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Effect of Egyptian Date Palm Pollen (*Phoenix dactylifera L.*) and Its Hydroethanolic Extracts on Serum Glucose and Lipid Profiles in Induced Diabetic Rats

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Abstract

Diabetes is a major health global problem that has reached alarming levels. The present study aims for studying the effect of date palm pollen (*Phoenix dactylifera L.*) El-Hayani cultivar on serum glucose and lipids profile in induced diabetic male albino rats. Palm pollen chemically analyzed besides chemical constituents, mineral contents, polyphenols and flavonoids. Male Albino rats (36 rats weight 170 - 190 gm) were divided into 6 groups. 1: Normal control (−), 2: Alloxanized diabetes control (+) (150 mg/Kg rat body weight). Diabetic groups 3 and 4 had 0.5%, 1.0% date palm pollen, respectively, also diabetic groups 5 and 6 had 100 ppm, 200 ppm date palm pollen extract, respectively. At the end of the experiment (4 weeks) rats were fasted overnight and anesthetized and blood samples were taken for analysis of serum glucose, lipids profile and renal-hepatic function parameters, relative organ weight data obtained are statistically analysis. Results showed that the major polyphenolic components were that e-vanillic acid (16.33 mg/100 g), pyrogallol (15.02 mg/100 g), epicatechin (11.04 mg/100 g), catechin (10.96 mg/100 g). While, date palm pollen was rich in hesperidin (8.84 mg/100 g), Kaempferol 3,2 p-coumaroyl glucose (6.92 mg/100 g), hesperitin (5.10 mg/100 g), rutin (3.11mg/100 g) as flavonoids components. Date palm pollen has high content of protein, calcium and iron (30.87 g/100 g, 510.82 and 236.50 mg/100 g), respectively. Also, serum glucose decreased significantly in diabetic groups (3, 4, 5 and 6, respectively) (179.47, 137.80, 156.77, 145.47 mg/100 mL, respectively). Lipids profile, renal and liver functions were improved significantly ($P < 0.05$) in diabetic groups which had date palm pollen or its extracts. It is concluded that the dried date palm pollen 1% in the diet

and 200 ppm extract are more effective compared with controlling diabetes mellitus, also improve renal and liver functions. Diabetics are advised to eat date palm pollen and are considered treatment foods for Diabetes Mellitus.

Keywords

Date Palm Pollen, Polyphenols, Flavonoids, Diabetes Mellitus, Serum Glucose, Lipids Profile

1. Introduction

Diabetes mellitus (DM) is considered a metabolic disorder which has a huge economic and physiological burden all over the world, and causes different acute and chronic complications ranged from frequent urination, increased hunger and thirst to serious problems such as diabetic ketoacidosis, cardiovascular disease, kidney disorders, foot ulcers, eye damages and finally death [1].

The global diabetes prevalence in 2019 is appreciated to be 9.3% (463 million people), rising to 10.2% (578 million) by 2030 and 10.9% (700 million) by 2045. The prevalence is higher in urban (10.8%) than in rural (7.2%) areas, and in high-income (10.4%) than low-income countries (4.0%). One in two (50.1%) people living with diabetes do not know that they have diabetes. The global prevalence of impaired glucose tolerance is projected to be 7.5% (374 million) in 2019 and projected to reach 8.0% (454 million) by 2030 and 8.6% (548 million) by 2045 [2].

Much attention has been paid to health promotion related to photochemical activity, and the isolation of novel bioactive phytochemicals which derived from special medicinal plants in the past few years. Date palm (*Phoenix dactylifera L.*) is one of the most important fruit crops in the Middle East and North Africa that produce edible and delicious dates. Date palms are spread across Iraq, Iran, Saudi Arabia, Egypt, Tunisia, Algeria, Libya, United Arab Emirates (UAE), Bahrain, and Oman [3].

Date palm pollen is a natural product produced from male palm flowers and consists of 36% crude protein, crude fiber 8.81%, crude fat 11.80%, ash 9.26% and carbohydrate 17.11%. While minerals content of Ca, K, Mg, Fe, Zn, Mn was 530, 760, 310, 225, 125, 310 mg/100 g, respectively [4].

