Potential Effects of Lemon Peel and Sidr Leaves in Streptozotocin-Induced Diabetic Rats and Quality Evaluation of Fortified Cupcakes

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Potential Effects of Lemon Peel and Sidr Leaves in Streptozotocin-Induced Diabetic Rats and Quality Evaluation of Fortified Cupcakes

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Abstract

Current study investigated to clarify the potential hypoglycemic effect of adding dry lemon Citrus limon peel, Sidr Ziziphus spina christi leaves and their mixture on rats with hyperglycemia and to evaluate the quality attributes of cupcakes enriched with lemon peel, sidr leaves and their mixture. A total of thirty five (35) male albino rats; Sprague-Dawley Strain were used; the rats were divided into two main groups, (1) the negative control (first group 7 rats), and the second represented diabetic rats (28 rats) which subjected to intraperitoneal injection with Streptozotocin to induce hyperglycemia and then sub divided into 4 groups (each 7 rats) as follows: (2) positive control group fed on standard diet, (3) 5% Sidr Leaves group, (4) 5% lemon peel group and (5) mixture of 5% Lemon peel+ 5 % Sidr leaves group. By the end of study (4weeks) Results showed that, positive control group had the highest levels of blood glucose, glycated hemoglobin, HOMA-IR, serum triglycerides, total cholesterol and MDA compared with negative control. Feeding on lemon peel, Sidr leaves and their mixture had a beneficial effects on blood glucose, glycated hemoglobin, HOMA-IR and lipid profile with elevation of serum total antioxidants and immunoglobin productions and decrements of MDA, diet supplemented with lemon peel, Sidr leaves or their mixture had a protective effects on renal functions as evident by decrements of serum urea and creatinine. Quality attributes of cupcakes enriched with mixture of 5% Lemon peel+ 5 % Sidr leaves; followed by 5% lemon peel showed the higher acceptability score by panelists compared to control sample. The results indicated the potential positive impact of lemon peel and Sidr leaves in controlling negative effects of hyperglycemia.

Key words: Lemon peel, Sidr, hyperglycemia, lipid profile and renal functions.

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Introduction:

Diabetes mellitus (DM) affects varied body organs leading to many harmful health consequences; and in accordance with the World Health Organization **(WHO, 2004),** DM considered as one of the ten foremost universal causes of deaths.

Vegetables and fruit of Plant kingdom are rich sources of varied metabolites, and they contain many bioactive phytochemicals. Phenolic compounds, flavonoids, Alkaloids, glycosides, and saponins (**Devanooru *et al.*, 2015).** Lemon *Citruss Limon* production in Egypt considered as high yielding crop which processed into variety of products; and the peel of Lemon are rarely used in food manufacturing; and a huge amount of food waste yields each year putting heavy burden on local environment, meanwhile the lemon peels are rich sources of many bioactive compounds including polyphenols among other bioactive constituents. **Gao *et al.*, (2021)** stated that, in lemon peel the flavonoids are considered as the most important bioactive compounds that might be utilized as natural sources that have no adverse effects.

Sidr Tree *Ziziphus spina-christi* is a fruit tree with distinctive uniqueness and values. It is considered as an excellent source of a variety of bioactive compounds, which aid in liver protection and improvement of the antioxidant enzyme actions among other beneficial health effects **(Brodowska, 2017).** Sidr leaves are good source of antioxidants including flavonoids, polyphenols, saponins, triterpenoids, and tannins, **(Rialdi *et al.*, 2023).**

This study aims to investigate the potential hypoglycemic effect of adding dry lemon *Citrus limon* peel, Sidr *Ziziphus spina christi* leaves and their mixture on Streptozotocin (STZ) induced diabetic rats and to evaluate the quality attributes of of cupcakes enriched with lemon peel, sidr leaves and their mixture.

Material and Methods:

Materials

Lemon fruits and leaves of Sidr were obtained from Agriculture research center, institute of horticulture research, Cairo, Egypt. The Streptozotocin and biochemical Kits were obtained from Gamma Trade Co., Egypt. Gallic acid, quercetin dihydrate and Folin-Ciocalteu phenol reagent were supplied by Sigma-Aldrich. Dietary ingredients: DL-Methionine, cellulose, casein, and powdered choline chloride were acquired from Morgan Co. in Cairo, Egypt.

