The Antidiabetic Effect of Dietary Persimmon (Diospyros kaki L. cv. Sangjudungsi) Peel in Streptozotocin-induced Diabetic Rats

SYNG-OOK LEE, SHIN-KYO CHUNG, AND IO-SEON LEE

ABSTRACT: The phytochemical composition of persimmon (Diospyros kaki L. cv. Sangjudungsi) peel (PP), a waste byproduct of dried persimmon, and its possible antidiabetic influence in streptozotocin-induced diabetic rats were examined. Dietary fiber was found to be the major component of PP, with a high content of 40.35% (w/w). PP also contains high levels of antioxidants including total carotenoids, vitamin C, and total phenolics. A 2-wk dietary supplementation of PP at both 5% and 10% (w/w) significantly lowered food intake, blood glucose, plasma triglyceride, and total cholesterol levels in diabetic rats. Dietary PP also restored the reduced plasma high-density lipoprotein (HDL)-cholesterol levels in diabetic rats. Although regression of the hypertrophies of liver and kidney was not observed in diabetic rats, dietary PP showed the partial or complete restoration of plasma aspartate amino transferase (AST), and creatinine levels, which serve as indicators of liver and renal dysfunctions, respectively. Therefore, PP containing high levels of dietary fiber and antioxidants with antidiabetic properties represents a potential dietary supplement for improving hyperglycemia and diabetic complications.

Keywords: persimmon peel, dietary fiber, antioxidants, streptozotocin, antidiabetic effect

Introduction

Diabetes mellitus, a metabolic disorder, is the most prevalent chronic disease and cause of death in developed countries. The cost of diabetes in the United States has been estimated to be $44 billion in 1997 (WHO 2002). A previous review revealed that 15% to 20% of patients with diabetes have insulin-dependent diabetes mellitus (IDDM) (Urger and Foster 1998). Although numerous studies of the causes of diabetes and effective therapies have been reported, the causes and mechanisms involved remain unclear, and no satisfactory effective therapy is currently available to cure the disease.

The treatment of diabetes involves improving dietary control, exercise, and the use of antidiabetic diets and drugs (Betteridge 1997); thus, substantial efforts have been made to identify both natural and synthetic antidiabetics. In particular, after the recommendations of the World Health Organization that investigations of hypoglycemic agents from medicinal plants warrants further evaluation (WHO 1980), renewed interest has arisen in plant sources such as vegetables, fruits, and medicinal plants for use as more effective and safe antidiabetics.

More than 200000 metric tons of persimmon are produced annually, and some of these fruits are processed to dried persimmon and persimmon pulp. A large amount of persimmon peel (PP), a byproduct in the production of dried persimmon, is discarded as a waste and creates severe environmental contamination in areas where dried persimmon is produced in Korea (Kim and others 2005).

Both dietary fiber and polyphenols have been reported to exert antihyperglycemic effects. Some authors have proposed the use of persimmon as a good source of nutritional antioxidant vitamins, dietary fiber, and polyphenols. The contents of these important components are higher in the peel than in the pulp (Gorinstein and others 1994). Indeed, a previous study showed that a diet supplemented with PP has hypocholesterolemic and antioxidant potential in rats fed cholesterol and that PP is more efficient than persimmon pulp (Gorinstein and others 1998). PP has also been shown to have antitumor properties on several tumor cell lines in vitro (Kawase and others 2003). However, the antidiabetic effects of PP have not been examined to date.

In this article, therefore, we describe the effects of dietary PP powder on hyperglycemia and lipid metabolism in streptozotocin (STZ)-induced diabetic rats based on its phytochemical composition. In the 1st stage of this study, the proximate composition and antioxidant content including total carotenoids, vitamin C, and total phenolics in PP were determined. In the 2nd stage, the effects of PP on blood glucose, lipid profiles, and liver and kidney functions were investigated in diabetic rats.