Date palm pollen (DPP) (*Phoenix dactylifera L.*), belongs to the Aceraceae family, is widely cultivated in Egypt and is considered the male reproductive cells of palm flowers and commonly used in the Middle East, the ancient Chinese and Egyptians used palm pollen as a medicinal agent. It is considered as an effective natural and functional dietary food supplement due to its remarkable contents of protein, vitamins, minerals, trace elements, carbohydrates, lipids, organic acids, sterols, nucleic acids, enzymes and cofactors. Besides bioactive volatile unsaturated fatty acid and phenolic components, such as flavonoids, phenolic acids, which play a crucial role as strong antioxidant, anti-breast-cancer [5].

The research aims to evaluate date palm pollen as a natural hypo-diabetic

agent.

2. Materials and Methods

2.1. Materials

Plant

Date palm pollen of Egyptian date palm (*Phoenix dactylifera L.*), El-Hayani cultivar was bought as powder at the end of March 2020 from Agricultural Research center, Giza, Egypt. One kg in transparence plastic bag and was kept refrigerated at 4˚C.

Basal Diet (Reeves *et al.*, 1993) [6]

1) Corn oil and starch were purchased from the local market.

2) Casein, cholesterol, cellulose, vitamin mixtures, mineral mixtures were purchased from El-Gomhouria Pharmaceutical Company, Cairo, Egypt.

Kits for chemical analysis

To determine serum glucose, cholesterol (T.C), triglycerides (T.G), high density lipoprotein (HDL), low density lipoprotein (LDL) and alloxan were purchased from Sigma chemical company.

2.2. Methods

2.2.1. Chemical Constituents of Date Palm Pollen

Moisture, ash, total protein, total lipid, crude fiber and contents were determined according to A.O.A.C [7]. While, total carbohydrate calculated by difference.

2.2.2. Determination of Minerals Content in Date Palm Pollen

Minerals content were determined using Atomic Absorption Spectroscopy as described in A.O.A.C [7] and pH values were measured by using Beckman pH meter with glass electrode at 25˚C.

2.2.3. Extraction Preparation of Date Palm Pollen

Extract was prepared from fresh date palm pollen (var. El-Hayani). (50 g) as dry matter was extracted by 100 ml ethanol (70%). Each hydroethanolic extract was filtrated then evaporated by using a rotary vacuum evaporator at 45˚C. The extract was kept at 4˚C until used [8].

2.2.4. Experimental Animals

Thirty-six male albino rats (Sprague Dawley strain) weighing an average between (170 - 190 g) from Animal House, Food Technology Research Institute-Agriculture Research Center-Giza.

Rats were kept under normal healthy conditions and fed on the basal diet [6] without any treatment for one week before the experiments for adaption to laboratory conditions, all practical parts are applied in agriculture research center, Giza, Cairo, Egypt.

2.2.5. Induction of Diabetes

Rats (30) were injected with alloxan (150 mg/Kg body weight) according to [9];

all rats were fed on basal diet three days, fasting blood was measured [10].

2.2.6. Experimental Design

- **The first group:** (6) control (−) group (normal) fed on basal diet only.
- **The second group:** (6) Diabetic control (+) group fed on basal diet only.
- **The third group:** (6) Diabetic rats fed on basal diet + 0.5% date palm pollen.
- **The fourth group:** (6) Diabetic rats fed on basal diet + 1% date palm pollen.
- **The fifth group:** (6) Diabetic rats fed on basal diet + 100 ppm date palm pollen hydroethanolic extract, orally.
- **The sixth group**: (6) Diabetic rats fed on basal diet + 200 ppm date palm pollen hydroethanolic extract, orally.

The experimental period (4 weeks), rats were individually weighted at the beginning, and 10 days. Each hydroethanolic extract fed on orally (3 ml extract/day for each rat). At the end (30 Days) of the experiment period, body weight gain % (BWG%), feed intake (FI) and feed efficiency ratio (FER) were calculated.

2.2.7. Collection of Blood Samples

At the end of the experiment (after 4 weeks), rats were anaesthetized with light ether and sacrificed by decapitation after an overnight fast, and the blood from each rat were withdrawn from the hepatic portal vein was collected in heparinized tubes. The blood samples were centrifuged for 10 minutes at 3000 rpm to separate the serum (under conditional lab temperature 20˚C ± 2˚C). The serum was carefully separated into dry clean Wassermann tubes by using a Pasteur pipette and kept frozen till analysis at −20˚C.

2.2.8. Serum Analysis

1) Determination of serum glucose

Serum glucose was determined according to Tietz [11].

