

Effects of different doses of *Prunus laurocerasus* L. leaf extract on oxidative stress, hyperglycaemia and hyperlipidaemia induced by type I diabetes

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The fruits and leaves of the *Prunus laurocerasus* (PL) plant are used in traditional medicine for many purposes because of their anti-diabetic properties. This study aimed to determine the anti-hyperglycaemic, anti-hyperlipidaemic, anti-inflammatory and antioxidant effects of PL leaf extract on experimental type I diabetes. Different doses PL extracts were administered orally for 25 days to rats. Biochemical and immune histochemical analyses were performed at the end of the study. Antioxidant test results showed that the PL had a very high antioxidant capacity. The study also revealed that different doses of PL increased SOD ($p < 0.001$) and GSH ($p < 0.05$ in PL500 group) levels but decreased TBARS ($p < 0.001$) levels in the kidney tissue. Significant increases were noted in the SOD levels of liver tissue ($p < 0.01$). In addition, HDL cholesterol levels ($p < 0.05$) significantly increased while LDL ($p < 0.05$, $p < 0.05$, $p < 0.001$, respectively) and TG levels ($p < 0.05$ in PL1000 and PL1500 groups) decreased when the PL groups were compared with the DC group. Eventually, the anti-hyperglycaemic effects of PL were not determined. However, PL was found to be highly effective in reducing oxidative stress and hyperlipidaemia. Based on the current study, PL leaf extract may be useful in preventing hyperglycaemia, hyperlipidaemia and oxidative stress, which are chronic complications of diabetes.

Keywords: *Prunus laurocerasus* L., Hyperglycaemia, Oxidative stress, Hyperlipidaemia, Immunohistochemistry

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Diabetes mellitus is a metabolic disorder that is diagnosed with hyperglycaemia resulting from defects in insulin secretion, insulin action or both¹. Chronic hyperglycaemia can adversely affect various organs, such as the eyes, kidneys, liver, nerves, heart and blood vessels^{2,3}. Oxidative stress is significantly increased in patients with both type I and II diabetes and in diabetic animal models, because of prolonged hyperglycaemia increases the formation of cytotoxic free radicals via various metabolic pathways (non-enzymatic and oxidative glycosylation, increased activity of protein kinase C, and increased activity of the sorbitol and hexosamine pathways)^{4,5}. The existing drugs do not treat diabetes but are used only in the prevention of complications. The current lack of certain diabetes treatments has directed researchers to find new sources of treatment. Because they have few or no side effects, herbal sources are considered to be a promising candidate in the treatment of diabetes⁶.

The extract used in this study was obtained from *Prunus laurocerasus* L. (syn: *Laurocerasus officinalis* M. Roem.) leaves. PL is a member of the Rosaceae family, which is also known as wild cherry or cherry laurel⁷. A tree having glossy, aromatic evergreen leaves, white flowers and purplish-black fruit, cherry laurel is cultivated worldwide in temperate regions and is used mostly as an ornamental plant⁶. It is found mainly on the Turkish coast of the Black Sea and is locally referred to as 'taflan' or 'karayemiş'^{8,9}. In Turkey, the fruit of the plant is largely consumed in fresh, dried, canned or pickled forms and in jam, marmalade or drinks⁸. The leaves of PL contain higher polyphenolic components than the fruits. The PL leaf extract has been reported to contain six polyphenolic components. These include chlorogenic acid, o-coumaric acid, quercetin 3-glucoside, luteolin 7-glucoside, apigenin 7-glucoside, kaempferol 3-glucoside, and naringenin. The most common component in the PL leaf extracts was chlorogenic acid¹⁰. High antioxidant activity and a high content of phenolic compounds makes the PL valuable as a

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source of antioxidant and bioactive compounds^{10,11}. This species, also well known as a traditional medicine in Northern Anatolia, is used for its analgesic, antispasmodic, narcotic and diuretic effects as well as its usefulness in the treatment of asthma, cough, indigestion and haemorrhoids^{12,13}. It also has been found to have antifungal, anti-nociceptive and anti-inflammatory effects when prepared with water and ethanol extract⁹. Additionally, cherry laurel leaves have been observed to reduce headaches and 'burning stomach'^{14,15}. In Northern Anatolia, the fruit and seeds of the cherry laurel are widely used to treat diabetes and its complications^{14,16}.