Materials and Methods

Materials

All chemicals were obtained from Sigma Chemical Co. (St. Louis, Mo., U.S.A.) unless otherwise indicated. The glucose assay kit was obtained from Sigma, and the enzyme assay kits, which were used to determine triglyceride (TG), total cholesterol, high-density lipoprotein (HDL) cholesterol, alanine amino transferase (ALT), aspartate amino transferase (AST), and creatinine levels were purchased from AsanPharm (Asan Pharmaceutical Co., Republic of Korea).

Preparation of PP powder

Fresh PPs, obtained from a local dried persimmon production unit, were washed and then dried at 40 °C for 5 h in a hot-air drier. The dried peels were ground in a multimill and passed through a 40- to 60-mesh sieve to give a fine powder.
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Proximate composition
An analysis of the proximate composition was performed according to the AOAC methods (AOAC 1995). The moisture content was determined based on weight loss after heating in an oven at 105 °C, and the ash content was determined by incineration in a muffle furnace at 550 °C. The crude protein content was determined by a semimicro Kjeldahl method, and the conversion factor used was %N × 6.25. The crude lipid was determined by a Soxhlet extraction method. The soluble and insoluble dietary fiber contents were determined by an enzymatic-gravimetric method according to Asp and others (1983). Soluble sugars were extracted with 70% ethanol under reflux at 80 °C. After centrifugation, the supernatant was combined and the ethanol was evaporated under vacuum using a speed-vac system. The soluble sugars were analyzed by high-performance liquid chromatography (HPLC) with a refractive index detector (LC-10A, Shimadzu Co., Japan), using a carbohydrate column (d6.5 × 300 mm) in an isotropic run with H2O as the eluent (0.5 mL/min). Total soluble sugars (TSS) are given as the sum of glucose, fructose, and sucrose levels.

Determinations of antioxidants
The content of total carotenoids was determined by the method described by Kim and others (2005). After extraction with 50% MeOH, the resulting precipitate was extracted twice with acetone at room temperature. The extract was evaporated under reduced pressure and extracted with diethyl ether and saturated with NaOH. After centrifugation, the supernatant was saponified with 10% KOH for 24 h and separated with saturated NaOH for 3 h. The resulting supernatant was dehydrated with anhydrous Na2SO4 and evaporated under reduced pressure. Each extract was dissolved in chloroform, and the absorbance was measured at 465 nm using β-carotene as a standard. The vitamin C content was analyzed photometrically after oxidation of ascorbic acid to dehydroascorbic acid with metaphosphoric acid, which reacts with 2,4-dinitrophenylhydrazine (DNP) to form a red complex (Mill and others 1999). The absorbance was measured at 540 nm using ascorbic acid as a standard. Total phenolics were determined by the Prussian blue method described by Graham (1992). The absorbance was measured at 700 nm and the content of total phenolics was expressed as the gallic acid molar equivalent.

Animals and treatments
Six-wk-old male Sprague-Dawley rats, initially weighing between 160 and 180 g, were kept in a 21 ± 2 °C room maintained under 55% ± 5% humidity and 12 h light-dark cycles and acclimatized to the facility for 10 d before the start of the experiments. The rats were fed ad libitum with a commercial standard rat diet (Sam Yang Co., Republic of Korea) and tap water. Animals were given STZ at 45 mg/kg in 0.01 M citric acid buffer (pH 4.5) intraperitoneally. After 48 h, the 21 hyperglycemic animals with blood glucose levels over 300 mg/dL were then randomly divided into 3 groups of 7 animals each. The treatment groups included untreated control group (normal), STZ-induced diabetic group (diabetic control), diabetic group treated with 5% PP (diabetes + 5% PP) or 10% PP (diabetes + 10% PP), and the experiment lasted 2 wk. The weight was recorded 3 times per week, whereas food and water intake were recorded daily.