Preparation of Lemon peels and leaves of Sidr Powder:

Lemons were washed under running water, a peeler was then used, and the peels were equally distributed in drying trays and placed in a tray dryer that was set to 50 °C for 96 hours. Dried peels were further grounded into a powder using a grinder and sieved using a 250 μm mesh screen. The leaves of Sidr were dried at room temperature 96 hours and powdered by electric mixture. The resultant powder was placed in airtight bags and kept in dedicators for additional examination.

Total phenolic and flavonoids quantification:

Using the methods mentioned by **Singleton *et al.*, (1999)** and **Marinova *et al.*, (2005)** the total phenolic and flavonoids were determined, respectively.

Ethical approval

The scientific Research Ethics Committee (Animals Care and Use), Faculty of Women for Arts, Science and Education, Ain Shams University, Egypt, approved the study's biological experiments as ethically acceptable.

Biological Experimental

Animals

Induction of Diabetes Mellitus*:* hyperglycemia induced in rats by using an intra peritoneal injection (*i.p.*) with 60 mg streptozotocin / kg body weight (single dose) as mentioned by **Masiello *et al.*, (1998).** After 48 hours, blood samples were collected by retro-orbital method and glucose

levels in blood were estimated. Animals showed hyperglycemia (blood glucose levels >240 mg/dl) were assigned to the study **(OECD, 2001).**

Experimental design:

Thirty-five (35) male albino rats *Sprague-Dawley* Strain weighing (185+ 15g) were obtained from Vaccine and Immunity organization, Helwan, Egypt. the rats were divided into two main groups, (1) the first negative control group (7 rats), and the second main group represented diabetic rats (28 rats) which subjected to *i.p.* with Streptozotocin (60 mg/ kg body weight) to induce hyperglycemia and then distributed into 4 groups (each 7 rats) as follows: (2) positive control group fed on standard diet, (3) 5% Sidr Leaves group, (4) 5% lemon peel group and (5) mixture of 5% Lemon peel+ 5 % Sidr leaves group. All rats have free access to water and diet; rats were maintained at temperatures of 18-23 ^{o}C. In accord to **Reeves *et al.*, (1993)** the standard control diet was prepared. Diets of 5% Lemon peel, 5% Sidr leaves and mixture of 5% lemon peel+ 5% Sidr leaves groups were prepared by adding of dry lemon peel and Sidr leaves powder and their mixture at predetermined levels.

Blood sampling: All rat groups at the end of study were anesthetized and blood was collected. First part of the blood was collected in heparinized tube for the determination of blood glucose and glycated hemoglobin (HbA1c), and the remaining part was centrifuged to obtain serum which stored at -20° C till further analysis.

Biochemical analysis

Blood glucose and glycated hemoglobin (HbA1c) were estimated according to **Trinder (1969)**, and **Goldstein *et al.*, (1986),** respectively. The determination of insulin Hormone was carried out according to **Defronzo *et al.*, (1979).** Homeostatic model assessment for insulin resistance (HOMA-IR was computed as per **Caumo *et al.*, (2006)** following equation:

$$\text{HOMA-IR} = \frac{\text{fasting serum insulin} \quad \mathbf{X} \quad \text{fasting serum glucose}}{405}$$

The methods of **Draper *et al.*, (1993)** and **Miller *et al.*, (1993)** were used to determine Malondialdehyde (MDA) and Total Antioxidant Capacity (TAC), respectively. In accord to the method of **Lim *et al.*,** (1994) the Immunoglobulin was estimated. Serum triglycerides was determined as described in the method of **Fossati and Prencipe, (1982);** and the methods of **Allain *et al.*, (1974), and Burstein *et al.*, (1970)** were used for the determination of total cholesterol and HDL, respectively. The method of **Friedwald *et al.*, (1972)** was used to estimates LDL; and the VLDL was calculated (VLDL= TG/ 5). Procedural methods of **Searcy *et al.*, (1967), Caraway (1955),** and **Bohmer, (1971)** were applied to estimate serum urea, uric acid and creatinine, respectively.