In this study, we aimed to determine the effects of administering cherry laurel leaf extract orally and insulin subcutaneously for 28 days on fasting blood glucose and HbA1c levels, oxidative stress, lipid profile, pro-inflammatory TNF- α levels and insulin-containing pancreatic β cells.

Methodology

Experimental design

This study was conducted with the approval (2014/4) of the Kafkas University Animal Experiments Local Ethics Committee. A total of 60 Sprague Dawley rats, aged 2 months, divided into 6 groups of 10 animals, were used. The rats were fed according to standard *ad-libitum* conditions.

Normoglycaemic control group (NC): This group received physiological saline intraperitoneally (IP).

Diabetes control group (DC): This group received 50 mg/kg streptozotocin (STZ) IP (50 mL citric acid + 40 mL disodium hydrogen phosphate buffer pH 4.5) + physiological saline solution.

500 mg/kg *Prunus laurocerasus* leaf extract (PL500): This group received 50 mg/kg STZ IP + 500 mg/kg PL leaf extract via oral gavage for 25 days.

1000 mg/kg *Prunus laurocerasus* leaf extract (PL1000): This group received 50 mg/kg STZ IP + 1000 mg/kg PL leaf extract via oral gavage for 25 days.

1500 mg/kg *Prunus laurocerasus* leaf extract (PL1500): This group received 50 mg/kg STZ IP + 1500 mg/kg PL leaf extract via oral gavage for 25 days.

Insulin Group (I): This group received 50 mg/kg STZ IP + 2 IU insulin subcutaneously (Levemir Flexpen) for 25 days.

The rats were defined as diabetic if the fasting blood glucose levels were higher than 200 mg/dL after 72 h of STZ administration. At the end of the study, blood samples were collected under 0.4 ml/kg pentobarbital sodium anaesthesia via the intra-cardiac route. The blood samples were centrifuged according to the kit

procedures, and the serum samples were stored at -20 °C until use. A homogenizer was used to homogenize the liver and kidney samples in phosphate buffer saline (1:9). The homogenates were centrifuged at 10000 g for 5 min at 4 °C, and the supernatants were separated.

Preparation of extract

PL leaves were collected from Turkey's Trabzon province and dried in the shade. The leaves were then ground into powder at the mill and dissolved in a mixture of ethanol and water (2:8) with a ratio of 1:5 (leaf:solvent) according to the procedure described by Hamza *et al.*¹⁷. This mixture was maintained at room temperature for 2 days in a shaking water bath. The mixture was filtered through filter paper, and an evaporator was used to evaporate the solvent at 50 °C; 10.51 g of extract was obtained from 250 mL of maceration.

Determination of total phenolic components and antioxidant activity in PL leaves

Determination of total phenolic content

The total phenolic content was measured according to Slinkard and Singleton's method: 1.0 mL of extract solution (containing 1.0 mg) was added to 45 mL of distilled water and 1.0 mL of Folin-Ciocalteu reagent. After 3 min, 3.0 mL of 2 % sodium carbonate was added and maintained at standard room temperature for 2 h; the absorbance was measured at 760 nm¹⁸.

Determination of Fe (III) – Fe (II) reduction activity

The ability of the PL water-ethanol extracts to reduce Fe (III) was assessed using the method described by Oyaizu¹⁹. First, 250 μ L of extract was mixed with 2.250 μ L 0.2 M phosphate buffer (pH 6.6) and 2.500 μ L of a 1 % potassium ferricyanide solution. After 30 min of incubation in a 50 °C water bath, 2.500 μ L of 10 % trichloroacetic acid was added, and the mixture was centrifuged for 10 min at 4500 rpm. After centrifugation, 2.500 μ L of distilled water and 500 μ L of 0.1 % FeCl₃ were added to 2.500 μ L of supernatant. After a 10 min incubation period, the absorbance was measured at 700 nm.