Plasma and tissue preparations
At the end of the 2 wk treatment period after an overnight fast, rats were sacrificed under ether anesthesia, and blood was collected in a heparinized tube. The collected blood was centrifuged at 3000 rpm for 20 min, and the plasma was stored at −80 °C until processed. The liver and kidney were removed immediately, washed in ice-cold saline, and weighed.

Biochemical analysis
Blood glucose level was determined using a colorimetric enzyme assay kit according to the manufacturer’s instructions. Total plasma lipid level was measured by the Phospho-vanillin method described by Frings and Dunn (1970). Plasma TG, total cholesterol, HDL cholesterol, ALT, AST, and creatinine levels were measured using commercial enzyme assay kits according to the manufacturer’s instructions.

Statistical analysis
The results were expressed as means ± standard deviation (SD) and statistically analyzed by analysis of variance (ANOVA). Duncan’s multiple range test was performed to determine significant differences among the groups and differences at P < 0.05 were considered to be significant.

Results and Discussion

Proximate composition of PP
Table 1 shows the proximate composition of the hot-air dried PP powder used in this study. Dietary fiber represented 40% of the formula weight of PP powder, and N-free extract (NFE) was the 2nd main component, at about 43%. In addition to persimmon fruit itself, in which the total dietary fiber (TDF) content is in the range of 1.20% to 1.76% (Gorinstein and others 1999), the peel is also a good source of dietary fiber, as calculated by the sum of the soluble fiber and insoluble fiber, which accounts for 40.35% of the dry weight. Most of the TDF of PP was insoluble fiber, whereas the comparative content of soluble fiber with insoluble fiber in persimmon fruit has been reported (Gorinstein and others 1999). The relationship between the insoluble and soluble dietary fiber in PP was not well balanced, according to the recommendation of Spiller (1986) who indicated that the ratio should be in the range of 1.0 to 2.3 to provide the appropriate physiological effects that are typically associated with both the soluble and insoluble fibers. The ratio in PP was much higher (15.54) and close to those in cereals such as wheat bran and oat bran (Grigelomo-Miguel and Martin-Belloso 1999). The ratio in most other fruits such as apple, pear, orange, peach, and lime, however, is well balanced (Larrauri and others 1996; Grigelomo-Miguel and Martin-Belloso 1999). The moisture content of PP powder was about 7%. The TSS content, as calculated from the sum of glucose, fructose, and sucrose, was about 5.39%, and glucose (2.62%) and fructose (2.38%) were the major soluble sugars with only marginal amounts of sucrose present (data not shown). The crude protein and lipid contents of PP were very low. These results are in agreement with previous studies of fruit by-products which, in general, showed low contents of protein and fat (Grigelomo-Miguel and Martin-Belloso 1999).

Antioxidants of PP
The contents of various antioxidants, total carotenoids, vitamin C, and total phenolics, in PP are shown in Table 2. The content of total carotenoids was very high in PP with about 340 mg/100 g of dried peels as β-carotene equivalents and this value is much higher than values for the peels of other fruits such as banana (Subagio and others 1996) and apple (Yang and Kim 1995). Kim and others (2002) reported that β-cryptoxanthin (about 42%) was the major carotenoid in PP followed, in decreasing order, by zeaxanthin, lutein and β-carotene. The contents of vitamin C and total phenolics were relatively high and comparable to other fruit peels, vegetables, and medicinal plants, which have shown pharmacological potential such as antioxidant and hypocholesterolemic effects (Johns and others 1999; Leontowicz and others 2002; Lee and others 2005). According to previous reports (Gorinstein and others 2001; Leontowicz and others 2002), the major phenolic compounds in persimmon and apple peels are P-coumaric acid, caffeic acid, gallic acid, and ferulic acid.
General feature of the animals

The STZ-induced diabetic rats were characterized by major hyperglycemia, along with hyperphagia, polydipsia, and depressed body growth. In addition, hypercholesterolemia and hypoinsulinemia were also evident in this model.