2) Lipids Profile

Serum samples were used for the determination of total cholesterol and triglycerides according to the methods described by Allain *et al.* [12]. HDL-C and LDL-C were determined in the serum according to the methods described by Lopes–Virella *et al.* [13] and Wieland and Seidel [14], and Very low-density lipoprotein (VLDL-C) was calculated according to formula

$$\text{VLDL} = \text{Triglycerides}/5 \text{ DeLong } et\ al. \text{ [15].}$$

$$\text{While LDL-C} = \text{Total Cholesterol} - [(\text{vLDL-C}) + (\text{HDL-C})] \text{ [14].}$$

3) Hepatic functions

Aspartate amine transaminase (AST), Alanine amine transaminases (ALT), and Alkaline phosphates (ALP) were measured according to the method described by Tietz *et al.* [16].

4) Renal functions

Uric acid was determined in the serum according to the method described by Fossati *et al.* [17]. Urea nitrogen and Creatinine were determined according to Young [18].

2.2.9. Statistical Analysis

Results are expressed as the mean standard deviation ± SD. Data were statistically analyzed for variance "ANOVA" test at ($P \leq 0.05$) [19], using SPSS statistical software, version 13.0 was used for these calculations.

3. Results and Discussion

3.1. Chemical Constituents (g/100 g) and Mineral Contents (mg/100 g) of Date Palm Pollen (on Dry Weight Basis)

Date palm pollen was analyzed for their constituents of moisture, ash, crude fiber, crude fat, crude protein and carbohydrate. The obtained data are given in Table 1 indicated that moisture content of palm pollen grains was 21.16%. This value was nearly matched with (20% - 30%) [20], and less than (28% - 29%) [21].

The present study showed that lipids content, ash and crude fiber were 19.80, 5.06% and 1.86%, respectively. These values are comparable to those reported by [21] who found that the ash of pollen ranged from 4% - 6%, Crude fiber content of pollen ranges from 1% - 2% and lipids content ranges from 20% - 31%, and nearly matched with 0.11% crude fiber and 5.58% ash contents [22]. Crude protein and Carbohydrate content of palm pollen showed 30.87% and 16.73%. This value nearly matched with (31.11% and 13.41%), respectively [23] and (36.28 and 17.14 g/100 g), respectively [5].

The mineral components of date palm pollen were shown in Table 1. The obtained results revealed that palm pollen constitute a rich source of mineral elements. The predominant minerals were potassium 740.5 mg/g, followed by calcium 510.82 mg/g, magnesium 196.65 mg/g and iron 236.50 mg/g. Date palm pollen also contains useful content of zinc 224.45 mg/g, manganese 170.00 mg/g.

Table 1. Chemical Constituents (g/100 g) and Mineral Contents (mg/100 g dry weight) of fresh Date Palm Pollen.

Chemical Constituents	g/100 g
Moisture	21.16
Total carbohydrate	16.73
Total sugars	4.52
Protein	30.87
Total lipids	19.80
Crude fiber	1.86
Ash	5.06
Mineral Contents	**mg/100 g**
Potassium (K)	740.50
Calcium (Ca)	510.82
Magnesium (Mg)	196.65
Iron (Fe)	236.50
Zinc (Zn)	224.45
Manganese (Mn)	170.00

3.2. HPLC Analysis of Polyphenols Compounds and Flavonoid Compounds (mg/100 g) in Hydroethanolic Extract of Date Palm Pollen

Polyphenols are phytochemicals, meaning compounds found abundantly in natural plant food sources that have antioxidant properties [24]. There are over 8000 identified polyphenols found in food such as tea, wine, fruits, vegetables, and herbals. Polyphenols play an important role in maintaining your health and wellness. Polyphenols are a hot topic among functional food proponents due to increasing evidence that they can impact your health in positive ways [25]. Results in **Table 2** indicated the polyphenols content in date palm pollen, which showed that e-vanillic acid (16.33/100 g), pyrogallol (15.02 mg/100 g), epicatechin (11.04 mg/100 g), catechin (10.96 mg/100 g). On the other hand, the results are recorded that vanillic acid (8.04 mg/100 g), protocatechuic acid (7.25 mg/100 g), ellagic acid (5.84 mg/100 g) and ferulic (3.78 mg/100 g). The results are parallel

Table 2. HPLC Analysis of Polyphenols Compounds and Flavonoid Compounds (mg/100 g) in Hydroethanolic Extract of Date Palm Pollen.