Determination of nitric oxide radical scavenging activity

Nitric oxide (NO) scavenging activity was determined by modification according to the methods of Badami *et al.*²⁰ and Kumar *et al.*²¹: 2.0 mL of sodium nitroprusside (10 mM) was mixed with 0.5 mL 0.1 mM PBS buffer and 0.5 mL extract solutions of different concentrations (10–200 μ g/500 μ L) and

incubated at 25 °C for 2.5 h. A Greiss reagent was prepared at a 1:1 ratio mixed with 1% sulfanilamide and 0.1% naphthylethylenediamine-dihydrochloride. After 1.25 mL of Greiss reagent was added and solution incubated at 25 °C for 30 min, the absorbance was measured at 546 nm.

Biochemical analyses

Blood glucose levels (before the study and during the study at 72 h, 7 days, 14 days, 21 days and 28 days) were determined with a glucometer (Counter TS-Bayer) after 8 h of fasting. Insulin, HbA1c, HDL, LDL and TG levels were obtained from serum samples, whereas TBARS, SOD, CAT, GSH and TNF- α levels in liver and kidney tissues were obtained by spectrophotometry using ELISA test kits (Elabscience-USA).

Histomorphologic and Immunohistochemical investigations

Histopathologic investigations

Pancreatic tissue samples were collected, fixed in a 10 % phosphate buffered formaldehyde solution and embedded in paraffin. After 5 μ thick sections were cut, they were stained with haematoxylin and eosin (H&E) and observed under a light microscope for histopathological changes.

Immunohistochemical investigations

Pancreatic tissue sections were immunohistochemically stained for insulin/proinsulin using the streptavidin biotin immunoperoxidase complex method and 3,3'-diaminobenzidine tetrahydrochloride as the chromogen. Briefly, following blocking endogen peroxidase activity via treatment with 0.3 % hydrogen peroxide for 15 min and antigen retrieval by microwave treatment in 0.1 M sodium citrate solution, pH 6.0 at 600 W for 10 min, primer antibody, anti-insulin/proinsulin antibody (Thermofisher Scientific, Catalogue No: MA1-16710), diluted 1:500, was applied to the sections and incubated for 1 h. Negative control was provided by exchanging the primary antibody with PBS. A semi-quantitative (negative, weak, moderate or strong immunoreactivity) grading system was used to score the immunoreactivity.

Statistical analysis

All biostatistical evaluations were performed using SPSS 18 software. One-way ANOVA was used to determine the differences between the treated groups and the control group. Duncan's multiple range test was used to detect alterations between the groups. A p-value < 0.05 was considered significant.

Results

The quantity of total phenolic substance in the medium was determined using the Folin-Ciocalteu solution. The absorbance value of 1 mg PL leaf extract added to the medium was found to be 84.79 at 760 nm. The total phenolic content of the water-ethanol extract of the PL plant was determined to be the equivalent of phenolic substance in the microgram pyrocatechol using the equation obtained from the standard pyrocatechol graph ($R^2 = 0.9995$). It was determined that 1 mg of PL leaf extract contains 84.79 μ g of the phenolic equivalent of pyrocatechol.

The NO radical scavenger effect of the PL extract compared to that of the routine standard substance. The data obtained from the experiments were evaluated by linear regression analysis and revealed that the IC₅₀ value of the PL extract sweeping 50 % of the NO radical in the medium was 49.4 μ g/mL (Fig. 1a).

Butylated hydroxytoluene (BHT) was used to compared the Fe (III) – Fe (II) reduction activity of the PL leaf extract. As a result of the analyses, it was determined that the PL extract had strong iron-reducing activity. Fig. 1b presents a comparison of the BHT and PL leaf extract reductive abilities.

