liver and kidney confirmed a gradual improvement in all treated groups. Crackers were made with proportions 5, 10 & 15% of JAP, sensory evaluation findings indicated that all cracker samples had an overall acceptance greater

than 75%. In conclusion, the current study indicates that JA tubers has an effective impact in lowering blood sugar in diabetic rats, and reducing its complications. JA Tubers powder can be used as a complement in the diet of diabetic patients.

key words: Jerusalem Artichoke tubers - crackers - hyperglycemia- liver enzymes - lipid profile - antioxidant enzymes.

Introduction

Diabetes mellitus (DM) is a lifelong chronic ailment that affects the person, the family, and the community. It is one of the most rapidly spreading disease **(Nabolsi, 2020).** In Egypt, diabetes is becoming public health trouble as a result of rising obesity rates, changing dietary patterns, and a rise in the incidence of hepatitis C **(Hegazi *et al.*, 2015).** Diabetes can damage many vital organ systems, such as diabetic liver disease, diabetic nephropathy, diabetic vascular disease, diabetic cardiomyopathy, ect. **(Gan *et al.*, 2020),** these diabetes-related complications increased morbidity and mortality **(Roglic, 2016).**

Medicinal plants consist of some compounds of therapeutic value that help to control diseases. Although no one method fits all people for preventing and treating diabetes, techniques are needed to reduce the disease complications **(Devi *et al.*, 2021).** Many plants have been characterized as having hypoglycaemic action and being useful in lowering oxidative stress and its serious impacts **(Akinyemi *et al.*, 2018)**. One of these plants is Jerusalem Artichoke *(Helianthus tuberosus L.)*, a member of the sunflower family (Asteraceae) and grows naturally in many hot areas **(Okada *et al.*, 2017 and Ozgoren, *et al.*, 2019).**

Jerusalem Artichoke (JA) tubers are an excellent source of minerals and store carbohydrates as inulin rather than starch. Inulin is a polysaccharide compound consists of D-fructose linked together by β (2→1) glycosidic links of varying lengths with a terminal glucose unit linked to the fructose chain by an α (1→2) bond **(El-Kholy and Mahrous, 2015).** Due to this particular β-bond configuration between fructose monomers, inulin is not digested in the human intestine and therefore not absorbed and is classified as a

non-digestible carbohydrate and functional dietary fiber, and also act as prebiotics **(Ceylan *et al.*, 2021 and Díaz *et al.*, 2019).**

Inulin improves gastrointestinal health by promoting the formation of good microflora and inhibiting the growth of harmful bacteria in the large intestine **(Munim *et al.*, 2017)**. Because fermentation in the large intestine releases short-chain fatty acids, which are then taken into the body with an extremely lower caloric content than conventional digestible carbohydrates, it can function as a low-calorie sugar replacement **(Mutanda *et al.*, 2014).**

On the other hand, Inulin can act as a fat substitute due to its low caloric value and ability to emulate the texture of traditional fat. Hence, it is contributing to a diet that may prohibit the risk of intestinal infections, metabolic syndrome, obesity, type 2 diabetes, and colon cancer **(Ozgoren et al., 2019).** Additionally, tubers of JA contain a significant percentage of protein, dietary fiber, and minerals that probably contribute to improved bone health, antioxidant status, and non-specific immunity **(Wang et al., 2020).**

JA affects on decreasing blood glucose concentrations and improving insulin secretion; this effect could be attributed to its fructan, which has a degree of polymerization ranging from 2 to greater than 60 and is labeled inulin, which is the major form in the JA **(Wang et al., 2016).** Consumption of Jerusalem Artichoke tubers controls blood pressure and digestive system function, protects the liver and kidneys **(Yu et al., 2018),** and has good antioxidant activity **(Kim et al., 2010).**

Functional foods are used to describe foods that have useful functions, and they are one of the most important research and innovation sectors in the food industry **(Ceylan *et al.*, 2021).** In light of the foregoing, the current study investigated the effects of various ratios of Jerusalem Artichoke powder on biochemical markers in diabetic rats. In addition, the sensory properties of crackers made from Jerusalem Artichoke Tubers were evaluated.

Materials and Methods

Materials

- Jerusalem Artichoke Tuber harvest of 2020 was obtained from Horticulture Research Institute, El-Kanater El-Khairia, Ministry of Agriculture, Egypt.

- Casein, vitamins, minerals, cellulose, choline chloride and alloxan were purchased from El-Gomhoriya Company for Trading Drugs, Chemicals and Medical instruments, Cairo, Egypt.

- All ingredients used in crackers formulation (Wheat flour 72%, Wheat starch, sugar powder, corn oil, salt and baking powder) were commercially available and obtained from the local market from Damietta Governorate, Egypt.

Methods

Preparation of Jerusalem artichoke powder

Jerusalem Artichoke tubers were washed with water. Tubers were sliced 2mm in thickness. The slices were dipped immediately into hot water (85˚C, 1-L water/25 mL lemon juice) for about 30 min. The tubers slices were dried at 50 - 60˚C in an oven until samples reached a constant weight. Dried slices were ground into powder by using an electrical blender (Moulinex, LM 207041, France) and sieved. The dried powder was kept in a plastic bag at below 40C until analysis.