Polyphenols compounds	(mg/100 g)	Flavonoid compounds	(mg/100 g)
Gallic acid	2.15	Rutin	3.11
Catechein	10.96	Naringenin	1.03
Pyrogallol	15.02	Hesperidin	8.84
Catechol	3.13	Quercetrin	2.16
Epicatechein	11.04	Apigenin	1.07
Vanillic acid	8.04	Kaempferol	0.35
Caffeine	1.99	Luteoline-6-arabinose-8-glucose	11.22
Salycilic acid	2.62	Luteoline-6-glucose-8-arabinose	2.32
Ferulic acid	3.78	Narengin	1.14
Iso-ferulic acid	1.98	Apigenin-6-arabinose-8-galactose	6.69
Cinnamic acid	0.46	Apigenin-6-rhamnose-8-glucose	1.06
e-vanillic acid	16.33	Apigenin-6-glucose-8-rhamnose	1.98
4-Amino-benzoic acid	2.37	Quercetin	2.15
Protocatechuic acid	7.25	Luteoline-7-glucose	3.76
Chlorogenic acid	2.18	Quercetin-3-O-glucoside	1.97
Ellagic acid	5.84	Rhamnetin	1.21
Caffeic acid	2.27	Apigenin-7-O-neohespiroside	1.31
ρ-coumaric acid	4.08	Kaempferol-3,7 dirhamoside	1.06
α-coumaric acid	3.26	Kaempferol 3,2 p-coumaroyl glucose	6.92
Reversetrol	1.05	Apigenin-7-O-glucose	1.41
3,4,5-methoxy-cinnamic acid	1.59	Rosmarinic	0.95
Coumarin	0.88	Hesperitin	5.10

with data obtained by [26]. The antioxidant activity of the polyphenols compounds is related to the presence of a hydroxyl group that donates protons to free radicals and removes them. It was previously reported that epicatechin, vanillic, coumarin and caffeic acid have a significant potential of antioxidant activity [8].

Flavonoids are a diverse group of phytonutrients (plant chemicals) naturally occurring in plants [27]. Flavonoids are the largest group of phytonutrients, with more than 6000 species. Some of the most common flavonoids are hesperitin, quercetin and kaempferol [28]. Being nature's antioxidants flavonoids have been shown to reduce the damages induced by oxidative stress in cells. Besides being an antioxidant, flavonoids are demonstrated to have anti-infective properties (antiviral, antifungal, anti-angiogenic, anti-tumorigenic, and immunomodulatory bio-properties) [29].

Data in the Table 2 showed that date palm pollen contained high amounts of the flavonoids such as hesperidin (8.84 mg/100 g), Kaempferol 3,2 p-coumaroyl glucose (6.92 mg/100 g), hesperitin (5.10 mg/100 g), rutin (3.11mg/100 g), quercitrin (2.15 mg/100 g), narengin (1.14 mg/100 g), apigenin (1.07 mg/100 g), narengenin (1.03 mg/100 g) and recorded that contained rosmarinic (0.95 mg/100 g), and kampherol (0.35 mg/100 g). These results were in agreement with what previously reported by [26] who worked on similar compounds inethanol extracts of date palm pollen. Date Palm pollen contained high amount of rutin, also isorhamnetin-3-Oglucoside, Apigenin, Luteolin-7-O-glucoside and Naringin with estradiol, estriol, estrone were determined [30].

3.3. The Effect of Different Ratio of Date Palm Pollen and its Hydroethanolic Extracts on Serum Glucose

Diabetic groups showed a significant ($p < 0.01$) increased in serum glucose after injection with alloxan compared to normal group (control −). Data in Table 3 showed that glucose level began to decline after 10 days of supplemented with date palm pollen and its extracts. Serum glucose was decreased when rats fed on

Table 3. Effect of different ratio of Date Palm Pollen and its Hydroethanolic Extracts on Serum Glucose (mg/100 ml).

Groups		Zero Time	After 10 days	After 20 days	After 30 days
		Mean ± SD	Mean ± SD	Mean ± SD	Mean ± SD
Negative control group (−)		$98.83^{c} \pm 0.63$	$96.27^{e} \pm 0.47$	$88.63^{e} \pm 0.47$	$88.57^{f} \pm 0.63$
Diabetic control group (+)		$257.00^{a} \pm 3.95$	$246.83^{a} \pm 3.77$	$229.67^{a} \pm 0.57$	$189.87^{a} \pm 2.87$
Date Palm Pollen (Fresh)	0.5%	$253.67^{ab} \pm 6.70$	$241.67^{b} \pm 1.32$	$224.43^{b} \pm 0.52$	$179.47^{b} \pm 0.84$
	1%	$251.17^{b} \pm 5.14$	$232.80^{d} \pm 1.08$	$192.70^{d} \pm 1.40$	$137.80^{e} \pm 0.70$
Date Palm Pollen (Extract)	100 ppm	$258.67^{a} \pm 1.59$	$244.60^{a} \pm 2.83$	$224.17^{b} \pm 1.68$	$156.77^{c} \pm 1.09$
	200 ppm	$254.67^{ab} \pm 2.22$	$236.40^{c} \pm 1.11$	$219.87^{c} \pm 1.03$	$145.47^{d} \pm 0.57$
F		1546.224	4728.366	16,105.984	4096.169
Sig.		0.000	0.000	0.000	0.000