The fasting blood glucose levels of all the groups were initially between 79.8 mg/dL and 82.4 mg/dL. It

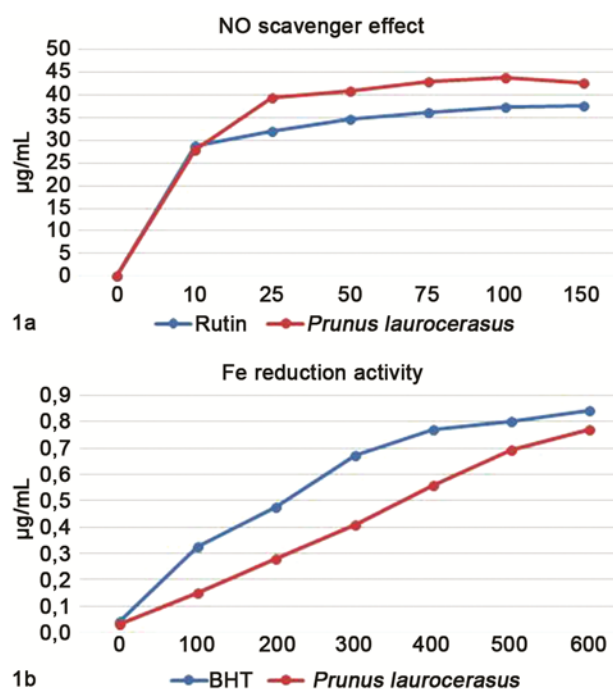


Fig. 1 — (a) Comparison of NO Radical Scavenging Activities of PL and Routine, (b) Comparing Fe Reducing Ability of PL and BHT

Table 1 — Fasting Blood Glucose (mg/dL) and Serum HbA1c (ng/mL), Insulin (ng/mL), TNF- α (pg/mL), HDL (ng/mL), LDL (μ g/mL), and TG (ng/mL) levels in control and experimental groups

		NC	DC	PL500	PL1000	PL1500	I
Glucose	0 th	79.8 \pm 4.4	80.7 \pm 4.3	81.0 \pm 7.6	82.4 \pm 4.8	81.9 \pm 12.8	81.1 \pm 8.0
	3 rd	79.5 \pm 4.6	347.7 \pm 88.8 ^{###}	383.6 \pm 55.4	390.5 \pm 45.6	377.0 \pm 27.8	389.6 \pm 33.1
	7 th	81.5 \pm 6.4	380.9 \pm 47.0 ^{###}	335.4 \pm 54.6	355.8 \pm 58.6	381.1 \pm 50.8	306.4 \pm 42.0*
	14 th	82.0 \pm 5.8	393.4 \pm 14.7 ^{###}	363.6 \pm 63.9	371.7 \pm 26.3	379.3 \pm 23.0	314.6 \pm 27.9**
	21 st	83.3 \pm 2.9	406.0 \pm 14.5 ^{###}	357.6 \pm 35.5	375.0 \pm 52.5	374.4 \pm 36.1	316.1 \pm 38.8***
	28 th	81.5 \pm 5.6	404.1 \pm 18.5 ^{###}	379.6 \pm 14.7	380.6 \pm 12.1	376.2 \pm 23.4	312.5 \pm 42.9***
HbA1c		190.2 \pm 14.0	276.3 \pm 35.9 [#]	254.6 \pm 51.0	251.0 \pm 55.3	238.0 \pm 40.7	218.8 \pm 32.9
Insulin		84.3 \pm 9.4	53.9 \pm 9.1 ^{###}	54.8 \pm 6.4	54.4 \pm 10.7	56.9 \pm 8.8	62.5 \pm 9.0
TNF- α		1,40 \pm 0.18	1,83 \pm 0.14 ^{##}	1,65 \pm 0.24	1,73 \pm 0.07	1,72 \pm 0.12	1,55 \pm 0.20
HDL		245.4 \pm 12.1	189.0 \pm 18.5 ^{###}	219.4 \pm 12.2*	216.0 \pm 15.2*	216.4 \pm 16.8*	232.0 \pm 14.9***
LDL		0.39 \pm 0.08	1.01 \pm 0.09 ^{###}	0.86 \pm 0.08*	0.86 \pm 0.08*	0.84 \pm 0.07**	0.60 \pm 0.07***
TG		3798 \pm 568	5928 \pm 666 ^{###}	5172 \pm 485	5042 \pm 477*	4991 \pm 464*	4110 \pm 478***

: $p < 0.05$, ## : $p < 0.01$, ### : $p < 0.001$ as compared with normoglycaemic control,

* : $p < 0.05$, ** : $p < 0.01$, *** : $p < 0.001$ as compared with diabetic control group