Determination of gross chemical composition

Jerusalem Artichoke powder (JAP) were analyzed for moisture, ash, total protein, crude fiber and fat contents, while total carbohydrates were calculated by difference according to **A.O.A.C. (2000).** Caloric value was calculated according to the following equation: Caloric value% = 4 (protein%+ carbohydrates%) + 9 (fat%). Antioxidant capacity was determined by the method of **Gaoa *et al.* (1998)**. Toxicity was determined by the method of **Bruce (1985).**

Biological assay

The biological studies were carried out in accordance with the Institute of Laboratory Animal Resources, Commission on Life Sciences, National Research Council **(NRC, 2011).** Thirty adult male albino rats (Sprague Dawley Strain) each weighing (150±10g) were obtained from Nile Center for Experimental Researches, Mansoura City. Rats were individually kept in wire cages in a standard laboratory setting and were fed on a basal diet for one week as an adaptation period. The basal diet was prepared using the following formula, as recommended by **Reeves *et al.* (1993):** casein (14%), corn oil (4%), vitamin mixture (1%), mineral mixture (4%), choline chloride (0.25%), cellulose (5%), and the remained is corn starch. The used vitamins mixture component was formed by **Campbell (1963)**, while the salts mixture used was created according to **Hegested *et al.* (1941).**

After that, rats were randomly divided into two main groups, the first group [group 1: negative control group (C-), 6 rats] fed on a basal diet and the second group (24 rats) was injected subcutaneously with alloxan (150 mg/kg BW) to induce diabetes in rats after fasting overnight **(Buko *et al.*, 1996),** which classified into four subgroups of 6 rats each as follow; subgroup 1: positive control (C+) fed on a basal diet, subgroup 2: fed on a basal diet containing JAP 5%, subgroup 3: fed on a basal diet containing JAP 10% and subgroup 4: fed on a basal diet containing JAP 15%. Rats were maintained under standard conditions (23±2°C temperature, 55±5% relative humidity, 12h light/12h dark cycle). The animals were fed diet and water ad-libitum for a period of 4 weeks. The diets consumed and body weights were recorded twice weekly.

At the end of the experiments, all rats were fasted up to 12 hours and then sacrificed. Blood samples were collected from the aorta. The blood samples were centrifuged, separated and stored frozen at -20°C until further analysis. Internal organs: liver and kidney of each rat were removed, washed in saline solution, dried by filter paper and weighed separately according to the method mentioned by **Drury and Wallington (1980).**

Biochemical analysis

Blood glucose: Enzymatic determination of serum glucose was carried out calorimetrically according to the method of **Yound (1975).**

lipids profile: Serum total cholesterol, triglyceride and high density lipoprotein were determined using the methods described by **Allain *et al.* (1974), Fassati and Prencip (1982), and Lopez-virella (1977)**, respectively. The determination of low density lipoprotein cholesterol and very low density lipoprotein cholesterol were carried out according to **Lee and Nieman (1996).**

Liver functions: Serum levels of aspartate aminotransferase (AST) and alanine aminotransferase (ALT) activities were measured according to **Tietz (1976),** while Alkaline phosphates (ALP) activity was determined according to **Vassault *et al.* (1999).**

Kidney functions: Serum levels of uric acid, urea nitrogen and creatinine were determined according to **Fossati *et al.* (1980), Patton and Crouch (1977), and Bohmer (1971),** respectively.

Antioxidant enzymes: RBC's activities levels of superoxide dismutase (SOD), glutathione peroxidase (GPx), catalase (CAT) were measured according to the methods described by **Mc Cord and Fridovich (1969)**, **Flohé and Gunzler (1984), and Aebi (1984),** respectively.

Histological examination

Tissues from the liver and kidneys of the sacrificed rats were examined as described by **Bancroft and Cook (1998).**

Formulation and preparation of crackers

Crackers were prepared by using the **Isik and Topkaya (2016)** method with a little modification. The control and the other formulations are presented in Table (1). In a mixing bowl, the dry and liquid ingredients were mixed for 3-4 minutes to form the dough, then left to rest for 10 minutes. The dough was rolled out as thin as possible -no thicker than 1/8 inch and cut out as square-shaped crackers. Crackers were baked in an electric oven at 200°C for 10

minutes. After baking, crackers were left in the oven for an additional 2 minutes with the heat off but with forced air circulation. This process simulated the drying and cooling stages of a commercial baking oven. Baked crackers were then removed from the oven and allowed to cool down to room temperature. Crackers samples were stored in air-tight containers before sensory evaluation.