date palm pollen extract 200 ppm from 254.67 ± 2.22 to 236.40 ± 1.11 and also reduced when using other ratios. Results also recorded that, all supplemented groups which treated with different ratio of date palm pollen and its extracts decreased the levels of serum glucose significantly ($p < 0.05$), as compared to the diabetic group (control +). Data in Table 3 and Figure 1 refers to a decline in the proportion of serum glucose after 20 days, the result was 192.70 ± 1.40 in diet containing date palm pollen 1%.

After 30 days (Final glucose) was 179.47 ± 0.84 in diet containing date palm pollen 0.5%, 137.80 ± 0.70 in diet containing date palm pollen 1%, 156.77 ± 1.09 in diet containing date palm pollen extract 100 ppm, orally and 145.47 ± 0.57 in diet containing date palm pollen extract Table 5. 200 ppm, orally, respectively.

The normoglycemic effect of date palm pollen may be due to its minerals, polyphenols and phytoestrogens constituents. Minerals that are present in palm pollen play an important role in diabetes mellitus management such as magnesium which plays an essential role in regulation of insulin action and insulin-mediated-glucose uptake. Zinc stimulates the insulin formation and release, while chromium Strengthens the insulin action, and selenium, which has been shown to induce glucose uptake, regulates glycolysis and pentose phosphate pathways. Also, the same author added, polyphenols compounds found in date palm pollen are considered to be a strong inhibitor of alpha glycosidase and alpha amylase, leading to reduction of carbohydrates digestion and absorption that may combat the hyperglycemia present in diabetes mellitus [31].

The antidiabetic effect of date palm pollen through elevated plasma insulin with normalization of plasma glucose, triacylglycerol, and cholesterol in alloxan-induced diabetes rats. It is important to investigate the true cause of increased plasma insulin, if this results to increase in the efficiency of healthy

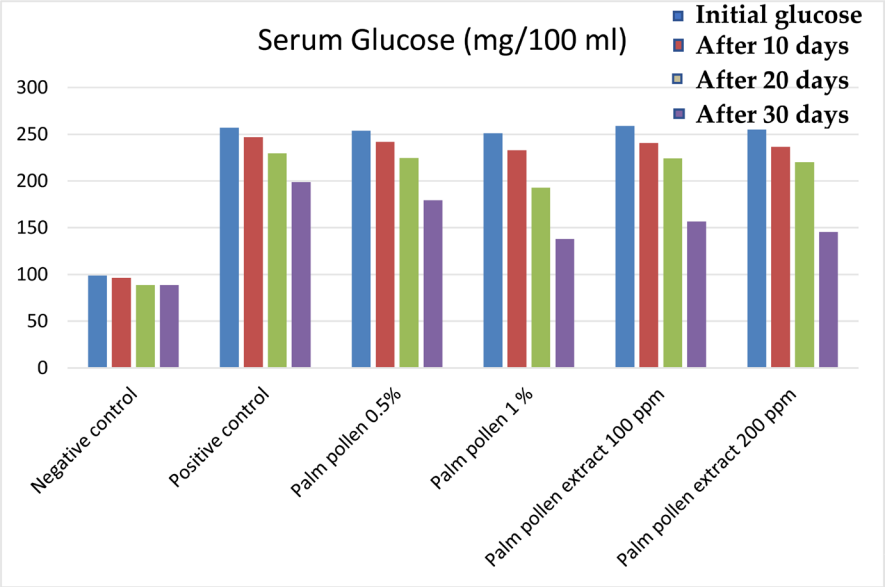

Figure 1. Effect of different ratio of date palm pollen and its Hydroethanolic extracts on serum glucose of diabetic rats.