Data for total body weight gain, food and water intake, and food efficiency are shown in Table 3. The diabetic groups had significantly less body weight, compared with the normal group 2 wk after STZ administration. No differences were found among the diabetic groups. Diabetic animals consumed significantly more water and food than the normal group. While no difference in water intake was found among the diabetic groups, food intake for the PP supplemented groups was decreased significantly, compared with the diabetic control group. The food efficiency ratio (FER) for the diabetic groups was significantly lower than that of the normal group but no differences were found among the diabetic groups.

Dietary supplementation with PP caused a decrease in food intake to a marked extent, indicating the attenuating effect of PP over diabetic hyperphagia. This could be, in part, the result of improved glycemic control caused by the dietary PP. However, other characteristic symptoms of diabetes such as polydipsia and muscle wasting were not improved by the dietary PP.

Tissue weight

Under conditions of hyperglycemia, several minor pathways of glucose metabolism have been reported to contribute to diabetic complications including liver hypertrophy and nephropathy complications (Zador and others 1993; Iwai and others 2004). Liver hypertrophy in diabetic rats is believed to be caused by lipid accumulation through the insulin-dependent impaired glycemic response (Greger and others 1975). In the kidney, the formation of sorbitol (Beyer-Mears and others 1984), the nonenzymatic glycosylation of proteins (Brownlee 1991), and the de novo formation of fatty acylglycerides (Craven and others 1990) are the basis for recent hypotheses on the mechanisms of nephropathy, such as renal hypertrophy.

Thus, the effects of dietary PP on hypertrophies of the liver and kidney induced by STZ treatment and/or diabetic condition were evaluated. Table 4 shows changes in the liver and kidney weights of rats 2 wk after STZ administration. The weight ratios of the liver and kidney to body weight were significantly increased in diabetic rats and the dietary PP did not lead to a decrease in these hypertrophies of either the liver or kidney in diabetic rats. Several chemicals such as vanadate, which exert a hypoglycemic effect in STZ-induced diabetic rats, have been shown to cause the regression of renal hypertrophy and this effect is generally believed to be because of the normalization of blood glucose levels. Although a PP-supplemented diet also partially reduced blood glucose levels in diabetic rats (Figure 1), regression of renal hypertrophy was not observed.

Plasma glucose level

Hyperglycemia, the primary clinical manifestation in diabetes, is associated with the development of certain diabetic complications and impaired glucose metabolism, which leads to oxidative stress, and in particular, the glycation of proteins produces free oxygen radicals (Baynes 1991).

Figure 1 shows plasma glucose levels for overnight-fasted diabetic rats treated with or without the dietary PP for 2wk. The plasma glucose level of the diabetic groups was significantly higher than that of the normal group, but supplementation with PP at both 5% and 10% levels led to significantly decreased glucose levels in diabetic rats, by 17% and 15%, respectively.

Because glycemia in STZ-induced diabetic rats is greatly influenced by food intake (Al-Awadi and others 2004), the antihyperglycemic effect of the dietary PP in diabetic rats can be explained by the reduction of food intake and/or the absorption of nutrients. Although the antihyperglycemic mechanism of the dietary PP is not clear, the possibility that the high content of phytochemicals in PP, such as dietary fiber and various antioxidants as mentioned in Table 1 and 2, are responsible, cannot be excluded. Based on food intake, the diabetic rats fed with diets supplemented with 5% and 10% PP consumed 0.8 g and 1.46 g of additive dietary fiber and 0.88 and 1.61 mg of polyphenols, respectively, on a daily basis.

Numerous animal and epidemiological studies have shown that the consumption of dietary fiber and plant polyphenols is correlated with the improved glycemic control in diabetes (Thompson and others 1984; Brennan 2005). The underlying mechanisms responsible for this property of polyphenols have been explained by a reduced production of reactive oxygen species and lipid peroxidation and direct starch-polyphenol interactions as the result of the increased dietary antioxidants consumed (Yokozawa and others 2002; Singh and others 2005). On the other hand, it has been proposed that the antihyperglycemic effect of dietary fiber is because of delayed gastric emptying and slower transit through the small intestine, resulting in a slower rate of glucose absorption and a lower glycemic response (Gorinstein and others 2001).