Table 2 — TBARS (μ M), CAT (pg/mL), SOD (U/mL) and, GSH (μ g/mL) levels of the kidney and liver tissues

	Tissue	TBARS	CAT	SOD	GSH
NC	Kidney	68,3 \pm 3.0	11.8 \pm 1.5	0.011 \pm 0.002	0,11 \pm 0.03
	Liver	61.3 \pm 3.8	6.9 \pm 0.9	0.065 \pm 0.008	0.08 \pm 0.01
DC	Kidney	87.6 \pm 6.0 ^{###}	8.0 \pm 0.4 ^{###}	0.007 \pm 0.002 [#]	0.13 \pm 0.01
	Liver	76.6 \pm 5.9 [#]	5.0 \pm 0.4 ^{###}	0.043 \pm 0.009 ^{###}	0.12 \pm 0.04
PL500	Kidney	72.1 \pm 5.2 ^{***}	8.4 \pm 1.1	0.013 \pm 0.002 ^{***}	0.17 \pm 0.01*
	Liver	67.0 \pm 5.5	5.2 \pm 0.2	0.061 \pm 0.009 ^{**}	0.11 \pm 0.03
PL1000	Kidney	73.6 \pm 1.4 ^{***}	9.6 \pm 0.6	0.014 \pm 0.003 ^{***}	0.19 \pm 0.03
	Liver	71.2 \pm 1.8	6.2 \pm 0.8	0.063 \pm 0.006 ^{**}	0.15 \pm 0.06
PL1500	Kidney	76.1 \pm 3.1 ^{***}	9.3 \pm 1.0	0.015 \pm 0.003 ^{***}	0.17 \pm 0.02
	Liver	66.4 \pm 10.4	6.0 \pm 0.5	0.063 \pm 0.005 ^{**}	0.12 \pm 0.05
I	Kidney	76.8 \pm 2.0 ^{***}	11.4 \pm 1.6 ^{**}	0.013 \pm 0.001 ^{***}	0.20 \pm 0.04 ^{***}
	Liver	61.1 \pm 8.2*	6.5 \pm 0.9*	0.063 \pm 0.008 ^{**}	0.12 \pm 0.03

was observed that fasting blood glucose levels significantly increased in all the groups beginning 3 days after STZ injection ($p < 0.001$). However, there were no statistically significant differences between the diabetic experimental groups ($p > 0.05$). Blood glucose levels in the insulin-treated group significantly decreased beginning with day 7 ($p < 0.05$, $p < 0.01$, $p < 0.001$ and $p < 0.001$, respectively). At the end of the study, the blood glucose levels of the PL500, PL1000 and PL1500 groups were lower than those of the DC group, although this reduction was not significant ($p > 0.05$) (Table 1).

In the DC group, serum insulin levels decreased ($p < 0.001$) despite increased HbA1c and pro-inflammatory cytokine TNF- α levels ($p < 0.05$). However, there were no significant changes in the insulin, HbA1c and TNF- α levels in the experimental groups ($p > 0.05$) (Table 1).

TG and LDL cholesterol levels were increased in the DC group ($p < 0.001$) but significantly reduced in the groups of PL500 ($p < 0.05$), PL1000 ($p < 0.05$), PL1500

($p < 0.05$, $p < 0.01$), and I ($p < 0.001$). HDL cholesterol levels decreased significantly in the DC group ($p < 0.001$), while these levels significantly increased in the experimental groups ($p < 0.05$, $p < 0.05$, $p < 0.05$ and $p < 0.001$, respectively) (Table 1).

The increased liver TBARS levels in DC group ($p < 0.05$) significantly decreased after insulin administration ($p < 0.05$). The liver CAT levels increased in the group I compared with the DC group ($p < 0.05$). Despite decreases in the SOD levels of the DC group ($p < 0.001$), these levels significantly increased in the liver tissue of all the experimental groups ($p < 0.01$). There were no significant changes in the GSH levels in the liver tissue ($p > 0.05$) (Table 2).