For the evaluation of sensory quality attributes of cupcakes enriched with 5% lemon peel, 5% sidr leaves and mixture of 5% lemon peel+ 5% sidr leaves; the method of **Dubat, (2010)** was used to produce cupcakes with aforementioned levels of lemon peel and sidr leaves and their mixture. The backed products were cooled and submitted to panels in order to rate them for sensory quality attributes using hedonic scale as mentioned by **Moretti *et al.*, (2004).**

Statistical Analysis: Data were analyzed by using SPSS software (V.16), and analysis of variance (ANOVA) followed by Duncan's were applied, and the differences among groups were considered significant at $P \leq 0.05$ **(Snedecor and Cochran, 1967).**

Results and Discussion:

As shown in table (1) Total phenolic of lemon peel and Sidr leaves were 42.56+ 0.58 and 192.8+ 0.65 mg GAE/g DW respectively, where flavonoids in lemon peel and Sidr leaves were 34.16+ 0.84 and 46.42+ 0.80 mg QE/ g DW, respectively. **Barakat et al., (2024)** found that, Sidr powder had a total phenol content of 179.53 to 197.7 mg GAE/100 g DW. Also, the total flavonoids of Sidr powder ranged from 411.72 to 455.03 mg/100 g DW.

TABLE (1): TOTAL PHENOLIC AND TOTAL FLAVONOIDS CONTENTS IN LIMON PEEL AND SIDR LEAVES SAMPLES (MEAN± S.D).

	Total Phenolic mg GAE/ g DW	Flavonoids mg QE / g DW
Lemon Peel	42.56± 0.58^{b}	34.16± 0.84^{b}
Sidr Leaves	192.8± 0.65^{a}	46.42± 0.80^{a}

Means within the same column having different letters were significantly differed at $P \leq 0.05$.

Table (2) illustrated that, streptozotocin induced diabetic rats (positive control group) showed significantly highest levels of fasting blood glucose (301.53± 17.26 mg/ dl), glycated hemoglobin (9.27± 0.50 %) and HOMA-IR (5.20 ±0.85) and significantly lowered serum Insulin (6.99 ±0.72 **µ**IU/ml) in comparison with that of negative control group values. Adding of 5% lemon peel to the diet of diabetic rats effectively and significantly decreased blood glucose (118.94 ± 1.11), HBA1c (4.07 ±0.16 %) and HOMA-IR (2.24±0.14) with significant increments of Insulin (7.63 ±0.85), followed by diet containing 5% Sidr leaves which resulted in a significant reductions of blood glucose(133.85± 5.53 mg/ dl), HBA1c (4.59± 0.23 %), HOMA-IR (2.35 ±0.19) and significant increments of Insulin (7.12±0.64) compared to that of positive control group. The mixture of lemon peel and sidr leaves group had a significantly lowered level of blood glucose followed by group of 5% lemon peel and group of 5% Sidr leaves.

Table (2): Mean blood glucose, HBA1c, fasting blood Insulin and HOMA-IR of rat's groups fed on lemon peel, Sidr leaves and their mixture (Mean+ S.E.)

	FBG mg/dl	HbA1c %	Insulin µ IU/ml	HOMA-IR
Negative control	88.09 ^{e} ± 3.19	2.97 ^{d} ±0.08	8.01 ^{a} ±1.11	1.74 ^{c} ±0.11
Positive control	301.53 ^{a} ± 17.26	9.27 ^{a} ±0.50	6.99 ^{c} ±0.72	5.20 ^{a} ±0.85
5% Lemon peel	118.94 ^{c} ± 1.11	4.07 ^{b} ±0.16	7.63 ^{b} ±0.85	2.24 ^{b} ±0.14
5% Sidr Leaves	133.85 ^{b} ± 5.53	4.59 ^{b} ±0.23	7.12 ^{b} ±0.64	2.35 ^{b} ±0.19
5% Lemon peel+ 5% Sidr leaves	105.23 ^{cd} ± 3.82	3.73 ^{c} ±0.25	7.91 ^{ab} ±0.87	2.06 ^{bc} ±0.16

Means within the same column having different letters were significantly differed at $P \leq 0.05$.