Therefore, the observed antihyperglycemic properties of PP could be because of the combined effect of dietary fiber and antioxidants such as polyphenols that are present in PP. The extent of diabetic complications is correlated with elevated blood glucose levels, and it is thus widely believed that excessive glucose is the major cause of tissue injury. Thus, PP would be expected to prevent diabetic complications by controlling glucose level.

Plasma lipid profile

Diabetes is associated with profound abnormalities in the plasma lipid and lipoprotein profiles including hypertriglyceridemia and...
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Table 3—Effects of persimmon peel (PP)-supplemented diets on body weight, water intake, food intake and food efficiency ratio (FER) in streptozotocin (STZ)-induced diabetic rats\(^a\)

<table>
<thead>
<tr>
<th>Group</th>
<th>Body weight change (g/2 wk)</th>
<th>Water intake (mL/d)</th>
<th>Food intake (g/d)</th>
<th>FER(^b)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal</td>
<td>79.00 ± 18.29a</td>
<td>43.88 ± 3.58b</td>
<td>22.78 ± 2.90a</td>
<td>24.71 ± 4.51a</td>
</tr>
<tr>
<td>Diabetic control</td>
<td>-6.75 ± 10.41b</td>
<td>242.74 ± 11.08a</td>
<td>40.60 ± 2.30c</td>
<td>-1.24 ± 1.87b</td>
</tr>
<tr>
<td>Diabetes +5% PP</td>
<td>5.60 ± 28.65b</td>
<td>229.88 ± 26.25a</td>
<td>36.96 ± 2.74b</td>
<td>1.08 ± 5.54b</td>
</tr>
<tr>
<td>Diabetes +10% PP</td>
<td>-3.43 ± 22.27b</td>
<td>235.57 ± 19.33a</td>
<td>36.50 ± 3.35b</td>
<td>-0.67 ± 4.36b</td>
</tr>
</tbody>
</table>

\(^a\) Each value represents the mean ± SD for 6 to 8 rats. Different letters in the same column indicate significant differences between groups at \(P < 0.05\) by Duncan’s multiple comparison test.

\(^b\) FER: body weight gain (g/2 wk)/food intake (g/2 wk) \(\times 100.\)

hypercholesterolemia. Hypertriglyceridemia is also associated with the metabolic consequences of hypercoagulability, hyperinsulinemia, insulin resistance, and glucose intolerance (Betteridge 1997).

A reduction of plasma lipid levels through dietary or drug therapy in diabetics appears to lead to a decrease in the risk of vascular disease and related complications (Brown and others 1993). In addition, a significant reduction in total cholesterol and an increase in HDL cholesterol are desirable biochemical states for the prevention of other aspects of the metabolic syndrome such as atherosclerosis and coronary heart disease (Luc and Fruchart 1991).

Thus, effects of the dietary PP on lipid profiles were evaluated in diabetic rats. As shown in Table 5, the levels of total plasma lipid, triglyceride, and total cholesterol were significantly higher in diabetic rats, compared with the normal group. Dietary PP completely restored the triglyceride levels and reduced total cholesterol levels in diabetic rats. We also observed that HDL cholesterol levels were significantly reduced in diabetic rats and that dietary PP restored the reduced HDL cholesterol level to normal levels, possibly by controlling the hydrolysis of certain lipoproteins and their selective uptake and metabolism by different tissues (Ahmed and others 2001). The ratio of HDL cholesterol to total cholesterol, which indicates the antiatherogenic index, was significantly increased by dietary PP in diabetic rats. However, total lipid levels were unaffected by the dietary PP in diabetic rats.