Table (I): Formulation of Crackers

Ingredients (g)	Control	5% JAP	10% JAP	15% JAP
Wheat flour 72%	450	427.5	405	382.5
JA powder	-	22.5	45.0	67.5
Wheat starch	50	50	50	50
Water	200	250	250	250
Corn oil	75	75	75	75
Sugar	5	5	5	5
Salt	5.5	5.5	5.5	5.5
Baking powder	5.0	5.0	5.0	5.0

JAP: Jerusalem Aatichoke Powder

Sensory evaluation

Sensory evaluation of crackers was done as described by **A.A.C.C. (2002).** Using 10 panelists of staff members from the Home Economic Department, Faculty of Specific Education, Damietta University, Damietta, Egypt. Samples of the crackers were prepared one day earlier before the evaluation, cooled for 1-2h at room temperature (25±3ºC). Sensory attributes for color (20), taste (20), odor (20), texture (20), general appearance (20) and overall acceptability (100) were evaluated.

Statistical Analysis

The data were statistically analyzed by SPSS computer software SPSS 2000. 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

Gross chemical composition and toxicity of Jerusalem Artichoke Powder:

Data presented in table (2) showed the gross chemical composition of Jerusalem Artichoke Powder and its toxicity. It could be observed that Jerusalem Artichoke Powder (JAP) contained 7.40, 8.21, 1.07, 5.38, 6.15, 71.79%, and 329.63kcal/100g for moisture, crude protein, crude fat, ash, crude fiber, total carbohydrates, and caloric value, respectively. On the other hand, the amount of total antioxidant capacity was 2482.5mg/100g.

These results were in the line with those found by **Sayed (2017)** who reported that Jerusalem Artichoke powder (JAP) contains 8.84% crude protein, 3.25% fiber, 10.5 moisture, 0.61% total fats, 6.22% ash and 70.579% for total carbohydrate content. With regard to total antioxidant capacity, the content of JAP samples was also in accordance with findings which was reported by **Puyanda *et al.* (2020)** as 2712.88± 356.95mg Trolox/100g dry mass of JA tuber powders.

The same table (2) showed that the sample of Jerusalem Artichoke powder was free of toxins. Such data are in accordance with that obtained by **Judprasong *et al.* (2018)** who reported that *Helianthus tuberosus* can be used safely in food as there is no toxicity in it.

Table (2): Gross chemical composition of Jerusalem Artichoke powder (%On dry weight basis)

Components	Ingredients
Moisture (g)	7.40±0.09
Crude Protein (g)	8.21±0.46
Fat (g)	1.07±0.03
Ash (g)	5.38±0.18
Crude fiber (g)	6.15±0.25
Carbohydrate* (g)	71.79±0.23
Caloric Value (K.cal)	329.63
Total antioxidant capacity (mg/100g)	2482.2
Toxicity (part/billion)	ND**

Each value represents the mean ± SD.
* Total carbohydrates were calculated by differences
** Less than the device sensitivity

Feed intake, body weight gain% and relative weight of internal organs:

Data in Table (3) observed the effect of feeding JAP diet on feed intake FI, body weight gain BWG% and relative weight for internal organs of rats suffering from diabetes. From data, it could be noticed that the mean values of FI (g/day/each rat) and BWG% in diabetic rats (C+) were significantly lower than that of the healthy rats (C-) which fed on a basal diet (12.35 and 10.61±1.14 vs. 14.67 and 25.23±2.25, respectively. Supplementing the rats' diet with JAP at different levels leads to an increase in the mean values of FI and BWG% by the rate of 7.21, 11.17, and 13.36%, respectively for FI; while 44.02, 73.13, and 79.55%, respectively for BWG%, as compared to the control positive group.

Data in the same table (3) showed that the relative weight of some internal organs (liver and kidney) of diabetic rats (C+) increased significantly at ($p \leq 0.05$), as compared to the normal group (C-). Non-significant changes in the mean values of liver and spleen

weight/body weight% between the group treated with (15% JAP) as compared to the negative control group.

Table (3). Effect of JAP on feed intake, BWG % and some organs relative weight of diabetic rats

Parameters / Groups	FI g/day/rat	BWG %	Organs relative weight	
			Liver	Kidney
Control (-)	14.67	25.23^{a} ±2.25	2.17^{d} ±0.08	0.55^{d} ±0.02
Control (+)	12.35	10.61^{e} ±1.14	3.32^{a} ±0.16	0.63^{a} ±0.04
5% JAP	13.24	15.28^{d} ±1.51	2.64^{b} ±0.10	0.61^{b} ±0.02
10% JAP	13.73	18.37^{c} ±1.38	2.43^{bc} ±0.15	0.60^{bc} ±0.02
15% JAP	14.00	19.05^{b} ±1.64	2.25^{cd} ±0.14	0.59^{cd} ±0.01

JAP: Jerusalem Aatichoke Powder
Means in the same column with different superscript letters are significantly different at $p \leq 0.05$.

These findings are consistent with those obtained by **Yokozawa *et al.* (2002)** who indicated that inulin at a high level reverses the reduction in body weights and organ weights in diabetic rats. **(Zaky, 2009)** reported that diets fortified with *Helianthus tuberosus* at various levels improved the body weight gain and feed efficiency ratio of alloxan-injected diabetic rats compared to the positive control group. Also, **Byung-Sung (2011)** discovered that the diabetes group's liver weight was significantly denser than the inulin treatment groups at ($p \leq 0.05$).