FBG, fasting blood glucose; HBA1c, glycated hemoglobin and

Naim *et al.*, (2012) illustrated that in diabetic rats, lemon peel polyphenols reduced glucose absorption and lowered blood glucose level through the inhibiting actions of polyphenols (hesperidin and eriocitrin) on α- amylase and α- glucosidase; the enzymes used in carbohydrate digestion. Where the results of **Lv *et al.*, (2018)** showed that treatment with lemon peel extract may alleviate Type 2 Diabetes (T2D) symptoms by restoring antioxidant activity. Moreover, **Alor and Chinko, (2022)** reported that, the anti-hyperglycemic effect of lemon peel could be due to its enhancements of glucose tolerance, reducing insulin resistance and increasing of blood antioxidants. These anti-hyperglycemic effects of *C. limon* were positively correlated with its flavonoids content especially hesperidin, hesperetin, naringin and naringenin **(Lv *et al.*, 2018).**

Saaty (2019) concluded that *Ziziphus spina-christi* extract possesses anti-diabetic activities among other positive health effects, which attributed to its antioxidant actions. **Ben Younes, *et al.*, (2018)** reported that flavonoids and tannins had an anti-diabetic effect; and **Khaleel *et al.*, (2020)** confirmed that, sidr leaves *Z. spina-christi* were rich sources of phenolic, flavonoids and alkaloids and tannins; these bioactive compounds may be attributed to the anti-hyperglycemia of sidr leaves. Results of **Abdel-Zaher *et al.*,(2005, and Hussein *et al.*, (2006), (Abdel-Zaher *et al.*, 2005, and Hussein *et al.*, 2006)** showed that, sidr leaves improved glucose metabolism and utilization as it stimulated the secretion of insulin and enhanced carbohydrate metabolism.

Streptozotocin induced diabetic rats fed on *Ziziphus spina-christi* leaves extract showed decrements of blood glucose, HBA1c level and increments of insulin level **(Michel *et al.*, 2011, Niamat *et al.*, 2012** and **Khaleel *et al.*, 2020)**; and that could be due to the saponin and polyphenols in *Ziziphus spina-chrsiti* leaves which were reported to be responsible for modifications in glucose metabolism and the significant increments of total antioxidant capacity as mentioned by **(Michel *et al.*, 2011)**.

Recently **Cao *et al.*, (2024)** illustrated that Saponins reduced blood glucose through increments of insulin secretion and decreasing insulin

resistance. **Goulas *et al.*, (2022)** showed that, 85% of plant samples from Mediterranean region showed anti-diabetic effects and that was due to their inhibitory effects on α- glucosidase and α- amylase, both of these enzymes were correlated to the postprandial hyperglycemia **(Wang *et al.*, 2010).** In addition, **Goulas *et al.*, (2022)** summarized the effects of flavonoids on hyperglycemia and linked their anti-diabetic effects with: (1) enhancement secretion of insulin or its sensitivity, (2) enhancing glucose utilization, and (3) enhancing lipid oxidation.

Table (3) illustrated that, streptozotocin induced diabetic rats (positive control group) showed significantly highest level of MDA (8.55± 0.84 nmol/ mL) and significantly lowered serum TAC (0.62 ± 0.04 mmol/ L), IgM (72.34 ±1.12mg/dL) and IgA (76.35 ±1.05mg/dL) in comparison with values of negative control rats group. On the other hand, adding lemon peel, Sidr leaves and their mixture to the diet of hyperglycemic rats effectively and significantly decreased MDA with significant increments of TAC, IgM and IgA when compared with the values of positive control group. However, the best result was showed in mixture group.

Table (3): Mean Serum MDA, TAC and immunoglobins of rat's groups fed on lemon peel, Sidr leaves and their mixture (Mean± S.E.)

	Serum MDA nmol/ mL	Serum TAC mmol/ L	IgM (mg/dL)	IgA (mg/dL)
Negative control	3.46 ^{d} ±0.41	1.52 ^{a} ±0.10	113.12 ^{a} ±٢.65	124.71 ^{a} ±٣.96
Positive control	8.55 ^{a} ±0.84	0.62 ^{c} ±0.04	72.34 ^{d} ±1.12	76.35^{d} ±1.05
5% Lemon peel	5.12 ^{b} ±0.19	1.07 ^{b} ±0.05	94.76 ^{b} ±1.14	102.87 ^{b} ±٢.72
5% Sidr Leaves	5.22 ^{b} ±0.23	0.99 ^{b} ±0.03	85.43 ^{c} ±1.05	90.95 ^{c} ±1.25
5% Lemon peel+ 5% Sidr leaves	4.10 ^{c} ±0.49	1.23 ^{a} ±0.08	99.96 ^{b} ±1.87	111.38^{b} ±٢.78

Means within the same column having different letters were significantly differed at $P \leq 0.05$.