β-cells or due to the regeneration of alloxan-injured cells. One of the antihyperglycemic effects of palm pollen is the inhibition of either *α*-glucosidase and *α*-amylase *in vitro* potentially which may delay the digestion and absorption of carbohydrates leading to normalization of plasma glucose levels [32].

3.4. Effect of Date Palm Pollen and its Hydroethanolic Extracts at Different ratio on Serum Lipids Profile of Diabetic Rats

Table 4 and Figure 2 illustrate the effect of different ratio of date palm pollen and its extracts on serum cholesterol and triglyceride (mg/100 mL) of diabetic rats. Results showed significant increase in total serum cholesterol and triglyceride of diabetic group (control +) than normal group (control −) (98.50 ± 0.56 mg/dl and 96.83 ± 0.57 mg/100 mL) vs. (83.93 ± 1.21 mg/100 mL and 87.10 ± 0.76 mg/100 mL), respectively. After supplemented diabetic groups with different concentration of date palm pollen and its extracts induced significant decrease ($p < 0.05$) in total serum cholesterol and triglyceride as compared to diabetic group (control +).

The total serum cholesterol and triglycerides have been decreased significantly with the increasing concentrate of date palm pollen. Diabetic group supplemented with date palm pollen 1% showed significant decrease ($p < 0.05$), as compared to diabetic group which supplemented with 0.5%, and supplemented group with date palm pollen extract 200 ppm showed significant decrease ($p < 0.05$), as compared to diabetic group fed on date palm pollen 100 ppm extract, orally.

The effect of different ratio of date palm pollen and its extracts on high density lipoprotein (HDL-c), low density lipoprotein (LDL-c) and very low-density lipoprotein (VLDL-c) are presented in Table 5 and Figure 2. The mean value of HDL-c of diabetic group (control +) showed significant decrease ($p < 0.05$), compared to normal group (control −). Diabetic groups supplemented with palm pollen and its extracts increased levels of HDL-c significantly ($p < 0.05$),

Table 4. Effect of Date Palm Pollen and its Hydroethanolic Extracts at Different ratio on Serum Cholesterol and Triglyceride of Diabetic Rats (mg/100 ml).

Groups		Total cholesterol (mg/100 ml)	Triglycerides (mg/100 ml)	Total lipid (mg/100 ml)
6 rats/group		Mean ± SD	Mean ± SD	Mean ± SD
Negative control group (−)		$83.93^{e} \pm 1.21$	$87.10^{d} \pm 0.76$	$171.03^{e} \pm 1.15$
Diabetic control group (+)		$98.50^{a} \pm 0.56$	$96.83^{a} \pm 0.57$	$195.33^{a} \pm 1.02$
Date Palm Pollen (Fresh)	0.5%	$93.67^{b} \pm 0.84$	$92.50^{b} \pm 0.39$	$186.17^{b} \pm 1.17$
	1%	$84.53^{e} \pm 0.41$	$87.17^{d} \pm 0.46$	$171.71^{e} \pm 0.63$
Date Palm Pollen(Extract)	100 ppm	$88.87^{c} \pm 0.90$	$92.47^{b} \pm 0.35$	$181.34^{c} \pm 0.95$
	200 ppm	$85.60^{d} \pm 0.50$	$90.70^{c} \pm 0.52$	$176.30^{d} \pm 0.99$
F		327.030	295.658	525.327
Sig.		0.000	0.000	0.000

Table 5. Effect of Date Palm Pollen and its Hydroethanolic Extracts at Different ratio on Serum Lipoprotein Fractions of Diabetic Rats (mg/100 ml).

Groups		HDL (mg/100 ml)	LDL (mg/100 ml)	vLDL (mg/100 ml)
		Mean ± SD	Mean ± SD	Mean ± SD
Negative control group (−)		$75.53^{a} \pm 0.52$	$69.90^{b} \pm 0.55$	$17.42^{d} \pm 0.15$
Diabetic control group (+)		$58.60^{e} \pm 0.41$	$74.60^{a} \pm 0.51$	$19.37^{a} \pm 0.11$
Date Palm Pollen (Fresh)	0.5%	$66.67^{c} \pm 0.45$	$69.93^{b} \pm 0.74$	$18.50^{b} \pm 0.08$
	1%	$70.07^{b} \pm 0.57$	$62.17^{d} \pm 0.62$	$17.43^{d} \pm 0.09$
Date Palm Pollen(Extract)	100 ppm	$64.52^{d} \pm 0.45$	$70.23^{b} \pm 0.60$	$18.49^{b} \pm 0.07$
	200 ppm	$69.70^{b} \pm 0.44$	$65.10^{c} \pm 0.62$	$18.14^{c} \pm 0.10$
F		870.795	307.783	297.786
Sig.		0.000	0.000	0.000