Serum glucose and liver enzymes activity:

Excessive fat buildup in the liver and hyperglycemia are associated with excessively increased liver enzymes, led to damage hepatocytes and rise morbidity and mortality in diabetics **(Omodanisi *et al.*, 2017 and Oguntibeju, 2019).** Jerusalem Artichoke tubers contain inulin, which can be used as a low-calorie sugar replacement since it doesn't stimulate a glycemic response. **(Long *et al.*, 2016)**.

The finding in Table (4) presented the effect of JAP on serum glucose and liver enzymes activity of rats suffering from diabetes. The results indicated that serum glucose concentration (mg/dl) of the positive control group increased significantly at ($p \leq 0.05$), as compared to the negative control group (183.03±12.08 vs. 81.10±10.07 mg/dl), the increase in serum glucose may suggest disrupted carbohydrate metabolism due to enhanced breakdown of liver glycogen **(Abd el Halim, 2020).** Serum glucose concentration decreased gradually with increasing the levels of JAP in all treated groups, the highest decrease in serum glucose recorded for the group of rats fed on a basal diet containing 15% JAP, this result was due to its soluble fiber content of mainly fructooligosaccharides and inulin.

These results are in agreement with those found by **Zhao *et al.* (2017)** who mentioned that giving *Helianthus tuberosus* led to a significant decrease in blood glucose concentrations in type I and type II diabetic rats. **Chang *et al.* (2014)** discovered that the Jerusalem artichoke's fructose and inulin content might help prevent type 2 diabetes if ingested regularly. 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 lowers glycemia.

From the same Table (4), it could be observed that the mean value ±SD of serum AST, ALT, and ALP in the (C+) group increased significantly ($p \leq 0.05$), as compared to the (C-) group (129.06±1.92, 81.63±3.55 and 431.20±39.90 vs. 56.12± 3.71, 21.80±1.32 and 247.00±19.49 U/l, respectively). This was due to the injection of alloxan which increased serum levels of liver enzymes in diabetic rats. Treating rats on diet containing different levels of JAP led to a significant decrease in serum AST, ALT and ALP enzymes, as compared to the positive control group. The highest level of JAP (15%) recorded the best results in AST, ALT and ALP enzymes. Ingestion of JAP diet (5,10&15%) in diabetic rats partially prevented the rise of mean serum AST, ALT, and ALP enzymes. The rate of preventative was enhanced with the increase of the JAP ratios. The rate of increment in the serum AST, ALT, and ALP levels were lowered and recorded 12.95, 15.22, and 12.84% for a diet containing 5% JAP, 26.10, 44.38, and 31.44% for a diet containing 10% JAP and 43.13, 71.57 and 41.37% for a diet containing 15% JAP,

respectively. Which means, the treatment with different ratios from JAP improving the damaged liver of the alloxan-induced diabetic rats.

The results are in harmony with **Abul-Fadl *et al.* (2016)** who reported that diabetic rats fed on a diet containing 6 and 9% JA tubers recorded the lowest (P≤0.05) activities of AST and ALT. **Kim and Han (2013)** found that a water extract of Helianthus tuberosus L. improved the damaged liver in STZ-induced diabetic mice, lowering blood glucose, serum cholesterol, and triglycerides while also increasing insulin secretion. Also, **Daubioul et al. (2005)** indicated that, adding inulin from Helianthus tuberosus L. to the diet led to decreased triacylglycerol accumulation in the liver tissue and decreased significantly serum alanine aminotransferase and aspartate aminotransferase after three weeks in the serum of diabetic rats.

Table (4): Effect of JAP on serum glucose and liver enzymes activity of diabetic rats

Parameters / Groups	Glucose	AST	Alt	ALP
	mg/dl	U/l		
Control (-)	81.10^{c} ±10.07	56.12 ^{e} ± 3.71	21.80^{d} ±1.32	247.00^{d} ±19.49
Control (+)	183.03^{a} ±12.08	129.06 ^{a} ± 1.92	81.63^{a} ±3.55	431.20^{a} ±39.90
5% JAP	150.40^{b} ±9.16	112.81 ^{b} ± 2.79	69.20^{b} ±3.38	375.80^{b} ±42.99
10% JAP	127.20^{b} ±10.34	95.37 ^{c} ± 3.27	45.40^{c} ±1.67	295.60^{c} ±25.38
15% JAP	94.80^{c} ±11.71	73.16 ^{d} ± 3.25	23.20^{d} ±3.60	252.80^{cd} ±23.12

JAP: Jerusalem Aatichoke Powder
Means in the same column with different superscript letters are significantly different at p≤0.05.