The TBARS values increased in the DC group ($p < 0.001$), although these values decreased in the kidney tissue of the groups of PL500, PL1000, PL1500, and I ($p \leq 0.001$). The CAT enzyme levels decreased in the DC group ($p \leq 0.001$) and increased

only in the I group ($p < 0.01$). The reduced SOD levels in DC group ($p < 0.05$) increased in the kidney tissue of all the treatment groups ($p < 0.001$). It was observed that GSH levels increased with substance applications, but this increase was significant only in the groups of PL500 ($p < 0.05$) and I ($p < 0.001$) (Table 2).

Pancreatic tissue from the rats in the NC group were observed to be in accordance with the normal histomorphology of the organ (no picture is shown). The number and distribution of the islets of Langerhans and acinar formations in this group were in normal conformation. In the DC group, the islets of Langerhans were totally or mostly absent in a given section (no picture is shown). When seen, they were comparably smaller in size and showing cellular depletion. Pancreatic acini in these rats, as in the control animals, were of normal structure. Similarly, the blood vessels and inter- and intra-lobular ducts showed no pathologic changes in both groups. In the PL500, PL1000 and PL1500 groups, pancreatic tissue histomorphologies were similar and showed no apparent differences (no picture is shown). The islets of Langerhans were generally small in size and showed cellular depletion when compared to the control group, although few numbers of normal-appearing islets were recognized in some of the animals in each of these groups (no picture is shown). Other structures, such as acini, blood vessels and intra- and inter-lobular ducts showed no pathologies that were similar to the other groups. In the I group, the histomorphology of the pancreatic tissue was similar to that of the DC group (no picture is shown).

Immunohistochemical staining for insulin/pro-insulin on the pancreatic tissues of the NC group animals showed strong immunoreactivity. Anti-insulin/pro-insulin immunoreactivity in these animals was solely present in the islets of Langerhans and showed strong staining (Fig. 2a). No immunoreactivity was observed in the acini or in any other structures within the pancreatic tissue sections. In the DC group, anti-insulin/proinsulin immunoreactivity in the pancreatic sections where the islets of Langerhans remained was shown to be very weakly present in a few cells. Additionally, in a given islet, few cells showed immunoreactivity in this group (Fig. 2b). Moreover, no immunoreactivity was seen in those sections in which the islets of Langerhans were completely wiped out. In all the extract groups, similar immunostainings were observed (Figs 2c,d&e). In most of the animals in these groups, in compliance with the small-sized islets of

Langerhans, little staining and few stained cells were seen. On the hand, stronger staining was observed in a few animals in these groups. In the group I, the pattern of immunoreactivity in the pancreatic tissue sections was similar to that of the DC group (Fig. 2f).

Discussion

Representing one of the world's most significant costs to mortality and morbidity as well as to the its health systems, diabetes and its macrovascular and microvascular complications cause more than 2 million deaths every year^{22,23}. There is currently no treatment for type I diabetes. Existing treatment modalities aim only to alleviate diabetic complications. For this reason, scientists have made efforts to investigate the use of traditional herbs and their antihyperglycaemic, antihyperlipidaemic and antioxidant effects in the treatment of diabetes⁴.

Turan *et al.* stated that PL fruit extract decreased blood glucose levels in alloxan-induced type II diabetic rats, whereas Gliclazide-induced hypoglycaemia increased blood glucose levels to normal level²⁴. Orhan