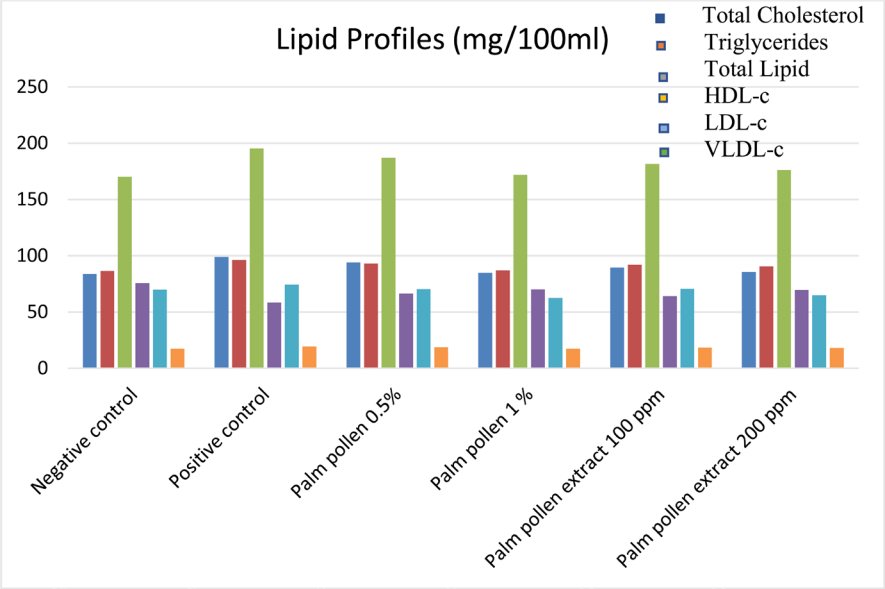

Figure 2. Effect of different ratio of Date Palm Pollen and its Hydroethanolic Extracts on Serum Lipid Profiles of Diabetic Rats.

As compared to diabetic group (control +). Diabetic group supplemented with date palm pollen 1% led to increase HDL-c, more than those supplemented with 0.5%, and diabetic group which supplemented with date palm pollen extract 200 ppm led to increase HDL-c, more than those treated with 100 ppm, orally.

Results showed that diabetic group (control +) recorded a significant increase in the mean value of serum LDL-c, as compared with normal group (control −). Serum LDL-c in diabetic groups supplemented with date palm pollen and its extracts decreased significantly ($p < 0.05$), as compared to diabetic group (control +). On the other hand, LDL-c in serum diabetic groups decreased with increasing the ratio of date palm pollen. Diabetic groups which treated with palm pollen 1% led to decrease LDL-c, more than those treated with 0.05%, and diabetic

groups which treated with date palm pollen extract 200 ppm, orally led to decrease LDL-c, more than those treated with 100 ppm. The diabetic group (control +). recorded significant increase in the mean value of serum VLDL-c, as compared to the control negative group (19.37 ± 0.11 vs. 17.42 ± 0.15), respectively. Serum VLDL-c in diabetic groups supplemented with date palm pollen and its extract decreased significantly ($p < 0.05$), as compared to (control +) group.

From all the above results we can conclude that date palm pollen and its hydroethanolic extract have hypolipidemic effects. The mechanism of hypolipidemic effects of date palm pollen may be due to its known constituents, such as phytosterols, polyunsaturated fatty acids (which decreased plasma total and LDL-c compared with saturated fatty acids). Also, fatty acids and sterols in date palm pollen may interfere with the cholesterol intestinal absorption [30].

3.5. Effect of Different Ratio of Date Palm Pollen and Its Extracts on Liver Function of Diabetic Rats

Data in Table 6 showed that, to diabetic group (control +) had significant increase ($p < 0.05$) in the mean value of Aspartate Amine Transferase and Alanine Amine Transferase (ALT and AST) compared with that of the (control-) group (31.30 ± 0.72 and 39.87 ± 0.63 vs. 26.70 ± 0.51 and 39.23 ± 0.54 IU/L), respectively. From results of Table 6 it could be observed that, the dietary supplemented with date palm pollen and its extracts caused a significant decrease ($p < 0.05$) in the mean values of AST and ALT enzymes, as compared to diabetic group (control +). The highest decrease in AST and ALT enzymes was observed in supplemented group with date palm pollen 1%, while the lowest decrease was recorded in rats fed on date palm pollen extract 100 ppm, orally.