Serum lipid fractions:

The effect of JAP on serum lipid fractions of diabetic rats is presented in Table (5). The results showed that the mean values of TC (195.80±6.53 mg/dl), TG (97.20±4.21 mg/dl), LDL-c (141.61±3.76 mg/dl), VLDL-c (19.63±0.98 mg/dl) and TC/HDL-c ratio (8.71±1.24 mg/dl) increased significantly at (P≤0.05), whereas HDL-c (26.80±4.09 mg/dl) declined significantly at (p≤0.05) for the (C+) group, as compared to the (C-) group. Results illustrated that the mean values of serum TC, TG, LDL-c, and VLDL-c in all treated groups decreased gradually with raising the ratios of JAP, compared with the C+ group. On the contrary, HDL-c had higher mean values than the C+ group. The rate of amelioration in lipid fractions increased with the increase of the JAP.

The results coincide with those obtained by **OKada *et al.* (2017)** who indicated that the intake of *Helianthus tuberosus* powder inhibits the accumulation of fat and glycogen in the liver. **Lin *et al.* (2014)** reported that inulin and fructooligosaccharides are beneficial in lowering triglyceride levels, particularly through lowering VLDL under post-absorptive circumstances. **Osman *et al.* (2013)** found that feeding rats on diet containing *Helianthus tuberosus* led to a decrease in the level of TC, TG, LDL-c, and increased HDL-c. Also, **Cieslik *et al.* (2005)** in their nutritional experiment with rats found that total cholesterol level was decreasing with growing proportions of Jerusalem Artichoke flour supplement in the diet.

The results coincide with those obtained by **OKada *et al.* (2017)** who found that consuming Jerusalem Artichoke tuberosus powder prevents fat and glycogen buildup in the liver. **Lin *et al.* (2014)** indicated that inulin and fructooligosaccharides are beneficial in lowering triglyceride levels, particularly through lowering VLDL under post-absorptive circumstances. **Osman *et al.* (2013)** found that feeding rats on diet containing Helianthus tuberosus led to a decrease in the level of TC, TG, LDL-c, and increased HDL-c. Also, **Cieslik *et al.* (2005)** discovered that as the amount of Jerusalem Artichoke flour supplement in the diet increased, overall cholesterol levels decreased.

Table (5): Effect of JAP on lipid fractions of diabetic rats

Parameters / Groups	TC	TG	VLDL-c	HDL-c	LDL-c	TC/ HDL-c %
	(mg/dl)					
Control (-)	79.20^{e} ±4.35	54.80^{d} ±4.80	10.68^{c} ±1.36	47.40^{a} ±4.89	20.56^{e} ±6.80	1.59^{e} ±0.22
Control (+)	195.80^{a} ±6.53	97.20^{a} ±4.21	19.63^{a} ±0.98	26.80^{d} ±4.09	141.61^{a} ±3.76	8.71^{a} ±1.24
5% JAP	176.21^{b} ±5.56	84.26^{b} ±3.10	16.52^{b} ±1.62	32.45^{c} ±4.53	127.20^{b} ±5.20	5.03^{b} ±1.18
10% JAP	159.42^{c} ±4.51	70.64^{c} ±3.96	14.18^{b} ±1.81	40.21^{b} ±4.10	104.08^{c} ±5.45	3.25^{bc} ±0.76
15% JAP	128.45^{d} ±4.1	59.13^{d} ±3.24	11.73^{c} ±0.95	44.50^{ab} ±5.40	73.05^{d} ±7.73	2.73^{d} ±0.16

JAP: Jerusalem Aatichoke Powder
Means in the same column with different superscript letters are significantly different at $p \leq 0.05$.

Serum kidney functions:

Data obtained in Table (6) showed the effect of JAP on kidney functions of diabetic rats. As shown, the mean values ±SD of urea, uric acid, and creatinine of the positive control group were higher than the negative control group, being 65.60±3.53, 5.56±0.49, and 1.08±0.12 vs. 31.54±2.18, 3.22±0.18, and 0.62±0.07 mg/dl, respectively. All diabetic rats fed on a diet containing different ratios from JAP revealed significant decreases in the mean values of the same parameters as compared to the positive control group. The values were 57.48±5.31, 5.06±0.47, and 0.95±0.07, respectively for a diet containing 5% JAP; 45.16±3.41, 4.55±0.27, and 0.74±0.15, respectively for a diet containing 10% JAP, and 36.15±3.76, 3.46 ±0.26 and 0.69±0.08, respectively for a diet containing 15% JAP. The best treatment was recorded for the group treated with 15% of JAP, which had improved kidney functions. This indicates that JAP treatment in different ratios improved the kidney functions of alloxan-induced diabetic rats.

The results were in line with **Reshetnik (2011)** who reported that Helianthus tuberosus has therapeutic effects in patients with hyperuricemia and kidney stones. **Zaky (2009)** showed that adding powdered Jerusalem artichoke tubers to the rats' diet decreased hyperglycemia and improved liver and kidney functioning.