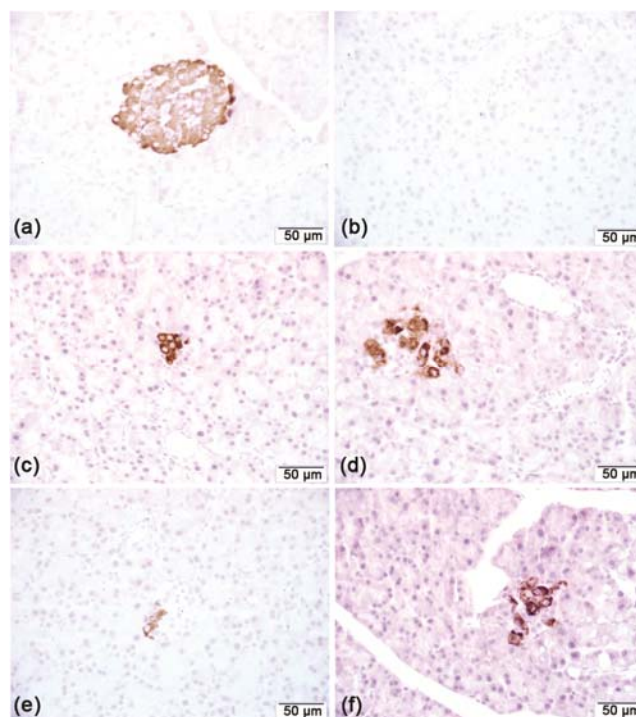


Fig. 2 — Immunohistochemical staining for insulin/proinsulin a) NC: Strong immunoreactivity over the islet of Langerhans b) DC: Almost no immunoreactivity over a comparably small sized islet of Langerhans c) PL500 group: Few immunostained cells, d) PL1000 group: Few immunostained cells, e) PL1500 group: Few cells showing immunoreactivity, and f) Group I : Few cells showing immunoreactivity

et al. suggested that PL seed extract decreased blood glucose levels in type I diabetic rats, whereas fruit extract was not effective⁸. Another study indicated that PL seed extract reduced blood glucose and increased insulin levels in type I diabetic rats²⁴. Kutlucan *et al.* reported that HbA1c levels did not change in patients with type II diabetes who consumed PL leaves²⁵. In the current study, it was observed that administering different doses of PL leaf extract to type I diabetic rats had no significant effect on blood glucose, HbA1c, insulin and pro-inflammatory cytokine TNF- α levels. Histomorphologic and immunohistochemical results supported the present biochemical results.

A study reported that on the edible portion of the fruit of *Laurocerasus officinalis*, the hydroxyl, DPPH and superoxide radical scavenging activity was similar to or higher than that of the standard reference materials⁹. Likewise, in this study, we found that the antioxidant capacity of the cherry laurel leaf extract was quite high as a result of iron reduction, NO scavenger and total phenolic component analysis. In another study, it was reported that cherry laurel fruit extract increased total antioxidant status (TAS), SOD, CAT and GPx levels while reducing the total oxidant status (TOS) and malondialdehyde (MDA) levels in a dimethoate-induced toxicity model²⁶. In the current study, increased GSH (in kidney tissue) and SOD (in liver and kidney tissues) levels and decreased TBARS (in kidney tissue) levels show that cherry laurel leaf extract has high antioxidant activity in diabetic rats.

Liyana-Pathirana *et al.* suggested that *Laurocerasus officinalis* juice and its concentrated juice (*pekmez*) are powerful superoxides and have DPPH radical scavenging activity. In the same study, it was found that *Laurocerasus officinalis* juice and *pekmez* were important inhibitors of human LDL cholesterol oxidation²⁷. Karabegovi'c *et al.* maintained that cherry laurel leaf extract has polyphenolic components of chlorogenic acid, o-coumaric acid, quercetin 3-glucoside, luteolin 7-glucoside, apigenin 7-glucoside, kaempferol 3-glucoside, and naringenin, whereas fruit extracts contain chlorogenic acid, vanillic acid, caffeic acid and routine components¹⁰. Chlorogenic acid, the major agent of PL, has been reported to have hypoglycaemic, hypolipidaemic and insulin resistance-reducing effects²⁸. Many researchers have maintained that chlorogenic acid is effective in lowering MDA and TBARS levels with total cholesterol, TG, and LDL cholesterol²⁹⁻³¹. In another study, it was reported that in an STZ-NAD induced type II diabetes model, there

were reduced TG, LDL and very low-density lipoprotein cholesterol levels, while HDL cholesterol levels increased³². Similarly, the current study found that different doses of PL leaf extract significantly reduced LDL cholesterol and TG levels while significantly increasing HDL cholesterol levels in the diabetic rats.

No results were found in our study to indicate that PL leaf extract has anti-hyperglycaemic effect. However, it was determined that PL leaf extract is highly effective in alleviating hyperlipidaemia and oxidative stress, the most significant complications of diabetes.

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Conflict of interest

The authors declare that there are no conflicts of interest.

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