Regarding the numerous studies on the hypolipidemic effects of dietary fiber and nutritional antioxidants, the observed antihyperlipidemic effect may be because of decreased cholesterol absorption, cholesterologenesis, and fatty acid synthesis (Gorinstein and others 1998; Sachdeva and Khemani 2003). Indeed, it has been previously revealed that phenolic compounds in PP were the main constituents responsible for its hypocholesterolemic and antioxidant effects on rats that were fed cholesterol (Gorinstein and others 2000; Leontowicz and others 2002).

Table 4—Effects of persimmon peel (PP)-supplemented diets on the liver and kidney weight in streptozotocin (STZ)-induced diabetic rats\(^a\)

<table>
<thead>
<tr>
<th>Group</th>
<th>Liver</th>
<th>Kidney(^b)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>g/100 g of BW</td>
</tr>
<tr>
<td>Normal</td>
<td>11.7</td>
<td>3.4</td>
</tr>
<tr>
<td></td>
<td>±1.35</td>
<td>±0.20b</td>
</tr>
<tr>
<td>Diabetic control</td>
<td>11.5</td>
<td>4.3</td>
</tr>
<tr>
<td></td>
<td>±1.52</td>
<td>±0.19a</td>
</tr>
<tr>
<td>Diabetes +5% PP</td>
<td>11.29</td>
<td>4.14</td>
</tr>
<tr>
<td>Diabetes +10% PP</td>
<td>11.67</td>
<td>4.3</td>
</tr>
<tr>
<td></td>
<td>±1.94</td>
<td>±0.24a</td>
</tr>
</tbody>
</table>

\(^a\) Each value represents the mean ± SD for 6 to 8 rats. Different letters in the same column indicate significant differences between groups at \(P < 0.05\) by Duncan’s multiple comparison test.

\(^b\) Mean of 2 kidneys.

**Plasma AST, ALT, and creatinine levels**

Several investigators reported increases in AST and ALT in the serum of diabetic rats induced by STZ (Lee and others 2003; Singh and others 2005). Hepatocellular necrosis, which results in the release of hepatocellular cytoplasmic enzymes such as AST and ALT into the systemic circulation, serve as indicators of liver function. Diabetic hyperglycemia also induces an elevation in the plasma level of creatinine, and its level is considered to be a significant marker of renal dysfunction (Almdal and Vilstrup 1988).

To determine whether dietary PP is able to protect against hepatoxictiy and renal dysfunction induced by STZ treatment and/or the diabetic condition, plasma AST, ALT, and creatinine levels were determined in rats 2 wk after STZ administration. The diabetic groups showed significantly higher levels of AST and ALT, compared with the normal group (Figure 2a). Although the AST level was not completely restored to its normal level by the dietary PP, its level in the PP supplemented groups was significantly decreased, compared with the diabetic control group. However, the dietary PP produced a slight but statistically non-significant decrease in ALT levels in the diabetic groups. Moreover, the diabetic groups showed significantly higher levels of creatinine, compared with the normal group (Figure 2b). However, the level of plasma creatinine was significantly decreased.
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in PP-supplemented diabetic rats. Although it is not clear whether the liver and renal dysfunctions are caused by directly by streptozocin or secondarily by diabetic condition, these results showed that dietary PP is capable of ameliorating the impaired liver and kidney function, to some extent, in STZ-induced diabetic rats.

Diabetes is associated with significantly reduced pancreatic function resulting in a decrease in secretion of an adequate amount of digestive enzyme, especially amylase. This condition is linked directly to the endocrine pancreas, which is unable to secrete insulin or the effect of insulin is impaired (Kumar and Clark 2002). Indeed, serum amylase activity in STZ-induced diabetic rats is significantly lower than in normal rats, and its activity is considered to be a marker of pancreatic function (Barneo and others 1990; Mori and others 2003). In the present study, we found a tendency for amylase activities to be lower in diabetic rats than normal rats, but the decreased amylase activity was not changed by the dietary PP (data not shown), indicating that impaired pancreatic function in STZ-induced diabetic rats is not ameliorated by dietary PP.