Streptozotocin selectively destroys the pancreatic ß-cells, reduce their activity, and cause diabetes **(Szkudelski, 2001),** and the illustration of **Newsholme *et al.*, (2019)** demonstrated that, hyperglycemic resulted in

antioxidant imbalance by decreasing antioxidant level and increments of reactive oxygen species (ROS) production; which play a role in the dysfunction of the pancreatic β-cell and consequently increased resistance to insulin. **Papachristoforou *et al.*, (2022)** postulated that, hyperglycemia decreased body antioxidants through increments production of glycation endproducts (AGEs) which resulted in increment of insulin resistant and impairment of insulin secretion with accompanied oxidative stress. In addition, it was reported that lemon peel flavonoids (LPF) supplementation in mice enhanced the level of SOD and CAT activities with lowering of MDA **(Bao *et al.*, 2020).** Furthermore, **Gao *et al.*, (2021)** showed that, Lemon peel polyphenols (LPP) contains gallic, neochlorogenic, caffeic, isochlorogenic, rosmarinic and proto-catechuic acids, in addition to (+)-catechin, (-)-Catechin gallate; the treatment with LPP resulted in decrements of MDA with increments of SOD, Cat and GSH; which may attributed to the LPP protecting effect of cells. **Yao, *et al.*, (2022)** confirmed that, *Citrus lemon* considered as an excellent source of flavanone erioctrin, which effectively decreasing oxidative stress in hyperglycemia**. José *et al.*, (2017)** showed that diets enriched with dried lemon peel at 1.5% and 3% levels, for a period of 15 days; showed improved humoral (seric immunoglobulin M) and cellular (peroxidase activity) immunity. In adition, **Ramasamy *et al.*, (2020)** illustrated that, dried lemon peel enriched diets enhanced the rate of growth and the antioxidant status as well as immune related gene expression; and dietary polyphenols reduce inflammation **(Hira *et al.*, 2021).**

From table (4), it is clearly obvious that hyperglycemia negatively affect the lipid profile in hyperglycemic rats (positive control); as levels of TG (281.97 ± 3.14mg/ dl), Cholesterol (200.67 ± 3.11mg/ dl), and LDL (111.51 ± 2.01mg/ dl) were considerably increased compared to the values of negative control of 90.17 ± 1.57mg/ dl, 89.81 ± 1.50 mg/ dl, and 20.61 ± 1.75 mg/ dl, respectively. On the other hand group of rat fed on 5% lemon peel had significantly lower triglycerides, Cholesterol and LDL cholesterol levels (122.01± 2.28 mg/ dl, 113.^5 ± 2.14 mg/ dl and 47.07± 1.36 mg/ dl, respectively) compared with values of positive control group; the group fed

on 5% Sidr leaves as significant reduction of triglycerides, cholesterol and LDL cholesterol were 124.39± 2.10 mg/ dl, 117.71 ± 2.10 mg/ dl and 48.15± 1.49 mg/ dl, respectively, compared with values of positive control. The rats fed on mixture of 5% Lemon peel+ 5% Sidr leaves had the lowest TG levels (112.46± 2.09 mg/ dl) compared to the values of the positive control group. Serum cholesterol level in group of 5% lemon peel+5%Sidr leave (105.٩٣ ± 2.02 mg /dl) was significantly lower in comparison with positive control group value, while LDL cholesterol level reach 33.66± 1.88 mg/dl which is lower than that of positive control.

TABLE (4): MEAN SERUM TRIGLYCERIDES (TG), TOTAL CHOLESTEROL, VLDL, LDL AND HDL OF RAT'S GROUPS FED ON LEMON PEEL, SIDR LEAVES AND THEIR MIXTURE (MEAN± S.E.)