3.6. Effect of Different Ratio of Date Palm Pollen and Its Extracts on Kidney Function of Diabetic Rats

Table 7 showed the effect of different ratio of date palm pollen on serum uric

Table 6. .Effect of different ratio of Date Palm Pollen and its Hydroethanolic Extracts on Liver Function of Diabetic Rats (IU/L).

Groups		S.ALT (IU/L)	S.AST (IU/L)
		Mean ± SD	Mean ± SD
Negative control group (−)		26.70^{b} ± 0.51	39.23^{a} ± 0.54
Diabetic control group (+)		31.30^{a} ± 0.72	39.87^{a} ± 0.63
Date Palm Pollen (Fresh)	0.5%	22.53^{e} ± 0.54	27.37^{c} ± 0.57
	1%	22.17^{e} ± 0.36	23.27^{d} ± 0.52
Date Palm Pollen (Extract)	100 ppm	25.53^{c} ± 0.42	32.97^{b} ± 0.84
	200 ppm	24.93^{d} ± 0.26	33.27^{b} ± 0.55
F		277.835	669.035
Sig.		0.000	0.000

Table 7. Effect of different ratio of date palm pollen and its Hydroethanolic extracts on kidney function of diabetic rats.

Groups		Uric acid (mg/100 ml)	Creatinine (mg/100 ml)	Urea (mg/100 ml)
6 rats/group		Mean ± SD	Mean ± SD	Mean ± SD
Negative control group (−)		$2.28^{c} \pm 0.20$	$1.26^{b} \pm 0.15$	$35.04^{f} \pm 0.39$
Diabetic control group (+)		$3.04^{a} \pm 0.14$	$2.07^{a} \pm 0.06$	$48.55^{a} \pm 0.36$
Date Palm Pollen (Fresh)	0.5%	$2.70^{b} \pm 0.19$	$1.05^{c} \pm 0.04$	$42.30^{c} \pm 0.33$
	1%	$2.37^{c} \pm 0.29$	$1.04^{c} \pm 0.06$	$39.92^{e} \pm 0.24$
Date Palm Pollen (Extract)	100 ppm	$2.68^{b} \pm 0.20$	$1.10^{c} \pm 0.07$	$43.76^{b} \pm 0.14$
	200 ppm	$2.41^{c} \pm 0.21$	$1.09^{c} \pm 0.11$	$40.53^{d} \pm 0.44$
F		11.086	119.105	1091.340
Sig.		0.000	0.000	0.000

acid, creatinine and urea nitrogen (mg/dl) of diabetic rats.

Treating diabetic rats with date palm pollen and its hydroethanolic extracts resulted in significant decrease ($p < 0.05$), in serum uric acid as compared to diabetic group (control +). All treated groups with date palm pollen and its hydroethanolic extracts recorded significant increase ($p < 0.05$) in serum uric acid as compared to the control negative group (healthy rats). The least concentration of serum uric acid among all treated groups was (2.37 ± 0.29) observed in diabetic rats fed on basal diet and treated with date palm pollen 1%. All tested groups showed a significant decrease ($p < 0.05$), in serum urea nitrogen, as compared to the control positive group (diabetic rats). The least concentration of serum urea nitrogen among all treated groups was 39.92 ± 0.24 mg/100 ml observed in diabetic rats fed on basal diet and treated with date palm pollen 1%. Also, in Table 7 Treating diabetic rats with date palm pollen and its hydroethanolic extracts resulted in significant decrease ($p < 0.05$), in serum creatinine as compared to diabetic group (control +).

The nephroprotective activity of date palm pollen has demonstrated that the protective effect of palm pollen against various nephrotoxicity may be due to the polyphenols and antioxidant vitamins content present in date palm pollen [31].

4. Conclusion

The results of the present study showed that date palm pollen and its extracts had a hypoglycemic effect in alloxan induced diabetic rats which may be due to phytochemical contents in date palm pollen as polyphenols, flavonoids and minerals contents. In addition, they were highly effective in managing diabetes mellitus complications such as hyperlipidemia and weight loss. The antidiabetic effects of date palm pollen and its hydroethanolic extracts may be mediated by increasing insulin secretion, stimulating glucose uptake and glycogen synthesis by cells, and protection of pancreatic β-cells from alloxan- and glucose-induced

oxidative stress.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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