In this study, dietary PP did not result in dose-dependent effects on most of the biochemical parameters tested in diabetic rats. From the point of view that the extent of diabetic complications is correlated with elevated blood glucose levels, the dietary PP, therefore, would be expected to ameliorate diabetic complications including hypertriglyceridemia and hypercholesterolemia by controlling glucose levels. Thus, 1 reason for this phenomena seems to be its higher glycemic response derived from the higher content of soluble sugars in the 10% PP-supplemented diet than in the 5% PP-supplemented diet, even when higher contents of potential components such as dietary fiber and phenolic compounds were present in the 10% PP-supplemented diet, as shown in Table 1 and 2. Thus, a 5% PP supplement was reasonable, in terms of improving diabetic alterations in rats.

Conclusions

PP is rich in dietary fiber and various antioxidants such as carotenoids and polyphenols. A PP-supplemented diet possesses an antihyperglycemic effect and has a positive influence on lipid metabolism, and organ functions in STZ-induced diabetic rats could be, in part, due to the combined effects of dietary fiber and antioxidants present in PP. These results suggest that persimmon peel, a byproduct of dried persimmon or persimmon pulp and an environmental contaminant, may represent a good source of dietary fiber and antioxidants and be a useful dietary supplement for assisting synthet-ic antidiabetic drugs.

Acknowledgments

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References


Table 5—Effects of persimmon peel (PP)-supplemented diets on plasma lipid profiles in streptozotocin (STZ)-induced diabetic rats

<table>
<thead>
<tr>
<th>Group</th>
<th>Total lipid (mg/dL)</th>
<th>Triglyceride (mg/dL)</th>
<th>Total cholesterol (TC) (mg/dL)</th>
<th>HDL-cholesterol (HC) (mg/dL)</th>
<th>HC/TC ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal</td>
<td>183.85</td>
<td>56.06</td>
<td>57.65</td>
<td>22.83</td>
<td>0.42</td>
</tr>
<tr>
<td>±28.25b</td>
<td>±14.34b</td>
<td>±2.64c</td>
<td>±2.73c</td>
<td>±0.05b</td>
<td>0.41</td>
</tr>
<tr>
<td>Diabetic control</td>
<td>264.4</td>
<td>133.09</td>
<td>75.67</td>
<td>32.3</td>
<td>0.41</td>
</tr>
<tr>
<td>±30.65a</td>
<td>±51.45a</td>
<td>±8.21a</td>
<td>±5.5ab</td>
<td>±0.08b</td>
<td>0.41</td>
</tr>
<tr>
<td>Diabetes</td>
<td>229.43</td>
<td>71.69</td>
<td>66.94</td>
<td>37.02</td>
<td>0.56</td>
</tr>
<tr>
<td>+5% PP</td>
<td>±22.72a</td>
<td>±11.01b</td>
<td>±5.12b</td>
<td>±4.94a</td>
<td>±0.07a</td>
</tr>
<tr>
<td>Diabetes +5%</td>
<td>233.36</td>
<td>79.59</td>
<td>63.92</td>
<td>29.5</td>
<td>0.53</td>
</tr>
<tr>
<td>Diabetes +10% PP</td>
<td>±28.75a</td>
<td>±28.32b</td>
<td>±1.33bc</td>
<td>±2.30b</td>
<td>±0.05a</td>
</tr>
</tbody>
</table>

Each value represents the mean ± SD for 6 to 8 rats. Different letters in the same column indicate significant differences between groups at P < 0.05 by Duncan’s multiple comparison test.

Figure 2—Effects of persimmon peel (PP)-supplemented diets on the plasma levels of alanine amino transferase (ALT), aspartate amino transferase (AST) (a), and creatinine (b) in streptozotocin (STZ)-induced diabetic rats. Each value represents the mean ± SD for 6 to 8 rats. Different letters indicate significant differences between groups at P < 0.05 by Duncan’s multiple comparison test.
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