	TG mg/dl	Cholesterol mg/dl	VLDL mg/dl	LDL mg/dl	HDL mg/dl
Negative control	90.17 ^{d} ± 1.57	89.81 ^{d} ± 1.50	18.03^{d} ± 1.71	20.61 ^{d} ± 1.75	51.17 ^{a} ± 1.73
Positive control	281.97 ^{a} ± 3.14	200.67 ^{a} ± 3.11	56.39 ^{a}± 1.27	111.51^{a} ± 2.01	32.77 ^{c} ± 1.71
5% Lemon peel	122.01 ^{b} ± 2.28	113.٨5 ^{b} ± 2.14	24.40 ^{b} ± 1.36	47.07 ^{b}± 1.36	42.38 ^{b} ± 1.09
5% Sidr Leaves	124.39 ^{b} + 2.10	117.71 ^{b} ± 2.10	24.88 ^{b} ± 1.98	48.15 ^{b}± 1.49	44.76 ^{b} ± 1.66
5% Lemon peel+ 5% Sidr leaves	112.46 ^{c} ± 2.09	105.٩٣ ^{c} ± 2.02	22.49 ^{c} ± 1.88	33.66 ^{c} ± 1.88	49.78 ^{a} ± 1.25

Means within the same column having different letters were significantly differed at $P \leq 0.05$.

As shown in table (4), the effect of hyperglycemia on HDL in positive control diabetic rats; as level 32.77 ± 1.71 mg/ dl, was decreased compared to the value of negative control 51.17 ± 1.73 mg/ dl. While, the rats fed on mixture of 5% Lemon peel, 5% Sidr leaves, and their mixture had higher levels of HDL; and highest levels were observed in mixture of lemon peel and sidr leaves comparing to the levels observed in hyperglycemic positive control rats.

From results of a previous study, it was found that, levels of triglycerides and cholesterol were decreased when rats treated with lemon peel extract; and they attributed these effects to inhibition effects of D-

limonene on the activity of HMG-CoA reductase (cholesterol synthesis key enzyme); and further Hesperidin increases lipoprotein lipase activity and lemon peel pectin bind with cholesterol and preventing its absorption **(Kurniyati, 2021).** Additionally, Lemon peel flavonoids in particular, hesperidin was found to modulate the metabolism of lipids as **Liu *et al.*, (2023)** demonstrated that, Hesperidin Methyl Chalcone (HMC) enhanced the activity lipolysis enzyme namely lipase; and prevented the liver from fat accumulation.

Khaleel *et al.*, (2020) rported that**,** extract of *Ziziphus* significantly decreased triglycerides in diabetic rats, showing that Sidr leaves may have lowering effects on blood lipid in diabetic rats. Furthermore, **Al Ameri *et al.*, (2024)** illustrated that, the extract of *Z.Spina Christi* leaves have lowering effects on total cholesterol and low density; and that might be due to its saponins and flavonoids content; which have a hypolipidemic effects in hyperlipidemic rats as indicated by **Zhang *et al.*, (2004).** In addition, **Cao *et al.*, (2024)** reported that saponins bind with cholesterol and increase its excretion as saponins inhibit lipase and decrease lipid digestion.

As shown in table (٥), the hyperglycemic positive control rats had significantly higher serum urea, uric acid and creatinine (38.02 $\pm$ 1.35, 8.63 $\pm$ 0.12 & 2.01 $\pm$ 0.11 mg/ dl, respectively) in comparison with the values of for the negative control group 24.17 $\pm$ 0.79, 3.59 $\pm$ 0.07 and 0.91 $\pm$ 0.03 mg/ dl, respectively,; while groups of rats fed on 5% lemon peel, 5% Sidr leaves and their mixture showed significantly lower levels of aforementioned parameters.

Hassan *et al.*, (2003) and **Abdelhaliem and Sheha (2018)** stated that, long time supplementation with peel of lemon enhanced renal function parameters. Recent study by **Yao *et al.*, (2022)** revealed that, *Citrus limon* considered as rich sources of flavanone eriocitrin which is more potent in repressing ROS generation in hyperglycemic rats; eriocitrin had powerful antioxidant, anti-diabetic and anti-inflammatory activities. In addition, **Jing *et al.*, (2020)** showed that, in rats eriocitrin have nephroprotective effects against Cisplatin-induced renal toxicity by lessening oxidative stress;

eriocitrin lowered serum urea, creatinine, NO, and lipid peroxidation. Furthermore, **Huang *et al.*, (2022)** illustrated that**,** limonene had an inhibitory effect on Xanthine Oxidase; an enzyme that catalyzes xanthine to uric acid. On the other hand**,** Sidr leaf aqueous fractions showed dose dependent nephroprotective effects **(Al Ghamdi *et al.*, 2019);** and **Almeer *et al.*, (2019)** attributed these nephroprotective effects of *Zizphus spina-christi* to its chelating, antioxidative and anti-inflammatory properties. Based on the findings of **Dkhil *et al.*, (2018)** *Ziziphus sapina c.* leaf extract has resulted in decrements of MDA, NO and increments of antioxidant enzymes and most importantly it protect against damages of the kidneys provoked by hyperglycaemia.