Table (6): Effect of JAP on kidney functions of diabetic rats

Parameters / Groups	Urea	Uric acid	Creatinine
	mg/dl		
Control (-)	31.54^{e} ±2.18	3.22^{c} ±0.18	0.62^{c} ±0.07
Control (+)	65.60^{a} ±3.53	5.56^{a} ±0.49	1.08^{a} ±0.12
5% JAP	57.48^{ab} ±5.31	5.06^{ab} ±0.47	0.95^{a} ±0.07
10% JAP	45.16^{c} ±3.41	4.55^{b} ±0.27	0.74^{b} ±0.15
15% JAP	36.15^{d} ±3.76	3.46^{c} ±0.26	0.69^{bc} ±0.08

JAP: Jerusalem Aatichoke Powder
Means in the same column with different superscript letters are significantly different at $p \leq 0.05$.

Antioxidant enzymes activities:

Oxidative stress is caused by an increase in intra- and extracellular free radical concentrations, which is caused by hyperglycemia **(Salazar *et al.*, 2014).** Dyslipidemia, impaired glucose tolerance, β-cell dysfunction, and lastely liver failure are all symptoms of oxidative stress in diabetes **(Omodanisi *et al.*, 2017).** Also, long-term hyperglycemia reduced activity of antioxidant proteins (glutathione), enzymes (glutathione peroxidase, superoxide dismutase, catalase), vitamins (C, E, and A), and minerals (selenium and zinc), consequently stimulate the production of inflammatory cytokines and chemokines **(Oguntibeju, 2019)**

Antioxidant defense system in RBCs in diabetic rats feeding on Jerusalem Artichoke tubers powder was assessed by measuring antioxidant enzymes activities including superoxide dismutase (SOD), glutathione peroxidase (GPx), and catalase (CAT) presented in Table (7). From data, it could be noticed that diabetic rats had a significant reduction at ($p \leq 0.05$) in the mean values of SOD, GPx, and CAT activities at 20.62 ±1.31, 11.50± 0.56, and 135.34± 3.00, as compared to normal rats, respectively. All groups received basal diets supplemented with 5, 10 and 15% of JAP had a significant increase

in antioxidant enzymes concentration by the ratio of 22.01, 60.47, and 89.62%, respectively for SOD, 18.69, 50.61, and 72.43%, respectively for GPx, and 5.77, 15.42 and 19.23% respectively for CAT, as compared to the positive control group. All of these improvements could be principally attributed to the strong antioxidant activities of Jerusalem Artichoke powder. The best effect in SOD, GPx, and CAT enzymes activities in diabetic rats which received a basal diet containing 15% JAP followed by 10%.

Results are in line with **Yu *et al.* (2018)** found that inulin from *Helianthus tuberosus L.* enhanced hepatic SOD activity in high-fat diet rats. According to **Catană *et al.* (2018),** Jerusalem artichoke powders have antioxidant potential and may be included in a healthy diet to help avoid ailments caused by free radicals.

Table (7): Effect of JAP on antioxidant enzyme activities in RBCs diabetic rats

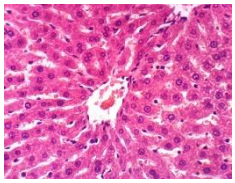
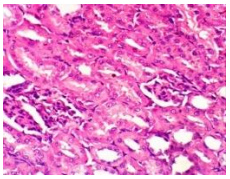
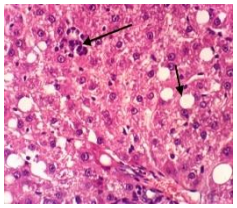
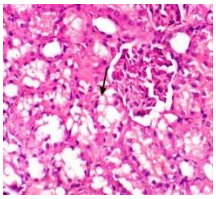
Parameters / Groups	SOD	GPx	CAT
	U/g Hb		
Control (-)	48.55 ^{a} ± 1.12	22.09 ^{a} ± 0.89	173.15 ^{a} ± 3.01
Control (+)	20.62 ^{e} ± 1.31	11.50 ^{e} ± 0.56	135.34 ^{e} ± 3.00
5% JAP	25.16 ^{d} ± 1.05	13.65 ^{d} ± 0.70	143.16 ^{d} ± 2.08
10% JAP	33.09 ^{c} ± 1.87	17.32 ^{c} ± 0.43	156.21 ^{c} ±2.23
15% JAP	39.10 ^{b} ± 1.38	19.83 ^{b} ± 0.23	161.36 ^{b} ± 2.49

JAP: Jerusalem Aatichoke Powder
Means in the same column with different superscript letters are significantly different at $p \leq 0.05$.

Histopathological examination of liver and kidneys tissue:

Photo (1) & (2) showed the histopathological examination of liver and kidneys tissue. Photo (1) & (2) showed the histopathological examination of liver and kidneys tissue. Microscopically, the liver and kidneys of rats from the control negative group which fed on basal diet showed the normal histological structure of both hepatic lobule and renal parenchyma in (Photo A1 & A2, respectively). While significant changes were observed in the liver and kidneys of diabetic rats from the positive control group (Photo B1 & B2). Meanwhile, diabetic rats that received a basal diet containing different ratios from JAP showed a gradual improvements in both liver tissue (Photo C1, D1 & E1) and kidneys tissue (Photo C2, D2 & E2).