TABLE (5): MEAN SERUM BLOOD UREA NITROGEN, CREATININE AND URIC ACID OF RAT'S GROUPS FED ON LEMON PEEL, SIDR LEAVES AND THEIR MIXTURE (MEAN± S.E.)

	Urea mg/dl	Uric Acid mg/dl	Creatinine mg/dl
Negative control	24.17 ^{c} ± 0.79	3.59 ^{d} ± 0.07	0.91 ^{c} ± 0.03
Positive control	38.02 ^{a} ± 1.35	8.63 ^{a} ± 0.12	2.01 ^{a} ± 0.11
5% Lemon peel	26.47 ^{b} ± 0.83	6.98 ^{b} ± 0.15	1.04 ^{b} ± 0.02
5% Sidr Leaves	24.25 ^{c} ± 1.14	6.15 ^{b} ± 0.20	1.02 ^{b} ± 0.08
5% Lemon peel+ 5% Sidr leaves	24.02 ^{c} ± 0.43	5.14 ^{c} ± 0.10	0.95 ^{c} ± 0.08

Means within the same column having different letters were significantly differed at $P \leq 0.05$.

From table (6) it could be noticed that, adding of lemon peel at 5% level and adding of mixture of 5% lemon peel+ 5% sidr leaves to cupcakes have no significant effects on appearance, color and overall quality attributes; whereas adding of 5% sidr leaves resulted in a significant reduction of aforementioned quality attributes. Scores for sensory quality attributes were highest in the control sample, including appearance, color, texture, taste and overall quality.

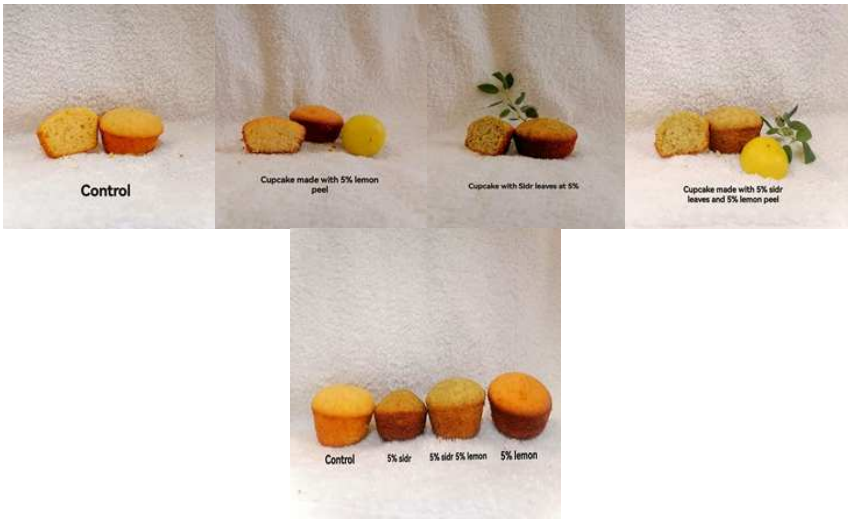
González-Molina *et al.*, (2010) illustrated that, lemon peel essential oils and flavonoids are main contributors of flavor and that explain its role in enhancing sensory scores; on the other hand **Ali *et al.*, (2021)**

demonstrated that, the strong herbal taste and bitterness in sidr leaves due to its phenolic and alkaloids content are the reason for its flavor. Mixing of lemon peel with sidr leaves enhanced sensory properties in cupcake samples and that could be due to the fact that the citrus flavor of lemon peel balanced the bitterness of sidr leaves, and these interactions of varied bioactive compounds have been resulted in enhancement of sensory quality attributes (**Chaudhary *et al.*, 2020**).