In tis recpect, **Abdel-Hamid *et al.* (2015)** indicated that, JA tubers therapy resulted in normal hepatic cords, reduction in necrosis, and least fatty infiltration with the following decrease in hepatic fibrosis score. Histological studies by **Okada *et al.* (2017)** indicated that, fat and glycogen accumulation decreased in rats fed a high-fat diet which recieved *Helianthus tuberosus* in thier.

Photo (1): Effect of JAP on histological examination of liver tissue		**Photo (2): Effect of JAP on histological examination of Kidney tissue**	
	**Photo (A1): Control-** Normal histological structure of hepatic lobule (H & E X 400).		**Photo (A2): Control-** Normal histological structure of renal parenchyma (H & E X 400).
	**Photo (B1): Control+** Cytoplasmic vacuolization of hepatocytes and portal infiltration with inflammatory cells (H & E X 400).		**Photo (B2): Control+** Cytoplasmic vacuolization of epithelial lining renal tubules (H & E X 400).

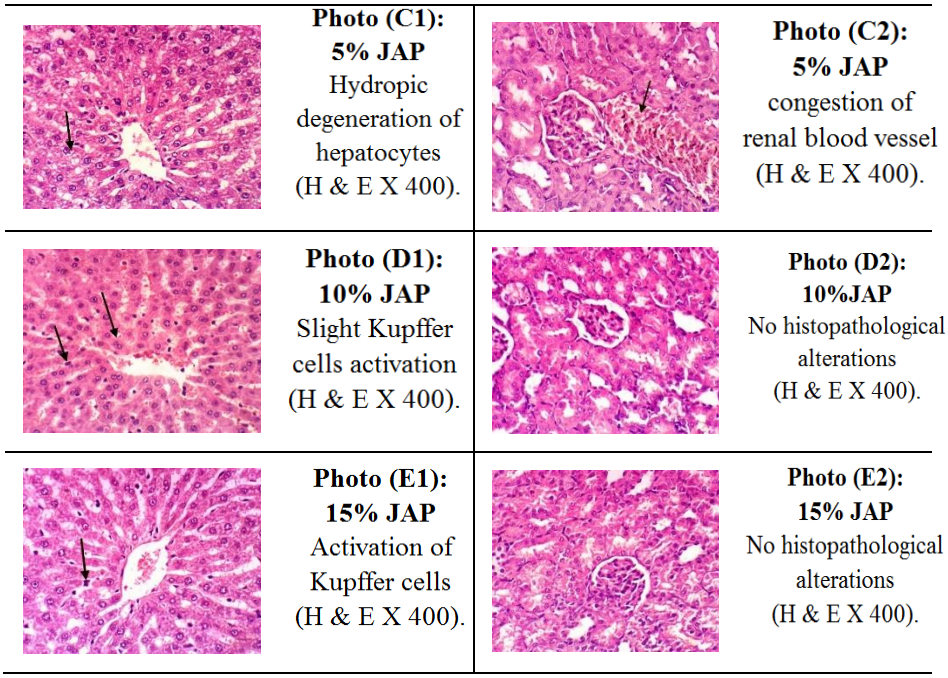


Fig (1): Histopathological examination of liver and Kidney

Sensory characteristics of crackers:

Crackers are popular snack in the human diet. Crackers are described as thin, crisp wafers or biscuits, often composed of unsweetened dough **(Isik and Topkaya, 2016).** Additionally, **Celik *et al.* (2013)** illustrated that, inulin has a neutral taste and is colorless, so it owns a little impact on the organoleptic characteristics of the product. The high solubility of inulin approve it to be supplemented in many products like dairy products and desserts. Supplemented by inulin or Jerusalem artichoke flour to bread typically offers numerous benefits, such as improved crumb softness, longer preservation, and enhanced bread volume.

Table (8) presented the sensory characteristics of prepared crackers with Jerusalem Artichoke powder. The data showed that most formulations were acceptable in all sensory evaluation attributes (color, taste, flavor, texture, and general appearance), and

no significant variations (P≤0.05) between the formulas prepared with 5 & 10 % JAP as compared with control crackers. Whereas

Table (8): Sensory characteristics of crackers prepared with JAP

Sensory Characteristics	Control 0%	Crackers with JAP		
		5%	10%	15%
Color (20)	19.18^{a} ±1.50	18.23^{a} ±1.06	17.66^{ab} ±0.612	16.02^{c} ±0.544
Taste (20)	19.35^{a} ±1.58	18.75^{a} ±1.27	17.43^{ab} ±0.653	16.31^{c} ±0.730
flavor (20)	19.52^{a} ±1.92	18.42^{a} ±0.913	17.31^{ab} ±0.957	15.93^{c} ±0.626
Texture (20)	19.41^{a} ±1.65	18.33^{a} ±0.545	17.46^{ab} ±0.875	16.24^{c} ±0.835
General Appearance (20)	19.29^{a} ±1.66	18.59^{a} ±0.692	17.52^{ab} ±0.584	16.19^{c} ±0.754
Overall Acceptability (100)	95.48^{a} ±1.94	91.55^{b} ±1.22	86.20^{c} ±1.85	80.65^{d} ±1.42

JAP: Jerusalem Aatichoke Powder
Means in the same column with different superscript letters are significantly different at p≤0.05.

substitution with high levels from JAP by 15% caused a slight changes (P≤0.05) in the same sensory evaluation. In general, results from overall acceptability observed that all samples obtained higher than 75%, which means that Jerusalem Artichoke powder is acceptable and can be used in the preparation of crackers that is appropriate for diabetic patients.

Conclusion

The present study has revealed that Jerusalem Artichoke Tubers powder serves as an important source of many therapeutically efficient chemicals. Consumption of Jerusalem Artichoke powder improves glucose homeostasis and lipid fractions. Also, maintains the integrity of the liver enzymes activity, kidney functions, and lowering oxidative stress in the body. Ultimately, Jerusalem

Artichoke powder can be integrated up to 15% into functional foods to produce healthier alternatives to traditional baked foods.

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المجلة العلمية للتربية النوعية والعلوم التطبيقية
The Scientific Journal of Specific Education and Applied Sciences

تأثير درنات خرشوفة القدس علي الفئران التى تعانى من مرض السكر ومضاعفاته

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الملخص

استهدفت الدراسة التعرف علي تأثير النسب المختلفة من مسحوق درنات خرشوفة القدس على الفئران التي تعاني من مرض السكر ومضاعفاته. استخدمت الدراسة ٣٠ فأر من نوع الالبينو (١٥٠±١٠جم)، قسمت الفئران إلي مجموعتين رئيسيتين، المجموعة الاولي (٦ فئران) أصحاء كمجموعة ضابطة سالبة، المجموعة الثانية (٢٤ فأر) تم تغذيتهم علي الوجبة الاساسية، ثم حقنهم تحت الجلد بمادة الالوكسان (١٥٠ملجم/كجم من وزن الجسم) للحث على ارتفاع سكر الدم، تم تقسيمها الي ٤ مجموعات فرعية كالتالي: المجموعة (٢) تم تغذيتها علي غذاء اساسي كمجموعة ضابطة موجبة، المجموعات (٣ و٤ و٥) أضيف لغذائهم الاساسي نسبة ٥ و١٠ و١٥٪ من مسحوق درنات خرشوفة القدس. أظهرت النتائج أن التركيب الكيميائي لمسحوق درنات خرشوفة القدس يحتوي على٧,٤٠ و٨,٢١ و ١,٠٧ و ٥,٣٨ و ٦,١٥ و ٧١,٧٩٪ للرطوبة والبروتين والدهون والرماد والألياف والكربوهيدرات علي التوالي، بينما سجلت السعرات الحرارية ٣٢٩,٦٣كيلو كالوري/١٠٠جم، وقد بلغت قيمة مضادات الأكسدة ٢٤٨٢,٥ ملجم/١٠٠جم، كما وجد ان مسحوق درنات خرشوفة القدس خالي من السمية. أسفرت نتائج الدراسة عن ارتفاع مستوي سكر الدم و مستوى دهنيات الدم (الكوليسترول، الجلسريدات الثلاثية وكوليستيرول البروتينات الدهنية المنخفضة و منخفضة الكثافة جدًا) ومستوي انزيمات الكبد ووظائف الكلى في المجموعة الضابطة المصابة بالسكر، بينما انخفض مستوي كوليستيرول البروتينات الدهنية العالية الكثافة و مضادات الاكسدة الانزيمية. وقد أظهرت المعاملات المعالجة بالمستويات المختلفة من مسحوق درنات خرشوفة القدس تحسنًا تدريجيًا في

مستويات التقديرات السابقة عند مقارنتها بالمجموعة الضابطة المصابة بالسكر، سُجل التحسن الأكثر وضوحاً في المجموعة المعالجة بنسبة ١٥٪. كما أوضحت نتائج الفحص الهستولوجي تحسناً تدريجياً في أنسجة كل من الكبد والكلي لدي كافة المجموعات المعالجة. تم عمل مقرمشات بالنسب ٥ و١٠ و١٥٪ ، أظهرت نتائج التقييم الحسي أن جميع عينات المقرمشات كانت مقبولة حيث حصلت على اجمالي درجات أعلي من ٧٥٪. أشارت الدراسة الي ان درنات خرشوفة القدس ذات تأثير فعال في خفض سكر الدم وتقليل مضاعفاته لدي الفئران المصابة بمرض السكر، وبذلك يمكن استخدامها كمكمل في النظام الغذائي لمرضى السكري.

الكلمات المفتاحية: درنات خرشوفة القدس - مقرمشات - ارتفاع السكر في الدم - انزيمات الكبد - دهنيات الدم - مضادة الأكسدة الانزيمية.