Table (6): Quality attributes of cupcakes enriched with lemon peel, Sidr leaves and their mixture as predicted by Sensory evaluation (Mean ± S.D)

	Appearance	Color	Taste	Texture	Overall Quality
Control	0.73^{a}± 9.6	9.7^{a}±0.65	9.6^{a}±0.43	9.4^{a}±0.66	9.5^{a}±0.54
5% lemon peel	8.9^{a}±0.05	9.1^{a}±0.34	9.5^{a}±0.24	7.8^{c}±0.28	8.8^{ab}±0.53
5% Sidr leaves	7.3^{b}±0.16	7.9^{b}±0.52	7.7^{c}±0.41	7.0^{c}±0.12	7.8^{c}±0.56
5%lemon peel+ 5% Sidr leaves	9.1^{a}±0.75	9.1^{a}±0.60	8.9^{ab}±0.99	8.4^{b}±0.50	9.2^{a}±0.54

Means within the same column having different letters were significantly differed at $P \leq 0.05$.



Picture (1): Control cupcake, cupcakes with 5%lemon peels, 5% sidr leaves and their mixture.

Conclusion: previous results suggested that mixture of both lemon peel and Sidr leaves synergistically ameliorate the negative effects of hyperglycemia on lipid profile and renal function due to their bioactive compounds' actions against hyperglycemia, oxidative stress, and inflammation. Lemon peel and Sidr leaves can be mixed in a backed product to maintains high sensory appeal and improving functional and nutritional qualities.

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التأثيرات المحتملة لقشر الليمون وأوراق السدر في الجرذان المصابة بمرض السكرى المستحث بالستربتوزوتوسين وتقييم جودة الكب كيك المدعم

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الملخص العربي

هدفت الدراسة الحالية الى دراسة التاثير المحتمل لاضافة قشور الليمون واوراق السدر المجففه وخليطهما على الفئران المصابة بمرض السكري المستحث بالستربتوزوتوسين بالإضافة الى تقييم الخصائص الحسية للكب كيك المدعم بقشر الليمون وأوراق السدر وخلطيهما. تم الاستعانة بعدد ٣٥ من ذكور الجرذان البيضاء حيث تم تقسيمهم الى مجموعتان رئيسيتان: (١) المجموعة الرئيسية الاولى كانت المجموعة الضابطة السلبية والمجموعة الرئيسية الثانية تم حقنها بالستربتوزيتوكين بالغشاء البريتوني لاحداث ارتفاع بمستوى سكر الدم ومن ثم تم تقسيمهم الى اربع مجموعات فرعية وهي (٢) المجموعة الضابطة الموجبة و(٣) مجموعة تغذت على ٥٪ من قشور الليمون و(٤) مجموعة تغذت على ٥٪ من اوراق السدر و(٥) المجموعة التي تغذت على خليط من ٥٪ قشور الليمون +٥٪ من اوراق السدر. وبعد مرور فترة التجربة (٤ اسبوع) اظهرت النتائج حدوث ارتفاع بمستويات الجلوكوز ومستوى السكر التراكمى ومستوى مقاومة الأنسولين وكذلك الجلسريدات الثلاثية والكوليستيرول ومستوى المالون داي الدهيد بالمجموعة المصابة بارتفاع سكر الدم (المجموعة الضابطة الموجبة) مقارنة بتلك في المجموعة الضابطة السلبية، بينما اظهرت المجموعات التي تغذت على قشور الليمون واوراق السدر وخليطهما تحسنا ايجابيا بانخفاض مستويات سكر الدم ومقاومة الأنسولين والدهون مع ارتفاع مستوي مضادات الاكسدة الكلية بالدم وزيادة إنتاج الغلوبين المناعي وانخفاض بمستوي المالون داي الدهيد. كما اشارت النتائج التاثير الايجابي لاضافة قشور الليمون واوراق السدر على وظائف الكلى كما وضح من حدوث انخفاض بمستويات اليوريا والكرياتينين. كما أظهرت نتائج التقييم الحسى ان الكب كيك المدعم بخليط ٥٪ قشر الليمون +٥٪ أوراق السدر يليها العينة المدعمة ب ٥ ٪ اوراق الليمون حازت قبولا اعلى من قبل أعضاء المحكمين بالمقارنة بالعينة الكنترول. وتشير نتائج الدراسة الى التأثير الايجابي المحتمل لقشور الليمون واوراق السدر للحد من اضرار ارتفاع سكر الدم.

الكلمات المفتاحية: قشور الليمون، اوراق السدر، ارتفاع مستوى سكر الدم، صورة دهون الدم ووظائف الكلى

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